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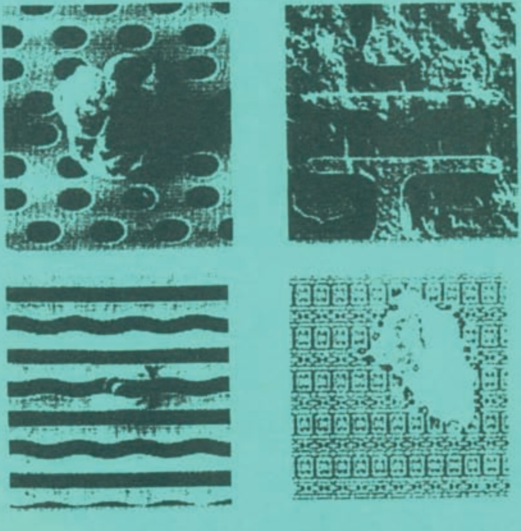

Міністерство освіти і науки України
Вінницький державний технічний університет

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Затверджено Ученою радою Вінницького державного технічного університету як навчальний посібник для студентів бакалаврського напрямку 6.091101 - “Лазерна та оптоелектронна техніка”. Протокол № 8 від 28 березня 2002 р.

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Б 14 **Збірник вправ і текстів англійською мовою з лазерної та оптоелектронної техніки.** Навчальний посібник – Вінниця: ВДТУ, 2002.- 179 с.

Навчальний посібник містить вісімнадцять уроків, які складаються з граматичного та додаткового матеріалу для читання.

Граматичний матеріал вводиться невеликими порціями, що сприяє інтенсифікації навчального процесу.

Додатковий матеріал складений з текстів щодо використання лазерних та оптоелектронних систем у різних галузях народного господарства.

Навчальний посібник призначений для студентів бакалаврського напрямку 6.091101 - “Лазерна та оптоелектронна техніка” і може бути корисним для спеціалістів, що займаються проектуванням та конструюванням оптико-електронних і лазерних систем.

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ЗМІСТ

Список умовних скорочень

AMLCD	active matrix liquid crystal display
APD	avalanche photodiode
ATE	Advanced Technological Education
AWGs	arrayed waveguide gratings
CBIR	content-based image retrieval
CCD	charge-coupled-device
CIPE	Center for Image Processing in Education
CIS	Carlson Center for Imaging Science
COIE	Consortium for Optics and Imaging Education
COP	coefficient of performance
DL	diode laser
DLL	dynamic link library
DM	directly modulated
DMD	digital multimirror device
DOEs	diffractive optical elements
DSF	introduced dispersion-shifted singlemode fiber
DWDM	dense-wavelength-division-multiplexing
DWDM	count dense-wavelength-division-multiplexing
EDFA	erbium-doped fiber amplifier
ELA	EuroLaser Academy
ETOP	Education and Training in Optics and Photonics
FBG	fiber Bragg grating
FDPM	frequency-domain photon migration
FWM	four-wave mixing
IC	integrated circuit
IMSC	Integrated Media Systems Center
IR	infrared
IRS	indian remote sensing
ITV	interactive television

LAAPD	large-area avalanche photodiode
LANs	local area networks
LASER	light amplitude stimulation emission radiation
LCD	liquid crystal display
LED	light-emitting diode
LCoS	liquid-crystal-on-silicon
LOET	Laser Optical Engineering Technology
MEMS	microelectromechanical systems
NA	network analyzer
NTP	network time protocol
NDT	nondestructive testing
NZ-DSF	nonzero dispersion-shifted fiber
OLED	organic light-emitting diode
OST	Optical Systems Technology
OXCs	optical cross-connects
PD	photodiode
PDT	photodynamic therapy
PLCs	planar lightguide circuits
SEM	scanning electron microscopy
SIMNET	similarities with immersive environments.
SOA	semiconductor-optical-amplifier
SPIE	The International Society for Optical Engineering
TIA	transimpedance amplifier
UV	ultraviolet
VCSEL.	vertical-cavity surface-emitting laser
VOAs	variable optical attenuators
WOL	wireless optical link
WONs	wireless optical networks
XPM	cross-phase modulation

Передмова

Навчальний посібник призначений для студентів III курсу технічного вузу факультету електроніки і лазерної техніки. Він складений з урахуванням вимог програми цільової підготовки фахівців з іноземної мови і призначений для самостійної роботи студентів в аудиторії під керівництвом викладача та поза аудиторією.

Ним можуть користуватися також аспіранти та науковці, що працюють у різних галузях оптоелектронного приладобудування.

Мета посібника – забезпечити студентів систематизованим навчальним матеріалом на базі найсучаснішої фахової літератури для подальшого вдосконалення навичок читання для отримання необхідної інформації.

Тексти посібника, які взяли з оригінальних джерел, розкривають сучасний рівень досягнень в галузі оптоелектроніки. Різноманітність текстів та їх об'єм, а також запропоновані форми роботи моделюють умови реальної інформаційно – пошукової діяльності фахівця.

Автори вважають своїм обов'язком висловити подяку д.т.н., професору Осадчуку В.С., к.філол.н., доценту Кім Л.М, к.філол.н., доценту Степановій І.С. за цінні зауваження, завідувачам кафедр лазерної та оптоелектронної техніки та іноземних мов д.т.н., професору Кожем'яці В.П. і к.філол.н., доценту Старовойту Ю.Л. за моральну підтримку, а також студентам кафедри лазерної та оптоелектронної техніки Чернусі Ані, Маслову Роману та Дудненко Тетяні за допомогу при підготовці навчального посібника.

Методичні вказівки для роботи з посібником

Перша частина – 18 уроків, друга – додатковий матеріал, що містить список умовних скорочень, словник спеціальних термінів, таблицю неправильних дієслів.

Кожен урок складається з текстів, що взяті з оригінальних технічних журналів та монографій на англійській мові. Вони скорочені, але не адаптовані. Деякі з них супроводжуються рисунками. Послідовне розміщення текстів дає змогу поступово ознайомитися з найтиповішою термінологією, словосполученнями та фразеологією оптоелектроніки. Кожен урок включає також лексико-граматичні вправи, що спрямовані на всебічне закріплення матеріалу уроку. Оскільки тексти містять граматичні форми і обороти, що характерні для оригінальної науково – технічної літератури, в уроках надаються вправи на закріплення навичок перекладу типових граматичних явищ, що становлять складність під час перекладу їх на рідну мову. Особлива увага приділяється таким граматичним темам, як інфінітив та інфінітивні конструкції, дієприкметник та дієприкметниковий оборот, модальні дієслова.

В систему лексичних вправ входять вправи на підбір синонімів, антонімів, на розпізнавання знайомих інтернаціональних слів.

Для полегшення роботи з перекладом слів автори надали таблицю неправильних дієслів англійської мови.

UNIT 1

1. ***Memorize the following words:***

- challenge
- gap
- to require
- approach
- background
- exchange
- lack
- relevant
- to involve
- to promote
- to conduct
- to employ
- to participate
- to search
- to look for
- to mean
- to increase
- current

2. ***Translate the international words without a dictionary:***

type, aspect, principle, model, decade, technique, fraction, calculation, complex, intensive, miniature, category, electronic, technology, mathematical.

3. ***Translate these synonyms and memorize them:***

- include *(v)*, involve, contain, comprise
- convert *(v)*, change, transform
- basic *(adj)*, fundamental
- begin *(v)*, start, commence
- type *(n)*, kind
- numerous *(adj)*, many
- reduce *(v)*, decrase
- important *(adj)*, significant
- allow *(v)*, permit, let
- almost *(adv)*, nearly

4. ***Translate the following sentences with modal verbs and their equivalents:***

- The scientists are able to perfect this system operation due to the application of superconducting materials.

- The engineers must test a new receiver for using it in this system.
- We have to increase the current strength by decreasing the resistance of the circuit.
- After finishing the experiment the scientists will have to discuss the results.
- The students will be allowed to conduct this experiment in the laboratory.
- The compass used by a pilot has to be small and light in weight.
- The open end of the tube is connected to the apparatus the pressure within which is to be measured.
- The energy which has to be supplied by the generator or battery in order to overcome the opposition is transformed into heat within the conductor.
- We shall have to work out an experiment in which we shall be able to keep the particles in the plasma.
- We are sure we shall be able to overcome all the difficulties in our research.

5. Translate the texts:

Text A. **Education and Training in Optics and Photonics**

The need for technicians, engineers, and scientists in the field of optical science and engineering is very important, and many countries perceive a challenge in trying to fill the gap between the existing brain and man power and the brain and man power required by the development of new industries in this domain. It is fantastic for those who have fought for the development of optics for many years to see their dreams becoming a reality. However, it is scary to see how many skilled people this new industry is looking for. It is especially scary when we see that the number of youths choosing a scientific career is not really increasing. We hope that the ETOP conferences will help in this way.

ETOP, which stands for Education and Training in Optics and Photonics, is a series of conferences run by the International Commission of Optics, SPIE - The International Society for Optical Engineering, and the Optical Society of America. These conferences are growing in importance since all developed countries have a big lack of the brain and man power required to fulfill the needs of industry.

Many groups, in many countries, think that the best way to start recruiting people for optical science and engineering must necessarily begin at the elementary school level. So, as did the SPIE Education Committee, those groups want to develop simple experiments and demonstrations that will generate interest and curiosity that children will surely want to satisfy. Unfortunately, the mission that the SPIE Education Committee gave to itself is very well adapted for U.S. education but not as well adapted for other countries. It should be very important to include in this committee volunteers from different ethnic communities since perception and understanding is largely dependent on each individual culture. It would be very interesting to put together all that expertise to look for a common denominator that would permit identification of the best approach in each culture. The same could be done at the high school level, since the passage from elementary schools to technical schools or universities varies a lot from one country to another, again depending on the cultural background. Consequently, working on a K-12 education kit may give tools to educators in many countries, but in some countries, they will not know how to really adapt it for their needs.

I had the chance in the last nine months to participate in the ETOP conferences in Mexico, Singapore, and Senegal. In each of those conferences, it is evident that the difference between Quebec, Canada, France, Mexico, Senegal, and the U.S. is so large that although we can find some very promising candidates for the booming industry in optical science and engineering, we are all working with such unequal tools that it makes exchange difficult. In America, we are discussing ways to attract youths to optical science and engineering include optics. However, I saw in Senegal, for example, that their needs are basic papers and basic apparatus to do experimental work to train their students. High-speed communication is not yet there even though they use cellular phones everywhere.

My recent experience in Senegal, talking with scientists from surrounding countries, shows me that since we cannot fulfill here the needs expressed by our rapidly developing industry, we must be prepared to spend time and funds to help those countries that do their best with what they have, even though their economy does not permit them to buy equipment. We can find in some countries very good scientists who will do theoretical work because they cannot afford to buy experimental equipment.

I will not go farther on this topic since I would like to keep this editorial short, but I hope that these few lines will say just enough to you that you will start searching for ways to help those scientists who really want to join the optical science and engineering club but from which they all will be excluded if we are not doing our best to help them. I think this can and must be done for the benefit of our field.

(By Roger A. Lessard, Optical Engineering, Vol. 39, № 6)

Text B. **Engaging in optics**

A new consortium raises student awareness of photonics and helps educators bring science to light.

Ask middle-school or high-school students what they plan to become when they grow up, and you're likely to hear predictable responses: doctor, lawyer, athlete, musician, politician, and so on. Few will mention careers as designers, engineers, technicians, or scientists in the photonics and electronic-imaging fields. Most young people simply do not know that such career options exist or even understand the importance of photonics and imaging in their daily lives.

The Consortium for Optics and Imaging Education (COIE) is dedicated to helping correct this lack of awareness. Funded in the summer of 2000 by the Advanced Technological Education (ATE) program of the National Science Foundation, COIE is a collaborative effort of the Optical Systems Technology (OST) program at Monroe Community College and the Chester F. Carlson Center for Imaging Science (CIS) at the Rochester Institute of Technology, both of Rochester, NY, and the Center for Image Processing in Education (CIPE), a Tucson-based nonprofit organization.

"The photonics and imaging industries want people with technical skills—now!" says Robert Novak, principal investigator for the consortium and chairman of the OST program at Monroe Community College. "But we have a difficult time attracting students into our program. Even though we're situated in Rochester, an optics and imaging center, students coming to Monroe Community College don't know what photonics and imaging are. Worse yet, they haven't prepared themselves properly to enroll in a technical program."

According to Novak and a growing number of educators, industry representatives, and policymakers, two key trends are challenging the ability of the United States to address a growing shortage of technical personnel in the photonics and imaging fields. Foremost is a declining interest in science among young people. Second is a lack of perceived need among students to seek academic preparation in physics, chemistry, and mathematics. Many students do not see the subjects as relevant to their current lives or future careers.

COIE hopes to counter these trends by involving young people in hands-on explorations of photonics and imaging concepts. The consortium will promote these explorations by developing a photonics- and electronic-imaging-based curriculum for teaching physical science. COIE also will conduct professional development workshops for high-school and college educators to help them integrate photonics and imaging science into their teaching. The new materials will be derived from the discovery-based style of instruction fine-tuned by CIPE under a previous ATE grant. This approach to education involves students in the use of imaging and optics technologies as early as grades three and four.

A nonprofit organization that promotes computer-aided visualization as a tool for teaching and learning, CIPE conducts workshops and develops instructional materials that use image analysis and geographic information systems technologies as platforms for teaching about science, mathematics, and technology. CIPE's approach to science education captures students' interest because it is visual, interactive, and self-guided. Students use the same tools employed by scientists and technicians in research and industry.

Because the $600,000 COIE project will provide a model for preparing optics and imaging technicians nationwide, it already has attracted the participation of leading corporations, and professional associations. The Eastman Kodak Co., Tropel Corp., American Precision Optics Manufacturers Association, Melles Griot, all located in Rochester, and the Society for Imaging Science and Technology (Springfield, VA) are participating in the consortium.

"Photonics and electronic imaging are the killer applications for the twenty-first century," says Roger Easton, imaging science faculty at CIS and a co-principal investigator on the project. "Once students appreciate the photonics and imaging science behind the miracles of everyday technologies—and that real people like themselves make those miracles happen—the rest will be easy. Instead of having to search for good people to work in these fields, they'll come looking for us."

(By Steven Moore, Center for Image Processing in Education, OE magazine, April, 2001)

Text C. **Building the Photonics Army**

It's a tune that is becoming just a little too familiar in the photonics arena: As the industry grows, so too does the need for capable engineers and technicians. Unfortunately, the demand for these qualified employees—particularly recent college graduates—outweighs the current supply. Universities are feeling the squeeze as much as companies looking to hire, and some, like the Oregon Institute of Technology (OIT; Klamath Falls, OR), are hoping to come up with alternatives to start bulking up the future of the optics industry.

In order to meet the industry's employment needs, the Laser Optical Engineering Technology (LOET) program at OIT is planning a move to Portland in 2002. By moving to a larger market, Richard Oram, program director and assistant professor with LOET, hopes to double the size of the current 40-person program. "Even though the career path for our graduates is well defined and very bright, OIT, like other universities throughout the United States, is having a difficult time recruiting quality high-school students with an interest in the optics field," he says. "Moving to a metropolitan center with a larger population base will increase the profile of the high-quality optics education that we offer."

Oram also hopes that with the move, the program will be able to extend courses to a more varied group of students, including those already employed part time or full time, or those who want to retrain or update their skills. A number of photonics firms are located in the Portland area, including Flir Systems Inc., Electro Scientific Industries, Blue Road Research, and GN Nettest.

LOET aims to equip graduates with both theoretical and pragmatic information required by optics employers, according to Oram. By graduation, students have completed more than 600 hours of work in various optics laboratories, with topics including geometric and physical optics, photonic devices, image processing, optical detection, laser principles, holography, and optical thin films. Besides the hands-on lab experience, optics students at OIT complete up to three internships in the field. "This applied emphasis seems to pay off, as the feedback we receive from the industry is that our graduates are useful from day one," Oram says.

The feedback is so positive, in fact, that employers are eager to hire graduates as soon as possible. "Our graduates are being snapped up three to four months before graduation," Oram says.

Optics companies have to be quick to hire because of the small pool of candidates in the field. Oram estimates that only 250 graduates in the United States receive optics-related degrees each year. "For companies looking to hire new people, it's a frighteningly small number," he says.

In order to increase enrolment, however, the program needs the proper funding, which currently comes from student tuition fees and the state of Oregon. "Right now we're running at half-capacity, which means we have only half the funds to work with," Oram says. "Our budget is limited. With our grads being more and more sought after, we're having to do more and more with fewer resources."

Although optics companies donate equipment such as lasers and optical components, no money actually comes from these companies. And with only three professors for 40 students, raising money via research has been difficult. "Because we are so focused upon teaching, the faculty doesn't have time to get involved in much research work-- usually just over the summer break," Oram says. "So we don't have any mechanisms in place to raise extra money that we need to grow."

Recruitment, therefore, becomes the key in obtaining more students and increasing the program's funding. However, recruitment also presents its own set of challenges. Like other universities across the United States, OIT is having difficulty attracting high-school students with an interest in optics and a solid science and math background, says Oram. One of the most successful approaches still proves to be education outreach, and the program at OIT is using its own students as its strongest tool. "We continue to send our current LOET students back to their own high schools on education outreach activities," he says.

By working from the inside out, current students might just be the key to bringing new recruits to an already vital program.

(By Holly Andren, OE magazine, May, 2001)

UNIT 2

1. Memorize the following words:

- reliability
- to feature
- to perform
- performance
- range
- to deliver
- include
- capability
- rate
- advantage
- remote
- fiber
- application
- reflection
- to propagate
- bandwidth
- care
- to support
- to distinguish
- to reduce

2. Translate the international words without a dictionary:

material, cylinder, portion, energy, radiation, temperature, thermal, adequate, absolute, special, emission, normally, local, unique, distance, immune, interference

3. Translate these antonyms and memorize them:

- be present *(v)*, be absent
- primary*(adj)*, secondary
- relative *(adj)*, absolute
- outside *(adj)*, inside
- majority *(n)*, minority
- common *(adj)*, special
- external *(adj)*, internal
- slow *(adj)*, quick, rapid
- free *(adj)*, bound
- strong *(adj)*, weak

4. *Translate the following sentences with modal verbs and their equivalents:*

1. The energy, which had to be supplied by the generator or battery, was transformed into heat within the conductor.
2. For improving the system operation the designer was to use low weight equipment.
3. The designer was able to conduct a new device by using semiconductors.
4. We may say that photoelectric properties of transistors are largely used in TV-sets.
5. The frequency of an oscillator is to be kept constant by means of an oscillating crystal.
6. Some operations for this computer have to be changed and new instructions have to be added.
7. The instructions are recorded in the order in which they are to be carried out.
8. The main task of this article was to show the results of research work.
9. You have to remember the names of the scientists who have contributed to the development of your speciality.
10. The lecture was to begin at 9 o'clock.

5. *Translate the text:*

Text A. **Facts About Fiber**

Optical fiber is central to the successful operation of a wide variety of high-speed communications applications, from local area networks (LANs) to long-haul systems to emerging metropolitan area networks. Each of these applications has unique technical requirements, for which a specific optical fiber has been developed to provide optimized performance and high value.

Every optical fiber has the same two basic elements: a core and a cladding. The core is the inner, light-guiding section; the cladding surrounds the core. Because the refractive index of the core is higher than that of the cladding, the index mismatch causes total internal reflection at the interface—light that enters the core at an angle reflects off the core/cladding boundary and propagates down the length of the fiber. Over distance, the signal experiences some attenuation. Nevertheless, all optical fibers combine low signal loss with very high bandwidth and are lightweight, small, have high tensile strength, and are immune from electromagnetic interference.

Modes in multiples

There are two main designs for communications-type optical fiber: multimode fiber and singlemode fiber. Each is the size of a human hair, with identical outer diameters of 125 μm. The important difference is in the size of each fiber's core. The core of singlemode fiber is 7 to 10 μm in diameter, while the core diameter of a multimode fiber is much larger, generally 50 μm or 62.5 μm. Core size is critical to how a fiber transmits data.

Light propagates down the fiber core in a stable path known as a mode. Multimode fiber supports hundreds of modes in the core, each of which is a different length. If we launch a single pulse of light into a fiber, the light will excite multiple modes, entering at various angles to bounce off the core/cladding interface. In other words, the light in each mode will travel a different distance depending on the modal path, so the light in some modes will arrive at the far end of the fiber later than others. The pulse will be spread out in time, a phenomenon known as modal dispersion. If multiple pulses are launched into the fiber and they all suffer modal dispersion, adjacent pulses may overlap until the receiver cannot distinguish one pulse from another, which causes bit errors.

Multimode fiber can be optimized to reduce modal dispersion using a graded refractive index profile in which the refractive index of the core glass decreases slowly as a function of the radial distance from the center of the fiber. The lower the index of refraction, the faster light travels; therefore, light travels slower at the center and faster toward the core-clad interface. If this graded index profile were perfect, all modes would arrive at the receiver simultaneously. In practice, modal dispersion can be minimized but not eliminated, and it is the principal bandwidth-limiting factor in multimode fiber.

Nevertheless, with more than sufficient bandwidth for current and future applications, multimode fiber is ideal for the LAN environment. Moreover, its large core enables the use of inexpensive light sources such as light-emitting diodes or vertical-cavity surface-emitting lasers (VCSELs). These sources, combined with new laser-optimized multimode fibers, provide the means to cost effectively transmit data at gigabit speeds over distances required by LANs.

Multimode fiber is available in two core sizes: 50 μm and 62.5 μm. While 62.5 μm has been widely adopted in North America, 50 μm fiber is becoming increasingly important in global premises cabling because it offers up to three times the bandwidth of standard 62.5 μm fiber at 850 nm, the current operating wavelength for VCSELs. The combination of laser-optimized 50 μm multimode fiber and VCSELs represents the lowest-complexity, lowest-cost option for high-speed premises networks as they move steadily into multigigabit data rates.

Staying single

In singlemode fiber, the core is so narrow that it only supports one mode, eliminating modal dispersion effects. The index profile is a step function that gives good reflection from the core/cladding interface. Singlemode fiber works very well for long-distance communication because it can transmit signals quite far before signal strength diminishes to the point at which amplification is required. In telephony applications, for example, amplifiers typically are placed at intervals of 80 km or more.

The primary bandwidth-limiting effect for singlemode fiber is chromatic dispersion, the spectral spreading of an optical pulse. Light at shorter wavelengths travels down a fiber more rapidly than light at longer wavelengths. Because all laser sources have some finite spectral bandwidth, an optical pulse spreads as it propagates down the fiber, undergoing chromatic dispersion. If pulses spread too much, intersymbol interference and signal-to-noise ratio degradation occur: The receiver cannot distinguish 1's from 0's, and bit errors result.

For years the workhorse of telecommunications networks has been standard singlemode fiber, which is optimized for the minimum dispersion window of 1310 nm. This is a useful wavelength, because high-capacity, low-cost components are readily available for operation around that wavelength. However, signal loss of optical fiber is lowest around 1550 nm, an important wavelength region because it is also in the operating range of erbium-doped fiber amplifiers (EDFAs), which goes from 1520 nm to 1610 nm. EDFAs allow network operators to boost the power of multiple wavelengths simultaneously and extend distance between electronic regenerators. They have been crucial in the development of dense-wavelength-division-multiplexing (DWDM) systems for long-distance transmission.

Dealing with dispersion

In the mid-1980s, manufacturers introduced dispersion-shifted singlemode fiber (DSF) to take advantage of the 1550 nm transmission window by altering the composition of the fiber core to shift the zero-dispersion wavelength to 1550 nm, where signal loss is lowest. The fiber worked well for single wavelength systems at 1550 nm, but DSF created serious problems for the DWDM systems introduced shortly after.

Local dispersion refers to dispersion of the fiber at a defined wavelength as measured in ps/nm/km. A small, finite amount of dispersion helps to offset optical pulses that would otherwise travel together uniformly. This offset helps to counter the effects of cross-channel nonlinear interactions called four-wave mixing (FWM), in which channels interfere with each other and generate noise. When a network transmits optical signals at different wavelengths, the absence of local dispersion drastically enhances FWM. The amount of power introduced into the fiber also plays a critical role in affecting FWM (and other nonlinear penalties). More power means more nonlinear penalties.

Nonzero dispersion-shifted fiber (NZ-DSF) overcomes FWM by moving the zero-dispersion wavelength outside the 1550 nm operating window. The practical effect of this is to have a small but finite amount of dispersion at 1550 nm, which minimizes four-wave mixing while allowing for 10 Gb/s transmission over distances spanning several hundred kilometers without the need for costly dispersion compensation.

Nonlinear effects are more pronounced at high data rates, however, which challenge even conventional NZ-DSF. Increasing the effective area of a fiber is one method for addressing this problem. Effective area refers to the equivalent area of the fiber in which optical power is transmitted. In the case of singlemode fiber, this is roughly proportional to the core area. Fiber with a large effective area offers reduced optical power density, raising the power threshold for nonlinear penalties.

In the metro loop

Metropolitan area networks often consist of rings, or a system of rings, with a combined circumference in excess of 80 km. The principal limiting factors are dispersion, network complexity, and cost.

Although they are an inexpensive alternative, directly modulated (DM) lasers introduce positive transient chirp, which is a slight increase in frequency over time as the pulse is transmitted that causes each pulse to contain a range of wavelengths that travel at slightly different velocities. By adding a negative dispersion profile in the optical amplifier window (1530 nm to 1625 nm), NZ-DSF can be tailored to extend the uncompensated transmission distance of DM lasers without the need for expensive dispersion compensation equipment and regeneration along the network path. The negative dispersion generates pulse compression at the beginning of the signal path, and leads to path lengths exceeding 300 km for DM laser signals.

Optical fiber technology continues to keep pace with speed and bandwidth demands that grow exponentially year to year. A broad selection of multimode and singlemode fibers meets the specific needs of various network applications, providing the means to transport massive amounts of information rapidly and economically

(By Alan Dowdell, Corning Inc., OEmagazine, June, 2001)

Text B. **Picking Up Speed**

Ultrafast lasers make their way out of the lab and into the market.

Titanium-doped sapphire (Ti:sapphire) ultrafast lasers have come a long way since the devices were introduced in the early 1990s, and their makers are hoping they'll continue their march out of the lab and into industry. Ultrafast lasers operate with pulses ranging from tens of femtoseconds to a few picoseconds. The short-pulse durations allow the lasers to deliver energy precisely without causing heat to spill over beyond their target. This permits measurement of still-living tissue, for example, or treatment of materials without damaging the surrounding area. Sandia National Laboratory (Albuquerque, NM), for instance, uses ultrafast lasers to cut explosives without setting them off.

One of the big markets for ultrafast lasers is biological science, for example in a variation of confocal microscopy called multiphoton excitation (MPE), says Marco Arrigoni, general manager of the scientific business unit at Coherent (Santa Clara, CA). A pair of photons strikes a tissue sample that has been treated with a fluorescing dye, which fluoresces only in the focal spot. The advantage of Ti:sapphire is that it is tunable from 700 to 1000 nm, covering the excitation wavelengths of most standard visible dyes.

In the old days, researchers had to be equal parts laser physicist and biologist to perform experiments using temperamental ultrafast lasers. With the advent of diode pumping, systems became more compact and turnkey, but even recently, Arrigoni says, lasers that covered a range greater than 100 nm required manual tuning and were two-box systems, with the pump laser separated from the main resonator. Coherent recently introduced the Chameleon, a computer-controlled single box tunable from 720 to 930 nm.

"Doctors and biologists don't want to deal with knobs and tuning the laser," says Arnd Krueger, director of marketing for the industrial and scientific laser unit at Spectra-Physics (Mountain View, CA), which makes its own hands-off, tunable femtosecond laser, the Mai Tai. "In the past, these ultrafast lasers have been huge systems that occupied an entire table, and you needed a laser jock to operate them," Krueger says. "Everything is really easy now."

new spots

While ease of operation is making ultrafast systems attractive to users, new applications are also beginning to open up. For instance, as printed circuit board designers try to pack more circuits into a tighter space—inside cell phones, for example—femtosecond lasers provide a way to drill holes in the boards without damaging the area around the hole. The systems can perform drilling operations in the manufacture of ink-jet cartridges or fuel injectors for automobiles. Such applications generally don't require that the lasers be tunable, but they need to deliver higher pulse energy than MPE requires. Whereas energy for MPE is usually measured in nanojoules per pulse, an application like writing waveguides in glass would require tens of nanojoules. Drilling holes in stainless steel fuel injectors requires millijoules. Researchers are studying material systems that might deliver more energy and are trying to extend available wavelengths into the UV spectral region.

"The reality is that every one of these customers has an application-specific requirement," says Jeremy Weston, president of Positive Light (Los Gatos, CA), which manufactures the amplifiers used to increase the power of ultrafast lasers. Adding amplifiers and oscillators, of course, increases the complexity of the systems as well as the cost. Some complex systems can run from $225,000 to $300,000, Arrigoni notes.

"It's not very easy to build generic lasers for industrial customers," Weston says. "It's not really possible to just build a laser for micromachining."

Industry journalist David Belforte says a potential customer for these lasers needs to be able to justify the cost. "The customer has got to have a real need that makes economic sense, and those things are difficult to find," he says. That doesn't mean they won't be found, though—it may take time. "Look how long it took excimers to get accepted."

(By Neil Savage, OEmagazine, September, 2002)

UNIT 3

1. *Translate the following words:*

- to provide
- to enable
- ongoing
- deployment
- demand
- steady
- exclude
- to occur
- sophisticated
- tunable
- breakthrough
- wave length
- frame
- to handle
- to consider
- to reflect
- to encounter
- immunity
- reason
- division

2. *Translate the international words:*

to vary, to control, to absorb, to indicate, to tend, to limit, to discuss, to form, to escalate, display, commercial, product, extensive, to start, to start, miniaturization, barrier, physics.

3. *Translate these antonyms and memorize them:*

- remain*(v)*, leave
- correct*(adj)*, wrong
- simple*(adj)*, complicated
- continue*(v)*, interrupt
- lose*(v)*, gain
- attract*(v)*, repel
- stop*(v)*, start
- strongly *(adv)*, weakly
- externally *(adv)*, internally
- open *(adj)*, closed

4. Translate the following sentences paying attention to the different infinitive functions:

1. To create a powerful energy source was of prime importance for a constructor.
2. To obtain new data on the wave traveling was necessary for future investigations.
3. The purpose of the experiment is to convert heat directly to electricity.
4. The object of this system is to provide a powerful energy supply.
5. The designer has to test the system to be used in the laboratory.
6. Cells to be connected in parallel should be of the same type and voltage.
7. The question to be considered is of great importance for our research.
8. Academic Yoffe was the first to notice the great use of transistors for future technology.
9. To discover new sources of energy and to develop methods of power generation is the main problem of our scientists.
10. To study the ionosphere and radio waves in outer space numerous sputniks have been launched.

5. Translate the texts:

Text A. **Photonics in Fast-Forward**

History repeats itself, and this time we may get it right.

Now that we're in the age in which everything is moving at the speed of light, it's no wonder that our technological advances in photonics are racing to keep up. Although the technology is improving in record time, the challenge is for companies in the industry to meet production and standardization needs.

When the wave of microchip technology hit the market in the 1970s, it revolutionized the industry. One aspect of this revolution was the need to produce mass quantities of a family of entirely new products that had to be delivered to the market in as short a period of time as possible. The microchip industry has had more than 20 years to evolve to a point at which giant corporations like Intel (Santa Clara, CA) make the devices by the millions.

Capital equipment vendors, such as Applied Materials (Santa Clara, CA), Novellus (San Jose, CA), and KLA Tencor (San Jose, CA), have had ample time to develop the sophisticated systems necessary to fabricate these products. Many of these large, successful companies began as small start-ups in Silicon Valley. They were nurtured on process technology and tasked with the challenge of building the equipment that would make Moore's Law a reality. More than 20 years later, they have evolved into world-class suppliers of precision automation technology for chip manufacturers.

We now are seeing a similar revolution taking place in the optoelectronics industry. Optoelectronic microchips not only carry information through electrical currents but also transmit and receive signals through coherent light waves generated by semiconductor lasers. The voracious demand for the optoelectronic components that constitute the core building blocks of telecommunication networks has created a severe global shortage of these devices. This is largely due to the fact that optoelectronic devices currently used in the field by telecommunication network providers are so new that there simply has not been enough time to design them with high-volume production in mind. There also has not been enough time to develop machines that can produce these devices at a rate of thousands per day.

In today's fast-paced global market, however, no one can wait for this industry to go through decades of evolution before it reaches the level of maturity of the semiconductor electronics industry. Photonics companies are attempting to squeeze 20 years of technical evolution into two or three years. Equipment vendors are uniquely positioned to answer this need and to take the leadership role in blazing the trail that will lead to economical, high-volume production of fiber-optic components. But there are challenges in achieving this goal.

One problem is that so many types of optoelectronic components are finding their way so rapidly from R&D laboratories to the manufacturing floors that there is little or no process or component design standardization. This makes the design of fully automated machines very challenging because the essence of automated manufacturing is performing the same task over and over on the same type of product.

Another challenge is that, unlike electronic devices, optoelectronic devices have optical fibers hanging from them. These fibers are very fragile, they require submicron directional alignment, and they are awkward to deal with. As a result, the devices need to be handled manually by skilled technicians at many stages of the manufacturing process. This leads to a situation in which your process becomes operator dependent, thus lowering yield levels and throughput.

Consequently, the key to building high-volume-production photonics assembly lines and factories is not necessarily the mechanization of the same old manual process, but rather the definition of new automation strategies and machine platforms that can make the manufacturing process independent of the operator and highly repeatable. Once you achieve repeatability, it is possible to gain control over your process and ramp up both your production capacity and yield levels. This results in an economical operation. The next-generation automated fiber-optic component production lines are based on this concept.

For the fiber-optic component industry to thrive in this emerging optically enabled world, we need to learn from the lessons of the microelectronics experience gained since the 1970s: By rapidly embracing automation technology as a yield-enhancement tool, photonics can leap past the early years of its evolution to the long-term benefit of all.

(By Robert Deuster, Newport Corp,. OEmagazine, February, 2001)

Text B. **At the Speed of Light**

Spectra-Physics (Mountain View, CA) turns 40 this year. And no, it's not facing a midlife crisis, but the timing does provide an opportunity to take a look at where the industry has been and where it's going.

The company was founded in 1961, less than a year after the invention of the laser, and has been around through the development of the gas laser, the ion laser, the next generation of argon ion lasers, and the development of high-power helium-neon (HeNe) lasers.

Through the late 1970s, the primary market for laser applications was scientific. That changed with the availability of HeNe lasers, which opened a couple of significant OEM markets: bar-code scanning and high-speed, noncontact printing. In 1986 fiber-coupled semiconductor-based lasers set a new industry standard for reliability and ease of use. In 1993 high-power models of these products enabled the growth of the direct-to-press thermal-imaging market. Meanwhile, despite ongoing technological advances in gas lasers, the overall market saturation threshold remained low.

Through the 1980s and early 1990s, researchers laid the foundation of what was to become the semiconductor-based laser revolution. The development and deployment of high-power diode lasers and diode-pumped lasers, manufactured in progressively higher volumes at progressively lower costs, have mirrored the evolution of the electronics industry from transistors to integrated circuits. As a result, the laser-industry paradigm has shifted from conventional technology (gas- and flashlamp-pumped systems) to the semiconductor-based technology (diode lasers and diode-pumped solid-state lasers) that is leading to the photonics opportunity of the 21st century.

The view today

Photonics—the use of light to move data, process materials, and make measurements—continues to feed the escalating demand created by the Internet for computer power and network bandwidth. High-power semiconductor-based lasers deliver dramatically lower operating costs, smaller size, greater efficiency, and higher reliability for a wide variety of applications in diverse markets.

The scientific research market, which remains a steady consumer of pump and seed lasers, and the image recording market, which encompasses commercial printing and graphics, remain steady. Today's major growth markets include telecommunications, computer and microelectronics manufacturing, industrial manufacturing, and medical photonics. Diode lasers are the workhorses of optical networking, while applications for diode-pumped solid-state lasers range from semiconductor and computer display manufacturing to confocal microscopy to prototyping of industrial materials.

Even with the current economic uncertainty, market forecasts from industry experts support this proliferation of applications. The worldwide laser market, excluding telecommunications, has grown at a compound annual rate of 23% since 1993 and is expected to reach $4.6 billion in 2001. Application markets for high-power lasers, both conventional and semiconductor-based, are projected to increase

18% to $2.6 billion in 2001. Sales of high-power semiconductor-based lasers are estimated to grow 19% to $347 million.

Almost 25 years passed between the invention of the transistor in the late 1950s and the commercial deployment of the personal computer in the early 1980s. And the world of electronics, which includes semiconductors, PCs, software, and telecommunications, has gone through countless growth cycles in the last 20 years. Applying the earlier industry parallel, it took 25 to 30 years for lasers to evolve from large, expensive, scientific products with limited power and reliability to the cost-efficient, multifunctional, solid-state photonics engines of today. Relatively speaking, photonics powered by semiconductor-based lasers is still in its infancy.

It seems that 90% of the change in the industry has occurred in the last 10% of time. And given the speedy growth of the passive and active segments of the telecommunications market, we can expect the pace of change to continue accelerating. It took us a long time to get here, but we have an even longer way to go. Happy birthday to the commercial laser industry (and Spectra-Physics). Life begins at 40.

(By Patrick Edsell is the chairman, president of Spectra-Physics, OE Magazine, June, 2001)

Text C. **Tools of the Trade**

Photonics provides scientists with sophisticated tools such as ultrafast, tunable lasers, high-sensitivity detectors, and various other types of analysis instrumentation.

There was a time when science meant beakers and microscopes, electricity and balances. These days, researchers have added more sophisticated tools to their labs. Whether it's particle image velocimetry, laser-assisted mass-absorption spectroscopy, or optically tracked polymerase chain reaction for DNA studies, photonic technologies are increasingly becoming the tools for scientific investigation.

The strongest trend in the last decade has been the development of sophisticated turnkey ultrafast and tunable scientific laser systems. In the early 1990s, tunable ultrafast systems were large and finicky, requiring precisely controlled environmental conditions and elaborate power and cooling apparatus. In the time since, laser manufacturers have produced optical parametric amplifiers, optical parametric oscillators (OPOs), and tunable ultrafast laser systems that scarcely require the owners to crack the box. "You used to have to have some touch capability and be a laser jock to run a tunable laser," says Charles Miyaki, vice president of business development at Aculight (Bothell, WA). "Now you just have to point and click."

Bruce Craig, vice president and general manager of industrial and scientific lasers at Spectra-Physics (Mountain View, CA) agrees. "Since the introduction of diode-pumped high-power green lasers in the mid 1990s, there has been limited technical revolution in the products. Mainly there have been engineering breakthroughs--[designing for] better performance, lower noise, better stability, more reliability, better utilities, compactness, and then ultimately taking all those things and putting them into a single box." And as the technology has become simpler to use, it has attracted greater interest from less sophisticated users.

The first multiphoton microscopy experiment, for example, took place in 1991 with a colliding pulse, mode-locked dye laser system. "It was difficult to imagine how that would ever become a commercial application," Craig says, "and it wouldn't without the advent of titanium-doped sapphire (Ti: sapphire) lasers, the solid-state laser, and, ultimately, commercial systems. We've come a long way—there's no doubt about it."

Though not as spectacular—or cyclical—as the telecom and semiconductor markets, the scientific laser market remains solid. "It's a steady market that's pretty predictable from year to year," says Craig. "The other thing that's vital is that it keeps us in close contact with pioneers, people who are pushing the envelope on next-generation technology and people who are pushing the envelope on applications."

Extending the reach of applications no longer requires extensive experience with lasers. Miyaki recalls an experiment in 1986 that required multiple wavelengths in the near infrared. "We used a krypton ion laser pumping a CW ring dye laser, then pulse amplified it in a YAG-pumped pulsed dye laser, and then amplified it further in a pulsed Ti: sapphire laser. This was an experiment with six beamlines that took nine 4 ft. * 8 ft. benches," says Miyaki. "Now you can buy each beamline in one box."

(by Kristin Lewotsky, OEmagazine, June 2001)

UNIT 4

1. Memorize the following words:

- switch
- fabrication
- multiple
- layer
- pattern
- to deposit, deposition
- to release
- benefit
- cutting-edge
- attenuator
- substrate
- node
- negligible
- to face
- on one hand, on another hand
- to maintain
- capacity
- appropriate
- diffractive
- to sense

2. Translate the international words without a dictionary:

to focus, to generate, specific, effect, characteristic, constant, total, compact, military, medical, to invest, magic, film, intense, stability, to minimize, to modify, traditional, result.

3. Translate these antonyms and memorize them:

- best *(adj)*, worst
- constant *(adj)*, variable
- never *(adv)*, always
- increase*(v)*, decrease
- obtain*(v)*, lose
- take *(v)*, give
- different *(adj)*, similar
- normally *(adv)*, abnormally
- partial *(adj)*, total
- many *(adj)*, few

4. Translate the following sentences paying attention to the different infinitive functions:

1. To increase the reliability of large industrial centres, the latter are fed from several power plants jointed into a common network.

2. An automatic control system may be regarded as consisting of two main parts, the part to be control and the controlled unit.
3. The air must be compressed to occupy a smaller volume.
4. To be properly understood, the rule of safe work is to be explained once more.
5. Quite unexpectedly the engine, which was to have gained tremendous power, failed to work.
6. The best way to understand the current is to see how it acts in a circuit.
7. To build up a magnetic field requires the expenditure of a certain amount of energy.
8. To do the program the programmer must have a good understanding of the problem for the computer
9. To do the program for a computer is the main duty of a programmer.
10. The programmer must do a program to give accurate instructions to the computer.
11. To make possible communication from a human being and a computer is the main purpose of the input unit.

5. Translate the texts:

Text A. **Little Machines Make it Big**

Micromachines make their way into optical switches, multiplexers, and crossconnects to enhance data flow over optical networks.

Tiny machines, so small that they're invisible to the human eye, are tackling a wide array of challenges in the manufacturing of automobiles and airplanes, in chemistry and biology, and in medicine and sensing. In optical communications, these silicon micromachines—also known as micro-electro-mechanical systems (MEMS)--are showing up in optical switches, add/drop multiplexers, optical crossconnects, and other critical components. The devices have the potential to revolutionize lightwave systems or put the power of a laboratory in the palm of your hand.

Manufacturers make MEMS devices by using integrated circuit (IC) batch-processing techniques. Even though the fabrication process is complex, the volumes involved make it economically viable. A typical fabrication cycle begins with a silicon wafer on which multiple layers are deposited and lithographically patterned. Some of the layers are acid-soluble sacrificial oxides included as spacers. Once the deposition process is complete, sacrificial oxide layers are etched away to release elements that may be hinged, spring-loaded, or otherwise suspended (see figure 4.1). The microfabrication techniques used allow designers to build devices that are tens to hundreds of microns in size.

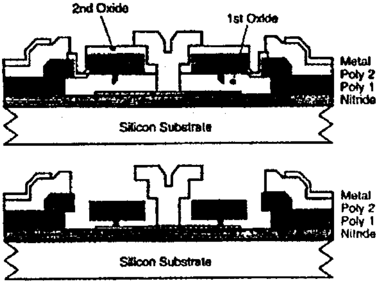

Figure 4.1. After deposition and patterning (top), the sacrificial oxide layers are etched away to release the device (bottom) so that individual parts can move under electrical actuation

MEMS manufacturing benefits from the considerable technological resources of the IC fabrication industry. At the same time, the scale of the devices allows them to be manufactured using previous-generation equipment. In an era in which an IC fab costs $1 billion and becomes obsolete in less than five years, the ability to reuse the equipment for a new class of cutting-edge products is enormously appealing.

IC fabrication techniques also allow designers to integrate micromechanical, analog, and digital microelectronic devices on the same chip, which produces multifunctional integrated systems. Despite their size, MEMS devices have proven to be robust and long lasting, especially those whose parts flex without microscopic wear points.

One of the interesting things about MEMS is that the physics of devices at the microscale can differ completely from physics at the macroscale. Richard Feynman predicted this behavior in a paper he wrote in 1959, well before MEMS became commonplace in the photonics industry. At the macroscale level, electromagnetic forces, for example, are strong and electrostatic ones are weak. At the microscale level, however, the situation is reversed. Another example of this role reversal is the relative importance of friction and inertia. For objects the size of human beings, inertia is relatively important, while friction is less so. At the microscale, friction becomes the dominant effect, while inertia is unimportant. A paramecium, for example, never would be able to discover inertia and Newton's second law.

At Bell Laboratories (Murray Hill, NJ), our group has focused on telecom devices such as optical modulators, variable attenuators, switches, add/drop multiplexers, active equalizers, and optical crossconnects. We see applications—and opportunities—for MEMS components throughout lightwave systems, in the core networks, in passive optical networks, and in metro rings. Indeed, in these places a MEMS-based solution may be the best choice.

Mirror, mirror, in the switch

Our team has developed a 1 * 2 MEMS optical switch that achieves a response time of less than 70 μs. The design features a mirror connected to an electrostatically activated see-saw that is driven by a flat plate. Applying a voltage between the suspended plate and the substrate generates a force that pulls the plate down and displaces the mirror. In the "on" position, the see-saw positions the mirror to deflect light from one fiber to another; in the "off" position, the mirror is pulled out of the way to allow the optical signal to pass undeflected. Depending on the design, the actuation requires from 1.24 V to 20 V, with negligible steady-state power consumption. It has loss of less than 1.5 dB with passive alignment and less than 1 dB with active alignment.

At each node in a fiber-optic network, some wavelengths must be added, dropped, or passed. An add/drop multiplexer can use an array of micromirrors to perform this function. A grating spectrally demultiplexes the signal and sends each channel to a separate mirror in the array that routes it to either the output port or the drop port. The array can switch up to 16 wavelengths at speeds of 20 μs with better than 30 dB switching contrast.

From a carrier viewpoint, the ideal network would allow flexible provisioning and rapid restoration after service interruptions. Large MEMS-based optical crossconnects offer a viable way to accomplish this. A typical design consists of an array of two-axis micromirrors facing a fixed mirror or a second MEMS array. Light from an input fiber is focused onto one of the micromirrors, which routes it to the appropriate output micromirror by bouncing it off the fixed mirror at a specific angle. The output micromirror then sends the signal to a designated output fiber. Such fabrics are low loss, require minimal power, and work independently of data rate and data format. They operate at both 1.3 μm and 1.5 μm and can scale to very large port counts.

(By David Bishop, Randy Giles, and Vladimir Aksyuk, Lucent Technologies, OEMagazine, May, 2001)

Text B. **Diffracting Light**

Diffractive optics can simulate the effects of many conventional optics while offering powerful optical performance in a lightweight, compact component.

When optical engineers talk about controlling light through diffraction, a number of terms get bandied about: binary optics, kinoforms, computer-generated holographic optical elements, and plain old diffraction gratings. The overall term that encompasses all of these concepts is diffractive optics, and for purposes of this discussion, the optical components described herein will be called diffractive optical elements (DOEs).

A DOE is a component that modifies wavefronts by segmenting and redirecting the segments through the use of interference and phase control. A kinoform is a DOE whose phase-controlling surfaces are smoothly varying (see figure 4.2). A binary optic is a simpler DOE that features only two phase-controlling surfaces, which introduce either a 0 or ¼ phase difference to the incident wavefront. When there are N masks, a multilevel binary optic can be generated, usually resulting in 2^N phase levels. A computer-generated hologram is a DOE that is created by reducing the calculated interference pattern to a series of phase or amplitude masks. It is similar to other diffractive optics except that the useful wavefronts tend to be one of several orders generated by the pattern. A optical element is a DOE generated by the interference of two wavefronts to produce a component that will be used as an optical component. The only distinction between this element and a hologram is that a hologram usually is intended to create a volumetric image of a scene.

Before giving a short survey of different types of DOEs, it might be useful to emphasize some concepts that can assist in understanding how diffractive elements work. The propagation of light by many optical components can be understood most easily as bundles of rays that are transmitted through an optical system to form images or to produce light patterns. To understand DOEs, however, it is best to think in terms of wavefronts. Perpendicular to the direction of propagation of the associated light ray, a wavefront is a continuous surface on which the electric field has the same phase and, usually, the same amplitude. For example, light rays coming from a source at infinity are parallel to each other, and the corresponding wavefront is a flat electric field perpendicular to the light rays, also known as a plane wave. When this plane wave is focused by a positive lens, the plane wave is converted into converging spherical waves centered on the focal point.

Refractive-diffractive continuum

Diffractive optical elements can be used in conjunction with other optical components, or they can produce effects on their own, depending on what the optical engineer requires to achieve a particular design goal. One way of surveying the range of diffractive optical elements is to place them on a continuum between a classical optical element, a lens, and a DOE with no classical counterpart, a general wavefront transformer.

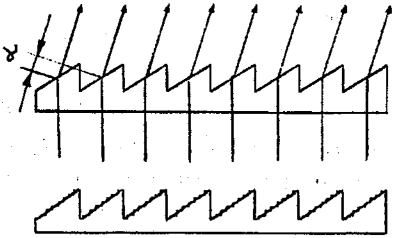

Figure 4.2. A kinoform features a smoothly varying surface (top), while a binary optic approximates the smooth surface with a series of steps (bottom)

At the classical end of this continuum is the hybrid lens, consisting of a conventional refractive lens with a diffractive structure etched into one of its surfaces. The diffractive surface can be used in lens design to correct the lens for image aberrations and color aberrations in a manner similar to the use of aspheric surfaces and additional refractive components. For example, the dispersion (variation of optical power with wavelength) of a diffractive surface is so great that only a weak diffractive lens needs to be added to a standard lens to provide the required color correction. In addition, the flexibility allowed in designing and making diffractive surfaces adds a useful tool to the lens-designer's

Because DOEs can generate specific wavefronts, they can simulate the effects of classical optical components, for example, converging and diverging lenses and mirrors (figure 4.3).

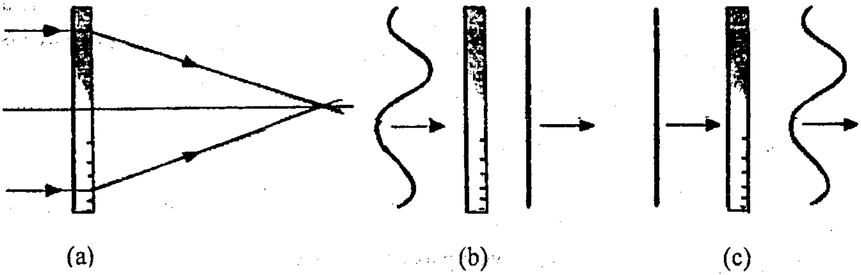

Figure 4.3. Diffractive optical elements can simulate lenses (a), wavefront correctors (b), or null connector plates (c)

Fabricated on flat surfaces, DOEs also can be used to correct aberrated wavefronts. Conversely, they can act as null correctors in optical testing, providing the precise wavefront that, when transmitted through the optical system under test, should generate a simple, easily detected plane or converging wavefront so that any deviations can provide information on residual errors in the tested optics. DOEs also can act as beam samplers, devices that divert a small fraction of a wavefront from the direction of propagation for testing and control while permitting most of the beam to be transmitted without modification (figure 4.4).

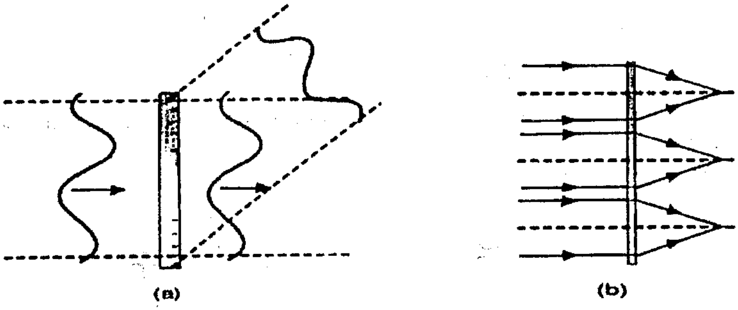

Figure 4.4. Other DOEs with classical analogs include beam samplers (a) and diffractive lens arrays (b)

Diffraction gratings

Another class of DOEs, called pattern generators, is based on a diffraction grating, Most people tend to think of a diffraction grating as a device for separating light into its spectrum of colors. If the incident light is monochromatic, the periodic structure produces a fan of regularly spaced beams. Their direction is given by the grating equation,

$$m\lambda = d \cdot \sin\theta_m, \tag{4.1}$$

where lambda is the wavelength of light, the θ_m is the angle of the diffracted order m, and d is the repeat distance of the grating. In contrast to conventional gratings, the microlithographic technology used to generate these DOEs can yield structures that control the relative intensities of the individual beams. This is done by shaping the profile within each repeat.

One particularly useful application of pattern generators is the optical interconnect. By engineering the diffraction efficiency of a diffractive optical element in its various orders, light from a number of sources, such as diode lasers, can be directed to a number of detectors (figure 4.5). These interconnects can be used both for switching applications and as the basis for arithmetic elements in an optical computer.

As fabrication technologies advance, additional applications of diffractive optics emerge. If we construct a grating with smaller and smaller grating constants, the beam fanout angles increase. Eventually we reach a point at which d is smaller than the wavelength of the illuminating radiation. At that point, according to Eq. 1, there are no diffracted orders, only the zeroth order. It would seem that such a device would be useless, but these subwavelength structures can be used to simulate the effects of antireflective surfaces and birefringent elements.

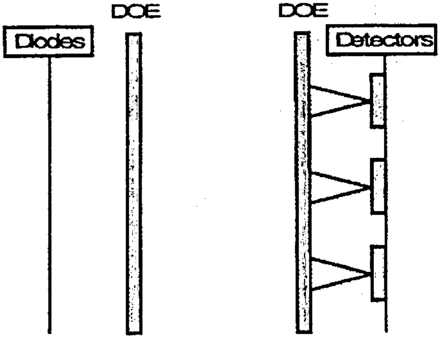

Figure 4.5. A simple optical interconnect made of two diffractive optical elements (DOEs) can provide multiple paths between arrays of diodes and detectors

Consider, for example, the triangular structure shown in figure 6, which is fabricated on the substrate of some optical element. If the refractive index and shape of the triangular structures are made properly, the serrated surface will transmit light of a particular wavelength with no reflections. It acts much like conventional antireflection films, but it has a number of advantages over standard multilayer coatings. There are no thermal expansion mismatches or surface adhesion problems. It has a large field of view and bandwidth, and it is lightweight and compact compared with other filters. Finally, it is fabricated from isotropic materials and can accommodate substantial refractive index mismatches. Because its profile is similar to that found in the eyes of moths, it often is called a moth's eye structure. Other subwavelength structures can be designed to function as filters and polarizers.

(By Donald O'Shea, Georgia Institute of Technology; Thomas Suleski and Alan Kathman, Digital Optics Corp.; and Dennis Prather, University of Delaware SPIE, OEMagazine, Ma,y 2001)

UNIT 5

1. *Memorize the following words:*

- alignment
- to emerge
- share
- disruptive
- to enable
- long-term
- to estimate
- transparent
- efficiency
- to dope
- band gap
- appropriate
- compound
- with the exception
- to improve
- innovative
- resolution
- to pattern
- to view
- to displace

2. *Translate these synonyms and memorize them:*

- place *(v)*, put
- control *(v)*, govern, regulate
- connect *(v)*, join, couple
- operate *(v)*, work
- ability *(n)*, capability
- amount *(n)*, quantity
- usually *(adv)*, generally, commonly, ordinary
- completely *(adv)*, entirely
- proper *(adj)*, suitable
- with respect to *(adv)*, with regard to

3. *Translate the international words without a dictionary:*

construction, structure, sum, element, component, variation, potential, circular, local, resource, actually, to configure, spectrum, ultraportable, positive, fraction, to realize, region, regular, ordinary.

4. Translate the following sentences paying attention to the infinitive constructions:

1. The sun is known to have a 11-year cycle of activity.
2. The ancients thought electricity to be invisible fluid.
3. Billions of stars are assumed to exist in the universe.
4. The proton is found to be 1840 times heavier than the electron.
5. We consider nuclear energy to be the prime source of heat energy.
6. The birthplace of man is believed to be somewhere in the eastern hemisphere, but in just what region or even on what continent it is still impossible to say.
7. We know an alternating current to be continually changing by rising, falling and changing direction.
8. Certain properties of matter are considered to be always the same under definite conditions.
9. Devices for accepting information are said to have been described in some magazines.
10. We know pressure to be required for forcing water through a pipe.

5. Translate the texts:

Text A. **Visionary Technology**

Disruptive technologies like LCoS and OLEDs are shouldering their way to the forefront of a microdisplay market in flux.

Where there is technology, there is change, and the display market is a case in point. Once upon a time, CRT technology was the lone contender of the display world, cornering every niche from monitors to televisions. Then liquid crystal displays (LCDs) emerged, moving into prominence when the development of active matrix liquid crystal displays (AMLCDs) made the laptop computer a reality.

Now, the geography of display manufacturing and technology is changing, yielding a market in flux. The opportunities, meanwhile, are tremendous. According to market research firm Stanford Resources, Inc. (San Jose, CA), the global microdisplay market alone will reach $1.4 billion in unit sales by 2006, doubling its current value. In such a market, there is room for new technology.

Market on the move

For years, the LCD market has been dominated by Japanese manufacturers, who held nearly 72% market share as recently as 1998, but there is a sea change ahead. According to Barry Young, vice president of DisplaySearch, Inc. (Austin, TX), Korean manufacturers such as L.G. Philips (Seuol, Korea) and Samsung (Seuol, Korea) are claiming an aggregate market share of more than 31%, a number that is growing annually.

Taiwan also is lining up for a piece of the action, though its current market share is only about 15%. "Taiwan has made a lot of bold commitments and bold announcements about investing," says David Mentley, senior vice president at Stanford Resources. "They've followed through for the most part, but it's a pretty bad time to be coming into the market. Nobody's happy right now because prices are really dropping."

According to DisplaySearch predictions, by 2005 Taiwan's market share will equal that of Japan's at 33%, with Korea running close behind at 29%. The Japanese hegemony over LCD display production appears to be ending.

Getting small

The real story, though, lies in some of the newer microdisplay technologies that are now coming to market. Liquid-crystal-on-silicon (LCoS) displays and organic light-emitting diode (OLED) displays are disruptive technologies that have the potential to change a marketplace dominated by CRTs and LCDs. The primary market sectors for LCoS, a reflective technology, consist of projection displays and various near-eye virtual imaging devices, such as mobile Internet viewers or head-up displays that superimpose images over a scene. A neurosurgeon, for example, could view an MRI image of a patient's brain while performing a delicate operation, or an aircraft mechanic could view plans or maintenance procedures while working on an airplane engine.

OLEDs, which are based on an emissive technology, are finding market potential as camcorder viewfinders, digital camera displays, and wireless phone displays. Eventually, OLED manufacturers hope to produce large-screen devices, or displays on flexible plastic substrates that might someday enable electronic newspapers, foldable electronic maps, or clothing with dynamic designs. Working with plastic substrates also opens up the possibility of web-based processing, which is enormously appealing from an economic point of view.

The market is poised for growth: According to Kim Allen of Stanford Resources, LCoS and OLED revenues are likely to reach $717 million by 2005, up from $2.6 million in 1999. The OLED wireless-phone display market alone should reach $40 million by 2005.

Attractive though it might be, the display industry in general is a challenge. "It's a very capital-intensive business," says Mentley. "The revenue per investment is quite poor, actually--for every dollar of capital investment the industry gets 80 cents in revenue. That's not going to change much with a technology as complex as active matrix [LCoS and OLED displays].

Other contenders

The digital multimirror device (DMD) from Texas Instruments, Inc. (Plano, TX) focuses on the same markets as LCoS. The device incorporates an array of tiny microelectromechanical systems (MEMS) mirrors (pixels) that can tip to reflect incident light to the viewing screen or deflect it.

Field-emission displays (FEDs), which consist of arrays of tiny electron guns that excite phosphors into emission, offer impressive performance, but the issues of manufacturability and cost remain. "There's a lot of uncertainty about manufacturing and long-term stability," says Mentley.

The saga of FEDs shows how difficult it is to take a new technology from the labs to the market, Mentley notes. "There are a lot of things that need to be invented. It's really hard for one or two companies to do that. With OLED displays the job isn't any less large but there are lots of people involved." He estimates that nearly 85 companies worldwide are involved in some level of the OLED effort.

Despite all of the activity on the research and development front, only two companies are actually shipping OLED products in volume. Passive matrix OLED displays from Pioneer (Tokyo, Japan) have appeared in cell phones from Motorola

(Schaumberg, IL) and in car stereo displays, and TDK (Tokyo, Japan) has fielded a similar product.

Growth and change appear to be the twin hallmarks of the display industry. Some of the new technologies will make an impact, then fade into the shadows. Others appear to be well-positioned for the future. One thing is certain: In eight to ten years, the display industry--and your wireless phone, your television, and your desktop--will look very different.

(By Kristin Lewotsky, OEMagazine, February, 2001)

Text B. **Brightness on Display**

In 1987 the research group at Eastman Kodak Research Laboratories (Rochester, NY) reported an organic electroluminescent diode with some rather remarkable characteristics. By choosing organic instead of inorganic semiconductors in a novel device resembling a conventional *p-n* diode, we produced intensive electroluminescence while using a low-drive voltage. This efficiency indicated great potential for display applications, and intense research and development efforts on organic light-emitting diode (OLED) ensued in numerous industrial laboratories, particularly in Japan. A little more than a decade later, the first OLED displays have been commercialized, and the technology is poised to challenge the dominance of liquid-crystal displays (LCDs) in many applications. Indeed, OLED technology is considered disruptive in the display industry because it can so radically change its landscape.

Structures and materials

OLED devices can be divided into two classes: small-molecule devices and organic-polymer devices. Small-molecule devices are fabricated using vacuum evaporation techniques, whereas polymer structures can be applied using spin-casting or even ink-jet printing techniques. Originating at Eastman Kodak Co. (Rochester, NY), the small-molecule technology has achieved commercialization.

The *p-n* diode structure proves to be a key feature for the OLED device. The basic structure consists of two layers of organic thin films -- a hole transport layer and an electron transport layer -- sandwiched between an anode and a cathode . These two organic layers, each on the order of about 500 Å thick, provide the appropriate media for transporting charge carriers, which are holes from the anode and electrons from the cathode, toward the interface formed between the two layers.

This two-layer design also is important because it provides the necessary energetic barriers at the interface to effectively localize the recombination of the oppositely charged carriers at or near the interface region. As a result, this organic interface region, on the order of 100 to 200 Å thick, is also primarily responsible for the light generation from the OLED device. The luminance efficiency as well as the colour of the OLED depends on the molecular compositions of this organic interface.

One of the most basic OLED device structures uses an organic material called NPB as the hole-transport layer and tris-8-hydroxyquinoline aluminum (alq$_3$) as the electron-transport layer. A typical structure incorporates layers of indium tin oxide/ NPB/alq$_3$/magnesium-doped silver (ITO/ NPB/alq$_3$/Mg:Ag), where ITO is the transparent anode and Mg:Ag is the cathode. The energy barriers between the highest occupied molecular orbital (HOMO) and lowest unoccupied molecular orbital (LUMO) levels are about 0.4 and 0.9 eV, respectively, which are sufficiently high to localize the holes in the NPB layer and electrons in the alq$_3$ layer. Recombination of these charges occurs across the barriers, with holes primarily moving into alq$_3$. This effect produces excited states or excitons in alq$_3$ that emit a green fluorescence with its characteristic efficiency. The overall external quantum efficiency is about 1% in photons emitted per charge passing through the OLED device.

Altering the basic two-layer structure to include a luminescent layer between the hole-transport layer and the electron-transport layer can yield OLED devices with much improved efficiencies. A well-known scheme is to dope the interface region with molecules of high fluorescence efficiencies, as in the three-layer NPB/alq$_3$:C540/alq$_3$ structure. Here, alq$_3$ is the host and C540, a coumarin laser dye, is the dopant present at a concentration of about 1%. The luminescent layer is simply a part of the alq$_3$ electron-transport layer doped with C540. Because of the enhanced fluorescence from the dopant, the electroluminescence efficiency of the doped OLED device can exceed that of the undoped device by a factor of two to three.

Doping for performance

The doping scheme is broadly applicable in producing OLED devices that can display a wide range of colours, including white. Green and red, or any color shades in between, can be readily produced using alq_3 as the host with a suitable choice of one or more dopants in the luminescent layer. By using a blue fluorescent dopant and a host material with a wider bandgap, researchers have obtained efficient blue OLEDs. Similarly, white devices have been made by selecting an appropriate dopant or a mixture of dopants in a blue-emitting host.

More recently, the doping scheme has been successfully applied to OLEDs using phosphorescent compounds as the dopant. Steve Forrest's group at Princeton University (Princeton, NJ) has obtained remarkably efficient devices using a platinum (Pt) porphorin as the red dopant and iridium polypropylene ($Ir(ppy)_3$) as the green dopant. The reason that these phosphorescent OLEDs can be much more efficient than the conventional fluorescent versions is that charge reccombination's in molecular solids or films statistically result in three times as many triplet (phosphorescent) states as singlet (fluorescent) states. But for most organic materials, phosphorescence from the triplet states is generally inefficient at room temperature, with the exception of a few classes of organometallic compounds containing heavy metal ions that help to relax the forbidden triplet-to-singlet transitions. Further optimization of device structure of the phosphorescent OLEDs has reportedly resulted in luminance efficiency as high as in excess of 50 cd/A.

The reliability of OLED devices has been the major concern for practical applications. It has, however, improved substantially over the years. Using various sets of organic materials, many laboratories have reported achieving luminance life (half decay) on the order of 10,000 hours in devices of all colors using various sets of organic materials. Some of the reliability problems, such as the deterioration of the reactive cathode, have been adequately addressed with engineering solutions. The more basic problem of organic material degradation is now better understood. For instance, it has been shown by Zoran Popovic of Xerox Canada, Inc. (Toronto, Ontario) that it is the hole carrier in Alq3 that is partially responsible for the OLED degradation, and remedies for such a degradation include deliberate introduction of stabilizing dopants.

OLED displays

An OLED is a current-driven device that is, the intensity of the output light is directly proportional to the electrical current flow through the device. An OLED display, therefore, requires the control and modulation of electrical current levels through individual elements (pixels) in order to display text or graphic images.

There are two types of OLED display architectures: passive matrix and active matrix. In a passive-matrix OLED display, the columns provide the data signal, and the rows are addressed one at a time. The current flow through a selected row is necessarily pulsed to a level that is proportional to the total number of rows in the display. This instantaneous current requirement places a restriction on the size and resolution of the passive matrix design. This restriction is removed in an active-matrix OLED display.

Although passive-matrix OLED displays are relatively simple constructs with intersecting anode columns and cathode rows, their fabrication requires an innovative solution. The major challenge lies in patterning the reactive cathode without interrupting the underlying organic layers. This problem is solved by the integrated shadow mask method, which involves patterning the cathode before the organic layers and the cathode itself are deposited. To fabricate *in-situ* cathode separators, manufacturers first pattern the ITO anode, then pattern the integrated shadow mask. Deposition of organic layers takes place next, followed by deposition and isolation of the cathode layer. In a useful design of the cathode separators together with the completed layer structures, the topological features are designed to break the continuity of the cathode layer, thereby forming electrically isolated buses .

In an active-matrix OLED display, each individual pixel can be designed to switch on or off within a frame time. As a result, the device does not suffer the resolution limitations or the high-instantaneous-current requirements of a passive-matrix design. A conventional active-matrix design features two transistors and one storage capacitor per pixel. Gate voltage modulation yields gray scale output.

Researchers have demonstrated active-matrix OLED displays based on polysilicon or crystalline silicon. The size and resolution of these displays are determined by practical considerations such as the constraints of the substrates rather than the OLED component. Low-temperature polysilicon permits the fabrication of display sizes as large as 5.5 in. on the diagonal. Crystalline silicon limits the display sizes but permits the manufacture of very-high-resolution devices with pixels as small as 12 μm. Because the pixel architecture and electrode geometry for the OLED element are already defined on the substrate, the fabrication of the OLED component is straightforward. The cathode is continuous over the entire display area, requiring no patterning.

In living colour

Production of full-colour passive-matrix, or active-matrix OLED displays requires a method for patterning the red, green, and blue colour pixels on a substrate. This is a major challenge because OLED materials and device structures are generally incompatible with conventional patterning methods. Researchers have developed useful techniques to surmount these difficulties, including precision shadow masking and use of a colour-changing medium.

In precision shadow masking, a thin stencil mask with precisely defined aperture holes selectively shadows the vapor stream during the organic layer deposition in the vacuum chamber. This method requires precision engineering of the shadow mask and also precision contact alignment between the substrate and the mask. Active-matrix OLED displays with roughly 50 mm color dot pitch have been demonstrated by Kodak/Sanyo. Pioneer (Tokyo, Japan) and other companies have produced 5.2-in QVGA displays using the shadow mask method.

The color-changing-medium (CCM) approach is unique to OLED technology and was first used by Idemitsu Kosan Co. (Chiba, Japan). In this method, a blue OLED display is fabricated on top of a colour-changing medium consisting of an array of fluorescent dots. The medium converts the blue display to a full-color display by down-shifting the blue emission from the OLED to produce blue, green, and red colours. Kosan's group has demonstrated colour 5.2-in. QVGA and 10.4-in. VGA devices.

OLED is a viable flat-panel display technology because it has an important set of attractive attributes: high luminous efficiency, colour, wide viewing angles, low drive voltage, fast response, and low process temperature. Passive-matrix products are appearing in consumer electronics products such as wireless phones, and prototype active-matrix, full-colour displays have gained considerable acclaims for their vivid image quality. There is no doubt that OLED will progressively displace LCDs in many applications and has the potential to become a display of choice for the future generations.

(By Ching Tang, Eastman Kodak Research Laboratories, OEmagazine, February, 2001)

UNIT 6

1. *Memorize the following words:*

- vehicle
- to convert
- to couple
- to provide
- to outline
- mainly
- respectively
- to impose
- absorption
- scattering
- redundancy
- mesh
- cost-efficiency
- impact
- reasonable
- etching
- undertaking
- breakthrough
- viable
- contamination

2. *Translate the synonyms and memorize them:*

- zero *(n)*, naught, cipher, 0
- damage*(v)*, break, destroy
- aid*(v)*, help
- present*(v)*, represent
- can*(v)*, be able
- make*(v)*, produce, manufacture, do, fabricate
- remove*(v)*, draw away, take away
- near*(adv)*, close to
- call*(v)*, name, term
- cause*(v)*, give rise to

3. *Translate the international words without a dictionary:*

mobile, to attack, approximation, to dominate, to patent, composition, fabrication, defect, complex, extraordinary, term, decade, container, universal, reality, radiation, integrated, evolution, serious.

4. ***Translate the following sentences paying attention to the infinitive constructions:***

1. We know B. Pascal to be the first inventor of the mechanical computer.
2. The magnetic recording is done on a disk which permits an information to be stored or read at one or several points on it.
3. Our engineers want the complex problems to be solved by computers.
4. Information has to be in the form of digits or characters for a digital computer to perform reasonable operations.
5. In the laboratory we saw the perforator punch holes in the cards of standart size.
6. It's quite necessary for the programmer to understand the work of all units of a computer.
7. We watched the floppy disk begin to operate.
8. They know these three factors to be the tube parameters or characteristics.
9. They consider most tubes of this type to use mercury vapour as the gas.

5. ***Translate the texts:***

Text A. **Meeting DWDM Demands**

Optics companies need to respond to the challenge of upscaling processes and capabilities if they want to survive the networking boom.

We all have seen the projections: The optical networking market is expected to grow at a rate of about 50 percent per year for the next five years. Implementation of these networks will require a huge volume of basic optical components, such as filters, mirrors, polarization optics, and prisms. These basic components deserve more attention in the network planners' efforts to connect the world.

Beginning in the mid-1990s, the demand for increasing production efficiencies in semiconductor fabrication drove up demand for high-quality optics. The industry also moved to deep-ultraviolet (UV) excimer lasers for lithography and into UV regions for inspection systems. Coinciding with these technical advances was the start of the electronics industry's biggest-ever building boom of wafer fabrication facilities.

The impact on manufacturers of laser optics was huge. Optics companies saw the opportunity to grow at unheard-of annual rates of up to 50 percent. But 50 percent growth in optics sales was not sufficient to draw capital investment into the industry at that time, so optics companies expanded using debt or internally generated funds. New companies were started but they were mostly undercapitalized. As a result, extremely long lead times and shortages were the order of the day.

After a two-year boom, the market for semiconductor fab equipment, following its normal strong cyclicality, petered out. Many optics companies struggled for survival. Some were weakened or bought out at very low valuations by stronger competitors.

Could this pattern happen again in the demand for dense-wavelength-division-multiplexing (DWDM) optics? If Intel's Andy Grove is correct and "only the paranoid survive," optics company managers have to consider this possibility as they respond to the requests for quotes (RFQs) for optics in annual quantities of hundreds of thousands, or even millions.

Differences in optics fabrication

So why can't companies fabricating high-quality optics react to the market demand as fast as the companies that incorporate those optics into component packages or systems for the end applications? I think there are three major factors at work.

First, most optics companies remain privately owned and don't have access to the public markets for capital. As a result, they have to be much more careful with what little capital they have. Expanding 50 percent to 100 percent per year is "betting the farm."

Second, high-quality optical fabrication techniques remain heavily skill and time oriented. People who visit a very good optical fabrication shop for the first time always remark, "How can they achieve such high-quality products with that equipment?" Some equipment manufacturers have attempted automation, but with mixed results and questionable cost efficiency.

Third, only rarely can people make the leap to master optician after just a few weeks of training and a few months of experience. In most high-quality optical fabrication, the individual technician makes a much more important contribution to the success of a production run than the equipment he or she is using. It may take years just to develop the skill needed to polish quartz to 1 Å rmf surface roughness.

Some might ask if the tens and hundreds of thousands of optical components manufactured annually for camera and telescope applications could be put to use for DWDM products. Yes, high-volume, high-speed techniques are used in manufacturing lenses and prisms for these applications, but those optics can tolerate very large imperfections in material and surface quality while still functioning adequately within the limits of human vision. The specifications for DWDM optical components are at the opposite end of the quality spectrum. The efficiency requirements of these systems will not allow vision-grade optics. The challenge is to scale up the capabilities of fabrication processes to yield volumes of higher-quality optical surfaces.

Teaming up on DWDM

In the last 12 months there has been overwhelming interest by the DWDM systems integrators in coating technology and capacity. Several private and a few public coating companies have been acquired for truly astonishing valuations. Partnership with a much larger parent gives these companies improved access to capital for capacity expansion and process development. It also provides the optics company with better market vision in product development efforts. This kind of partnership minimizes the risk a private company incurs when it dedicates itself to a single industry.

So far, interest and acquisitions have focused, with a few exceptions, on a single element in the DWDM system: thin-film bandpass filters. There is significant cause for concern about the world's capacity for high-quality micro lenses, prisms, beamsplitters, waveplates, polarization optics, and similar basic components, however. Will the industry direct capital and intellectual effort to the need for significant expansion in capacity for these optical components?

It is clear that appreciable capital will be necessary. If not forthcoming, these components may become the gating element in the system as other, more critical, issues are resolved.

(By Jim Higdon, CVI Laser, Inc. OEmagazine, March, 2001)

Text B. **Into Thin Air**

Under test as an access loop solution, optical wireless technology sends voice and data over free space.

Fiber-optic networks transmit enormous amounts of voice/data traffic around the world, but the technology is not the universal telecommunications panacea. Deployment of fiber networks is expensive and time consuming. Particularly in urban areas, laying fiber requires getting permits, tearing up streets, and digging ditches. For enterprise networks and the access networks that connect the edge of the metropolitan area network to the in-building network, the fiber-optic technology can be cost-prohibitive.

Wireless optical networks (WONs) offer an economical alternative to fiber. WONs operate building to building, sending a signal over free space across a clear line of sight. The output beam from a near-infrared (IR) laser source is modulated with a data stream and transmitted. At the other end of the link, a receiver gathers the beam and transfers it to focusing optics prior to detection by a photodiode and conversion to a data stream. A typical system is essentially bidirectional, operating on two separate, closely spaced beamlines. Most frequently, systems operate between rooftops, but they also can be mounted along building façades or behind windows. Depending on local conditions, links can range from 200 to 500 m, with data rates as high as 622 Mb/s (OC-12).

High-bandwidth wireless optical networks deployed building-to-building in an urban area offer fiber-class speeds at about one-fifth the cost of installing fiber. Moreover, network deployment takes days rather than months or years.

Nuts and bolts

Most WONs incorporate diode laser sources. The CD-ROM industry and the long-haul telecom industry have both developed diode lasers with broad bandwidths, high powers, and high reliability. Although long-haul dense-wavelength-division- multiplexing (DWDM) systems incorporate components operating at 10 Gb/s, using that technology for WONs is neither straightforward nor necessarily cost effective—the CD-ROM laser costs about $20 (AirFiber uses a 785-nm Class 1 eye-safe laser), and the long-haul DWDM laser (1310 nm or 1550 nm) costs about $1000.

For detectors, systems generally use either p-i-n photodiodes or avalanche photodiode (APD). WON receivers use large-area photodiodes because of beam degradation caused by atmospheric effects. Designs must thus be tolerant of relatively high-capacitance detectors. Generally transimpedance amplifiers are used, but designers must keep feedback resistance low due to high input capacitance. Thus, in many cases, the system becomes limited by detector noise. Designers therefore turn to APDs, which offer internal gain that greatly increases system sensitivity.

Systems suffer geometric loss, defined as the amount of transmitted signal that fails to reach the receiver. The divergence of the transmitter beam essentially sets this fraction, assuming the receiver aperture is smaller than the diameter of the beam at that point. Typical divergence for an AirFiber link is 1 mrad, measured at the $1/e^2$ point of the Gaussian beam. The fraction of received power is the inverse of the square of the divergence; for example, a system with a 2° beamwidth would suffer about 30 dB more power loss than one with a divergence of 1 mrad.

Most WON products use a combination of spatial and spectral (bandpass) filtering to reject solar interference and increase signal-to-noise ratio. Typical values are rejection of 25 dB or so compared with a nonfiltered system.

In the atmosphere

Atmospheric effects impose loss on a wireless optical link (WOL) through absorption, scattering, and scintillation. A good rule of thumb for determining link range is that if you can see it, you can communicate with it. This rule of thumb also gives potential users an intuitive feel for the relative importance of fog, snow, and rain in preventing link operation. Fog sometimes can obscure the building across the street. Rain hardly ever comes down hard enough to limit visibility severely. And snow lies somewhere in between the two. It turns out that this rule is a bit conservative—a WOL can send data reliably about twice as far one can see.

Many species of gases in the atmosphere can cause absorption, but water is the dominant factor for operating wavelengths of WONs. By using a transmission wavelength outside of the so-called water window and keeping the path lengths short, absorption can largely be ignored.

There are two types of scattering mechanisms: Rayleigh and Mie scattering. Due to its low cross-section, Rayleigh scattering is really only significant for very long path lengths. The effect scales as $1/\lambda^4$, making it significant only at shorter wavelengths. Scattering by particles, also known as Mie scattering, is a different story, particularly as the size of the particles approaches the wavelength of the transmitted light. Wavelengths near the particle size are scattered very effectively, hence the deleterious effect of fog, which can cause losses as high as 300 dB/km. To compensate for fog, systems can keep the link length short and increase laser power during episodes of decreased visibility.

Scintillation refers to small spatial variations in the refractive index of the atmosphere. The effect can introduce phase changes in the wavefront of the signal arriving at the receiver causing both null- and high-signal receive levels. Fortunately for short- range systems these effects are relatively small, on the order of several dB for a typical link span of 200 m.

Architecture

There are basically three types of network architectures: point-to-point, hub-and-spoke, and mesh. The most common architecture is point-to-point systems, linking buildings of a single enterprise. Network planning is simple and links are independent, but the optical link is a single point of failure without redundancy and is not suitable for carrier-grade systems.

The hub-and-spoke architecture allows traffic to be routed easily from a single point to the core network. Each link is a single point of failure, however, and hub location must be chosen to maximize the number of buildings with line of sight. Hub cost is generally high. Given that attenuation effects require short link lengths to ensure carrier-grade service, this is not a very economical architecture.

A mesh architecture offers a redundant system with near-realtime rerouting. Traffic is collected at specific points for efficient connection to the network. The disadvantage is cost (multiple links per building), and the network requires specialized network planning. Both mesh and the simpler loop architectures are for carrier-grade networks.

WON systems can be engineered to deliver fiber-like bandwidth and carrier-grade reliability at a fraction of the cost and time of laying fiber. The technology can bring OC-12 data rates to the campus and access loop easily and economically. In industrial and urban areas, optical wireless access loop technologies may well be the wave of the future.

(By Scott Bloom and Janet McVeigh, AirFiber, Inc. OEmagazine, March, 2001)

UNIT 7

1. Memorize the following words.

- thermal
- imaging
- streamline
- to determine
- to affect
- similar
- supplier
- to expend
- front-end
- to encompass
- issue
- broad band
- to navigate
- delivery
- edge
- immersion
- prior
- streaming
- playback
- to deal with

2. Translate these synonyms and memorize them:

- denote (v), mean, indicate, express, show, mark
- explore (v), research
- keep (v), retain, hold, preserve
- actually (adv), really
- various (adj), different
- intersect (v), cut, cross
- ascertain (v), determine, define
- shape (n), from
- in addition (to) (prep), besides
- rarely (adv), seldom, infrequently

3. Translate the international words without a dictionary:

term, function, static, linear, proportional, graphically, importer, double, impulse, neutralize, to accumulate, positively, to evacuate, actual, to utilize, attraction, barrier, audio, extremely, decade, national.

4. Translate the following sentences paying attention to the passive forms:

1. An ammeter should be connected to the circuit in series.
2. The transmitter section of the telephone is equipped with a special microphone and an amplifier to enlarge the voice of the speaker.
3. Electric signals are amplified with the help of a semiconductor device.
4. The student was asked if pure germamiune could be employed as a semiconductor material.
5. The grid must be placed between the cathode and plate.
6. This subject will be dealt with different elements.
7. The computer's role is influenced not only by its speed but also by its memory-size.
8. These digits are easily multiplied.
9. The sequence of reasonable operations has been performed by the computer.
10. They were explained how to solve this problem on a computer.

5. Translate the texts:

TEXT A. **IR Determines the Effectiveness of Drugs**

As the worldwide pharmaceutical market continues to grow, it requires more effective and quicker drug-testing methods in order to thrive. Thermal imaging may be the answer.

Thermogenic Imaging (Billerica, MA), a spinoff of FLIR Systems Inc. (Portland, OR) and GlaxoSmithKline PLC (GSK; Greenford, UK), has developed thermal-imaging technology designed to help streamline drug-discovery applications. An *in-vivo* version provides noninvasive, high-throughput screening of drug compounds in rodents. Another system, a fully automated 96-well microtiter plate reader, measures thermogenesis in cell culture. The company will eventually offer a portable system for investigatory human diagnostics.

"These systems could be quite useful," says Brent Stockwell, principal investigator of molecular biology at the Whitehead Institute (Cambridge, MA). "One can do more experiments with the lab animals and drug compounds in less time than with traditional invasive technology."

Temperature is directly related to disease, says Jay Tiech, CEO of Thermogenic Imaging. In the case of a tumor, for example, very tiny blood cells grow uncontrollably and feed the growth, which makes the tumor very hot. Temperature also is associated with the effectiveness of a drug. Cells produce heat as a byproduct of their metabolic activity. Cellular metabolism often changes as a result of receptor activation by a drug compound.

In the drug discovery process, researchers start with a protein that is found in a disease, says Stockwell. Then they try to find a small molecular drug that would inhibit the function of the protein in the test tube. "Usually you test hundreds of thousands of such molecules until you find the one that sufficiently inhibits the protein," says Stockwell. At that point, the researcher must determine whether the candidate drug works in a cell or an animal, typically by developing a cell-based assay or injecting the compound into a mouse.

Thermogenic's Mercury Wellplate reader measures thermal activity to determine how long and to what extent the cell may be affected by a drug. An automated compound delivery system deposits the experimental drug onto proprietary, note-sized wellplates containing cells. A robotic feeder moves the plates through the process. As the drug reacts with the cells, a gallium-arsenide quantum-well focal-plane-array detector reads the infrared (IR) radiation emitted by cells through an IR-transparent window on the bottom of each well. The refrigerator-sized instrument can measure thermal variations as small as 5 mK (0.005°C).

With a similar technique, the bench-sized animal reader images one to 10 animals *in vivo*. A heating pad under the holding pen warms the mice while a high-sensitivity IR camera takes an image. Simultaneous animal core temperature reading can be used as a correction factor.

"One can immediately see the rise in temperature as the drug reacts with the [sample/subject], then measure how long before it cools down as the drug wears off," says Tiech.

The thermal-based process can speed up individual tests and allow a researcher to move more drug candidates through the process, says Stockwell. Considering how many candidates fail, it is important to process as many potential drugs as possible in the hopes that one will be the solution.

"There is the potential for hundreds of millions of dollars in this [IR testing] market," says Skip Irving, managing director of Health Advances Inc. (Wellesley, MA). "We visit a company with one idea of how they might use the technology, and then they come up with six or seven others."

(By Laurie Ann Toupin, OEMagazine, 2001, Jule)

Text B. **Staying Ahead of the Game**

Maintaining diversity in an ever-changing industry is smart strategy.

Whoosh. Is that the sound of optical companies scrambling to support the needs of the telecom industry? Or is it the sound of the air rushing out of the telecom bubble? The problem is that it may be both.

As many have remarked, history does repeat itself, and we may be seeing the early warning signs in the optics industry right now. For many years, the optics industry put a lot of its eggs into the military basket. It was a safe, predictable, and often lucrative market. About ten years ago, the demand for military optics abruptly declined, forcing manufacturers to diversify into other markets. That led to a broader base of advanced photonics products for the medical, instrumentation, biotechnology, and telecommunications industries. The optics industry was necessary, but it had a low profile and low visibility in its support of those industries.

Telecommunications technology's rather sudden rise to financial stardom changed all of that. Optics are now recognized as a critical, high-profile component to the industry and were thus pushed into the spotlight. The demand of the telecom sector for optics has been overwhelming and lucrative. It is not difficult to understand why the sudden emergence of the market caught everyone's attention. Like the prospectors in any gold rush, many optics suppliers jumped into the telecom market hoping to get a piece of the action.

Accordingly, we have watched long-time optics players reposition themselves as telecommunications suppliers. Many of the industry stalwarts are now captives of the telecom players. At Edmund Industrial Optics, we also have experienced a frenzy of buying as the telecom giants protect their channels of supply, but we have resisted becoming too focused on this market to the exclusion of all others.

Navigating the downturn

Given the current market downturn, we now wonder if the expansion of telecom was just another bubble phenomenon. Are we confronting another period of correction similar to that of ten years ago?

Nevertheless, the rise of telecom has affected the optics industry in profound ways. Some of these effects will be long lasting and some will be transient. For example, companies that were heavily dependent upon orders from telecom companies must now scramble to serve other markets again.

The shift in focus to telecom applications also has contributed to some structural problems. The optics industry is already thin on engineering resources, and with a single market dominating the talent pool, we question whether the photonics industry will have the resources to service the needs of all the other markets. If not, work-force shortages will likely slow product development in other industries such as medical instrumentation, semiconductors, and consumer products that rely on optical technology.

Our team has found that a good strategy is to leverage a diverse customer base to develop single products to serve the needs of multiple markets. That way, precious product development and optical engineering resources are not expended on a single application. This also works well in under-resourced markets where we can provide optical know-how, stability, and consistency of service to gain many new and loyal customers.

As an industry, we need to understand that technology bubbles will come and go, and that in the future, Wall Street will play an even more influential role in the photonics industry. Flocking to the hot sector, while alluring, can be dangerous too. Steady, prudent management is needed to determine how our vital capabilities are used and protected so that the entire optics industry can remain healthy.

(John Stack is president of Edmund Industrial Optics Inc, OEMagazine, 2001, Jule).

Text C. **Communicating in Parallel**

Multimedia is poised on the edge of a major revolution as fiber brings high bandwidth to the access network.

Multimedia. Though the term is often bandied about, the definition, for many, is vague. Robert Aston, president of Market Vision (Santa Cruz, CA) and coauthor with Joyce Schwartz of *Multimedia: Gateway to the Next Millennium,* has followed the evolution of multimedia for more than a decade. According to him, multimedia involves communicating via multiple data types such as text, graphics, video, and audio. The forms must be digital, have a high degree of structure to define what the content is and how it is to be used, and must offer front-end navigability with a consistent computer-human interface that allows the content to be received in many ways per user direction.

Aston classifies multimedia applications into four major categories: dedicated professional, business, educational, and consumer. The dedicated professional category involves content developed for a specific user subset, such as interactive sites for medical doctors and their patients. The business category includes business-to-business e-commerce, publishing applications, and manufacturing support. The education area moves beyond universities and schools to encompass libraries, museums, and distributed learning for corporate education. Finally, the consumer category involves leisure-time applications, such as entertainment, gaming, communications, and learning

In the early 1990s, cable companies were trying to drive people to multimedia through interactive television (ITV). The emergence of the Internet at that time pulled attention away from ITV, but the early Internet offered such limited capabilities that it hampered the delivery of multimedia. "The very first Internet was not a multimedia environment," says Aston, noting that most multimedia was delivered via CD-ROMs and floppy disks. The emergence of the World Wide Web with Java and Java Script brought true multimedia to the Internet, although bandwidth limitation remains a major issue.

"The next stage, of course, is broadband," Aston says. "That delivery mechanism will provide a broad enough array of applications with enough bandwidth to deliver content using video, animation, and all of the multimedia technology that we can bring to bear." Unified messaging—a platform combining fax, e-mail, and voice—will be an early application. "The ultimate multimedia mail right now is the delivery of animation and video. We saw the first emergence with the interactive greeting cards. You can go to a site, create a card and send it to someone, and it will play an animation." Such cards often include audio as well as text and graphics.

"We're now up to the beginning of another phase in this whole process—the advent of broadband. Broadband is the limiting factor. When will we have the platform to support the applications? My guess is around the years 2004 and 2005. In the interim, the real task is to train people how to be comfortable with multimedia."

Indeed, Aston sees the issue of consumer habits to be as much of a block to multimedia as current bandwidth limitations in the access network. "It will take some major changes—not only in the infrastructure, but also in the behavior of people," he says, emphasizing the need for consumers to get comfortable navigating through menus similar to those currently available on some cable systems. "Consumers need to understand why they should take the time [to use multimedia]." Certain applications, such as the aforementioned medical information delivery, will help compel people to use multimedia and increase their comfort level. Aston says e-mail applications and web browsers are training people to navigate the types of menus required. "In a few years, people will be more comfortable with interactivity and will use it for a variety of things. The next big wave, whether people like it or not, will be interactive advertising."

As to what the future holds, Aston says the technologists are making progress. "We're now catching up with more sophisticated tools for the management of content and the delivery of content," he says. "We're on the verge of breaking through this next bandwidth barrier. We're on the edge of a major revolution in multimedia."

(By Kristin Lewotsky, OEMagazine, 2001, Jule)

Text D. **On Display**

Microdisplays based on III-nitride wide band-gap semiconductors put the future in our hands.

Microdisplays are tiny, but when put into an eyeglasses headset and viewed through a lens system, they can provide a virtual image comparable to viewing a

21-in. diagonal TV or computer screen or larger. Microdisplays can satisfy demands for hands-free and highly mobile applications in areas such as computing, entertainment, military, law enforcement, fire fighting, and medicine.

During military action, for example, a head-mounted microdisplay would not only link the pilot to vital information about aircraft systems and the environment; it also would provide hands-free capability, which is vital when making split-second decisions and actions that can determine the success or failure of a mission. In a few years, microdisplays may allow people to use computers and watch television without a real monitor, offering mobility, privacy, and fun.

Current microdisplays are based on liquid-crystal-display (LCD) or organic-light-emitting-diode (OLED) technology. Semiconductor microdisplays, which require the integration of a dense array of micro-size LEDs on a single semiconductor chip offer a number of advantages over more conventional approaches. They have yet to be successfully fabricated, however, because color conversion for full-color displays cannot be achieved in conventional III-V or silicon semiconductors.

The unique properties of III-nitride wide band-gap semiconductors may bring a solution to the problem of semiconductor microdisplays by potentially offering performance superior to that of LCD and OLED displays. Unlike LCDs, which normally require an external light source, III-nitride blue microdisplays are self-luminescent, use less space and power, and allow viewing from any angle without color shift and degradation in contrast. Although OLEDs are also emissive devices, they must be driven at much lower current densities than semiconductor LEDs, limiting output intensity. Depending on the alloy composition, III-nitride devices achieve band gaps ranging from 1.9 eV indium nitride to 3.4 eV gallium nitride (GaN) to 6.2 eV aluminum nitride. The incorporation of indium yields extremely high emission efficiency, and the robust devices offer high power and high temperature operation as well as simple down-conversion of output color from UV/blue/green to red or yellow. In addition, III-nitrides are grown on sapphire substrates that are transparent to light and hence can serve as a natural surface for image display, reducing the steps for device packaging.

Performance

The emission wavelengths of our μ-LEDs vary from violet to green (390 to 520 nm) as a function of the indium content in the InGaN active layers. Based on tests of the individual μ-LEDs in the display, plots of power output versus forward current indicate good uniformity of light emission between individual devices in the array. Despite the fact that we did not use lateral epitaxial overgrowth techniques to minimize threading dislocations in the GaN layers, the devices appear to be quite efficient. The escape cone for isotropic spontaneous emission from these μ-LEDs through sapphire substrate is about 100°, which demonstrates that μ-LED displays can provide a very wide viewing angle.

Operating speed is always a concern for displays. The turn-on response for our display is on the order of the system response (approximately 30 ps) and thus cannot be measured. The turn-off process, however, is in the form of a single exponential. We found that turn-off time τ_{off} decreases as a function of μ-LED size, dropping from 0.21 ns for a 15-μm device to 0.15 ns for an 8-μm device. This may be because the effects of surface recombination are enhanced in smaller μ-LEDs. Another possible explanation is an enhanced radiative recombination rate in μ-LEDs caused by the microcavity effect. With this fast speed and other advantages such as long operation lifetime, III-nitride μ-LED arrays may be used to replace lasers as inexpensive short-distance optical links, such as between computer boards, operating at frequencies as high as 10 GHz.

III-nitride microdisplays offer a number of advantages over conventional display technologies, including self-luminescence; high brightness, resolution, and contrast; operation at high temperature, power, and speed; wide field-of-view; full-color spectrum capability; reliability; robustness; long life; and low power consumption. Likewise, the ability of 2-D array integration with advantages of high speed, high resolution, low temperature sensitivity, and applicability under versatile conditions make III-nitride μ-LEDs a potential candidate for light sources in short-distance optical communications.

(By Hongxing Jiang and Jingyu Lin, Kansas State University, OEmagazine, July, 2001)

UNIT 8

1. Memorize the following words.

- incident
- versatile
- to fabricate
- lattice
- to collect
- junction
- excess
- gradient
- to diffuse
- to refer to
- penetration
- outside
- thickness
- response
- uniformity
- to involve
- source
- capacitance
- additional
- by far

2. Translate these synonyms and memorize them:

- beam (n), ray
- job (n), work
- accurate (adj), exact, precise
- essential (adj), necessary, important, main, principal
- broad (adj), wide
- accelerate (v), speed up
- several (adj), a few, some
- in effect, in fact
- consist of (v), be made up of, be composed of
- speed (n), velocity, rate of motion

3. Translate the international words without a dictionary:

system, form, focusing, visual, final, presentation, combination, intensity, polarity, sapphire, zinc, fluorescent, specialist, speciality, specifically, specialize, specification, special, specific.

4. Translate the following sentences paying attention to the passive forms:

1. The new department of laser and optical engineering has just been opened.
2. I was asked a lot of questions about my work.
3. A lot of articles on photonics and optoelectronic technology had been translated from English into Ukrainian by the end of last year.
4. The experiments on the microdisplays were being carried out during the whole month.
5. A new equipment was transferred into the next room yesterday.
6. The sequence of reasonable operations is now being carried out by this microcomputer.
7. The conference was addressed by a well-known scientist.
8. Fabrication of photodiodes was spoken of at the last lecture.
9. Modern personal computers are always looked at with interest.
10. Many new branches of industry have been developed in our country since World War II.

5. Translate the texts:

Text A. **Photodiodes See the Light**

The purpose of any photodetector is to convert electromagnetic radiation into an electronic signal—ideally one that is proportional to incident light intensity. Because they are compact, versatile, and can be produced economically in high volume, p-i-n photodiodes have become the detector of choice in applications from biomedical instrumentation to telecommunications.

Understanding the basics

Photodiodes are fabricated from semiconductor materials. The most popular choices are silicon (Si) or gallium arsenide (GaAs), and others include indium antimonide (InSb), indium arsenide (InAs), lead selenide (PbSe), and lead sulfide

(PbS). These materials absorb light over a characteristic wavelength range, for example: 250 nm to 1100 nm for silicon, and 800 nm to 2.0 μm for GaAs. When a photon of light is absorbed, it excites an electron and produces a single pair of charge carriers—an electron and a hole, where a hole is simply the absence of an electron in the semiconductor lattice. Current passes through a semiconductor when the charge carriers separate and move in opposite directions. The trick in a photodiode is to collect the photon-induced charge carriers as current or voltage at the electrodes, before they have a chance to recombine. This is achieved using a *pn* or *p-i-n* diode junction structure—hence the term *p-i-n* photodiode

An *n*-type semiconductor material is doped to produce an excess of electrons, whereas a *p*-type material has an excess of holes, or an electron deficiency. At the *pn* junction, this disparity creates a concentration gradient that causes electrons to diffuse into the *p*-layer and holes to diffuse into the *n*-layer. This diffusion results in an opposing electrical potential, often referred to as an internal bias (see figure 1). In a region spanning both sides of the junction, this electrical force causes any charge carriers to be rapidly swept to the appropriate layer. Because charge carriers cannot reside in this region, it is termed the depletion region (figure 8.1)..

In a generic *p-i-n* photodiode, light enters the device through the thin *p*-type layer. Absorption causes light intensity to drop exponentially with penetration depth. Any photons absorbed in the depletion region produce charge carriers that are immediately separated and swept across the junction by the natural internal bias. Charge carriers created outside the depletion region will move randomly, many of them eventually entering the depletion region to be swept rapidly across the junction. Some of them will recombine and disappear without ever reaching the depletion region. This movement of charge carriers across the junction upsets the electrical balance and produces a small photocurrent, which can be detected at the electrodes.

In many applications it is desirable to maximize the thickness of the depletion region. For example, device response is faster when most of the charge carriers are created in the depletion region. This also increases the quantum efficiency of the device, since most charge carriers will not have the opportunity to recombine. The quantum efficiency is defined as the ratio of the photocurrent in electrons to incident light intensity in photons.

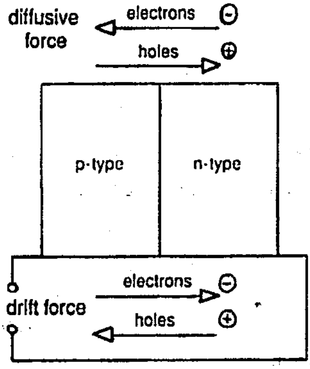

Figure 8.1. Charge carriers diffuse across the pn-junction (diffusive force) driven by a concentration gradient that produces an internal electrical field across the junction. This field drives the carriers in the opposite direction (drift force). The resultant equilibrium condition results in a small internal bias voltage.

The thickness of the depletion region can be modified by varying the semiconductor doping levels. However, the easiest way to expand this layer is to apply an external electrical bias (voltage). This is referred to as photoconductive operation, since the signal is detected as a current. Conventional unbiased operation is referred to as photovoltaic operation, because the signal is detected as a voltage. The latter is preferable for applications requiring high linearity of response and/or low dark noise.

Device optimization

Manufacturers produce photodiodes in a wide range of shapes and sizes, with each design optimized to meet the specified parameters. The most important performance characteristics are response speed, quantum efficiency at the wavelength of interest, size and shape of the active area, response linearity, spatial uniformity of response, and dark noise or other noise sources that impact the sensitivity. Photodiode sensitivity is very important in low-light applications and is typically quantified by noise equivalent power (NEP), defined as the optical power that produces a signal-to-noise ratio of unity at the detector output. NEP is usually specified at a given wavelength and over a frequency bandwidth of 1 Hz and is therefore expressed in units of $W/Hz^{1/2}$.

Because the various performance parameters are interrelated, device design often involves careful tradeoffs to achieve optimum performance. For example, an application based on the detection of an unfocused source of light may require a detector with a large active area. If this application also requires high speed, then some compromise will have to be made because increasing device area raises capacitance, thereby increasing the R-C time constant, which slows device response. As a result, the majority of successful OEM applications use application-specific photodiodes.

Most performance parameters, particularly speed and noise, also are strongly influenced by the design of the signal-processing electronics. The electrical characteristics of even a simple photodiode can be remarkably complex, however, so engineers often represent the photodiode with an equivalent circuit. This is a virtual circuit consisting of multiple components whose overall behavior matches that of the photodiode. Certain photodiodes can be represented as a current source in parallel with a diode, a capacitor, and shunt resistance, in addition to series resistance, for example. In more complex devices, the various noise sources (shot noise, Johnson noise, and 1/f noise) can be represented as additional current sources in parallel to the signal current source.

There are a number of types of signal processing electronics regularly used with photodiodes, but by far the most common is the transimpedance amplifier (TIA). Normally, generating a highly amplified voltage from a given input current requires a high input impedance. The downside of a high input impedance is that it increases the R-C time constant. The TIA uses an operational amplifier to circumvent this problem and to deliver a high effective input impedance while maintaining a circuit time constant several orders of magnitude lower than a conventional amplifier with the same impedance. Moreover, a well-designed TIA delivers several orders of magnitude of linear response and therefore does not compromise the inherent high linearity of a photodiode.

The majority of photodiodes are destined for OEM applications. Advanced packaging and integration technologies deliver increasing levels of sophistication and functionality to OEM customers. Typical examples of integrated products are photodiodes with on-chip TIAs and photodiodes with integrated thermoelectric (TE) coolers. Some assemblies also include sophisticated signal processing to ratio or normalize signals from a multi-element photodiode, for example. They may also incorporate optical elements to condition the light before it reaches the photodiode active area.

Avalanche photodiodes

One limitation of the *p-i-n* photodiode is the lack of internal gain—an incoming photon produces only one electron-hole pair. Low-light applications require detectors with internal gain to boost the signal above the noise floor of subsequent electronics and signal processors. For many years, however, the only device that provided such gain was the photomultiplier tube (PMT). Although it offers high gain, the PMT has a number of practical limitations: It is a bulky vacuum tube; it generates heat; and compared to a photodiode, it offers limited linearity, a narrow spectral response range, and a low QE (< 25%). Fortunately, the avalanche photodiode (APD) now offers a solid-state alternative for most PMT applications (see figure 8.2).

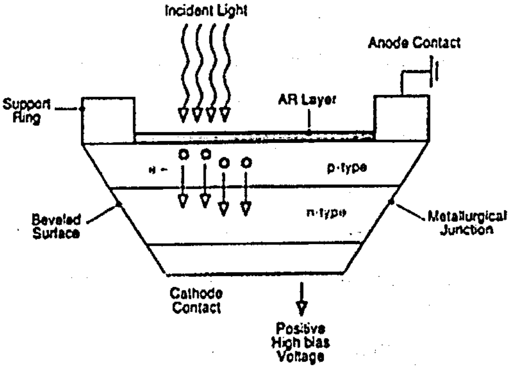

Figure 8.2. In the avalanche photodiode, a large (up to 2kV) external bias accelerates photoelectrons so that each primary electron ultimately results in thousands of electrons at the electrode

In an APD, as with any other photodiode, incoming photons produce electron-hole pairs; however, the APD is operated with a large reverse bias (up to 2 kV for beveled-edge designs), which accelerates the photon-generated electrons. The electrons collide with the atomic lattice, releasing additional electrons via secondary ionization. These secondary electrons also are accelerated, which results in an avalanche of carriers, hence the name.

For many years, APDs were only available with small active areas (less than 1 mm diameter). This limited their use to tightly focused or fiber-coupled applications. In the past three years, however, the large-area avalanche photodiode (LAAPD) has emerged as a mature device, with active areas up to 16 mm diameter and gains as high as 1000. Although the PMT still offers higher gain, the LAAPD features better quantum efficiency (up to 90%), lower noise, compact packaging, higher linearity, and better electrical efficiency. Furthermore, LAAPDs are available with integrated TE cooling for ultra-low-noise operation. As a result, LAAPDs are now replacing PMTs in applications such as flow cytometry and medical imaging.

Although photodiode technology has been available for many years, ongoing advances in areas such as packaging, device integration, and thin-film coating are continuing to yield more sophisticated and cost-effective products. Thus, it is likely that these robust devices will not only continue to dominate the existing light-detection market, but also will seamlessly adapt into most developing photonics applications.

(By Brock Koren, Advanced Photonix Inc. OEMagazine, 2001, August)

Text B. **Fiber Lasers Mark Their Territory**

Compact, efficient, and air-cooled, they're displacing Nd:YAGs in industrial applications, and they may make their way into telecom.

Lasers that use optical fiber for a resonator cavity are making inroads into industry, replacing bigger, bulkier devices. "It's a very interesting technology and something that really could be a disruptive technology in the laser business," says

Robert Steele, director of optoelectronic services at Strategies Unlimited (Mountain View, CA).

In a typical fiber laser, a single-mode fiber core is doped with erbium or erbium-ytterbium. An array of laser diodes, often fiber- pigtailed, pumps the core, which re-emits the desired wavelength. Many of the fiber lasers being developed for industrial use are based on double-clad pumping, in which the energy is pumped into an inner cladding layer (surrounded by its own cladding) and transferred into the core.

The advantage of such a setup, says Paul Rivett, CEO of Resonance Photonics (Markham, Ontario, Canada), is that it can put more power into the fiber. Resonance Photonics does not make the fiber lasers themselves but rather a power concentrator designed to increase the lasers' energy output. "We have customers talking to us about 100 W of original pump power," he says, which he estimates would translate to about 50 W of output power.

Most of the fiber lasers on the market today have outputs that range from 1 W to 25 W; higher outputs should be possible. The main area of application is in materials processing, specifically marking. About 60% of the industrial fiber lasers produced by the non-telecom end of JDS Uniphase (San Jose, CA) are for marking, says Ruediger Hack, product-line manager for fiber lasers.

From printing to soldering

Double-clad fiber lasers were originally developed by Polaroid Corp. (Cambridge, MA) in 1992 for use in the company's printers, Hack says. SDL purchased the technology from Polaroid in 1998, and JDS Uniphase inherited the technology when it bought SDL.

Hack says the fiber lasers are becoming popular for such applications as flexographic printing, in which the laser etches away a layer on print media. In comparison to diode lasers, which can only generate about 0.5 W, the fiber laser can go up to 25 W. Higher power means higher throughput—and bigger profits. For marking, the fiber laser is much more compact than the neodymium-doped yttrium aluminum garnet (Nd:YAG) lasers currently used in that application. It also does not require the complex optics of the YAG, and it is air-cooled. "When we talk about materials processing, the reason people go to the fiber laser is because of the compactness, low energy consumption, and ease of integration," Hack says. Steele adds that the lasers are highly efficient in terms of light conversion and power consumption.

Fiber lasers also show promise for such processes as microsoldering, microwelding, and microbending, which are in increasing demand as the number of portable electronics devices such as cell phones and disk drives grows. One downside, Hack says, is that fiber lasers cannot be Q-switched, locking them out of applications such as engraving metal and plastic. They can be mode locked, however.

Openings in telecom

Potential for fiber lasers also exists in the telecom market. Spectra-Physics Lasers (Mountain View, CA), for instance, makes a fiber laser with 5 W of output for accelerated life testing of the components in optical communications systems. The laser has the advantage that its output can be coupled directly from its SMF-28 fiber core into the component; whereas light from the titanium-doped sapphire lasers typically used for such testing has to be injected into the fiber, with the associated complexities.

Fiber lasers are also being developed as pump sources for Raman amplifiers for boosting telecom signals. So far, says Bill Holtkamp, Spectra-Physics director of sales for active telecom products, that application hasn't been very successful because the gain profile of such devices isn't flat enough for telecom uses. Spectra-Physics and Lucent Technologies (Murray Hill, NJ) are working on fiber lasers with three wavelengths, which may solve that problem.

(By Nell Savage, OEMagazine, 2001, August)

UNIT 9

1. Memorize the following words.

- kit
- collimator
- safety
- vital
- unique
- property
- shift
- band gap
- to yield
- to reduce
- alternative
- despite
- lateral
- angle
- brightness
- reliability
- robustness
- consumption
- sensitivity
- versatile

2. Translate these synonyms and memorize them:

- means (n), way, manner, mode
- method (n), technique
- material (n), substance, matter
- adjust (v), regulate
- give off (v), emit
- occur (v), happen, take place
- conduct (v), carry, transmit, convey, guide, lead
- select (v), choose
- highly (adv), very
- rapidly (adv), quickly

3. Translate the international words without a dictionary:

image, interval, pulse, period, amplitude, diagram, synchronizing, information, moment, oscillograph, accurately, superposition, horizontal, action, to block, to combine, matter, toregulate, box.

4. Translate the following sentences paying attention to the passive forms:

1. The instructions are recorded in the order in which they are to be carried out.
2. We were permitted to attend the conference on optical engineering.
3. Complex calculations are carried out with the help of a computer.
4. By means of instructions any computer is told what operations to perform..
5. Number or instructions are required for solving a problem by a computer.
6. Huge deposits of gas have been found recently.
7. A new thermal power plant was being built when I came to this city.
8. Different enterprises are being established at these river basins.
9. The availability of cheap water power in this place was much spoken about.
10. A lot of articles on semiconductor optical amplifiers have been referred to by the reporter.
11. We were informed about new trends in optics industry.

5. Translate the texts:

Text A. **Automated Inspection**

Automated image retrieval lets machine vision systems access historical data to interpret images.

The search for meaning

Manufacturers who depend on automated inspection systems for process monitoring and quality control generate large databases of product and defect imagery. As these image repositories grow in size, the manufacturer's ability to reuse this data is limited by the large volumes, and the difficulties and intricacies of automating the description of imagery for cataloging, searching, and retrieving purposes.

The technique of content-based image retrieval (CBIR) can address the issue of image reuse. CBIR refers to methods used to index and retrieve images from databases based on their pictorial content. Pictorial content is typically defined by a set of features extracted from an image that describe the color, texture, and/or shape of the entire image or of specific image regions. For the manufacturing environment, we contend that image content encapsulates process history and experience, and that it can be used to effectively index this information for search and retrieval to identify and characterize manufacturing issues.

At Oak Ridge National Laboratory, we are developing a CBIR technology called automated image retrieval (AIR), which is based on the premise that manufacturing processes or phenomena that are similar are likely to generate images that are visually similar. This simple concept implies that statistical information about processes associated with imagery can be quickly gathered to locate and solve current manufacturing problems based on image content. Thus, AIR facilitates the retention and retrieval of expert knowledge for diagnosing and controlling processes and improving

AIR in action

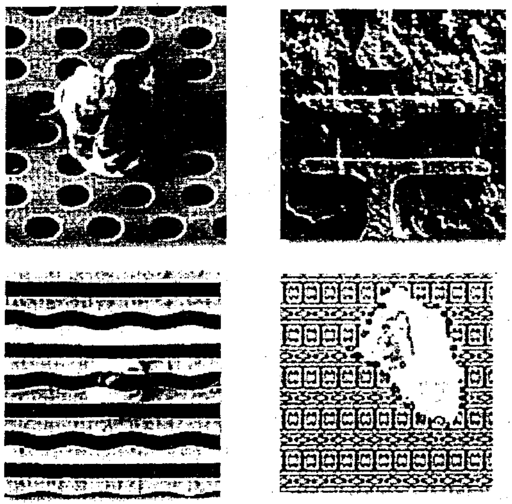

Figure 9.1. Examples of defects that occur on integrated-circuit device layers during manufacturing. These include surface and embedded particles, scumming, and pattern problems

The semiconductor industry relies heavily on automated inspection technologies for monitoring wafer fabrication, using methods such as confocal and optical microscopy, atomic-force microscopy, laser scattering, and scanning electron microscopy (SEM) to generate digital imagery for failure analysis between process steps (see figure 9.1). On average, more than 20,000 images are collected every week at a typical wafer fab. Fabrication engineers store this data in a data management system (DMS) and use it to diagnose and isolate manufacturing problems. The idea is good in principle, but the semiconductor industry currently has no direct means of searching a DMS using image-based queries. A system like AIR is necessary to optimize the usefulness of this data.

The defect mask is typically a binary representation that localizes the defect boundaries within the field of view. The defect mask is used in AIR to generate an extensive description of the defect region and the substrate region. There are currently 60 numerical features measured for the substrate that describe the color, texture, and structure. The defect itself is decomposed into 51 numerical features that describe the color, texture, and shape. The user can select various feature attributes when formulating a query so that, for example, a search can be accomplished to locate one defect shape on another product substrate by ignoring color attributes, which are likely to be highly variable from one process layer or product to the next. The user also can enable or disable other descriptive groups such as texture or shape.

Once a database of images has been represented as features, this list is maintained in a database and indexed for efficient retrieval. The goal of indexing is to organize the image features such that a ranked list of nearest neighbors can be retrieved without performing an exhaustive comparison with all the records in the database. For AIR, the database is indexed by building a binary decision tree of the image features; for this work we have adapted an approximate-nearest-neighbor (ANN) indexing and search method that builds on *kd*-tree methods.[4] Whereas an exhaustive nearest-neighbor search of the n vectors (i.e., images) in the database would be of $O(n)$ computations, the retrieval efficiency of the ANN method is proportional to $O((1/*)^{d/2}\log(n))$, where d is the dimension of the feature space, n is the number of data points, and ε is the nearest neighbor error.

The basic component of the AIR system is the indexing and retrieval engine, which is implemented as a Microsoft dynamic link library (DLL). In addition to the core AIR DLL, the system incorporates an ORACLE database, a set of interface DLLs and executables, and graphical user interfaces. The basic architecture of the AIR system includes a representation of the relational database that stores associated process data along with the image features.

Results from the field

In tests at two semiconductor manufacturing sites, the AIR system demonstrated good indexing and retrieval performance. For a typical database containing 80,000 optical and SEM images, the system is able to retrieve 128 nearest-neighbor images in about 8 s on a 750 MHz Windows PC. The time required to extract 111 defect and substrate features, associate them with the indexing structure, and add them to the database is approximately 0.7 s per image. These indexing and retrieval times are more than adequate for this data environment, and they demonstrate that the AIR system can maintain a sustained data rate of up to 100,000 images per day if required.

Of even greater interest is the system's ability to predict information about the manufacturing process based on the visual similarity between a query image and retrieved results. This was tested by treating the AIR system as a *k*-nearest neighbor (*k*-NN) classifier. For this test we looked at a query image's nonvisual information, e.g. the process layer or lot number from which a defect came, and attempted to predict this value by voting among the nearest *k*-returns from the database. The result was 70% correct classification performance for process layers in which there were more than 100 classes represented. The system performed well as a lot predictor, too, showing 62% correct classification out of the approximately 1100 lots represented. Although the system would not necessarily be used this way in practice, it demonstrates our basic premise that similar manufacturing processes generate visually similar imagery.

The AIR technology is now being integrated into commercial DMS systems for the semiconductor industry, but development activities continue in parallel. For example, inclusion of nonvisual information characterization data will provide an even stronger association of defects imagery with specific processes. Without the addition of content-based image retrieval, this large image repository of semiconductor data will remain virtually untapped as a resource for rapidly resolving manufacturing problems. Progress to date, however, gives every indication that CBIR-based technologies will find an important home in the field of automated inspection.

(By Kenneth Tobin and Thomas Karnowski,
Oak Ridge National Laboratory, OEMagazine, 2001, July)

Text B. **Smart Media Management**

A system is called 'smart' if a user perceives the actions and reactions of the system as being smart. Media is therefore managed smartly if a computer system helps a user to perform an extensive set of operations on a large media database quickly, efficiently, and conveniently. Such operations include searching, browsing, manipulating, sharing, and reusing.

The more the computer knows about the media it manages, the smarter it can be. Thus, algorithms that are capable of extracting semantic information automatically from media are an important part of a smart media-management system. As part of this effort, our lab at Intel Corp. (Santa Clara, CA) is focusing on tasks such as reliable shot detection; text localization and text segmentation in images, web pages, and videos; and automatic semantic labeling of images.

Calling the shots

A shot is commonly defined as the uninterrupted recording of an event or locale. Any video sequence consists of one or more shots concatenated by some kind of transition effects. Detecting shot boundaries thus means recovering those elementary video units, which in turn provide the ground for nearly all existing video abstraction and high-level video segmentation algorithms. In addition, during video production each transition type is chosen carefully in order to support the content and context of the video sequences; therefore, automatically recovering all their positions and types may help the computer to deduce high-level semantics. For instance, feature films often use dissolves to convey a passage of time. Dissolves also occur much more often in feature films, documentaries, and biographical and scenic video material than in newscasts, sports, comedies, and other shows. The opposite is true for wipes, in which a line moving across the screen marks the transition from one scene to the next. Therefore, automatic detection of transitions and their type can be used for automatic recognition of the video genre.

A recent review of the state-of-the-art in automatic shot boundary detection techniques emphasizes algorithms that specialize in detecting specific types of transitions such as hard cuts, fades, and dissolves. In a fade, the scene gradually diminishes to a black screen for several seconds; when a scene dissolves, it fades as the next scene becomes clearer, not to black as a true fade does. Today's cutting-edge systems can detect hard cuts and fades at a high hit rate of 99% and 82% and at a low false-alarm rate of 1% and 18%, respectively. Dissolves are more difficult to detect, and the best approaches report hit and false-alarm rates of 75% and 16% on a representative video test set.

Extracting text

Extracting truly high-level semantics from images and videos in most cases is still an unsolved problem. One of the few exceptions is the extraction of text in complex backgrounds and cluttered scenes. Several researchers have recently developed novel algorithms for detecting, segmenting, and recognizing such text occurrences.[2] These extracted text occurrences provide a valuable source of high-level semantics for indexing and retrieval. For instance, text extraction enables users of a video database to query for all movies featuring John Wayne or produced by Steven Spielberg. Or it can be used to jump to news stories about a specific topic since captions in newscasts often provide a condensation of the underlying news story.

Detecting, segmenting, and recognizing text in nontext parts of web pages also is a very important operation. More and more web pages present text in images. Existing document-based text segmentation and text recognition algorithms cannot extract such text occurrences due to their potentially difficult background and the large variety of text color used. The new algorithms allow users to index the content of image-rich web pages properly. Automatic text segmentation and text recognition might also help in automatic conversion of web pages designed for large monitors to small LCD displays of appliances, since the textual content in images can be retrieved.

Our latest text segmentation method is not only able to locate text occurrences and segment them into large binary images, but also to label each pixel within an image or video whether it belongs to text or not. Thus, our text detection and text segmentation methods can be used for object-based video encoding. Object-based video encoding is known to achieve a much better video quality at a fixed bit rate compared with existing compression technologies. In most cases, however, the problem of extracting objects automatically is not solved yet. Our text localization and text segmentation algorithms solve this problem for text occurrences in videos. Using this technique, the multiple video object video (multiple video object plane, or VOP) achieved a peak signal-to-noise ratio about 1.5 dB better than the single object encoded MPEG-4 video. Thus, encoding the text lines as rigid foreground objects and the rest of the video separately achieved a much better visual quality.

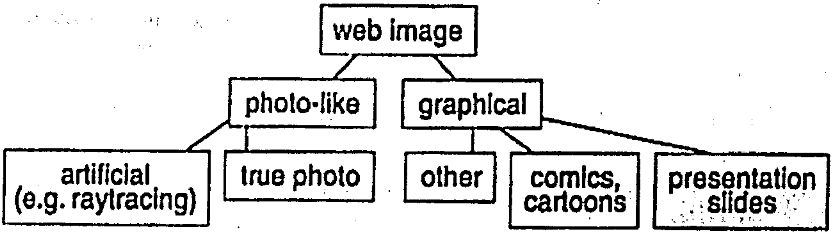

Figure 9.2. A classification scheme for web images enables an algorithm to sort automatically

Although much research has been published on extraction of low-level features from images and videos, only recently has the focus shifted to exploiting low-level features to classify images and videos automatically into semantically meaningful and broad categories. Examples of broad and general-purpose semantic classes are outdoor versus indoor scenes and city versus landscape scenes. In one of our media indexing research projects, we crawled about 300,000 images from the web. After browsing carefully through those images, we came up with broad- and general-purpose categories (figure 9.2).

Although it uses only simple, low-level features, such as the overall color diversity in the image, the average noise level in the images, and the distribution of text line positions and sizes, our classification algorithm achieved an accuracy of 97.3% in separating photo-like images from graphical images on a large image database. In the subset of photo-like images, the algorithm could separate true photos from ray-traced/rendered images with an accuracy of 87.3%, while the subset of graphical images was successfully partitioned into presentation slides and comics with an accuracy of 93.2%. Sample images illustrating the chaos before and the order after their classification are shown in figure 2.[5] We are now working to increase the number of categories that can be classified automatically and will have to explore how joint classification can be done accurately and efficiently.

Browsing media

Although automatic media content analysis capabilities provide the basis of a smart media-management system, efficient methods to browse a media database in a random but directed way are equally important. Every 3 s while the main selection is playing, the system queries the whole video database for shots that are most similar to the currently visible video sequence. The result of the query is shown as a decorative border around the main video player. At any time, the user can select any of those similar shots as the current video. In the example, similarity is based on color, but any similarity measure can be applied. For instance, similarity based on the text visually occurring in a video sequence can be a useful criterion for browsing through a database of newscasts recorded from a diverse set of broadcast channels.

Another equally important task is automatic video abstraction. A video abstract is a sequence of still or moving images (with or without audio). The video abstract is designed to rapidly provide the user with concise information about the content of the video while preserving the essential message of the original. Different abstraction algorithms for edited video (newscasts, feature films) and raw video (home video and raw news footage) have been developed in the past, but even better methods are needed for the future.

Many interesting challenges are still waiting to be addressed by researchers. The SPIE conference titled Storage and Retrieval of Media Databases (20–26 January, San Jose, CA) was one of the major research meetings on this topic. A new special feature track is on peer-to-peer media sharing and distributed media searching and indexing.

By Rainer Lienhart, Intel Corp., OEMagazine, 2001, July

Text C. Total Immersion

Streaming 3-D video, audio, and a sense of touch will surround people with a virtual environment over their high-speed Internet connections.

by now, the Internet has become an inescapable part of everyday life. What office could run without e-mail, for instance? But imagine adding a new optical component to the system—a three-dimensional, real-time visual display that puts the user in the middle of a scene being transmitted from somewhere else. As high-bandwidth optical communications makes transmission of such scenes possible, our group at the Integrated Media Systems Center (IMSC) at the University of Southern California (USC; Los Angeles, CA) is working on technologies to create total immersion in the scenes.

At IMSC, we think a total-immersion technology called Immersipresence will dramatically change our world within this decade, transforming our two-dimensional world of computers, TV, and film into three-dimensional immersive environments in our own living rooms—or practically anywhere else. Through Immersipresence, remote live scenes will be transmitted in 3-D over the Internet to augment the real environment. Transmissions will include graphics and animation. In essence, the real environment will become immersed in the remote environment.

For example, within 10 years, people will shop from their living rooms via an Internet home-shopping channel that will allow them to see and talk to lifelike, full-bodied human representations of store clerks. Within 15 years, they will be able to get a realistic sense of touching and feeling the products. Three-dimensional audio will make it sound like they are really shopping in a mall. These immersive environments could be a living room, factory floor, office, or classroom. Aided by unnoticed screens or special glasses, Immersipresence will touch the lives of everyone.

For this new immersive Internet, IMSC is developing such multimedia technologies as advanced interactivity features, video compression, 3-D facial modeling and animation, tracking technology, panoramic video technology, and audio. IMSC has continued to enhance the Media Immersion Environment (MIE), the center's software and hardware infrastructure, as a national test bed for the development and fundamental integration of new multimedia and Internet technologies. The MIE has a robust system infrastructure for the implementation and demonstration of multiple, diverse system applications in an operational environment. Using the MIE, the center is conducting experiments involving the use of IMSC's panoramic video technology and audio for Internet transmission of a concert at the USC Alfred Newman Recital Hall and a USC homecoming game at the Los Angeles Coliseum.

The MIE test bed spans a wide range of efforts and technologies. Other research efforts that overlap partially with MIE functionalities can loosely be classified into the following categories: tele-immersion, network media experiments, and simulated virtual environments. These categories address subsets of the research issues that the MIE encompasses and sometimes are a loose collection of related projects that do not address the important integration issues.

Tele-immersion

The vision of tele-immersion is to have people interacting with each other over a distance as three-dimensional human representations, or avatars. The vision has been pursued in various ways and forms for more than a decade. In the late 1980s, the Advanced Telecommunications Research Institute International (Kyoto, Japan) created a virtual meeting place where each participant's avatar was visible to the group. In the mid-nineties, a project at the University of California, San Diego modeled a dynamic scene from multiple camera images.

Efforts are underway in a joint project of the University of North Carolina (UNC; Chapel Hill, NC) and University of Pennsylvania (Penn; Philadelphia, PA), and at another project at Carnegie Mellon University (Pittsburgh, PA). The UNC/Penn project is a component of the National Tele-immersion Initiative funded by Advanced Networks and Services (Armonk, NY). Penn developed a six-camera array focused on a user at a desk/display system, while UNC deals with the stereo display system and the acquisition of a laser-scanned office background model, as well as haptics (touch-related technologies). To date, one or more users can observe prestored 3-D models of remote offices with live models of people in the foreground.

IMSC's vision differs from these projects because the center pursues the development of an integrated media system, focusing on a much greater range of issues in tele-immersion, including audio. All prior experimental systems have lacked immersive audio, which is a critical component to realizing the full benefits of sensory immersion. Another key part of IMSC's vision of tele-immersion is the integration of haptics technologies, and the center has been making progress in that area. We are developing panoramic video technology for scenes that are not practical to acquire with any 3-D scanner or camera technology. For example, our recent experiments at a football game and blues concert demonstrate the ability to acquire both immersive imagery and audio that allow a remote participant to experience the event. We integrate storage formats, synchronized streaming, and compression into a single system and provide real-time playback through a head-tracked and head-worn viewer.

Using the network

An important component of remote immersion is the ability to send and receive a multitude of session data from all participants via long-distance, high-speed networks. Various research groups have developed and tested network-centered applications within the past few years. The focus of these projects is generally the exploitation of next-generation networking hardware and software. For example, a musical performance at McGill University (Montreal, Quebec, Canada) was transmitted in real time over the Internet to an audience at New York University (New York, NY) in September 1999.[1] Researchers at the University of Washington (Seattle, WA) produced the first live high-definition television newscast over the Internet in April 2000. In November 2000, a group of universities in partnership with Optivision (Palo Alto, CA), recorded a music video at multiple locations using real-time streaming over Internet .

IMSC's MIE differs from these networking experiments in significant ways. These network experiments addressed synchronization issues with a manual approach. In contrast, we are developing a system that combines global positioning satellite (GPS) timing with a real-time operating system for a platform that will overcome synchronization problems. Given the best-effort nature of the Internet, Network Time Protocol (NTP) can only achieve synchronization within several hundreds of milliseconds for participants separated by moderate physical distances, thus producing noticeable delays. The GPS system, on the other hand, can maintain microsecond synchronization between any number of locations anywhere in the world.

The MIE architecture also includes specialized storage repositories for all different media types. IMSC has developed a real-time file server as a distributed, scalable continuous media server that addresses support for multiple media streams with different modalities and bandwidth requirements. It delivers media data over standard IP-based networks in real time, and synchronizes multiple media streams, such as panoramic video and audio. In short, the MIE provides a complete media processing architecture to build applications that send and receive the high-speed media streams.

Virtually real

Simulated virtual environments share similarities with immersive environments. SIMNET (an acronym formed from "simulated networking") is a large-scale networked simulation system developed by the U.S. Army and the Defense Advanced Research Projects Agency. It links simulators of tanks, helicopters, and airplanes into a realistic cyberspace battlefield. The SIMNET group developed the first standard protocol for distributed interactive simulations.

In another example, game engines offer a high level of realism, interaction, and cooperation in creating virtual 3-D worlds. At IMSC, we are exploring the use of the game engine 3-D GameStudio A4 for an application research project known as BioSIGHT, which is developing an interactive high-school biology curriculum as a prototype for curricula in all education from kindergarten through grade 12. At the same time, we are taking the opportunity to identify integration issues that we can transfer to the MIE architecture as components of the software modules mature. In general, IMSC's MIE differs markedly from simulation systems such as SIMNET and game engines, because the MIE is being developed as a generic development and execution platform, while these systems are limited by specific requirements and designs.

In order to deal with all of the issues facing researchers in tele-immersion, networking, and virtual environment simulation, the MIE focuses on integration. In addition to acquiring and displaying representations of 3-D scenes with visual and aural content, it addresses data storage, retrieval, indexing, streaming, compression, and network transport issues. Also, because of its broad scope and extensibility, IMSC's MIE allows for the integration of technologies developed by third parties at other universities and commercial enterprises. Addressing all these natural elements of any integrated media system is a truly novel approach for research in media immersion, and it provides a path to the immersive environment of the future.

(By Chrysostomos (Max) Nikias, Alexander Sawchuk, Ulrich Neumann, Dennis McLeod, Roger Zimmermann, and C. C. (Jay) Kuo, OEMagazine, 2001, Jule)

UNIT 10

1.Memorize the following words:

- ongoing
- to deliver
- throughput
- to extend
- dissipation
- array
- stack
- brightness
- density
- divergence
- value
- axis
- to collimate
- tradeoff
- in turn
- to degrade
- tight
- to assemble
- to rotate
- to prevent

2. Translate the international words without a dictionary:

adequate, accurately, discussion, diamond, terminal, situation, procedure, variety, neutral, crystalline, equivalent, trivalent, real, practically, radically, voltage, department, filtration, mixer, to compensate.

3. Translate these synonyms and memorize them:

- image *(n)*, representation
- period *(n)*, time, cycle
- steady *(adj)*, fixed, stable
- device *(n)*, gadget, instrument
- supply *(v)*, furnish
- show *(v)*, indicate, illustrate, demonstrate
- investigate *(v)*, research, explore
- accurately *(adv)*, exactly
- hence *(adv)*, so, then, therefore, consequently
- appear *(v)*, become visible

4. Translate the following sentences with Infinitive constructions:

- Light is thought to be...
- The speed of these particles is found to be.....
- The socket is known to be used....
- These forces are believed to act...
- These changes in the orbit are considered to be...
- These charged particles are supposed to possess...
- The planet is expected to have
- The direction of the current is assumed to be...
- The diameter of this star is reported to be
- These conditions are likely to be found
- Uranium is unlikely to exist...
- This cyclotron appears to develop...
- The rocket is found to develop speed...
- The rocket is found to have developed speed...
- The rocket has been found to develop speed...
- The rocket was found to develop speed...
- This limitation appears to have been overcome...
- This limitation appeared to be overcome...

5. Translate the text:

Text A. **Powering Brightness**

Innovative stacking techniques increase the output power and brightness of diode laser bars for materials-processing applications.

Semiconductor lasers are being used in a growing number of materials-processing tasks, including plastic and metal welding, marking, hole drilling, soldering, heat treating, and adhesive curing. Whether for direct use or pumping applications, ongoing research is focused on delivering higher laser output power, without sacrificing operating lifetime or beam quality. Higher power increases process throughput and extends the range of materials that can be processed by the lasers. Work on increasing semiconductor laser power currently focuses on three areas of the technology: device materials, heat dissipation technology, and beam-delivery optics.

The basic building block of a high-power semiconductor laser is the laser bar, a monolithic, linear array of laser edge emitters. A typical bar is about 10*1*0.1 (mm^3) and contains 20 to 70 individual emitters. With a specified operating lifetime of more than 10,000 hours, bars typically supply 40 to 50 W of continuous-wave (CW) output at wavelengths from 800 nm to 980 nm.

Individual bars can be combined into stacks to produce higher total output power. This is usually done by stacking the arrays vertically, so that the rows of emitters are very close together (less than 2 mm). In principle, there is almost no limitation on how many bars can be combined in this manner. Typical commercial products consist of stacks of six or 12 individual laser bars and offer CW output powers as high as 600 W. Custom products have gone as high as stacks of 36 bars that reliably deliver 1.8 kW CW.

For most applications, the high-power output generated by a diode bar is most useful if it appears to emanate from a relatively small source area. This is quantified by the parameter known as brightness, which is defined as the total power emitted by the source per unit solid angle, per unit area. The higher the source brightness, the more easily and efficiently it can be concentrated into a small focused line, spot, or area. In other words, a higher brightness source can deliver greater power density at the work surface.

The brightness of a laser bar is limited by its fill factor and output divergence. Fill factor is the ratio of the individual emitter length to the spacing between emitters-essentially the percentage of the bar's surface that emits light (see figure 10.1). Typical laser bar fill factor values range from 40% to 75%. For laser stacks, fill factor is also defined as the width of the output line from each bar divided by bar-to-bar spacing (called the pitch).

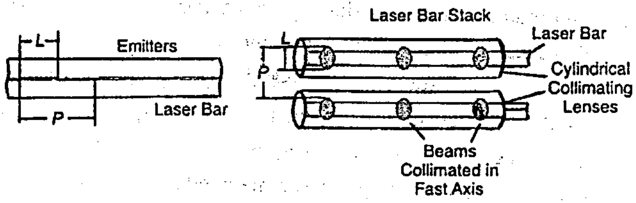

Figure 10.1. The fill factor for a laser bar is the individual emitter length divided by the emitter spacing. For a bar stack, fill factor is the beam height divided by the beam spacing

The output of each emitter in a laser bar emanates from an area that is very long and thin. The output in the axis of the smaller dimension, called the fast axis, diverges rapidly due to diffraction (typically 30° to 40° FWHM). However, because the source size is small in this dimension, the M^2 is low (typically around 1.5), and thus the beam can be collimated using simple cylindrical optics. In the longer emitter dimension, known as the slow axis, the divergence is much lower, usually about 10° FWHM. However, the larger source size results in a higher M^2 (even exceeding 1000), which limits the ability to collimate and/or refocus the light in this dimension.

Heat-sinking advances

There is a basic tradeoff in laser bars between output power and lifetime: The higher the power, the shorter the lifetime. The long-term performance of a high-power laser bar is limited by the laser temperature, the power density at the emitting facets, and the internal stress induced by bonding the laser to the heatsink. Laser temperature depends on drive current, which in turn depends on operating mode (CW, quasi-CW, or pulsed operation, average power, peak power, pulse width, repetition rate, duty cycle, etc.), and on the type of thermal dissipation (heat sinking and cooling) used.

Reducing thermally induced stress can be achieved by a combination of efficient cooling and innovative device architecture. High-power laser stacks can be thermally stabilized by microchannel cooling--running water through small channels in the heatsink attached to each laser bar. Ideally, the heatsink microchannel cooling ports are stacked, which enables all the water inlets and outlets to operate in parallel.

Our group has focused on reducing the thermally induced stress between the laser bar and heatsink. This stress occurs because the heatsink bonding process is performed at high temperature. As the assembly cools, the difference in the thermal expansion coefficient between the laser and heatsink produces mechanical stress that degrades device reliability. This problem can be mitigated by using a heatsink whose thermal expansion is more closely matched to the laser bar. We have made significant progress in this area by using a heatsink composed of a sandwich of materials, instead of a single material. Test data indicate that this technique should soon enable the production of laser bars that deliver more than 70 W of power with lifetimes of more than 10,000 hours.

Our microchannel cooling architecture uses a ceramic spacer to accurately position the individual bars and a spring foil to provide electrical contact from the *n*-side of one bar to the *p*-side of the next. With this construction, a stack having a 1.8-mm pitch can be produced with a pitch tolerance of less than 0.02 mm. The importance of this is that tight mechanical tolerances facilitate the accurate positioning of the fast axis collimation lenses, which have focal lengths of less than 1 mm.

Optical innovations

With a tight enough pitch, it is possible to use optical methods to increase laser brightness, in some cases virtually doubling the source brightness. In one approach, we begin by assembling two stacks side by side, but with a vertical offset between the two corresponding to half the stack pitch (see figure 3). The bars in each stack are collimated in the fast axis using a lens with a focal length short enough to produce a fill factor of less than 50%. The light from each bar in the stack on the left then passes through a plane parallel plate, whose height is half the stack pitch. Each of these plates is rotated so that the emergent light is shifted to the right by a distance that is half the spacing (center-to-center separation) between the stacks. Likewise, light from the bars on the right is shifted to the left the same distance by another set of plates. The result is that the output of the two stacks is interleaved, nearly doubling the source brightness. We have successfully used this approach to combine the output of two 15-bar stacks of 50 W CW lasers to yield a total power of 1.4 kW. Most importantly, the combined beam possesses the same M^2 as the individual laser stacks.

Laser brightness can again be doubled, without any degradation in M^2, by using a dichroic prism to combine the output of lasers having different wavelengths. We have demonstrated this experimentally with a 12-bar stack. The top and bottom three bars of this stack are 808-nm lasers, and the middle six have output at 940 nm. A dichroic prism deflects the two sets of 808-nm beams so that they emerged coincident with the 940-nm beams. The output of the dichroic prism, which consists of six dual-wavelength beams with a pitch of 1.8 mm, is then combined with the output from an identical system using the interleaving stack just described. There is nothing that prevents this technique from being scaled to even larger stacks.

Semiconductor lasers offer many desirable characteristics for industrial applications, including compact size, high reliability, long lifetime, and electrical efficiency. Improvements in laser bar output power and stacking technology will deliver even higher total power and higher brightness--critical advantages that can open up a new range of applications in materials processing.

By Franck Leibreich and Hans-Georg Treusch, Spectra-Physics Semiconductor Lasers, SPIE, OEMagazine, September 2001

Text B. **Market Makeovers**

Consumer-driven medical laser applications such as cosmetic surgery are propelling the industry.

If you're like most of the world, you associate medical lasers with aesthetic and ophthalmic procedures, courtesy of network news, daily papers, and magazines. Resurface your skin! Throw away your glasses and contacts! Never shave again! So far so good, but the reality is that many of the most powerful laser-based therapeutic and diagnostic techniques are still relatively unknown outside of medical circles.

For example, lasers offer a treatment for wet age-related macular degeneration (AMD), one of the leading causes of blindness in adults over 55. In wet AMD, the central portion of the retina, called the macula, becomes overgrown by fibrovascular tissue that leaks fluid, which reduces vision and eventually leads to blindness. Photodynamic therapy (PDT) offers an effective course of treatment for wet AMD. In PDT, the patient is injected with a photosensitive dye that has an affinity for the fibrovascular tissue. When the tissues are exposed to infrared light at the absorption peak of the dye, the excited photosensitizer generates singlet oxygen and reactive oxygen intermediates, which damage the endothelial cells of the abnormal vessels, stopping the leakage for a period of weeks or months. Unlike photocoagulation treatments, which leave the patient with a permanent blind spot, the PDT approach can be repeated.

On the research front, lasers are being used experimentally as powerful tools for the treatment of strokes. Laser tissue soldering and welding, under development as an alternative to sutures, provide faster healing with less inflammation than conventional methods. Other exciting emerging medical laser applications that have received or are near FDA approval include treatment of skin conditions such as psoriasis and acne.

According to Irving Arons, managing director of Spectrum Consulting (Peabody, MA), the global medical laser market for 2001 should reach $2.5 billion, up 13.6% from the total laser sales for 2000. Surgical lasers make up the largest segment at $810 million in 2000, slated to grow 17% to reach to $950 million in 2001. Ophthalmic lasers follow, rising 5% from $600 million in 2000 to reach $630 million in 2001.

Interestingly, lasers for conventional surgery are becoming less popular; the bulk of the number cited above is made up of lasers for cosmetic surgeries (skin resurfacing, tattoo and hair removal, etc.). "Lasers are being favored less by surgeons for cutting tissue," says Charlie Whelan, industry analyst at Frost & Sullivan (San Antonio, TX), who notes the growing popularity of electrosurgery, an economical technique in which current running through a wire heats the surface sufficiently to burn through tissue. "But cosmetic surgery is huge."

"Actually, cosmetic applications have been the only thing driving sales for the last three to five years," says Kathy Kincade, a writer who has specialized in the medical laser field for 10 years. "The bottom line is the consumer-driven application for which you can identify large populations so that ultimately you have enough procedures being done and systems being sold to lower the price of the technology. That seems to be the route to success.

"Nobody really makes a lot of money in this business," Kincade continues. "The problem is that to make money in the medical laser business, you can't be a one-trick pony. The smaller players really struggle because they can't make enough money with a single application or product line." She cites the recent sale of Coherent Medical Group (Santa Clara, CA) to ESC Medical, (now Lumenis Ltd.; Yokneam, Israel) as a sign of the times. "Even some like Coherent who had a broad product line just weren't getting a really fast turnaround from their investment anymore."

Scott Baily, senior vice president and senior analyst at Bluestone Capital (New York, NY), agrees. "In the mature segments, prices come down and unless you have a diverse product line in order to maintain margins, most laser companies are not that profitable." According to him, it's all about niche markets. "It's so competitive," he says. "The market and technology leaders in the laser industry are those players who have unique products." Baily, along with several other analysts, sees the dental market as taking off. "I think it's going to be one of the big growth markets in the next few years," he says. Like Kincade, he sees consumer-driven applications as the key. "The reason we're seeing this big groundswell is that all across the country you're getting press now for painless dentistry. It's becoming a patient-driven purchase."

Consumer demand for an array of innovative medical technologies will continue to drive the industry forward in future. Look for similar advances and demand in photonic-based medical diagnostics. Indeed, despite the current condition of the economy, the medical photonics market in general looks strong. "It's certainly been an up and down industry," says Arons. "It appears to be in an upsurge right now."

By Kristin Lewotsky, SPIE, September 2001

UNIT 11

1. Memorize the following words:

- to plug in
- tunable
- to present
- accuracy
- cavity
- to undertake
- to eliminate
- exact
- in advance
- reliable
- random
- incoming
- response
- to induce
- lasing effect
- stand-alone
- to protect
- externally
- loss
- facet

2. Translate these synonyms and memorize them:

- free (adj), loose
- often (adv), frequently
- substantial (adj), essential
- instant (n), moment
- pair (n), couple, two
- disrupt (v), break
- procedure (n), process
- create (v), build up
- radically (adv), completely, entirely
- variety (n), kind, change, difference

3. Translate the international words without a dictionary:

to combine, to prevail, to repeat, to diffuse, to generate, to inject, central, to accelerate, base, collector definition, proportion modern, analogous, porous, commercial, alpha, ampere, battery.

4. Translate the sentences with the Infinitive construction:

1. The machine is known to be the major and effective means of labour.
2. P.H. Yablochkov is known to be the inventor of the electric candle.
3. The method proposed by the young engineer is said to be very effective.
4. Electronics is believed to begin when the valve was invented.
5. Electronic equipment is said to have already been applied at the beginning of the XX century.
6. Electronics is sure to find an ever growing application.
7. Automation is believed to be the highest stage in the development of technology.
8. Electronic equipment has been proved to save millions of man and machine hours.
9. The action to be referred to is known as cathode bombardment.
10. These fluctuations are shown to have resulted in the development of hum in the tube output.

5. Translate the text:

Text A. **Tuning Up**

Widely tuneable telecom lasers may cut inventory cost and lead to new routing schemes.

As telecommunications carriers strive to increase the number of channels in their wavelength-division multiplexing systems from 40 to 80 to 160 and beyond, they're faced with having to plug in more and more lasers, one for each wavelength; they also need to have enough spares on hand to replace defective ones.

But widely tunable lasers, several of which are starting to ship to customers, could cut down on the numbers of lasers in a system and eventually lead to new switching and routing procedures. For instance, at the National Fiber Optic Engineers Conference (NFOEC; Baltimore, MD; 9–12 July), Blue Sky Research

(Milpitas, CA) presented its Programmable ITU laser, a tunable device intended to cover 80 channels across the C-band. The device has an output greater than 20 mW, a frequency accuracy of 3 GHz, and it tunes in less than a millisecond, the company says.

Bob Potenza, senior vice president of marketing and sales and one of the founders of Blue Sky, expects to be shipping the laser in volume by the first quarter of next year. The device uses an external cavity design with material properties controlled by current and voltage to tune the wavelength. An etalon locker locks the signal at the appropriate channel. Potenza would not go into detail on the technology but says that the tuning element is purely electro-optical, with no gratings, moving parts, or microelectromechanical systems (MEMS).

Varied methods

"There seem to be six approaches [to making tunable lasers] that I can count," Potenza says. "Three in external cavities, one in VCSELs, and two in grated approaches." An approach using vertical-cavity surface-emitting lasers (VCSELs) is being undertaken by the High-Performance Optical Components Solutions group of Nortel Networks (Brampton, Ontario, Canada). Their device uses MEMS to adjust the mirror on one end of the laser, thus changing the length of the cavity, and with it the wavelength. They've demonstrated tuning across 80 channels on the C-band. Tuning speed is typically under 10 ms, output is 20 mW, and wavelength accuracy is ± 2.5 GHz. Tom Dudley, vice president of marketing, says the laser should be qualified by October.

Agility Communications (Santa Barbara, CA) bases its tunable laser on sampled-grating distributed Bragg reflector (DBR) technology. It's built on an indium phosphide chip with a mirror on each end and divided into four sections. The front and back sections provide coarse tuning; the middle sections provide fine tuning and gain. By applying different levels of current to each of the four sections, the device can tune through 100 C-band channels in less than 10 ms with a wavelength accuracy of ±3 GHz and 4 mW output. Vice president of marketing Arlon Martin says that because the company can integrate additional devices, such as an electro-absorption modulator, onto the chip, they can eliminate other equipment, such as an external lithium niobate modulator, reducing transceiver costs.

From spare to driver

The initial market for tunable lasers, which started out tunable across only four to six channels, is in inventory control for vendors and spares for carriers. For a 48-channel DWDM system, for example, a vendor has to maintain a supply of 48 models of single-wavelength lasers to cover the different channels. It takes three months to build the lasers, and the exact wavelength may not be known until the process is complete; plus, it's hard to tell in advance what wavelengths will be needed. "From the vendor perspective it's a nightmare to maintain that kind of inventory," says Vladimir Kozlov, a senior analyst with market research firm RHK (South San Francisco, CA). With up to a 20% price premium, tunable lasers make more sense, he says.

But widely tunable lasers also hold the potential for new system architectures, in which the lasers are used for routing traffic and for dynamic provisioning, and that's what the manufacturers are looking toward. Kozlov says it remains to be seen which technology for tunable lasers wins out. Edge-emitting lasers based on a distributed feedback or DBR design are an established technology, but they're fairly expensive to make and produce lower output powers. VCSELs are cheaper and more powerful, but there is some concern as to how stable and reliable they are, Kozlov says. "The slowdown in the market might actually favor this VCSEL technology because it gives them extra time to address these concerns," he says.

Martin sees a transition to tunable lasers over the next three to four years and expects the market will be worth $8 billion to $10 billion. "I ultimately believe there is room for a couple of different players for that market," he says.

(By Neil Savage, OEMagazine, September, 2001)

Text B. Semiconductor Optical Amplifiers

SOAs offer a key technology for amplification, switching, wavelength conversion, and regeneration in optical networks.

As bandwidth demand rises, the construction of optical packet-switching nodes targeting optical routers would benefit from fast optical switches. Semiconductor-optical-amplifier (SOA) technology provides this high-speed switching capability as well as gain, high extinction ratio, and high integration potential. Moreover, it is a key technology for several other functions, including all-optical wavelength conversion, regeneration, wavelength selection, booster and in-line amplification, in-node optical preamplification, and mid-span spectral inversion.

An SOA is based on the same technology as a Fabry-Perot diode laser. Such a laser consists of an amplifying medium located inside a resonant (Fabry-Perot type) cavity. The amplification function is achieved by externally pumping the energy levels of the material. In order to get only the amplification function, it is necessary to protect the device against self-oscillations generating the laser effect. This is accomplished by blocking cavity reflections using both an antireflection (AR) coating and the technique of angle cleaving the chip facets. Unlike erbium-doped fiber amplifiers (EDFAs), which are optically pumped, SOAs are electrically pumped by injected current.

The basic SOA consists of a central active section about 600 μm long and two passive sections at the input and output sides of the chip, each around 100 μm long. The central active layer is based on a separate confinement heterostructure (SCH) and consists of a 0.2-μm-thick tensile bulk active layer embedded between two 0.1-μm-thick quaternary layers. It is tapered over a length of 150 μm, which allows optical coupling to an underlying passive waveguide. This type of structure provides a high optical confinement factor because of index mismatch between the layers in the gain section, together with a large spot size at the facets for achieving a high chip-to-fiber coupling efficiency.

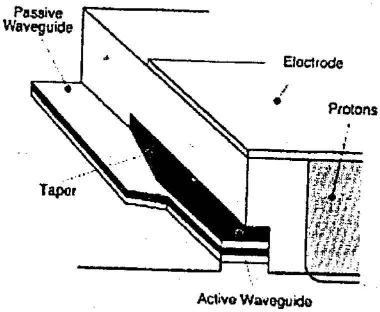

Figure 11.1. The principle of operation of the SOA for a nearly ideal traveling wave amplifier with very low residual reflectivity (R~0)

The key parameters required for an soa include:

- residual reflectivity of less than 10^{-4} to ensure a gain ripple below 0.5 dB
- low optical loss to achieve a net gain as high as 30 dB
- high material gain to allow low-drive current operation (20 to 30 dB fiber-to-fiber gain for a 100-mA drive current)
- high output saturation power, defined as the output power for which the gain is reduced by 3 dB
- chip-to-fiber coupling loss of less than 3 dB per facet, which is achieved using integrated mode-expanding tapered waveguides at the output facets.
- polarization sensitivity of less than 0.5 dB, because the polarization state of the optical signal coming from a link fiber is usually random. Material gain is isotropic in bulk material, however, so polarization sensitivity (differential gain between transverse-electric (TE) and transverse-magnetic (TM) modes) as low as 0.3 dB can be achieved with a near square (0.4 µm * 0.6 µm) active waveguide having almost the same confinement factor for both polarization states.

All these characteristics cannot be simultaneously obtained, so compromises must be found. A quantum-well (QW) SOA structure will satisfy requirements for low residual reflectivity and optical loss, as well as high material gain. On the other hand, such a structure is inherently polarization sensitive, as TE mode gain is greater than TM mode gain. The effect can be reduced by combining compressively strained QWs, which yield higher TE gain and tensile QWs, which yield higher TM gain.

Types of SOAs

Depending on the efficiency of the AR coating, SOAs can be classified as resonant devices or traveling-wave (TW) devices. Resonant SOAs are manufactured using an AR coating with a reflectivity around 10^{-2}. They typically feature a gain ripple of 10 to 20 dB and a bandwidth of 2 to 10 GHz. TW devices incorporate a coating with a reflectivity less than 10^{-4}. They show a gain ripple of a few dB and a bandwidth better than 5 THz (e.g., 40 nm in the 1550 nm window).

Telecom applications require a TW design, which can be used for applications such as single-channel or wavelength-division-multiplexed (WDM) amplification in the metro space, optical switching in core network nodes, wavelength conversion in optical cross-connects, and optical reshaping and reamplification (2R) regenerators or optical reshaping, reamplification, and retiming (3R) regenerators for long-haul transport networks.

The input optical power P_{in} injected into the SOA waveguide is amplified according to $P_{out} = G_{sp} P_{in}$, where G_{sp} is the single pass gain over the length L of the TW SOA such that $G_{sp} = \exp(g_{net} L)$. The net gain g_{net} is given by $g_{net} = \Gamma g - \alpha$ where Γ, g, and α are the optical confinement factor, the material gain, and the optical loss, respectively.

Using titanium oxide/silicon oxide (TiO_2/SiO_2) layers for the AR coating technology, it is possible to achieve reflectivities on the order of 10^{-5}. By combining tilted facets (about a 7° angle) with an AR coating, a device with a highly reproducible and extremely low residual reflectivity can be achieved, leading to gain ripples as low as 0.5 dB.

A large number of incoming channels can saturate an SOA. Gain saturation caused by one channel modifies the response of the other channels, inducing crosstalk between channels. WDM applications thus require a device with high output saturation power. To solve this problem, researchers at Alcatel have developed the gain-clamped (GC) SOA, which is based on distributed Bragg reflector (DBR) technology.

In a GC-SOA, the design is modified to incorporate a Bragg grating in each of the two passive waveguides. This creates a resonant cavity and thus a lasing effect. By programming the SOA to generate the lasing effect at a wavelength λ_{laser} located outside of the desired amplification bandwidth of the SOA, it is possible to stabilize the gain.

Typically, λ_{laser} is around 1510 nm for the SOA operating bandwidth corresponding to the C-band (1530 to 1560 nm). Due to the lasing effect, the charge carrier density N saturates, and the optical gain (which is proportional to N) saturates too, whatever the input signal level. Thus, the gain is stabilized, but at a lower level compared with the standard SOA structure (around 15 to 18 dB). On the other hand, the 3 dB saturation output power is higher (around 12 dBm). Discrete stand-alone standard and gain-clamped SOA modules have been developed and manufactured

SOAs in action

Amplifiers: Discrete stand-alone SOAs can be used as compact booster amplifiers (a standard device for single-channel operation, a gain-clamped version for WDM operation), or to achieve high-sensitivity optically preamplified receivers as an interesting alternative solution to replace avalanche photodiodes for data rates of 40 Gb/s or higher.

Noise figure is a key consideration for amplification applications. Noise figure is defined as n_{sp}/C_1 where n_{sp} is the inversion factor and C_1 is the overall input loss (mainly input coupling loss of about 3 dB). Because n_{sp} and C_1 depend on the polarization state of the input light, noise figure is defined for each polarization state. Usually, for nonpolarization-dependent amplifiers such as EDFA, noise figure is defined as $2n_{sp}/C_1$. Thus, a 3 dB difference exists between SOAs and EDFAs.

Switching: Optical cross-connects (OXCs) constitute a major application area for SOAs. High-capacity optical routers in WDM nodes must perform high-speed optical packet switching as well as all-optical wavelength conversion to avoid channel conflict and to provide wavelength reallocation. SOA gate arrays are well suited for fast switching of the WDM 1550-nm wavelength range.

An SOA gate array is an array of devices monolithically integrated on the same substrate and used as a gate. When injected current in an SOA is high, it passes light through with some amplification. When injected current falls near zero, the device blocks the light. Thus, an SOA array can act as a switch.

A number of SOA chips can be integrated on the same substrate to create high-density switching matrices. Hybridization on silicon or silica platforms can enable large-scale integration.

This technology provides self-alignment of the SOA array to input and output fiber bundles using V-grooves and alignment indentations performed in a silicon submount.

Table 11.1

Parameters	Standard SOA module	Gain-clamped SOA module
Wavelength of maximum gain	**1540 nm**	**1540 nm**
Fiber-to-fiber gain P_{in}=-25 dBm	**25 dB**	**17 dB**
Gain ripple	**0.5 dB**	**0.5 dB**
Polarization sensitivity	**0.5 dB**	**0.5 dB**
Noise figure nsp/C1	**7 dB**	**7 dB**
Saturation output power at 3 dB gain compression	**3 dBm**	**11 dBm**
Maximum output power	**10 dBm**	**11 dBm**
3 dB optical bandwidth	**40 nm**	**40 nm**
Lasing wavelength	**NA**	**1510 nm**
Driving current	**150 mA**	**150 mA**

Wavelength conversion and regeneration: Reconfigurable networks require wavelength conversion capabilities and all-optical regeneration. Wavelength conversion can be achieved through cross-phase modulation (XPM) performed in an SOA-based Mach-Zehnder interferometer. An input modulated signal at the wavelength λ_s modulates the carrier density of the SOA inside the interferometer due to cross-gain modulation (XGM). This effect modulates the refractive index of the material and thus modulates the phase of an incoming continuous-wave signal at the wavelength λ_c. The Mach-Zehnder interferometer converts this phase modulation into amplitude modulation. At 10 Gb/s, all-active Mach-Zehnder wavelength converters show input signal sensitivities as good as —10 dBm with a conversion penalty of less than 1 dB.

The method can perform up or down conversion for any wavelength within the C-band. A key advantage of the Mach-Zehnder structure is that the nonlinear response of the interferometer results in an increase in signal extinction ratio after conversion, leading to 2R regeneration.

A wavelength conversion operation incorporating a cascade of two SOA-based MZ-interferometer wavelength converters used in a co-propagation scheme can yield 3R regeneration. The first stage performs reshaping and retiming; then the second stage matches the chirp of the output data for transmission over a high dispersion link. In a differential-mode configuration, this approach can operate at data rates as high as 40 Gb/s.

Selection and inversion: SOA-based devices also can perform wavelength selection and midspan spectral inversion. A wavelength selector has been created using SOA gates positioned between two phased array wavelength demultiplexers. This scheme can achieve nanosecond-scale wavelength selection. The monolithic integration is very attractive in terms of compactness and compatibility with high-volume manufacturing.

Spectral inversion is a mirror effect achieved in the signal spectrum between higher frequencies and lower frequencies, which are inverted. It can be used as a dispersion compensation technique. It can be implemented using optical phase conjugation (OPC) in an SOA structure in high-bit-rate transmission systems using standard single-mode fibers. Such an approach can allow a system to operate even in the face of high chromatic dispersion.

The OPC is realized by generating four-wave mixing (FWM) in a long bulk type SOA structure (around 1200 μm long) optimized to show a high confinement factor ($\Gamma \sim 0.6$). The SOA, located at the midspan of the link, exhibits a high FWM conversion efficiency and optically conjugates the signal spectrum. The signal spectrum is inverted at the SOA output and the signal is regenerated after propagation in the second half of the link. Long-haul high-bit-rate transmission can be achieved using OPC in an SOA.

SOAs are an enabling technology for advanced optical networks. The potential for large-scale integration of SOA technology offers economical, high-performance devices that combine monolithic and hybrid solutions. Monolithic integration on indium phosphide can be used to create MZ-SOA wavelength converters or integrated wavelength selectors. SOA-arrays hybridized on silicon or silicon dioxide submounts can be made using the combination of both hybrid and monolithic technologies. Using SOAs, various devices can be built with enhanced functionalities as required for future optical networks.

(By Jean-Jacques Bernard and Monique Renaud, Alcatel,
OEMagazine, September, 2001)

UNIT 12

1. Memorize the following words:

- to lack
- approach
- laser-assisted
- laser welding
- to carry out
- to cause
- damage
- visible
- to capture
- feedback
- to focus
- to conduct
- to saturate
- gain
- to pump
- to amplify
- angle
- threshold
- to enhance
- to tune

2. Translate these synonyms and memorize them:

- meet (v), encounter
- every (adj), each
- maintain (v), support, keep
- prevail (v), predominate
- stop (v), cease
- increase (v), enlarge, raise
- affect (v), influence
- liberate (v), release, free

3. Translate the international words without a dictionary:

symbol, identical, phase, specific, physics, formation, formulation, to extract, to induce, to start, to pulsate, human, scheme, manner, design, idea, to utilize, engineering, expression.

4. Translate the following sentences paying attention to different infinitive forms:

1. The input and output units are known to be the parts of a computer.

2. Education system called EuroLaser Academy is known to have appeared quite recently in the Internet.
3. Oxygen concentration is known to influence many silicon wafer properties, such are a wafer strength, resistance to thermal warping, instability and resistivity.
4. New developments in materials are believed to be due to new manufacturing forms and vice versa.
5. The layout happens to specify the pattern of each layer of the I. C.
6. Plasma etching is expected to play an important role in manufacture of semiconductor and other devices requiring fine-line lithography.
7. To do the program for a computer a programmer must have a good knowledge of mathematics.
8. He described the tube to be used in all modern systems.
9. She appears to know everything about the properties of this substance.
10. We know emission to be controlled by space charge in the high-vacuum tube.
11. To reduce fluctuations is extremely necessary.

5. Translate the text:

Text A. **Sealing the Gap**

Mending tissue with laser welding or soldering provides stronger, cleaner healing than sutures.

Bonding the edges of human tissue is a vital step in most surgical procedures. In medicine today, surgeons suture or staple incisions, and the tissue bonding process occurs naturally. Laser-assisted bonding, which is in the developmental stages, may help improve post-operative bonding, ultimately speeding the healing process.

Researchers have known for 20 years about the benefits of laser heating, but the field has lacked definitive research on how it works or how to optimize the process. There are two fundamental approaches to laser-assisted bonding of tissue: laser welding (heating the adjacent edges of cuts in tissue by a laser beam) and laser soldering (applying a biological solder onto the adjacent edges and heating the solder and the underlying tissue); both are promising surgical techniques. They are, in principle, easier to master and faster to perform than standard suturing, and they generate an immediate watertight seal. Because these methods are less invasive, the patient experiences reduced tissue trauma and less reaction to foreign bodies. Welding and soldering lead to faster wound healing and better cosmetic results; both are compatible with endoscopic applications.

To exploit these techniques, we must understand the bonding mechanism and optimal parameters. In early experiments, we carried out pathological examination of tissues that had been heated by a laser beam. We found that heating incisions to temperatures of 40°C or lower causes no effect, while heating incisions to temperatures higher than 70°C may cause thermal damage. To investigate this range and determine the temperature band at which laser bonding works best, we developed a fiber-delivered laser system that allowed us to control tissue heating based on the tissue temperature. With this system, we tried to define the exact conditions for optimal soldering.

Building and optimizing

For beam delivery, our group developed unique optical fibers made of polycrystalline silver halides ($AgCl_xBr_{1-x}$), which are highly transparent in the mid-infrared spectral region (3 to 30 μm). We normally make fibers with diameters 0.5 to 1.0 mm and lengths up to 10 m. These fibers are flexible, nontoxic, and nonsoluble in water, and, unlike the "photographic" silver halides, they do not darken under visible light.

We used the fibers with a carbon-dioxide (CO_2) laser and an infrared (IR) detector to make a system for monitoring and controlling the temperature of a spot on the tissue surface. The AgClBr fiber carries less than 1 W of 10.6 μm radiation from a CO_2 laser to heat a 2- to 3-mm diameter spot on the surface of the skin to temperatures lower than 100°C. The heated spot emits mid-IR radiation whose intensity is determined by the surface temperature *T*. A second AgClBr fiber captures this radiation and delivers it to a pyroelectric IR detector, filtered to block reflections from the CO_2 laser. The detector drives a feedback loop that controls the power emitted by the laser, and thus the temperature of the heated spot. The stability of the surface temperature obtained *in vivo* (in animal models) was usually ± 3°C around the preset temperature.

We focused on laser soldering, rather than laser welding, and selected albumin as a biological soldering material. Albumin is a water-soluble protein that coagulates when heated. It is highly absorptive at CO_2 laser wavelengths, which allows us to more easily control the temperature of the albumin layer, and thus the bonded tissue. The solder also adds immediate mechanical strength and reduces the overheating of the underlying tissue.

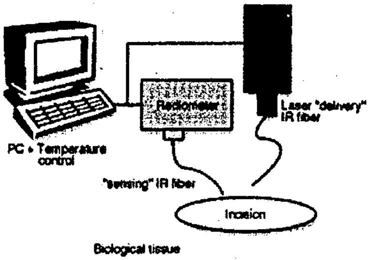

Figure 12.1. Fiber-optic CO_2 laser soldering system features temperature control.

We first investigated the optimal parameters for laser soldering of tissues by bonding incisions in animal subjects. We pulled the edges of the incisions close together and applied a thin layer of albumin. We then used the laser soldering system to heat a spot on the incision to a temperature T, for a time t. Using such spot soldering we closed the whole incision. In a control group we closed the cuts with standard sutures. We obtained the incisions for pathological testing at 3, 7, 14, and 28 days. The skin sections were subjected to either tensile strength measurements, tissue pathology tests, or scanning electron microscopy (SEM) analysis.

The strongest tensile strength was achieved for soldering at 60°C and roughly 8 to 10 s of exposure per spot. When soldering at 60°C and 8 to 10 s, the immediate tensile strength of the laser-soldered incision was lower than the strength of sutured incision. Tests conducted after the procedure, however, showed that the strength of the laser-soldered incision gradually increased, and it became as strong as a sutured incision after three days. We also used SEM and tissue pathology tests to compare the laser-soldered incisions at these parameters to the ones that had been sutured. The results of both methods confirmed that soldering at 60°C and 8 to 10 s gave optimal results. We used these parameters for all our further experiments on other types of tissue.

Test runs

Suturing or stapling incisions introduces foreign materials that cause inflammation and leave visible scars. In an attempt to determine whether laser soldering causes less damage and scarring in bonded tissues, we tested incision healing on animal subjects using both laser soldering and suturing.

After 10 days, laser-soldered scars looked better cosmetically than sutured ones. Microscopic studies indicated that the wound healed better and faster in soldered scars, compared with sutured scars. Pathological tests studying the inner layers of the skin (dermis and hypodermis) 3, 7, 14, and 28 days after the procedure indicated that the soldered incisions exhibited less inflammation than the sutured ones. Two weeks after the procedure, the inner layers of the soldered incisions looked exactly like normal tissue (without incision). In comparison, even after 28 days, the sutured incisions were still visible.

SEM results indicated that the albumin-assisted CO_2 laser soldering of cuts resulted in an even and smooth surface appearance, hardly distinguishable from that of normal intact skin. Suturing produced scars with surfaces free of debris, but the quality of the sutured incisions was inferior to that of the soldered ones.

When an area of the cornea is damaged, it is often necessary to perform a corneal transplant. A small disk is surgically removed from the cornea. A disk of the same size is removed from the cadaver of a donor and is sutured in place of the removed disk. The sutures may cause inflammation, and it is sometimes necessary to keep the sutures in the eye for more than a year. Laser soldering may offer an alternative way of attaching the disk to the cornea.

We tested the process on animals by soldering one eye and suturing the other. Under the operating microscope, the tissue surrounding the soldered area remained clear with no charring. The anterior chamber, which lies between the cornea and the lens and which contains a transparent fluid--the aqueous humor--also remained clear.

In samples for pathological tests taken 16 hours after bonding, the soldered incisions showed no thermal damage and minimal inflammatory reaction. Coagulated albumin solder bridged the small gaps between the edges of the incision. New epithelium was starting to form at the cut edges.

By comparison, in the sutured area, we found a moderate inflammatory reaction, and the gap between wound edges was larger than in the soldered corneas. Sutured incisions in both rabbit and pig corneas developed a multitude of new blood vessels around the sutures, which can cause rejection of the corneal transplant and reduces transparency of the cornea.

We also conducted preliminary experiments of laser soldering on incisions in other tissues such as blood vessels, urinary bladders, and ear drums. All exhibited good bonding.

Preliminary results

Laser welding and laser soldering have yet to be widely used in the clinical setting. This is probably due to three reasons: The initial tensile strength has been too low during the first few days compared with standard closure methods; there has been a lack of consistency in tests; and some methods result in thermal injury to neighboring tissue.[6] Few researchers have reported reliable results, and only a handful reported clinical trials of laser welding or soldering have taken place.

Our fiber-optic laser soldering system provides reliable bonding with sufficient tensile strength and minimal thermal damage. Using predetermined parameters, we found that on both skin and corneal incisions, soldered scars look better, get less inflamed, and are stronger than sutured scars. Preliminary results indicated that the same holds for blood vessels, urinary bladder, nerves, and other types of tissue. We expect that the fiber-optic system will make it possible to carry out laser soldering in many medical disciplines, and it may be viable to use this technique endoscopically.

(By Avi Ravid, David Simhon, Eyal Strassman, Nissim Loya, Noam Kariv, Tamar Brosh,
Marissa Halpern, Daniel Levanon, and Abraham Katzir,
OEMagazine, September, 2001)

Text B. **Packaging the Goods**

Packaging design for photonic components requires careful attention to the optical and electrical connections while maintaining performance in the face of thermal, mechanical, and vibrational stresses.

Every day, more and more applications use photonics components to enhance performance, reduce size, or reduce cost. The demand for volume deployment of photonics components has soared, and with it the need to effectively package these unique technologies in a reproducible and cost-effective way. In the microelectronics world, the term "packaging" typically refers to the encapsulation of the componentry into a form that can be easily connected into a circuit, while protecting it from assembly and test handling damage, as well as the environment in which it will eventually be used. In the photonics world, packaging often combines the need to provide not only for electrical connection, mechanical support, and thermal management, but also, more critically, an optical connection that is highly directional in nature and requires extremely precise control of positional tolerances between components. The packaging of photonic components represents unique requirements and challenges, but following a few rules of thumb about design and manufacturability simplifies the process.

Photonic components can be classed as active or passive (see table). Active devices are those requiring some sort of electrical connection. A common type of active device performs some sort of optoelectronic conversion, either converting electricity into light, as in a diode laser, or converting light into electricity, as in a photodiode. Other types of active devices either manipulate the signal (modulate, amplify, or attenuate) or change its direction or magnitude (switching, attenuation, scanning).

Passive devices are those that do not have any electrical connections. They simply filter or route the signal, based on wavelength, intensity, or polarization. In other words, the light passes through them without any electrical energy being added or extracted from the device. These devices typically have multiple fibers going into and/or out of them.

Both of these classes of devices share many common packaging requirements; yet each has some unique ones as well. It is easiest to distinguish these in the context of the optical, mechanical, electrical, and thermal design considerations.

Design requirements

The packaging design must be driven by the design requirements of the component. Not surprisingly, there are tradeoffs involved in the packaging design process, so it is important to understand the requirements.

The most critical aspect of any photonics package by far is the optical connection. Unlike electrical connections, these have some very interesting and challenging characteristics. Optical connections require extremely precise alignment and are highly sensitive to relative motions between the device and the optical components, which typically include some sort of lens and a fiber. Displacements on the orders of fractions of a micrometer can render the component useless. Passive devices often have many couplings, further complicating the assembly process.

The ability to effectively get light from the device into a fiber is characterized by a parameter known as coupling efficiency. To achieve good coupling efficiency, it is necessary to shape the beam to match the mode of the beam emitted by the device to that of the fiber. Diode lasers, for example, often emit high elliptical beams. Efficiently coupling these beams into a circular fiber core requires special lenses to reshape the beam. In general, high coupling efficiency (or low loss) is a property even more important for passive devices.

Many optoelectronic devices are sensitive to optical feedback, commonly caused by back-reflection from the coupling optics. Specialized coatings, angle-cleaved fiber, or optical isolators can minimize or eliminate this problem.

Stabilizing many active devices requires continuous monitoring of either power intensity or wavelength, requiring additional electronic and/or optical components (e.g., a monitor photodiode, etalon filters, etc.). This adds to the complexity of the device, and these typically require precise alignment/placement as well.

As mentioned above, only active devices require electrical connections, often to both the device itself and the cooling and/or monitoring elements as well. High-speed devices are currently running as fast as 40 GHz. At these microwave frequencies, the wiring tends to act as an antenna and can induce noise. Thus designers must pay particular attention to the design of the wire-bonding or die-bonding connections, as well as packaging shielding.

For both active and passive devices it is important to manage the thermal dissipation within or across the device because thermal gradients will typically lead to misalignments and reduced coupling performance, or degradation of the device itself. For active devices, the heat generated within the package is of primary concern. Active devices are typically cooled using thermoelectric (TE) cooling elements soldered to the package base, which is eventually mounted to an external heat sink.

Table 12.1

Examples of different classes of fiber-optic components

ACTIVE DEVICES	PASSIVE DEVICES
Transmitters	**Wavelength Division Multiplexers/DeMultiplexers (WDM)**
Receivers	**Filters**
Modulators	**Isolators**
Attenuators	**Couplers**
Switches	**Power Splitters**
Amplifier Pumps	**Arrayed Waveguides**
Semiconductor Optical Amplifiers (SOA)	

Many fiber-optic components go into underground or undersea optical networks, so device reliability is paramount. Packaging design and execution can have an important effect on device lifetime. To design for reliability, avoid using epoxies that produce curing or outgassing residues that can affect the devices or the optics. Telcordia specifications, the industry standards for environmental resistance, are very stringent. Component performance and hermetic seal integrity must be tested in the face of mechanical shock, vibration, and thermal cycling over a range as high as 100°C. When designing packaging for these components, it is important to pay particular attention to the quality and accuracy of mechanical attachments in order to maintain optical, thermal, and electrical connections during these tests.

The manufacturing process

A back-end packaging process can typically be broken down into a series of major steps: preassembly device test and sort, package assembly, optical assembly (or "pigtailing"), sealing, and final test and qualification.

The first step is preassembly device testing and sorting, in which initial performance characterization, inspection, burn-in, and sorting is done prior to assembly. To achieve high yields, it is important to devise appropriate methods for handling the devices, for example using submounts and specialized carriers.

The next step is package assembly—placing the components into a package or onto a submount prior to making the optical connection. Tolerances are typically in the 10 to 50 μm level for these types of placements, and automation systems with machine vision can ensure repeatably high yields. Special attention should be paid in the design phase as to how the parts are to be handled and transferred to minimize damage.

Optical assembly comes next. The optical assembly requires extremely specialized submicrometer alignment and an attachment process that will maintain the alignment both during assembly and in the field. Active optical alignment, in which power throughput is monitored during this process, is often necessary to assure high yields. In some cases, however, passive alignment (no electrical or optical power coupling required) is adequate, depending on the device and performance requirements. Vision-assisted positioning systems can achieve passive alignments of 1 μm.

Many components must be hermetically sealed after alignment. For active devices or optical elements that are sensitive to moisture, this is often preceded by a bakeout, which reduces or even eliminates moisture and contamination. Bakeout is followed by a backfill with inert gases. Many passive devices are potted within an external cylindrical housing. Occasionally the hermetic seal is performed prior to the pigtailing operation.

Once the device is completed, a full characterization is performed. It is important to prevent handling damage at this point, so again it is important to design appropriate carriers and handlers to assure high yields.

The major challenges that are uniquely associated with photonics packaging relate to the extremely tight assembly tolerances and the difficulty of handling fragile fibers during a volume production process. In order to achieve and maintain alignment, it is important to pay special attention to the bond joints and joining techniques. Some processes, like soldering and laser welding, allow for post-bond adjustment to correct for shrinkage or bonding misalignments. Compensation offsets can minimize or eliminate bond shift. Epoxies lend themselves to shrinkage compensation, though they are typically not reworkable.

Another unique and highly challenging aspect of packaging photonics versus electronics is the fiber itself. Often during the manufacturing process, the fibers must be stripped, cleaned, and cleaved; coupled into light sources and detectors; fusion spliced, coiled, and uncoiled—all of which can induce breakage or defects that lead to low yields. Designing package and manufacturing flow to minimize handling is critical.

Lessons to remember

First-generation photonic components were designed to achieve high performance, not low cost. Today's markets are demanding drastically reduced costs in order to prove the economic viability of bringing optical networks to the home, which makes packaging a critical issue for the telecom market in particular. Design for manufacturability and automation is essential for future generations.

Several lessons learned from the first-generation devices, along with some good common manufacturing sense, lead to the following design rules of thumb for new designs:

1. Think standardization. There are few standards out there—whenever possible, use off-the-shelf package bodies, fiber ferrules, and optical components.

2. Consider handling issues early in the design phase, especially when handling small optics and electrostatic sensitive devices (ESDs).

3. Perform critical alignment/attachments outside the package if possible. Working inside the package is like building a ship in a bottle.

4. Think automation; for example, put fiducial markings on the devices to assist machine vision systems.

5. Put a handling fixture onto all components that need to be manipulated. Prepackage or prealign subassemblies (fibers, optics, etc.) to facilitate rapid assembly and reduce the number of adjustments needed in any given process.

6. Watch your tolerances. The optics will eventually define how tight the assembly tolerances are, but there are design options that will make the assembly more forgiving while still maintaining device performance.

7. Be alert to the relative motion of components. Keep all critical components together on one submount if possible to avoid relative misalignments with temperature.

8. Adopt solutions from the electronics and semiconductor industry. These industries went through many of the same challenges early on, and some of their solutions apply readily to photonics.

The very sensitive assembly tolerances, along with the fragility of fibers and optical elements, combine to make photonics packaging a much more difficult task than their purely electronic counterparts. However, many principles for design, manufacturing, and automation can be applied from the electronics and semiconductor industries to help next-generation devices achieve order-of-magnitude lower costs.

(By randy Heyler, Newport corp. OEmagazine, September, 2001)

UNIT 13

1. Memorize the following words:

- deployment
- to package
- cost effective
- damage
- as well as
- tolerance
- to simplify
- to attenuate
- magnitude
- to route
- to distinguish
- unlike
- alignment
- displacement
- coupling
- flux
- to conserve
- aberrations
- constraint
- to tailor

2. Translate these synonyms and memorize them:

- modern (adj), up-to-date, latest, new
- gather (v), collect
- enter (v), come in
- associate (v), connect, join
- therefore (adv), hence, consequently
- evident (adj), clear, obvious, apparent
- case (n), example, instance
- moreover (adv), furthermore
- immediately (adv), at once
- due to (adv), thanks to

3.Translate the international words without a dictionary:

arithmetic's, negative, to dictate, to mount, personnel, contribution, to occupy, stress, visually, inertia, to examine, to migrate, resonant, to stabilize, unique, reproducible, to adopt, opposite, massive.

4. Translate the following sentences paying attention to the active and passive voice of Present Participle:

1. The electronic current passing through a wire will heat that wire.
2. X-rays are produced when matter is bombarded by a fast moving stream of negatively charged particles.
3. Being started on time, the preparations will be completed before the beginning of the test.
4. Pilots could fly jet airplanes quite successfully having new instruments at their disposal.
5. All electrical conductors dissipate heat when carrying current.
6. Being heated magnetized steel loses its magnetism.
7. The model being shown to us now has been made by one of he best specialists of our plant.
8. The material being referred to in the engineer's report is difficult to find.
9. The basic circuit of the device being built is described in detail in this article.
10. Radio waves are emitted from a conductor carrying the alternating current.

5. Translate the text:

Text A. **Taking the UV Challenge**

Many important commercial applications use ultraviolet (UV) lasers, including microlithography, marking and micromachining, fiber Bragg grating (FBG) fabrication, and medical procedures such as photorefractive keratectomy. One of the technical challenges encountered in the development of these applications has been the volume production of reliable, high-performance, laser-grade UV optics.

The UV spectral region begins around 400 nm and goes down to about 1 nm. As wavelength decreases, different substrate materials, coating materials, production methodologies, and cleaning techniques must be used. Thus, in a discussion of UV optics, it is useful to break this spectrum into several different bands.

Long Band

In the region from 300 nm to 400 nm, the most commonly used material for external cavity optics is fused silica, which possesses good chemical and physical characteristics for polishing. These optics are coated using the same materials and thin-film coating techniques employed in the visible spectrum. This includes the use of oxide coating materials such as hafnium oxide (HfO_2) and aluminum oxide (Al_2O_3), which offer a high refractive index, high damage resistance, and excellent mechanical (durability) characteristics. For low index layers, manufacturers also turn to fluoride materials such as magnesium fluoride (MgF_2), which are generally softer and more hygroscopic.

The biggest problem in this spectral region derives from the fact that as design wavelength shrinks, coating response narrows. For example, a typical quarter-wave stack high reflector has a bandwidth of about ±10%. At 512 nm, this translates into a total usable bandwidth of about 100 nm, while at 308 nm, it is only 60 nm. Therefore, as design wavelength decreases, it becomes increasingly important to center the coating on the nominal wavelength. This requires that layer thicknesses be more tightly controlled, and makes coating chamber distribution effects more pronounced. The same logic applies to substrate preparation: An optic with $\lambda/10$ flatness at 308 nm is more than twice as flat as a $\lambda/10$ optic at 633 nm, and is therefore more difficult to produce.

Midband

From about 240 nm to 300 nm, many oxide coating materials can still be used. In the case of substrates, however, systems must contain more than fused silica to achieve optimal performance. For color correction, in particular, designers use calcium fluoride and MgF_2. These are crystalline materials that are anisotropic, hygroscopic, and very prone to edge chipping and fracturing.

Many manufacturers have developed their own proprietary techniques for working with crystalline materials. At Alpine Research Optics, we have had the most success with pad polishing, as opposed to conventional pitch laps. However, probably the most important step we have taken is simply to environmentally isolate the crystalline material polishing area to prevent small airborne particulates from our glass- and silica-polishing operations from settling on the optics and causing scratches. Fine debris must also be continuously evacuated from within the crystalline material production area.

Short band

Absorption precludes the use of fused silica for transmissive optics below 193 nm and virtually all oxide coating materials below about 220 nm. Because optics manufacturers are restricted to using low-index fluoride coating materials, typical coatings must incorporate more layers than at longer wavelengths. This is because the number of layers required to achieve a given level of coating performance (such as the peak reflectivity in a quarter-wave stack high reflector) increases as the index difference between coating layers drops. Reliably producing coatings with larger layer counts presents practical challenges with fluoride materials, however, because of their physical characteristics. In particular, these films tend to be more brittle and prone to crazing. Producing durable coatings for wavelengths below 220 nm thus requires precise monitoring, a well-characterized process, and tight control of all deposition parameters, such as temperature, pressure, layer counts, and materials.

Contamination also becomes increasingly important at shorter wavelengths because most materials absorb strongly at UV wavelengths. When working below 250 nm, for example, contamination concerns necessitate the use of a dry pump system that utilizes no hydrocarbon oils whatsoever.

At 157 nm, contamination becomes the overriding issue. In fact, absorption is so strong at this wavelength that even a monolayer of surface contamination (oil, water, or oxygen) can cause losses of up to 15%. Furthermore, traditional cleaning methods and substrate heating are not sufficient to completely remove impurities on this scale. In response, some manufacturers of deep UV optics have developed proprietary cleaning methods. For example, we use a two-stage cleaning process. The first stage involves traditional cleaning using a methanol wipe with high-quality lens tissue and nanograde methanol. The second stage is a form of reactive cleaning performed in a sealed container that is continuously flushed with an ultrapure combination of inert gas and oxygen. The component is irradiated with either a deep UV laser or light from a deep UV discharge lamp. The reactive combination of energetic photons and oxygen removes most types of surface contamination. The oxidized and vaporized contamination is then flushed away by the gas flow. The two-stage method yields a typical surface transmission of better than 99.5%.

Driven by the needs of several commercially important applications, as well as the availability of more powerful laser sources, deep UV optics remains an area of very active development. Ongoing advances in both substrate preparation and thin-film coating technology should continue to yield optics that can withstand higher fluencies and larger pulse counts while operating at shorter wavelengths.

(By Wayne Pantley and David Collier, Alpine Research Optics, OEmagazine, October, 2001)

Text B. **Optical Engineers Build Photonics Foundations**

Optical design is more than just stringing components together

Like the bricks and mortar that hold up a building, optical engineering is the foundation of any system based on photonics. In a photonic system, the key to accomplishing a task is getting the photons where you want them to go, when you want them to be there, and in the proper form, whether that is a concentrated beam, a diffraction pattern, or a diffuse reflectance. That goal is accomplished by optical engineering, which involves design issues beyond just components. "It's a lot more than lenses and mirrors," says Robert Fischer, president and CEO of Optics1 (Westlake Village, CA), who prefers to use the term photon management. "You have to think about mechanical and optomechanical elements, packaging issues, configuration, cost, manufacturability—all the things they don't teach you in school."

An important part of optical engineering is design tradeoffs. Warren Smith, chief scientist at Kaiser Electro-Optics (Carlsbad, CA) points out the challenges in the hot area of LCD-based head-mounted displays. "The big problems amount to trying to get a big eyebox and a wide field of view simultaneously," he says. Indeed, optical design has always been about making tradeoffs and balancing requirements. "Wide field and high resolution for a given LCD are kind of an invariant—you can't raise one without cutting the other. The way people are doing it is to use more than one LCD."

Fischer agrees. His group recently completed a multispectral imaging system for the Navy that can simultaneously image a scene in the visible, medium-wave infrared (IR), and long-wave IR spectral regions. "There were a total of five different images that could in theory all be presented simultaneously. Completing it took all the aspects of optical engineering, including packaging, mechanical and optomechanical design, lens design, coating design, and issues regarding the IR sensors," Fischer says. "Then of course once you assemble it you have to align all of these things. It was a pretty massive project."

Image isn't everything

In recent years, optical engineering has broadened out to include sophisticated nonimaging system design, according to Fischer. "Ten years ago almost everything was imaging optics. Now with medical devices, sensors, and fluorescence measuring equipment where they're detecting photon flux, [nonimaging optical design] is becoming really important, much more than it ever was in the past," he says.

Nonimaging optics can range from illumination optics to concentrators and collectors for applications such as solar power, radiant heating, and signal detection. "You're basically building a light funnel," says Ben Jacobson, president of Illumitech (Chicago, IL). "The materials are invariably the same [as for lens designs]; the innovation is in the shape." Engineers are now designing collectors for nonplanar absorbers with tube shapes, for example. "You need quite different solutions," Jacobson says.

It also involves a different mind set. "Classical nonimaging optics is for applications where it's very important to get maximum efficiency and also radiance concentration within a specific aperture," Jacobson says. "Traditional optics allows you to collect all the energy and conserve radiance only for a single point or a small area. Once you get off-axis, you have aberrations, which force you to choose between conserving radiance and collecting all the energy. Nonimaging optics allows me to collect all of those off-axis points as well."

Doug Goodman of Polaroid (Waltham, MA) agrees. "An imaging system has constraints that a nonimaging system does not," he says.

What this basically means is that for nonimaging optical design, you need to throw away aberration theory and start from scratch—completely the opposite of most optical-design education. "Most of the practitioners don't come from an optics background," says Jacobson. "The analogies to thermodynamics and mechanical engineering are better than the analogies to imaging optics in some ways."

Nonimaging optics also involves tailoring, which is used to create a uniform illumination field or a specified irradiance distribution for applications such as transportation lighting, automotive lighting, traffic signals, and solid-state lighting. "LEDs are now more efficient than incandescent lamps, so people are willing to pay the cost penalty. The new generation of LEDs has such compelling benefits that lighting designers have to use them," says Jacobson. The change will open up opportunities for nonimaging optics designers. "The arrival of LED lighting is probably going to leverage another wave of changes in lighting optical design, and nonimaging optics is in the right place at the right time to ride on top of that."

(By Kristin Lewotsky, OEmagazine, October, 2001)

Text C. **Nanotechnology Packs a Big Punch**

In the nano regime, material characteristics are dominated by surface effects rather than bulk material effects, opening up a host of new possibilities.

Nanotechnology is one of those buzzwords that gets tossed around a lot yet doesn't seem to have a clear meaning. "The problem with nanotechnology is that everyone has a different definition," says Francisco Santiago of the U.S. Naval Surface Warfare Center (Washington, D.C.). One common misconception is that microelectromechanical systems (MEMS) technology and nanotechnology are synonymous. The reality is that MEMS structures are typically in the micro range and hence are distinct from the nano regime. The official definition of the U.S. National Nanotechnology Initiative is that nanotechnology involves "research and technology development at the atomic, molecular, or macromolecular levels, in the length scale of approximately 1 to 100-nm range, to provide a fundamental understanding of phenomena and materials at the nanoscale and to create and use structures, devices, and systems that have novel properties and functions because of their small and/or intermediate size." For involving such small stuff, nanotechnology is generating a huge amount of interest around the world.

According to a recent essay by Mihail Roco, chair of the White House/National Science and Technology Council/Nanoscale Science, Engineering, and Technology Subcommittee, and senior advisor for the National Science

Foundation, global governmental funding for nanotechnology R&D has jumped from $432 million in 1997 to $2154 million in 2002. Roco estimates that the worldwide annual industrial production for this sector will exceed $1 trillion in 10 or 15 years.

Anyone who has studied modern physics understands that scale has a profound effect on the behavior of our physical world. Nanotechnology is essentially another regime, a world in which the familiar macroscale behavior does not apply. In the macro regime, bulk material effects are most important. In the nano regime, however, surface effects become dominant, with the result that materials formed of nanoparticles, for example, exhibit very different behaviors than large volumes of that same material in the macro world.

Nanotechnology is cross-disciplinary, simultaneously drawing from and benefiting areas like materials science, physics, chemistry, and biology. Roco estimates that in ten to 15 years, nanotechnology markets will represent $340 billion per year in materials, $100 billion per year in chemical plants, $70 billion per year in aerospace, $300 billion per year in electronics, and $180 billion per year in pharmaceuticals. Indeed, nanotechnology is more about generating new solutions in different application areas than about nanotechnology for nanotechnology's sake. "It refers to the whole set of activities that exploit the technology and computer power for manipulating matter atom by atom," says U.S. presidential science advisor Jack Marburger. "By virtue of the instrumentation that's available to us now, we have the ability to create new materials structures that do what we want them to do. That's what nanotechnology is all about."

With all of the scientific effort and funding being poured into nanotechnology worldwide, it's natural to wonder when the discipline might come to fruition. "It is really anyone's guess when the 'real' nanotech products might be released," says Aryavarta Kumar, CEO of nanotechnology information source Atomasoft (British Columbia, Canada). "There are companies working toward real nano products. A lot of the commercial funding is actually supplied by venture capitalists." Kumar thinks infrastructure is currently the most important aspect of the market. "Breakthroughs will most likely be on enabling technology to create future products rather than a commercial product, at least at this time," he says. "Zyvex (Richardson, TX), for example, is working toward building a molecular assembler, which theoretically is an enabling device to kick off other nano products. Optimistic people believe that nano products could make an entry into commerce within several years."

(By Kristin Lewotsky, OEmagazine, Jule, 2002)

UNIT 14

1. Memorize the following words:

- evident
- acceptance
- capacity
- investments
- to join
- shell
- to vary
- thickness
- scaling
- surface
- core
- to bind
- a great deal of
- to possess
- appropriate
- to impart
- coating
- utility
- to collapse
- dramatically

2. Translate these synonyms and memorize them:

- because of (prep.), on account of
- above (adv), higher, over, more, greater than, more than
- diffuse (v), dissipate
- rapid (adj), fast
- via (adv), through
- equal (adj), equivalent, adequate, same
- conventional (adj), usual, common
- remember (v), keep in mind
- although (conj), though
- note (v), mention

3. Translate the international words without the dictionary:

correct, track, to generate, activity, to coordinate, separate, to discuss, to interpret, interpretation, to decode, automatically, accumulator, application, limited, attraction, to orient, industrial, tactics, routine, planning.

4. Translate the groups of words with Present and Perfect Participles:

1. The velocity of the particle being accelerated in the cyclotron corresponds ...
2. The type of reaction being investigated will be discussed ...
3. The wave theory being considered was proposed ...
4. Systems being developed for use with radioisotopes ...
5. Being associated with the movement of the Earth the satellite orbit changes ...
6. Being installed in the satellite the instruments recorded ...
7. Having accepted this concept we ...
8. Having bombarded uranium with neutrons the scientists obtained ...
9. Having gained the positive charge the body fails to attract ...
10. Having been put into an orbit the satellite moved ...

5. Translate the texts:

Text A. **Cycling Though**

Photonics companies must follow a plan of preparation, reorganization, and automation in order to thrive in the next economic phase.

Technical optics as an old-economy field has turned out to become a new-economy field called photonics. Several industrial nations have recently conducted strategic studies that suggest that the field of photonics bears an extraordinary market potential for the future. In the past few years, the industry has shown astonishing growth rates. Stock exchanges and analysts have reacted to this potential, and the values of photonics companies have increased tremendously due to the high expectations set.

The success of the photonics industry is based on solutions that would not be possible without optical technologies. Such examples include continuously decreasing the size of structures in microelectronics and significantly increasing communications data rates and the rates of high throughput screening processes for biotechnology applications. In the boom-cycle enthusiasm of the past several years, however, industry observers recognized that new, high-volume markets are hardly predictable. Naturally, it is very difficult to foresee how many customers will make use of a new capability. This effect is evident in the telecom industry, in which the combination of both hardware solutions and service offers—and especially the acceptance of these services by the public—is essential for a successful market development.

The semiconductor industry suffers remarkable market oscillations in spite of a high average growth rate. Such forecast uncertainties have led to substantial misjudgments of the future market situation. Capacities are designated at a low level over a long period and thus cannot meet demand. After a time lag, the capacities reach the desired level, by which time the markets are already in a slump again.

Today we face a strong downturn in the cyclic semiconductor and telecommunications markets. Moreover, the weak world economy is spurring the industry to reduce investments in all areas, including laser, medical, and biotechnologies. Dramatic personnel reduction and reorganization programs, especially in the telecom field, are implemented as a reaction to the critical market situation.

These layoffs obviously will cause severe problems when the markets go up again next year. Know-how gets lost when jobs are lost: Not only are semi-skilled workers laid off, but also engineers. Suppliers in the photonics field are hit even harder as their customers have too many products in stock. In some cases, manufacturers are reducing production to zero, with the associated staff reductions.

Seize the moment

What has to be done? Management should use this period not only for reorganization and downsizing processes but also for the vigorous development of future technologies. There is no doubt that the cyclic markets mentioned above will be major drivers in the future of photonics. Companies have to be prepared for a new soaring growth so that they can take advantage of the inevitable upturn.

The automation of production processes is a crucial topic to consider for photonics' future. Automated processes allow improved flexibility and higher output with lower personnel costs. Furthermore, capacities can be built up more easily. The rate of automation in photonics companies is still quite low; therefore, there is a good opportunity for development in this field. Moreover, I am convinced that we have to face this challenge in order to stand up to the coming pressure in pricing.

Another element to consider is the development of new products and production processes. The road maps are well-known in many fields. Manufacturers should focus on the development of new products during economically weak periods, for these are the products that will induce the next boom.

The managers of photonics companies should devote their time to some basic subjects. The industry has to close the gap in some essential areas, including rapid prototyping, mass production of micro-optical components, production of micro devices, and automation of assembly processes. Only when we meet these challenges will we be able to find promising solutions for the strongly cyclic markets and to take advantage of the options for recovery that these markets offer.

(By Gerd Litfin, Linos AG, OEmagazine, December, 2001)

Text B. **High-Tech Learning**

The EuroLaser Academy's educational program replaces lectures and laboratory training courses with electronic delivery.

The Internet is changing our world, including the way we deliver education. A multitude of conventional manufacturing processes worldwide, such as high-speed, quality cutting and welding, would benefit from the application of high-power lasers. In order to apply the technology to manufacturing, the European photonics industry needs engineers who are trained to work with lasers. This type of training is not necessarily readily available, however. Laser technology is essentially interdisciplinary, which means mechanical engineers, for example, lack the knowledge of very essential electric components for laser systems and thus need additional education.

Unfortunately the very engineers who need to apply laser technology to manufacturing cannot be fully trained because as full-time employees they cannot afford the time to attend lectures and do laboratory work. In order to reduce the time away from home and work for attendees, the European Commission has launched a postgraduate education system called EuroLaser Academy (ELA) to convert lecture-hall teaching to distance and home learning by creating "virtual lectures" on CD-ROM. The ELA has used technology to bring otherwise unavailable lectures to hundreds of students who are unable to travel to take courses.

The lectures on these CD-ROMs have been given in Liverpool, Berlin, Vienna, Marseilles, Valencia, and Athens by some of the most recognized laser scientists from the EU countries. The CD-ROMs demonstrate laboratory exercises in institutes with cutting-edge equipment. The user sees the lecturer's original transparencies and slides on the screen and hears the lecturer's words in voice-over. At present, virtual lectures are available on laser physics, high-power laser sources including multi-kilowatt semiconductor lasers, beam/workpiece interaction, materials processing, and safety.

ELA students still need to participate in laboratory exercises to acquire practical experience. The solution to this dilemma is the partial substitution of hands-on, trial-and-error lab-work exercises conducted off-site rather than in a university laboratory. This method employs computer simulations that allow users to "assemble" experimental setups from parts and elements by drawing them to appropriate locations on the screen and adjusting the necessary parameters such as laser power, processing speed, and other variables to chosen values. The ELA supplies the user with instructional tips in the actual program that simulate laboratory exercises in a very realistic and highly illustrative manner. The code uses the choices to model performance and presents the result on the screen, allowing the user to optimize performance. The demo version on CD-ROM allowed users to build a high-power CO_2 laser and to operate it at a desired power level. These types of CD-ROMs will be available from the Austrian Laser Association (ARGELAS) by the end of the year.

With the support of the European Commission and the Austrian government, the virtual experiments will be expanded within the framework of a project called VIRTUELA (by a technically and regionally complementary partnership), and will be released on DVDs, which are also supported by Internet meetings. After the attendees have successfully carried out all the virtual experiments, they must visit one of the main European laser laboratories for just an extended weekend, a significant reduction in off-site time commitment compared to conventional course requirements.

After 2003 the project will include DVDs with experiments on CO_2 lasers, Nd:YAG lasers, high-power semiconductor lasers, cutting, welding, surface treatment, rapid prototyping, and laser safety. The completion of the program in 2003 is expected to allow larger numbers of trained industry workers to bring laser technology into the production lines.

(By Dieter Schuoecker, Vienna University of Technology, OEmagazine, December, 2001)

Text C. **Tiny but Mighty**

By altering the size and thickness of metallic nanoshells, engineers can manipulate their interaction with light.

Joining nanotechnology with optics, a new class of materials called metal nanoshells can absorb selected colors of visible or infrared (IR) light, offering the potential for new applications in thin films and coatings, chemical and biological sensors, and optical switching. In conventional materials, bulk-material effects dominate. In the nano regime, surface effects dominate. We use this effect in metal nanoshells.

Metal nanoshells are nanoparticles consisting of a dielectric core (typically silica) and a metal shell (typically silver or gold) whose optical resonant properties are determined by the relative size of the core and shell layers. By varying the core diameter and shell thickness, the nanoparticle resonance can be placed anywhere across most of the visible and IR regions of the spectrum. Scaling the absolute size of a metal nanoshell up or down allows one to manipulate the relative amount of scattering versus absorption occurring at the resonant extinction wavelength of the nanoparticles.

This powerful resonant effect is based on the electromagnetic properties of layered nanostructures, and in fact has been known for more than 50 years. Recently in our laboratory at Rice University (Houston, TX), we have developed a method for reproducible and reliable fabrication of these types of nanostructures.

Making a nanoshell

The growth method for metal nanoshells is essentially planar fabrication on a nanoparticle surface and incorporates a variety of wet chemical procedures from colloid chemistry, chemical self-assembly, and electroless plating. Silica nanoparticle cores ranging in diameter from approximately 50 nm to 1 μm are either synthesized or obtained from commercial sources.

The nanoparticle cores by themselves are inert. To become functional, the surfaces must be chemically modified using a siloxane species with an amine or thiol group. This coating process terminates the nanoparticle surface with a chemical species capable of binding to a small metal colloid; a metal colloid of 1 to 2 nm in diameter is then bound to the nanoparticle surface.

We introduce the seed particle into an electroless plating solution where metal can be reduced onto its surface. This procedure produces a uniform metal shell on the dielectric core, with thickness ranging from nominally 5 to 20 nm. The method permits nanometer-by-nanometer precision of metal deposition, which allows us to tune the optical properties of the completed nanoshell with a great deal of control.

Metal nanoshells fabricated using this approach possess resonant properties that agree quantitatively with Mie scattering theory. We use the theory to design resonant nanoparticles by calculating the appropriate shell and core sizes based on the resonant wavelength desired. The current fabrication method produces nanoshells whose resonant wavelengths comfortably span the near IR spectral region, which has a wide variety of technological applications.

Freedom and flexibility

Unlike photonic crystals, which rely on long-range 2-D or 3-D periodicity to achieve tunable resonant properties, the optical properties of nanoshells are controlled by the structure of the individual nanoparticles. This offers enormous freedom and flexibility in developing optically active coatings, materials, or components. Metal nanoshells can be incorporated into a wide variety of media, such as polymers, gels, or liquids, imparting their optical properties to the resultant composite material. The shells can act as an intelligently designed optical absorber, for example, which may be of use in the development of filters, coatings, and other components in the optics industry. They also can produce enormous enhancements of Raman scattering of nearby molecules, an effect that can be optimized to specific pump-laser wavelengths and that could be of great utility in the development of ultrasensitive biological or chemical sensors.

Because of their metal coating, illuminating nanoshells gives rise to a very large photothermal response. This effect, when combined with temperature-sensitive polymers, has been used to develop new optomechanical nanoshell-polymer composite materials. When illuminated, these materials collapse to approximately 30% of their original volume. This effect is optically driven, so the photothermal collapse can be induced remotely. The addition of metal nanoshells has also been shown to dramatically increase the active lifetime of luminescent conducting polymer materials by effectively inhibiting their photo-oxidation, quite possibly circumventing the need for encapsulation of the final material or device.

(By Naomi Halas, Rice University, December, 2001)

UNIT 15

1. Memorize the following words.

- to transfer
- to compare
- state-of-the-art
- to lack
- complication
- counterpart
- multiple
- stringent
- tolerance
- loss
- mirror
- fusion
- initially
- coupler
- adjacent
- to eliminate
- resolution
- to match
- deviation
- adjustment

2. Translate these synonyms and memorize them:

- device (n), instrument, appliance
- mainly (adv), primarily, chiefly
- find out (v), learn
- specific (adj), special
- necessitate (v), require
- provide (v), furnish
- in order to (prep), so that, in order that
- earlier (adv), previously, before
- identical (adj), the same
- in accordance with (prep), according to

3. Match these synonyms:

1. with respect to
2. control (v)
3. connect
4. naught
5. keep
6. denote

(a) zero
(b) retain
(c) indicate
(d) usually
(e) govern
(f) name

7. generally
8. call (v)
9. cause (v)
10.completely

(g) entirely
(h) give rise to
(i) with regard to
(j) join

4. ***Translate the following sentences paying attention to Past Participle and the active and passive voice of Perfect Participle:***

1. We have to consider all the factors involved in the construction of socket engines.
2. The program developed was suggested by SPIE.
3. The temperature used depended upon the substances entering the reaction.
4. Having been published in 1687, the three laws of motion are still the basic for many scientific achievements.
5. Hi is known now that some early satellites were burned up in flight having been set on wrong orbits.
6. The method suggested by a designer was of great practical importance.
7. The experiments referred to in our article demonstrate the properties of a fiber.
8. Having bun impregnated, paper can be employed in the manufacture of cables, transformer coils.
9. A substance acted upon by heat changed its composition.
10. Computers sort the data received.
11. A computer processes the importation supplied.
12. Most of the problems solved have been of rather elementary nature.
13. Having been produced these devices were sent to various plants.

5. *Translate the texts:*

Text A. **Integration in 3-D**

Wafer-bonding techniques yield vertically integrated optoelectronic devices.

Photonic integrated circuits (ICs) have held the promise that the success of electronic ICs could be transferred to the realm of optics. Unfortunately, this promise has fallen short of expectations thus far. Compared with today's electronic ICs, which contain millions of transistors on a single silicon chip, the state-of-the-art for semiconductor photonic ICs has been limited to a handful of devices.

Three factors hamper the breakthrough of photonic ICs. First, the technology previously has lacked a large-scale market to push development, a situation that is beginning to change with the introduction of all-optical networks. Second, integrating a variety of photonic devices on one substrate material presents technical complications. Third, passive integrated optical devices and optical interconnects are significantly larger than their electronic counterparts.

Researchers are exploring rather complex processing techniques to overcome these problems. One technique is the universal substrate approach in which only a single compromise structure is grown. The design of this structure is such that perhaps all of the individual device structures depart from optimum to an extent, but their integration offers an overall functional advantage. A second technique uses multiple growth steps and etch processes to yield separately optimized device structures.[2] This method complicates waveguide alignment and coupling, however. A third approach relies on selective area growth, which gives a certain degree of freedom to selectively determine the local bandgap of different devices within a single plane simultaneously.

Problems with photonics

Even with these techniques, large-scale photonic ICs are far from reality, primarily because the size of photonic devices (from hundreds of microns to several centimeters) limits the number of components that can be cascaded on a single chip. Waveguide interconnects present another important limitation to miniaturization.

In electronic ICs, nanoscale "wires" interconnect millions of electronic components in three dimensions. Current devices can include up to seven vertically interconnected layers, a number that will probably increase to nine by 2012. Photonic ICs, on the other hand, still rely generally on a single plane of optical waveguide interconnections that have more stringent requirements and tolerances than their electrical counterparts. Electrical currents in wires can be directed arbitrarily to different positions and layers without suffering a high loss. In photonic waveguides, the confinement of optical waves is relatively weak due to the finite refractive index contrast and the requirement for single-mode operation. Waveguides with sharp bends suffer from an unacceptable optical loss. Integration with mirrors is difficult, although recent advances in photonic bandgap waveguides have shown the potential to solve the problem of sharp bending radius.

Another factor limiting the complexity of photonic ICs is that routing a large number of waveguides in two dimensions inevitably involves a large number of waveguide crossings, which increase crosstalk and loss. Conventional thin-film planar technology is not readily adaptable to vertically interconnecting multiple layers in three-dimensional (3-D) photonic ICs. Polymers may offer an option for this purpose, but without the optical properties of semiconductors, the functions of such photonic ICs are limited.

To address interconnect issues, our group is using wafer bonding or wafer fusion techniques to produce 3-D waveguides. Initially developed for integrating two dissimilar materials, wafer bonding can combine two patterned wafers and enables the processing of both sides of epitaxial films. Thus, it offers a viable method to stack planar processed circuits vertically to form novel 3-D devices and circuits.

Multiplexing in 3-D

One implementation of the technology is a four-channel multiplexer for optical networking applications that cascades two stages of 3-D vertical couplers of different lengths. In this device, two waveguides of 3-D vertical couplers are cascaded by coupling vertically and separating horizontally. The operating principle of multiplexing/demultiplexing via cascaded vertical couplers is the same as that of two-mode, interference-based multiplexers. The output intensity of each stage is a periodic function of optical frequency, with the period inversely proportional to the coupler length. Vertical couplers in the first stage are twice as long as those in the second stage, so the wavelength oscillation period (channel spacing) of the first stage is half that of the second one.

The epitaxial structure was grown using metal organic chemical vapor deposition (MOCVD). It includes a 0.8-μm indium phosphide (InP) front-side ridge layer, a 15-nm indium-gallium-arsenide-phosphide (InGaAsP) etch stop layer and a

0.1-μm InP cap layer. Next to this sandwich lies a 0.5-μm InGaAsP front-side guiding layer and a 0.6-μm InP coupling layer. For the back side we use the same guiding cap, etch-stop and ridge layers, and finally a 0.2-μm indium-gallium-arsenide (InGaAs) layer that facilitates removal of the InP substrate.

We fabricated the 3-μm wide front-side ridge waveguides by reactive ion etching (RIE) and chemical wet etching. A second photolithography/wet-etch step removes the front-side guiding layer above the back-side waveguides in noncoupling areas. Next, we invert the waveguide sample and bond it to a bare InP host substrate under pressure for 50 minutes at 630° C in a hydrogen atmosphere. After removing the original InP substrate and InGaAs etch-stop layer, we open the alignment windows, using an infrared (IR) mask aligner in which an IR camera is used to detect alignment marks beneath the surface, and wet etching exposes the marks. Then we fabricate the waveguides on the other side, and the unneeded guiding layers are removed as before.

To characterize the device performance, light from a tunable laser was coupled to an input waveguide by a single-mode fiber, and the device output was transferred to a detector by a second fiber. An infrared camera with a 20* lens recorded the near field images. The free spectral range is about 68 nm, as can be seen in the response of channel 2. The measured adjacent channel crosstalk ranges from -13 dB to -20 dB. We could further improve performance by fine-tuning the second stage of the vertical couplers to overcome fabrication imperfections. The channel spacing can be reduced by increasing the device length or by changing the wavelength dependence of the coupling coefficient.

Add/drop devices

Again using MOCVD on an InP substrate, we also have grown an x-crossing vertical add/drop filter. The structure consists of two vertically coupled ridge-loaded waveguides. As with the MUX/DEMUX example, wafer bonding and double-sided processing are the keys to realizing x-crossing structures. To fabricate this device, we first formed the lower InGaAsP ridge waveguides using reactive ion etching or chemical wet etching to generate a 0.8-μm-high, 3-μm-wide ridge. Next, using chemical etching we removed the 1.4 μm quaternary layer below the top 1.1-μm InGaAsP waveguides at two ends of the sample to eliminate unneeded coupling. We inverted the structure and fused it to a second InP substrate under pressure and in a hydrogen atmosphere; then we removed the original substrate and the etching-stop layer in another wet-etch step. After fabrication of the upper 1.1-

μm quaternary waveguides, we removed the 1.1-μm InGaAsP layer above the lower 1.4-μm InGaAsP waveguide region.

The transmission spectra of the TE mode from input port to the drop and through ports with the crossing angle of 0.25° show a 3-dB bandwidth of 6 nm. The device suppresses the sidelobe level to below -25 dB. The coupling efficiency from the add port to the through port, which strongly depends on the crossing angle, exceeds 97%.

Wafer fusion techniques also have been used to combine InP and gallium-arsenide (GaAs) waveguides. This method ultimately can be used to combine active and passive photonic devices based on different substrate materials, helping realize the early promise of photonic ICs. oe

Enhancing network performance

Planar lightguide circuits (PLCs) promise to reduce costs through high-volume wafer-scale processing while allowing integration of multiple functions on a single substrate to increase functionality while reducing the footprint. In many ways, the transition from discrete optical components to PLCs mirrors the transition in the electronics industry from the use of discrete transistors to the use of integrated circuits.

In a typical planar lightguide circuit, a silica (glass) waveguide is lithographically patterned on a silicon substrate. The fabrication technique allows wafer-scale processing, automation, integration of multiple functions, and customization to individual requirements. Silica-on-silicon is the most commonly used PLC platform due to its close index match to silica fiber and the maturity of the processing equipment, but waveguides can be fabricated using polymers, silicon-oxynitride, and pure silicon. While high-channel-count dense-wavelength-division-multiplexing (DWDM) technology allows network designers to greatly increase capacity on a fiber, it requires efficient and cost-effective filtering components. Thin-film filters are currently the most popular filter type, but they do not scale well to high channel counts or dense channel spacings. Arrayed waveguide gratings (AWGs), PLC components in which multibeam interference allows the simultaneous filtering of 40 channels or more, can provide the desired cost, size, and functionality needed for high-bandwidth systems.

In DWDM systems, it is critical to ensure equal power across the wavelength channels as the signals are transmitted through multiple optical amplifiers. Variable optical attenuators (VOAs) allow individual channels to be balanced to compensate for amplifier nonlinearities and to avoid receiver saturation. While single-channel VOAs exist, the same inefficiencies occur as with thin-film filters when the channel count increases. A VOA can be created on a PLC by creating an interferometric waveguide structure and controlling the relative phase of one arm. Heating one arm of the interferometric structure triggers controlled interference at the output, introducing attenuation. With solid-state design, the devices offer higher reliability and robustness than mechanical VOAs.

Switching is another function that is required in an optical network, either for protection routing or for cross connects. Low-port-count switches can be made with PLC structures very similar to the VOA described above, but with the output controlled to be either completely on or off. For high-port-count applications, other technologies may be more suitable.

Finally, hybrid products can be created by bonding active elements to the PLC platform. An example of such a product is an optical channel monitor, created by bonding a detector array to the output of an AWG to monitor individual channels. This type of product is needed as more functionality is created in the optical layer, for example to monitor the signal quality and detect if wavelengths are switched in a mesh network..

(By Ali Shakouri, University of California, Santa Cruz; Bin Liu, Calient Networks; and Maura Raburn and John Bowers, University of California, Santa Barbara, SPIE, OEmagazine, April, 2001)

Text B. **Hitting the Spot**

Successful positioning requires an understanding of geometry and positioner constraints.

As optical components find their way into increasingly complex setups, designers and researchers are faced not only with the need to know more about optical theory, but also with the need to know more about the practice of optical positioning. Because optical positioners are used to facilitate the alignment of the optical components in a system, it follows that choosing the right parts will have a significant impact on both system price and performance.

The key to selecting the appropriate optical positioning components is to determine the performance that is required, the number of positioners that are needed, and the types of positioners that are available.

A good place to start is to determine the number of degrees of freedom required to align the system. A degree of freedom is a unique movement used to position a three-dimensional object. For each dimension in 3-D space there is one linear and one angular degree of freedom—six degrees of freedom total. In Cartesian coordinates, the linear motions are usually referred to as x, y, and z, and the angular motions are typically $*_x$, $*_y$, and $*_z$. These angular motions also are referred to as roll, pitch, and yaw respectively.

A positioner is designed to provide adjustment in one or more degrees of freedom. Translation stages provide linear motion for applications such as focusing and centering; tilt stages provide angular motion for applications such as optical-axis orientation; height-adjustable stages provide linear vertical adjustment; and goniometers and rotary stages provide pure angular adjustment. In many cases, several stages, each providing a single degree of freedom are stacked to provide multiple motions.

Alignment

The three most common alignment problems are aligning an axis to a fixed point (e.g., a laser to a detector), aligning a point to a fixed axis (e.g., a ball lens to a laser), and aligning two axes with respect to each other (e.g., a collimator to a laser). For each of these configurations, there is a minimum number and type of positioners needed to facilitate the alignment.

Aligning an axis to a fixed point: A minimum of two linear adjustments or two angular adjustments is required. For the special case in which the angular adjustment rotates about the axis of linear translation, one linear adjustment and one angular adjustment can be used.

Aligning a point to a fixed axis: This problem requires at least two linear adjustments. Although it would seem that aligning a point to a fixed axis would require the same number and type of positioners as would aligning an axis to a fixed point, this is not the case since angular adjustments are meaningless to a nondimensional object such as a point. For maximum precision, the two linear adjustments should be orthogonal to each other and to the fixed axis.

Aligning two axes: This problem requires at least two linear adjustments and two angular adjustments. This is the most difficult alignment operation because adjusting the angle of an axis will simultaneously produce an unwanted translation effect. The process for aligning two axes requires, first, that the axes be made parallel to each other using the angular adjustments and then collinear using the translation adjustments. If focusing is required in conjunction with an axis-to-axis alignment, a third linear adjustment must be added to the system. This focus positioner, a translation stage, should be oriented parallel to the optical axis.

The preceding examples indicate the minimum number and type of adjustments needed to align a specific type of system. Many cases, however, require additional positioners, particularly when a single positioner cannot meet all of the performance requirements of a specific degree of freedom. For example, if focusing a lens requires both long-range and high-resolution adjustments on the same axis, it is difficult to find a single translation stage that can meet both requirements. Long-range positioners typically have relatively poor resolution, and high-resolution positioners typically operate only over a short range. Consequently, the best solution is to use two separate positioners: one for coarse (long-range) adjustment and another for fine (high-resolution) adjustment.

Resolving position

From the previous example, it is easy to see how the performance of an optical positioner can affect the selection of positioning components in an optical system. It is therefore necessary to have an understanding of the most common performance parameters associated with optical positioners: range, load capacity, resolution, and error.

Although the meaning of range and load capacity are self-evident, the meaning of resolution and error need clarification. Resolution is defined as the smallest move that can be made by a positioner. For manual positioners, resolution is heavily dependent upon the skill of the operator. Some people with extreme manual dexterity may be able to operate a positioner with significantly more resolution than others. Since most positioners are adjusted by rotating an actuator like a micrometer or a thumbscrew, the only way to make resolution in manual positioners non-user-dependent is to establish a reasonable minimum rotation on the actuators. To specify resolution, most manufacturers of manual positioning components assume a minimum actuator rotation somewhere between 1° and 5°.

For automated positioners like those incorporating stepping motors, the resolution is defined mechanically by motor-step size. In this case, each movement of a positioner is an integer multiple N of the resolution. This means that a positioner with a resolution of 5 μm, for example, can only locate an object N * 5 μm away from its starting point—5 μm, 10 μm, 15 μm, 20 μm, etc. The more important implication is that this positioner cannot move an object to a location other than an integer multiple of 5 μm away from its current position. Thus a move to a position 8 or 43 μm away, for example, would be impossible for this component. Clearly, the components selected for a system must have resolution to match or exceed the system requirements.

Like resolution, error is a measurement that reveals the performance limitations of a positioner. The most useful and frequently encountered error terms are straightness of travel, angular deviation, wobble, and eccentricity. Straightness of travel for a linear one-axis positioner is a measurement of nonintended linear movement along the other two linear axes. For example, 2.5 cm of intended linear travel along the x-axis might yield 10 μm of unintended linear travel along the y- and z-axes. Straightness of travel for the positioner, therefore, would be reported at 10 μm.

For a rotary stage, the straightness of travel equivalent is a term called eccentricity. Eccentricity is a linear displacement of the mechanical center of the stage from the axis of rotation and is sometimes called runout.

Angular deviation is a counterpart to straightness of travel in that it is a measure of unintended angular changes over the travel range of the linear positioner. Angular deviation covers all three of the angular degrees of freedom: pitch, yaw, and roll. For an angular positioner like a rotary stage, the applicable error measurement is wobble. Wobble is the unintentional tilting of the axis about which the positioner is rotating. This error manifests itself as an angular and linear movement in the component being positioned.

It is important to note that all angular errors have the potential to create linear errors above and beyond those contributed by straightness of travel. The name for this phenomenon is Abbe error, and it is defined as a linear deviation combined with a lever arm. The longer the lever arm, the larger the Abbe error and vice versa. It is therefore good practice to keep this lever arm as short as possible by keeping the stage and component in close proximity.

There are many factors to consider in selecting the best optical positioner for an application. Although it can appear complex at first, taking a close look at the characteristics of the optical system being designed and matching those characteristics to the performance level of available positioners can eliminate many of the variables, resulting in a successful implementation.

(By Richard Sebastian, Melles, OEmagazine, April, 2001)

UNIT 16

1.Memorize the following words.

- rapid
- to recover
- similar
- to yield
- to gain
- share
- advance
- length
- wiring
- resistance
- reason
- commodity
- to improve
- capacitance
- impediment
- to remove
- to interface
- convergence
- to record
- simultaneously

2. Translate these synonyms and memorize them:

- magnitude (n), value, size, largeness, meaning
- understand (v), realize
- make up (v), constitute, form, build up
- considerably (adv), very, greatly, substantially
- calculate (v), compute
- sufficient (adj), enough
- purpose (n), goal, aim, objective
- matter (n), affair, business
- similar (adj), alike, the same as
- as a matter of fact, in fact, in effect

3.Match these synonyms:

1. give off
2. means (n)
3. hence

(a) in effect

(b) emit

(c) stable

4. speed
5. steady
6. period
7. accurate
8. in fact
9. quickly
10.very

(d) precise
(e) highly
(f) velocity
(g) rapidly
(h) therefore
(i) cycle
(j) way

4.Translate the following sentences paying attention to the absolute participle construction:

1. Electron moving through the conductor, electrical energy is generated.
2. The current in a circuit was decreased when the resistance was increased, other factors remaining the same.
3. Transistors being very sensitive to light, engineers use this property.
4. Some radioactive materials have been found in nature, uranium being one of them.
5. The engineers using semiconductors, good results have been achieved.
6. The designers used some new tubes, the main characteristics remaining the same.
7. The speed of light being very great, we can't measure it by ordinary methods.
8. Many metals are good conductors, silver presenting one of them.
9. The principle of action being extremely simple, the device was widely used for various purposes.
10. Thermistors are very sensitive to light, this property being very important.

5. Translate the texts:

Text A. **View Finder**

Advances in sensors, imaging techniques, and software propel remote sensing to the top of its class for environmental monitoring.

The world is in constant flux: Everyday there are changes in land use, deforestation, erosion, and the earth's natural resources. Monitoring such alterations throughout the world would be nearly impossible without remote-sensing technology. In the 1990s, the dimensions of a new generation of container ships required the expansion of the river Elbe, the outlet leading from the harbor of Hamburg, Germany, to the North Sea. The long-term effects of the project on the river's ecosystem were uncertain, however, so the German Federal Waterways and Shipping Administration (WSV) asked Manfred Ehlers to establish a continuous monitoring program using remote sensing.

Ehlers, director of the Institute for Environmental Sciences (IES) at the University of Vechta, Germany, has been pioneering remote-sensing technologies since the 1970s. "This is the only technique that can get you current information on large geographical areas with accurate data recorded in a very short period of time," he says.

Seeing in color

In the past, the study requested by the WSV would have been nearly impossible. Researchers, supported by conventional aerial photographs, would have laboriously generated vegetation maps from extensive field work. "This expensive task requires much manpower and often lacks the necessary geometric accuracy," says Ehlers. In addition, inconsistencies occur whenever the person analyzing the photographs changes.

Modern remote-sensing techniques provided the solution. In cooperation with the German Aerospace Center (DLR; Berlin, Germany), Ehlers's group developed a three- to five-year monitoring program for the river that is based on the High Resolution Stereo Camera-Airborne (HRSC-A). Originally developed by the German space center for a Mars mission, this camera supplies high-resolution multispectral scanner data, including 8-bit panchromatic imagery (585-765 nm) and multispectral imagery (395 to 485 mn, 484 to 576 nm, 729 to

771 nm, 920 to 1020 nm), and 16-bit digital surface model (DSM) data. With 15-cm ground pixel resolution at 3750 m, the camera has an accuracy of ±10 cm along the x- and y-axes and ±15 cm along the z-axis.

The HRSC is a pushbroom-style scanner composed of a trio of 5184-pixel linear charge-coupled-device (CCD) detectors that operate simultaneously. One detector points forward, one to the nadir, and one to the back of the flight line. By combining the information from all three detectors in a technique similar to photogrammetry, one can obtain a "triplet" stereo image that yields the three-dimensional information necessary to develop a DSM. The unit incorporates global-positioning-satellite (GPS) measurements and inertial navigation systems to monitor its movements, providing geometrical corrections that allow an almost perfect overlay on a map or a geographic information system (GIS). "The HRSC is actually the best aircraft remote-sensing system I've ever seen because of its high geometric fidelity," says Ehlers.

The Geoinformatics group of the IES developed a context-based hierarchical image analysis and classification scheme that incorporates a priori GIS information, digital surface models, and multispectral image data. This image analysis process operates with advanced masking techniques, dividing the images into several semantically meaningful layers (for example, nonvegetation/tree vegetation/herbaceous vegetation) by using indices and threshold values derived from the original image data.

Mining data

The biggest challenge in remote sensing is making sense of the prodigious amounts of data. While the aircraft takes images of the scene from above, Ehlers sends in students to perform "ground truth" studies in which they record what is actually on the ground. Once these points are located by a GPS, Ehlers's group ties them in with a geographic information monitoring system, a software system for storing, retrieving, manipulating, analyzing, and presenting geographic information.

Using the ground-truth data and the remote-sensing images, Ehlers and associates "train" the image analysis software. Known as supervised maximum likelihood classification, this is a statistical procedure that classifies the whole image based on a set of true ground samples.

Ehlers and his group predominately analyze the images after they are taken. They perform classification, geometric rectification so that data fits with a map or GIS, and image enhancement such as filtering and contrast improvement.

"But this is not an easy task," he says. Because of the high resolution, a single image may be as large as 80 Gb. Handling such large data files requires significant changes in the commercial imaging software employed by the group. Ehlers begins with commercial packages such as Erdas, Earth Resources Mapper, and E-cognition, then writes add-on programs to fit his needs. "We use the format of the programs and write our own data processing and exchange algorithms. No one writes image-processing software from scratch anymore," he says.

Although the Elbe monitoring program will continue for another four or five years, short-term results show the tremendous advantages of the new method in terms of the richness of detail and geometric accuracy, especially when contrasted with older, conventional imaging maps of the same area. For comparison, resolutions for conventional satellite imagery range from 30 m for Landsat to 5 m to 20 m for the Indian Remote Sensing (IRS) satellite.

Current research

In the future, Ehlers's group hopes to develop an imaging spectrometer that can produce images over as many as 200 spectral bands, each 20 nm wide. Although such instruments do not provide stereo viewing capability, their narrow channel widths offer high spectral resolution that is useful for remote sensing. Imaging spectrometers can register subtle effects, for example, stress effects on vegetation indicated by changes at the chlorophyl absorption line. Standard wide-band remote sensors cannot detect these minute alterations.

In a separate project, the group is using 15-cm-resolution stereo-scanning data to produce a digital surface model through correlation techniques. This model enhances image interpretation by adding a third dimension, which is particularly useful in urban remote sensing for tracking the elevation of buildings or trees. "We have many areas in Germany where the ground is covered in concrete, buildings, bricks, parking lots, and streets," says Ehlers. In these places, the water runs off directly into the rivers without treatment. A renaturalization movement is afoot in the country to replace these covered places with lawns or partially open stone that would allow the water to percolate through to the water table, undergoing natural filtration.

There is also a practical reason behind the movement: water taxes. In Germany, property owners are billed on how much water runs off into wastewater treatment systems versus sinking into the ground. The government wants to enforce this tax, but because of the small lots in Germany, researchers have to visit each property to assess the situation. With high-resolution spectral and spatial images from aircraft for analysis of water run-off, coupled with groundwater models, the government will have an accurate assessment quickly and efficiently. "It is wonderful to see how people are trying to improve the environment and how remote sensing can help them," says Ehlers. oe

The man behind the technology

Manfred Ehlers is considered one of the pioneers of remote sensing, having spent his career focusing on the advancement of this sophisticated science that helps researchers monitor the earth's changing environment.

After receiving his degree in mathematics in Germany, Ehlers took up oceanography at the Institute for Marine Research in Kiel. When the German Ministry of Science and Technology started a program promoting a new technology called remote sensing, Ehlers and his associates applied it to their studies. "We used scanner data and aerial photography to monitor artificial dye patches in the Baltic Sea and to fit our observations to diffusion models," Ehlers says. The group tracked and simulated oil spills, and monitored eddies and ocean currents. "Remote sensing has been a part of my professional life ever since," he adds.

In 1977 he joined a special coastal and marine remote unit at the University of Hannover. "There was no commercial image-processing software for remote sensing available at the time," he remembers. So he developed software for the analysis of remotely sensed images.

After earning his Ph.D. in surveying engineering, he went to the University of Georgia (Athens, GA), where he switched disciplines to geography in 1984. His intended one-year stay in the United States stretched to six once he moved to Maine to help establish a remote-sensing program at the state university. He also became a research scientist at the National Center for Geographic Information and Analysis, as well as a member of the scientific policy committee.

In 1990 he returned to Europe to join the International Institute for Aerospace Survey and Earth Sciences in the Netherlands as a professor for aerospace data acquisition and photogrammetry, then subsequently headed the newly formed

Department of Geoinformatics. Two years later, he returned to his native country as a professor for geographic information systems (GIS) and remote sensing at the University of Vechta. There he started programs in environmental sciences and founded the Institute for Environmental Sciences and the Research Center for Geoinformatics and Remote Sensing, both of which he heads.

Although Ehlers works primarily on the application side, he cooperates closely with the scientific community to develop the equipment required for his work. In Europe, for example, remote sensing needs to be suitable for small field sizes and many buildings. In the United States one can get away with 30-m resolution because there is so much space. "[In Europe,] we need

1-m, 4-m, or 8-m resolution, which we now have," Ehlers says. He also requested imaging at narrow channels at red and near-infrared spectral bands to enable better image interpretation.

Ehlers now focuses on integrating the three major areas of his academic career: remote sensing, GIS, and image processing. "I would like to see GIS and remote sensing closer together on the analysis side," he says. Presently there is no true software package that is fully integrated with image analysis and vector GIS capability. Ehlers and associates are working to develop the requirements and prototypes for such a system, while he continues to teach and monitor the earth's environment.

(By Laurie Ann Toupin, SPIE, OEmagazine, April, 2001)

Text B. **Photonic crystal fibers**

Photonic crystal fibers offer extraordinary performance, including tailorable dispersion, single-mode behavior over many wavelengths, and useful nonlinear properties.

Over the past few years, photonic crystal fiber (PCF) technology has evolved from a strong research-oriented field to a commercial technology providing characteristics such as single-mode operation from the UV to IR spectral regions, large mode areas with core diameters larger than 20 μm, highly nonlinear performance with optimized dispersion properties, and numerical aperture (NA) values ranging from arbitrarily low to about 0.9.

PCFs can be made with parameters impossible to achieve in standard fibers, which has led some researchers to suggest that PCFs could become the ultimate transmission waveguide for electromagnetic fields. If PCFs fulfill their potential, they could have important applications in spectroscopy, metrology, biomedicine, imaging, and telecommunications. Although the fibers are still years of development away from fulfilling these projections, PCFs already provide researchers with a new optoelectronic tool for spectroscopy, metrology, biomedicine, imaging, and telecommunications.

Basics of PCFs

Research in the field of PCFs was stimulated by the prediction of a photonic bandgap analogous to electronic bandgaps in semiconductors. Initially, the photonic bandgap was the only guiding mechanism considered for this new class of optical fibers. Later, researchers discovered that by microstructuring and including airholes in the fiber, these devices could provide revolutionary features using the simpler and more conventional principle of total internal reflection.

A typical PCF has a 2-D cross-sectional structure in which the solid pure-silica core region is surrounded by a cladding region that contains airholes. These holes effectively lower the index of refraction, creating a step-index optical fiber. The fiber behaves in many ways like standard step-index fibers (which are typically made of a germanium-doped raised-index core surrounded by a pure silica cladding), but it has a number of advantages. PCFs are made of undoped silica, which provides very low losses, sustains high powers and temperature levels, and withstands nuclear radiation. Air in the cladding yields a fiber with a huge index step because of the large difference in the refractive index n between air ($n = 1$) and silica ($n = 1.45$). This index difference translates to fibers with NAs as high as 0.9.

A single PCF fiber may support single-mode operation over wavelength ranges from around 300 nm to better than 2000 nm. Also, because the mode field area in PCFs can be larger than 300 μm^2, which is several times larger than the 80 μm^2 or less provided by standard fibers, PCFs can transmit higher powers without running into nonlinear or damage barriers. On the other hand, the highly nonlinear fibers made as single-mode fibers have extremely small ($\sim 3\ \mu m^2$) mode field areas and confine light to the core region efficiently.

Fabrication

Designers can manipulate the dispersion characteristics of PCFs to create fibers having zero, low, or anomalous dispersion at visible wavelengths. The dispersion can also be flattened. Combining these features with small mode field areas results in outstanding nonlinear fibers. By altering the pattern of airholes or the materials used, it is possible to manipulate other characteristics of PCFs, such as the single-mode cut-off wavelength, the NA, and the nonlinear coefficient. The design flexibility is very large, and designers can use many different, fascinating, and odd airhole patterns to achieve specific PCF parameters. The triangular arrangement of round airholes in the cladding is typically used to create single-mode fibers (see figure 16.1). Increasing the air-filling fraction in the cladding typically leads to multimode behavior. An elliptical core can create a highly birefringent fiber that is polarization maintaining.

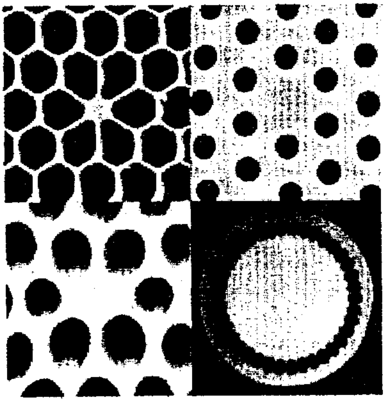

Figure 16.1. PCF structures vary according to application: (a) highly nonlinear fiber; (b) endlessly single-mode fiber; (c) polarization maintaining fiber; (d) high NA fiber

Silica provides superior fiber performance for most applications with wavelengths between 200 and 2500 nm, but using other materials can enhance specific parameters like nonlinearity or waveguiding outside this spectral region. Furthermore, one can combine the silica with a long list of dopants. Doped silica is now used in a variety of fiber lasers and amplifiers; these could be combined with the unique capabilities of PCFs to provide even more useful devices.

Thus far, fabrication of PCFs has been a highly labor-intensive and time-consuming process. The typical starting point is an array of hollow capillary silica tubes bundled around a pure silica rod replacing the center capillary (see image at top). A sleeving tube surrounds the entire assembly, forming the preform. In a fiber draw tower, the manufacturer heats the preform to around 2000°C and carefully pulls the preform, using gravity and pressure, into a fiber typically 125 μm in diameter. This microscale fiber maintains the structure of the preform. A protective polymer coating applied to the outside improves handling characteristics.

PCF technology has matured tremendously during the past few years. Production and control of fiber parameters, however, are still not comparable to those of standard fiber technology. In theory, manufacturers should be able to reduce losses in PCFs down to or below the level of standard single-mode fibers, which is about 0.2 dB/km at 1550 nm. However, water contamination during fiber drawing has so far limited the loss levels to around 1 dB/km or higher. Although perfecting of the production process should provide significant progress in this area, no one knows what the practical lower loss limit will be.

Coupling to PCFs is another issue: because the fibers may have extreme parameters such as a very large or very small mode field area and very high or very low NA, the coupling methods (and losses) could be very different from standard fiber methods. Users can strip and cleave the holey fibers with standard fiber tools. If the fiber end is left unsealed, the fiber capillary effect may suck up liquids or gasses, but this is typically easy to avoid.

Professionals couple PCFs using one of two proprietary processes: Either they pigtail the fiber (splicing the fiber to a standard fiber ending in a connector), or they hermetically close and connectorize the fiber. The latter solution is used if standard fiber performance spoils the benefits of the PCF. Both methods require special equipment and operations. Eventually these processes are likely to become widely deployed.

Applications

One of the first and still most remarkable applications of these new fibers is spectral broadening.[3] This so-called supercontinuum process exploits the high peak powers available from mode-locked femtosecond- or picosecond-pulsed lasers such as titanium-doped sapphire (Ti:sapphire), neodymium-doped yttrium aluminum garnet (Nd:YAG), or fiber lasers. Having a small core and low or zero dispersion close to the pumping wavelength, PCFs can broaden the spectral width of pulses to previously unknown levels. Such supercontinua might, for example, cover the wavelength range from 500 to 1300 nm with intense coherent light and have applications in areas such as metrology, spectroscopy, imaging, and microscopy. The wide spectral width of these supercontinua leads to previously unattainable submicron resolution for optical coherence tomography, for example.

The fact that the phase coherent spectrum spans more than one optical octave makes it useful for a number of metrology and spectroscopy applications. By mixing both a primary wavelength and its frequency-doubled harmonic with the supercontinuum, it is possible to obtain a direct link between the mode-locking repetition frequency of the microwave laser and the optical frequencies. This property could also be used as an optical clock alternative to the current cesium microwave frequency SI definition of the second, offering a potential accuracy of 1 in 10^{18}.

Within telecommunications, PCFs have several potential applications that range from low-nonlinearity large-core transmission fibers to signal-processing fibers for terminal equipment components. Examples of the latter feature dispersion-compensating fibers, including slope compensation; nonlinear fibers for wavelength conversion, switching, amplification and signal regeneration; and doped large-mode-area fibers for high-power amplification.

Large-mode-area fibers can provide high-power delivery for applications in astronomy, lithography, materials processing, imaging, femtosecond pulse guidance, and general laser pigtailing. For example, the European Southern Observatory utilizes large-mode-area fibers for diffraction-limited beam guidance (figure 16.2).

The excellent beam quality guidance provided by the single-mode fibers might also be used for filtering out higher order modes. These endlessly single-mode fibers can also be used for broadband fiber interferometry.

High NA fibers (typically multimode) collect light very efficiently from a very broad space angle and distribute light in a broad angle at the output end. They could find use for pigtailing broad-area-emitting lasers for lighting applications such as windmill warning signals and endoscopy. By combining a high NA fiber with a rare-earth-doped single-mode core, users could create an amplifying fiber that can be pumped by low-cost broad-area (high NA) emitting lasers.

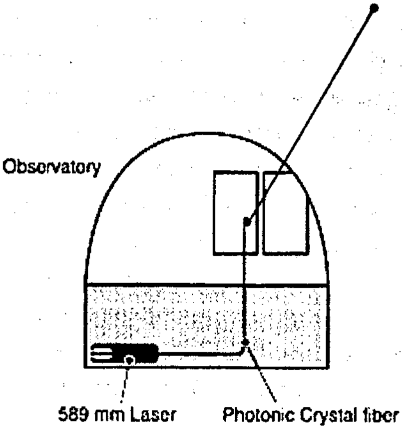

Figure 16.2. The European Southern Observatory guide star system uses large-mode-area PCFs to relay a high-power, diffraction-limited 589-nm laser beam for a laser guidestar without nonlinearities and fiber damage

Researchers have demonstrated simple designs using a simple index-guiding doped core and a high-NA (highly airfilled) outer cladding, as well as more advanced microstructured designs using a large-mode-area core and microstructured inner cladding. Such fibers are superior for creation of high-power single-mode lasers and amplifiers.

PCF technology continues to evolve. Single-mode operation from UV to IR wavelengths, large-mode-area fibers with core diameters larger than 20 μm, highly nonlinear fibers with optimized dispersion properties, and NA values ranging from arbitrarily low to about 0.9 are examples of offerings by this new technology.

(By René Engel Kristiansen, Crystal Fibre A/S)

UNIT 17

1.Memorize the following words.

- thermal
- excessive
- conventional
- precise
- pump
- to apply
- sink
- ambient
- benefit
- environment
- to discharge
- to insulate
- arrangement
- equal
- to mount
- available
- unlimited
- to occur
- to ensure

2.Translate these synonyms and memorize them:

- desire (v), want, wish
- avoid (v), escape, avert, evade
- total (adj), entire, complete, whole
- should (v), must
- assume (v), suppose
- extract (v), draw out
- vary (v), change, differ, alter
- condition (n), circumstance
- appropriate (adj), suitable, proper
- since (conj), as, for

3.Match these synonyms:

1. example	(a) collect
2. gather	(b) furthermore
3. associate	(c) consequently
4. moreover	(d) instance
5. immediately	(e) in order that
6. therefore	(f) require
7. rapid	(g) dissipate

8. in order to	(h) fast
9. necessitate	(i) connect
10.diffuse	(j) at once

4.Translate the following sentences paying attention to words with "ing" forms:

1. When applying mathematical methods to the solving of technical problems engineers are most often interested in obtaining finite numerical results.
2. Mathematical tables are necessary aids for performing computation work.
3. In modern computers LS circuits and RAM/ROM memories are used for executing sophisticated operations.
4. The students get the practical training when they are working at various plants.
5. A memory unit is used for storing information.
6. The designer was able to construct a new device by using semiconductor.
7. Microcomputers are effective for carrying out complicated computations.
8. For improving the system operation the designer was to use low weight equipment.
9. Translating from one language to another has been accomplished by a computer.
10. The Periodic Law pointed out the possibility of discovering new elements.
11. Heating the gas increases the speed of the molecules.

5.Translate the texts:

Text A. **Keeping Cool**

Thermoelectric coolers offer efficient solid-state heat-management options.

Thermal management is a key factor in optimizing optoelectronic device performance. Excessive heat compromises the wavelength stability of laser output and increases noise levels in detectors. Thermoelectric (TE) coolers, also known as

Peltier coolers, offer effective, practical options for heat management in compact optoelectronic devices such as dense-wavelength-division-multiplexing (DWDM) components and charge-coupled-device (CCD) detectors. In many cases, TE coolers offer significant advantages over more conventional cooling methods because they offer active cooling and precise controllability.

What is a TE module?

A TE cooler is a semiconductor-based electronic component that functions as a small heat pump. When low-voltage dc power is applied to a TE module, heat moves through the module from one side to the other in proportion to the applied voltage. One module face, therefore, will be cooled while the other is simultaneously heated. This phenomenon is fully reversible: With a switch in the polarity of the applied voltage, heat moves in the opposite direction. Thus, the same module can function as both a heater and a cooler, permitting very precise temperature stabilization.

Thermoelectric modules are not ideal for every cooling application, and there are many situations in which a simpler cooling device, such as a heat sink, is more appropriate. They also won't cool to as low a temperature as mechanical coolers, e.g. stirling coolers. There are situations, however, in which thermoelectric cooling is the only suitable solution or for which it presents significant advantages over other cooling methods. Unlike a heat sink, for example, a thermoelectric cooler can cool to below ambient temperature. The devices can be more efficient than chillers or fans, and they are generally more compact.

Thermoelectric cooling is particularly effective for cases requiring precise temperature control, such as laser cooling applications. With an appropriate temperature control circuit, TE coolers can stabilize temperatures to better than ±0.1°C. Aside from their performance benefits, TE modules are often used when system design criteria include factors such as high reliability, small size, low cost, and low weight. In the optoelectronics industry, they are often used for spot cooling (the direct cooling of one component rather than a whole system) or for testing scenarios that require temperature cycling of test components or systems.

It should be noted that the thermoelectric module is only one element in the overall cooling system. Its function is to continuously pump the heat away from a component or assembly. This heat then needs to be transferred from the thermoelectric module to the environment using a heat sink or similar device. Condensation issues must be addressed.

Principles of operation

Thermoelectric coolers are based on the Peltier effect, a phenomenon discovered by Jean Peltier in 1834. In a system with two dissimilar metal junctions, heat can be absorbed at one junction and discharged at the other when an electric current flows in the closed circuit.

A thermoelectric cooler generally consists of two or more semiconductor elements, usually made of bismuth telluride (Bi_2Te_3), that are connected electrically in series and thermally in parallel. These thermoelectric elements and their interconnects typically are mounted between two thin metallized ceramic substrates, which provide structural integrity, insulate the elements electrically from external mounting surfaces, and provide flat contact surfaces.

Both n-type and p-type Bi_2Te_3 materials are used in a thermoelectric cooler. This arrangement causes heat to move through the cooler in one direction only while the electrical current moves back and forth alternately between the top and bottom substrates through each n- and p-type element. The n-type material is doped so that it will have an excess of electrons while the p-type material is doped so that it will have a deficiency of electrons. The extra electrons in the n material and the "holes" resulting from the deficiency of electrons in the p material are known as carriers. These carriers move the heat energy through the thermoelectric material.

Most thermoelectric cooling modules are fabricated with an equal number of n-type and p-type elements where each n and p element pair forms a thermoelectric couple. The module has two pairs of n and p elements and would be termed a two-couple module. Heat flux—the heat actively pumped through the thermoelectric module—is proportional to the magnitude of the applied dc electric current. By varying the input current from zero to maximum, one can adjust and control the heat flow and temperature differential.

Typical thermoelectric modules generally have between seven and 128 couples and maximum operating current (I_{max}) ratings from 1.2 to 36 A, although larger and smaller modules are available. Modules can be mounted in parallel to increase the heat-transfer capacity, or they can be stacked in multistage cascades to increase the temperature differential.

Thermoelectric modules have no moving parts, so they are virtually maintenance free. They are also smaller and lighter than comparable mechanical cooling systems. Their solid-state construction ensures high reliability, which is an advantage when they are to be used in a system that is not easily accessible after installation. Operation is acoustically silent, and electrical interference is negligible.

Choosing a module

To select the correct TE cooler for a specific application, one must evaluate the total system in which the device will be used. For most applications, a standard module will be satisfactory, but custom designs are readily available.

Before attempting to select an appropriate thermoelectric module, you should ask yourself the following questions:

- At what temperature must the cooled object be maintained, and to what precision?
- How much heat must be removed from the cooled object?
- What is the expected ambient temperature range?
- What is the thermal resistance of the heat sink (hot side)?
- What is the allowable footprint and height for the module?
- What dc power is available? What voltage and current restrictions exist?
- What is the expected approximate temperature of the heat sink during operation? Is this temperature steady or variable?

These answers should yield enough information about the system in which the module is to be installed to permit module selection. Since module performance is often presented graphically, it is important to know how to use these graphs to determine which module is appropriate for your system.

There are three key graphs that are important to understand: heat capacity versus current (Q_c vs. I), input voltage versus current (V_{in} vs. I), and coefficient of performance (COP).

Heat sinks

It is important to remember that TE coolers require a heat sink or similar device to dissipate the heat pumped by the module. This heat sink must be capable of removing both the heat pumped by the module and the joule heat from the electrical power supplied to the module. Generally forced-convection or liquid-cooled heat sinks are used, although a natural-convection heat sink may be sufficient for applications requiring minimal heat removal.

A perfect heat sink would absorb an unlimited quantity of heat without exhibiting any increase in temperature. Since this is not possible in practice, a heat sink must be selected that can handle the total heat flow from the device while maintaining an acceptable tem- perature rise. Generally a heat-sink temperature rise of 5°C to 15°C is acceptable. Many optoelectronic systems that use TE cooling are designed such that the chassis acts as the heat sink. When this occurs, particular care must be taken to select a module with operating parameters that minimize the temperature increase to the chassis.

Surface flatness is another issue to consider when selecting a heat sink for use with TE modules. Many off-the- shelf units do not have adequate surface flatness. For satisfactory thermal performance, a surface flatness deviation of 1 mm/m (10^{-3} in/in) or better is needed. Special attention also should be given to the installation of the module and the heat sink. It is important to ensure that correct mounting techniques and interface compliant materials are used.

Compact and economical, TE coolers provide efficient thermal management solutions with solid-state reliability. For demanding optoelectronic or electro- optic applications, the technology is often the best choice.

(By Robert Otey and Barry Moskowitz, Ferrotec America Corp,.
SPIE, OEmagasine, March, 2001)

Text B. **Seeing the Light**

Biopsies may become rare as photon migration imaging develops into a powerful non-invasive diagnostic tool.

Technology and medicine have always been close partners. Diagnostic methods such as x-ray radiography, magnetic resonance imaging, ultrasound, and computed tomographies provide incredibly detailed anatomic information in demanding clinical settings. As these technologies progress and become standard-of-care, requirements for new methods based upon different technologies are emerging.

There is a pressing need for rapid, portable, and inexpensive devices that monitor tissue function noninvasively. Commercial emphasis has been placed upon rapid analysis instrumentation such as blood-gas analyzers, which recover biochemical information from drawn blood. But what if similar information could be obtained in real time without drawing blood? What if doctors could characterize suspicious lesions in mammograms without surgery, detect the effects of traumatic injury and progression to shock well before it occurs, or monitor the effects of tumor chemotherapies during treatment? Although this sounds too much like science fiction to be true, optical technologies now exist that could introduce these concepts into clinical practice within the next five years. Broad implementation of these optical diagnostic methods at the bedside would provide clinicians with critical feedback that could impact patient care.

Optics then and now

In the past, researchers have used optical techniques to look for shadows caused by hemoglobin absorption. In the 1920s, they worked with conventional sources and eventually progressed to laser sources in the 1980s. Initial optical breast-cancer detection devices lacked the required sensitivity and specificity to locate and classify breast lesions, however.

Today the situation is radically different. Coupled with exciting new concepts in tissue optics, telecom-driven technological advances have yielded noninvasive methods that provide completely new information from tissues. Photon diffusion techniques have painted a novel physiological portrait of the breast that may characterize lesions, chart the progression of disease, and monitor the effectiveness of anticancer therapies. Quantitative NIR optical spectroscopy provides an opportunity for revealing physiological information that is unobtainable by other radiological techniques. Instrumentation is compact and relatively economical, which suggests that the technology will be available to everyone.

Optics plays a role in other areas of medicine. Pulse oximeters are standard-of-care devices that monitor arterial hemoglobin oxygen saturation (the fraction of oxygen to total hemoglobin), usually during anesthesia. Technology of the 1960s and 1970s combined with an important clinical need made pulse oximetry broadly available. NIR spectroscopy is similarly poised for growth.

Network analysis

At the Beckman Laser Institute and Medical Clinic, we use an optical network analysis approach to extract quantitative information out of tissues using frequency-domain photon migration (FDPM). For example, to examine a device under test, a network analyzer sweeps over a range of source frequencies S. A fraction of S splits off as a reference R. The analyzer measures the electronic response of the device under test as a function of frequency by comparing the detected signal, either a reflection or a transmission, to R. The analyzer determines the amplitude and phase of the signal.

The same approach can be applied to measurements of tissue absorption and scattering. In such a case, the device under test is a tissue, such as breast tissue. Instead of monitoring the electrical response, we monitor the diffuse optical response, either as a reflection or transmittance. The phase and amplitude of the diffuse optical signal fit to an appropriate mathematical model provide enough information to determine the tissue absorption and scattering properties.

What information does this analysis provide? The frequency response of the tissue is determined by the photon path length L. Increased tissue absorption yields a shorter L, or a reduced average time of travel through the tissue, which yields a smaller amplitude and phase shift. Tissue absorption in essence acts like a filter: High absorption weakens the high-frequency response. Scattering, on the other hand, generally increases L, so that increased scattering will decrease amplitude but increase the phase shift. This is how optical network analysis can pick out differences in L, based upon the absorption and scattering of the tissue.

System design

The FDPM instrument begins and ends with a network analyzer (NA). The analyzer provides the radio frequency (RF) current, which is combined with a separate bias current source to form an amplitude-modulated electronic signal that, in turn, modulates the intensity of a diode laser source at frequencies ranging from 50 to 1000 MHz. Thermoelectric coolers stabilize the diode temperature. Relevant diode laser wavelengths lie in the range of 660 to 1000 nm.

The laser output is launched into graded-index optical fibers with 100 μm cores by either physical coupling (pigtailing) or optical coupling. Each of the individual lasers sends one optical fiber into a fully multiplexible 8 * 8 optical switch such that only one laser illuminates the tissue at a time. A computer controls both the RF switch network and the optical switch to ensure only one modulated laser signal reaches the tissue at any given moment.

A source fiber directs light from the switch to the tissue. An avalanche photodiode (APD) encased inside an RF-shielded module is placed 20 to 30 mm away and picks up the diffusely reflected signals. The APD module casing has machined attachments that hold the source fiber in place. In this configuration, the mean optical penetration depth is about 10 to 15 mm below the skin. The NA measures the amplitude and phase of the analog electronic signal from the APD. After correction for instrumental artifacts such as delays from electrical cables, the amplitude and phase are fit to a diffusive light transport model.

The FDPM instrument currently uses seven diode lasers that provide visible and NIR light at wavelengths ranging from 672 to 978 nm, allowing us to build an absorption spectrum; each wavelength provides sensitivity to different tissue chromophores. The optical power launched into the tissue ranges from 5 to 25 mW for each wavelength. Sweeping over all seven wavelengths requires 35 s. The NA acquires data in less than 3 s per wavelength, but there is a 2 s delay between each wavelength because of switching considerations. The entire system can be wheeled into a medical clinic and placed at the bedside.

The detector (Hamamatsu; Bridgewater, NJ) is an APD with a 1-mm-diameter active region, a 600 MHz cutoff frequency, and an intrinsic gain of 100. A miniature 1 GHz amplifier adds another factor of 100. The APD provides a unique combination of speed, sensitivity, and dynamic range, especially above 900 nm. In stark contrast, photomultipliers typically have much higher gain, but poorer sensitivity, especially above 900 nm, and slower response times.

There are many challenges associated with broadband electronics. Obvious problems include impedance mismatching and RF interference. Diode laser availability is another challenge, since manufacturers may stop producing certain sources. We have recently addressed this by integrating a complete steady-state spectrum (Ocean Optics; Dunedin, FL) together with our discrete laser diode measurements to produce a complete absorption spectrum from 650 to 1000 nm.[3] We may extract absorption coefficients from the steady-state measurements only because FDPM provides the tissue-scattering spectrum. The additional information from the complete absorption spectrum will help quantify tissue chromophores even better than before.

The use of off-the-shelf components simplifies assembly but limits size and versatility. For example, the analyzer sweeps through 101 frequencies in as little as 21 ms, but there is a long internal delay between each sweep. The recent boon in cellular telephones could provide the impetus to miniaturize fast, high-frequency driver circuits, and perhaps even reduce our cart instrumentation to the size of a cellular telephone, capable of operating in real time.

In the clinic

By testing the technique in a clinical setting, we can quantify the optical absorption differences between the breasts of premenopausal women and postmenopausal women and obtain spectra that yield quantitative concentrations of blood, water, and lipids. For example, the total hemoglobin concentrations are about 40 and 14 μM in the pre- and postmenopausal breast, respectively. The premenopausal breast is characterized by high blood concentration, high metabolism (low tissue saturation), high water, and low lipids, whereas the opposite is true of the postmenopausal breast. This noninvasive quantitative, physiological component analysis is unique to NIR optical methods.

We also have used the technique to characterize the absorption spectrum of a 1-cm diameter malignant tumor compared to normal breast tissue. This noninvasive measurement was obtained simply by placing the probe over the patient's suspicious lump and comparing the measurements to her opposite normal side. One can see distinctive quantitative differences between the spectra, which are mostly due to higher blood and water concentrations in the tumor relative to the normal tissue. Data that show the normal states of tissue eventually will lead to the quantitative classification of diseased tissue.

None of the innovations we describe will ever jump from the research bench to the clinical bedside unless technology helps guide the way. Inexpensive point-of-care optical devices could help individualize health care and improve disease prevention, therapy, and overall quality of life without breaking the bank.

(By Albert Cerussi and Bruce Tromberg, Beckman Laser Institute and University of California, Irvine SPIE, OEmagazine, February, 2001)

UNIT 18

I. Memorize the following words.

- source
- safety
- to experience
- to dismiss
- particularly
- hazard
- to happen
- secondary
- to enter
- to pose
- probability
- setup
- to update
- threshold
- irradiance
- pressing
- to cause
- protector
- proper(ly)
- significant(ly)

2.Translate these synonyms and memorize them:

- remember (v), forget
- subtract (v), add
- output (n), input
- last (adj), first
- top (n), bottom
- drop (n), rise
- presence (n), absence
- increase (v), lessen, reduce
- total (adj), partial
- difference (n), similarity

3.Match these synonyms:

1. Acceptance
2. Offer
3. Power
4. Need (n)
5. Attain
6. Actual
7. Sufficient
8. Calculate
9. Similar
10. Matter

a) energy
b) want
c) real
d) enough
e) recognition
f) the same as
g) business
h) compute
i) achieve
j) propose

4. Translate the following sentences paying attention to words with "ing" forms:

1. Testing a new receiver for the application in this system was the prime engineers' task.
2. Without testing the equipment it's impossible to use it in the experiment.
3. The main task of engineer is testing the equipment.
4. Testing the engine the engineer applied new methods.
5. In designing electronic computers we have passed from valves to transistors.
6. We can increase the current strength by decreasing the resistance of the circuit.
7. Part of the signal travelling along the ground is called the ground wave.
8. Obtaining new data on the waves travelling was necessary for future investigations.
9. Constructing simple radio-sets was followed by more complex devices using semiconductors.
10. The new receiver being tested will be used in this system.

5. Translate the text:

Text A. **Playing it Safe**

Following standards and using appropriate safety equipment can help eliminate the risk of eye injuries during laser use.

The high radiance or brightness of a laser provides the laser's great value in material processing and laser surgery, but it also accounts for its significant hazard to the eye. Even a small helium-neon (HeNe) alignment laser is typically ten times as bright as conventional bright-light sources such as a xenon arc or the sun.

The most serious eye injuries typically take place in R&D laboratories. Laboratory staff should alert students and newcomers from the start to the risks of working with lasers. Too often laser safety does not become an issue until someone loses eyesight. Instructing students in laser safety does not have to be a boring presentation of rules, however. Behind the safety standards are many interesting questions in physiological optics, vision, and the biophysics of laser-tissue interactions.

Examining the eye

A collimated beam entering the relaxed human eye will experience an increase of irradiance by about five orders of magnitude. In other words, a beam with irradiance of 1 W/cm^2 at the cornea is focused to a spot of 100 kW/cm^2 at the retina. The retinal image size is only about 15 to 20 µm, which is considerably smaller than the diameter of a human hair. Users may dismiss the hazard posed by such a small laser burn in their retina, reasoning that their eye contains millions of cone cells.

In reality, retinal injury is always larger because of heat flow and acoustic transients, and even a small disturbance of the retina can damage vision. This is particularly important in the area of central vision, the macula lutea (yellow spot), or simply the macula. The central region of the macula, the fovea centralis, measures about 150 µm in diameter and is responsible for detailed 20/20 vision. Damage to this extremely small central region can result in severe vision loss, even though 95% of the retina is unscathed. The surrounding retina is useful for movement detection and other tasks but possesses little acuity; for example, the reason your eye must move across a line of print in order to read is because your detailed vision covers a very small angular field.

At wavelengths beyond the 400- to 1400-nm retinal hazard region, the cornea—and even the lens—can be damaged by laser beam exposure. Staring into a UV or blue continuous-wave laser can lead to photochemical injury.

Injury by accident

Laser eye injuries can happen in a multitude of ways but always involve a laser beam inadvertently diverted into the eye. For example, a researcher in a physical chemistry laboratory is aligning the output beam of a neodymium-doped yttrium- aluminum-garnet (Nd:YAG) laser-pumped optical parametric oscillator (OPO) to direct it into a gas cell to study photodissociation parameters for a particular molecule. Leaning over a beam director, he glances down over an upward, secondary beam and approximately 80 µJ enters his left eye. The impact produces a microscopic hole in his retina. A small hemorrhage is produced over his central vision, and he sees only red in his left eye. Within an hour he is rushed to an eye clinic where an ophthalmologist tells him he has only 20/400 vision.

In another example, a physics graduate student attempts to realign the internal optics in a Q-switched Nd:YAG laser system—a procedure normally performed by a service representative, but one that the student has witnessed several times before. A "weak" secondary beam reflected upward from a Brewster window enters the student's eye and produces a similar hemorrhagic retinal with a severe loss of vision.

Though such accidents occur each year, often they do not receive publicity because of administrative reasons or litigation. Because almost all open-beam lasers pose a severe hazard to the eyes, scientists and engineers must wear eye protection or observe other safety measures. However, laser users often make excuses for not wearing eye protection. All too common, the familiar phrases "I know where the beams are," "I don't place my eye near a beam," and "Safety goggles are uncomfortable" are heard in the lab. Unfortunately, in most laser-related accidents, eye protectors were available but not worn.

Injuries do not always happen when eye protectors are not worn because the probability that a small beam will intersect the 3 to 5 mm pupil of a person's eye is small. For the people who don't wear goggles, the risk of injury appears to be acceptably low or they would choose protection. But consider the following scenario: If these same individuals were given an air rifle loaded with 100 BBs, placed in a stainless-steel-lined cubical room 4 m on a side, and told to fire all of the BBs in a random direction, how many would be willing to do this without heavy clothing and eye protectors? Not many—the risk of firing without protection would seem too high. Yet the probability of being hit with a BB in that scenario is about the same as that of sustaining a laser eye injury when not wearing goggles.

Comfortable laser goggles exist. The common complaint that one cannot see the beam to align it is readily solved; for example, the image converters and various fluorescent cards used to align IR beams can be used for visible lasers as well.

Nonvisible beams can pose subtle hazards. Our instinctive aversion to bright lights that can trigger a reaction to visible beams does not come into play for IR and UV beams—users may not know to look away from damaging beams until it is too late. The black anodized surface used in many lab setups can be a good reflector in the IR spectral region, which sets the stage for damage by a reflected beam.

Safety standards

Laser safety standards group all lasers into four general hazard classes and provide safety measures for each class. U.S. federal regulations require all commercial laser products to have a label indicating the hazard class. The safety measures recommended in these standards include beam blocks, shields, baffles, and eye protectors.

Documents such as the American National Standard, ANSI Z136.1-2000, "The Safe Use of Lasers," provide maximum permissible exposure (MPE) limits as sliding scales with wavelength and duration for all wavelengths from 180 nm to 1 mm and for exposure durations of 100 fs to 8 hr. The exposure limits of the American Conference of Governmental Industrial Hygienists (ACGIH) and ANSI became the basis for the U.S. Federal Product Performance Standard (21 CFR 1040) mentioned above.[8] With the proliferation of ultrafast lasers used in research laboratories, the MPEs recently have been updated to include limits for these picosecond and femtosecond pulse durations.

The development of exposure limits in the subnanosecond time domain has been difficult because the interaction mechanisms of laser radiation with biological tissues differs. Nonlinear damage mechanisms do not scale in the same way with wavelength, pulse duration, and retinal image size as do thermal and thermal acoustic damage mechanisms. For this reason, it has been necessary to perform a number of studies of damage mechanisms. Likewise, researchers have had to use histological techniques to study the range of effects that occur at subvisible threshold levels. Before setting exposure limits, the standard-setters must understand the consequences of exceeding the threshold.

Eye protection

The ANSI Z136.1 standard for eye protection includes factors such as comfort and fit, filter damage threshold, and periodic inspection, as well as the critical specification of wavelength and optical density. Opinions differ on how to rate eye protection. European standards emphasize filter burn-through and damage thresholds; in U.S. laser safety, officers are reluctant to demand that laser protective filters have damage-resistant irradiance values far exceeding skin damage thresholds.

Ordinary polycarbonate eye protectors can withstand irradiances of about 100 W/cm^2 (1 MW/m^2) for several seconds of illumination by a 10.6 µm wavelength. Because of this, some have proposed an alternative protocol to damage-based testing that would instead evaluate materials for saturable absorption by testing the optical density (OD) under CW and Q-switched irradiation conditions.

The most pressing issue in laser safety standards now is requiring laser eye protection to be marked in an intelligible fashion to ensure that the user will not misunderstand and select the wrong goggle. Several eye injuries appear to have been caused in the past few years by a user choosing the wrong protector for the wavelength. This is particularly likely in an environment where different laser wavelengths are in use, as in a research laboratory or a dermatological laser operation. In addition to the wavelength, the terms "ruby," "neodymium," "carbon-dioxide," and similar labels should be required on the specification sheet. In a location with a multiwavelength laser, however, this could still lead to confusion.

When used properly, lasers can be useful, productive instruments and tools. If scientists and engineers working with lasers use protective goggles, beam blocks, and other safety equipment regularly, they will significantly reduce the risk of injury to themselves and to others. Instructors have an ethical obligation to teach newcomers the risks of working with lasers and common-sense safety procedures. As laser safety becomes commonplace, catastrophic injury will become a thing of the past.

(By David Sliney SPIE, OEmagazine, July, 2001)

Text B. **Alferov Strikes Gold**

Nobel Prize winner Zhores I. Alferov is the 2002 SPIE Gold Medal Recipient

Recipient of the highest honor that SPIE bestows, the 2002 Gold Medal of the Society, SPIE Member Zhores I. Alferov has made an enormous impact on the field of semiconductor heterostructures. His contributions to physics and III-V semiconductor heterostructures led directly to the development of lasers, solar cells, LEDs, epitaxy processes, and the creation of modern heterostructure physics and electronics.

Alferov has been influencing the field of semiconductor heterostructures for more than 50 years. From his childhood fascination with chemistry to his life-long devotion to semiconductor technology, Alferov has been one of the outstanding physicists of the 20th and now the 21st centuries.In the beginning

Alferov's interest in science began early. He read his first book about physics, *Solar Substance* by Matvei Bronshtein, when he was only 10 years old. "The book was about the discovery of helium," says Alferov. "Bronshtein worked for the Ioffe Institute, and at 31 he was executed as 'an enemy of the people' in 1937. Books by 'enemies of the people' were destroyed in libraries, and my mother, who worked in a library at that time, could not do this and brought them home."

In sixth grade, Alferov started studying chemistry and physics and even had a small chemistry lab at home. During high school, he was influenced by his physics teacher, Yakov Borisovich Meltserzon. "The teacher loved physics devotedly and had a gift for making our imaginations work. His explanation of the cathode oscilloscope operation and talk on radar systems greatly impressed me," says Alferov.[1] On the advice of Meltserzon, Alferov went to Leningrad after graduation to study at the electronics department of the V. I. Ulyanov (Lenin) Electrotechnical Institute (LETI).

Alferov began working in the LETI laboratory during his third year at the institute with the assistant to the chair of vacuum physics, N. N. Sozina, who was studying semiconductor photodetectors. A year earlier she heard Alferov speak at a student conference on photo-effect; impressed by his presentation, she invited him to join her in the lab. Thus began his work with semiconductor detectors.

Years of research

After graduating in 1952, he joined the Ioffe Physico-Technical Institute the next year as a junior researcher. During the 1950s, Alferov and his research group focused on the properties and creation of transistors and germanium crystals. "In subsequent years, our team of researchers at the Physico-Technical institute expanded considerably and in a very short time the first Soviet germanium power rectifiers were created along with germanium photodiodes and silicon," says Alferov.[1]

In 1961, Alferov earned a Candidate of Sciences in technology at the Ioffe Institute, and in 1962 his work with III-V semiconductor heterostructures began. "As soon as the first work on semiconductor lasers appeared, it was natural for me to consider the advantages of employing in lasers the double heterostructure of p-i-n types," he says.[1]

"In 1963, having formulated the concept of double heterostructure (DHS) for making a low threshold room temperature operating laser, we immediately started our experimental work," says Alferov. "For several years we were on the wrong track (using GaP-GaAs) and only in the beginning of 1967 did we take the right way. From the very beginning we studied both the physics of heterostructures and their various applications (not restricting ourselves to lasers only). I think this wide approach predetermined our success."

Alferov's team applied heterostructures to devices such as lasers, LEDs, solar cells, and transistors. "From the beginning we considered optical communications as the most important application. It was a lucky coincidence Corning Glass worked out a low loss optical fiber at the same time. Already at that time, I dreamed of projection TV based on DHS lasers."

During this time Alferov became a senior researcher at the Ioffe Institute in 1964 and became head of the laboratory in 1967. That same year he married Tamara Darskaya in Leningrad.

Alferov completed his Doctor of Sciences degree in physics and mathematics at Ioffe in 1970. Later in the year he traveled to the United States and worked for six months in the semiconductor devices lab at the University of Illinois at Urbana-Champaign. He worked closely with Nick Holonyak and the two remain good friends.

During the 1970s, Alferov continued as head of the laboratory at Ioffe and led the creation of heterostructure-based solar cells, beating the Americans in the race for their early development. Alferov had a red-letter day in 1972; his son, Vanya, was born on the same day he received the Lenin Prize, the highest scientific prize in the, then, USSR. The next year Alferov became the chair of optoelectronics at the St. Petersburg State Electro- technical University, which was formerly LETI.

In the late '70s and '80s, research at the Ioffe Institute turned to revolutionary work on superlattices, quantum wells, and quantum dots. And in 1987 Alferov became the director of the Ioffe Institute, a position he continues to hold today. In 1988 he was appointed dean of the faculty of physics and technology at the St. Petersburg Technical University.

He was elected vice-president of the Academy of Sciences of the USSR in 1990. In 1991, he was re-elected vice-president of the new Russian Academy of Sciences and elected president of the St. Petersburg Scientific Center of the Russian Academy of Sciences.

"I believe in the future of science in Russia, but scientific achievements should be demanded by Russian industry first of all. I consider that without proper development of key industries based on high technology, the future of science in Russia, including basic research, will remain in a sad state."

Sweet rewards

For his innovative research, Alferov has received numerous honors, including Life Fellow of the Franklin Institute (USA), full member of the Russian Academy of Sciences, Fellow of the Institute of Physics (UK), and foreign member of the German, Polish, Belarussian, and Ukraine Academy of Sciences.

In addition, Alferov has won several awards, including the A.F. Ioffe Prize (1996), the A.S. Popov Medal (2000), and the Nick Holonyak Award (2000), to name a few. "My first international award was the Ballanytne Gold Medal of the Franklin Institute, in 1971. It has been of particular value for me," says Alferov. "The Lenin Prize in 1972 is also of particular value for me since my young pupils/colleagues shared it with me. And undoubtedly, the Nobel Prize for Physics in 2000."

Alferov has authored three books, 500 journal articles, and has 50 inventions in semiconductor technology. He is also editor-in-chief of the Russian journal, *Pis'ma v Zhurnal Tekhni- cheskoi Fiziki* (Technical Physics Letters), and a member of the editorial board of the Russian journal *Nauka i Zhizn'* (Science and Life).

(OEmagazine, July, 2002)

Таблиця найуживаніших нестандартних дієслів

I. Infinitive	II. Past Indefinite	III. Past Participle
arise виникати	arose	arisen
awake прокидатися	awoke	awoke/awaked
be бути	was (were)	been
bear носити	bore	born
become ставати	became	become
beat бити	beat	beaten
begin починати	began	begun
bend гнути	bent	bent
bind зв'язувати	bound	bound
blow дути	blew	blown
break розбити	broke	broken
bring принести	brought	brought
build будувати	built	built
burn горіти	burnt	burnt
buy купувати	bought	bought
catch ловити	caught	caught
choose вибирати	chose	chosen
come приходити	came	come
cut різати	cut	cut
deal мати справу з	dealt	dealt
do робити	did	done
draw креслити, тягнути	drew	drawn
drink пити	drank	drunk
drive приводити в дію	drove	driven
eat їсти	ate	eaten
fall падати	fell	fallen
feed годувати	fed	fed
feel почувати	felt	felt
fight боротися	fought	fought
find знаходити	found	found
fly літати	flew	flown
forget забувати	forgot	forgotten

I. Infinitive	II. Past Indefinite	III. Past Participle
freeze замерзати	froze	frozen
get отримувати	got	got
give давати	gave	given
go іти, ходити	went	gone
grind молоти	ground	ground
grow рости	grew	grown
hang висіти	hung	hung
have мати	had	had
hear чути	heard	heard
hide ховатись	hid	hidden
hit ударяти	hit	hit
hold тримати	held	held
keep зберігати	kept	kept
know знати	knew	known
lay класти	laid	laid
lead вести	led	led
learn вчити	learnt/learned	learnt/learned
leave залишати	left	left
lend позичати	lent	lent
let дозволяти	let	let
lie лежати	lay	lain
light запалювати	lit/lighted	lit/lighted
lose губити	lost	lost
make робити	made	made
mean означати	meant	meant
meet зустрічати	met	met
pay платити	paid	paid
put класти	put	put
read читати	read	read
ring дзвонити	rang	rung
rise підніматися	rose	risen
run бігти	ran	run
say говорити	said	said
see бачити	saw	seen
sell продавати	sold	sold
send посилати	sent	sent

I. Infinitive	II. Past Indefinite	III. Past Participle
shake трясти	shook	shaken
shine світити	shone	shone
shoot стріляти	shot	shot
show показувати	showed	shown
shut закривати	shut	shut
sing співати	sang	sung
sink занурюватися	sank	sunk
sit сидіти	sat	sat
sleep спати	slept	slept
slide ковзатися	slid	slid
speak розмовляти	spoke	spoken
spend проводити	spent	spent
split розщепляти	split	split
spread розповсюджувати	spread	spread
spring стрибати	sprang	sprung
stand стояти	stood	stood
steal красти	stole	stolen
stick приклеювати	stuck	stuck
strike вдаряти	struck	struck
swim плавати	swam	swum
swing коливати(ся)	swung	swung
take брати	took	taken
teach навчати	taught	taught
tear рвати	tore	torn
tell розповідати	told	told
think думати	thought	thought
throw кидати	threw	thrown
understand розуміти	understood	understood
wear носити	wore	worn
win вигравати	won	won
wind намотувати	wound	wound
write писати	wrote	written

Додаток Б

Стислий англо-український словник спеціальних термінів

A

aberration	аберація, спотворення
absorb	поглинати
absorption	поглинання
accuracy	точність
action	дія, вплив,
achromat, achromatic lens, appliqué	ахромат
amplifier	підсилювач
application	застосування
approach	підхід, метод
area	ділянка, зона
array	матриця, гратка

B

base	база, підкладинка
beam	промінь, пучок
boundary	межа, контур
brightness	яскравість, освітленість

C

capability	можливість, здатність
CCD	прилад із зарядовим зв'язком
cell	елемент, комірка
channel	канал
chip	кристал, інтегральна схема
circuit	ланцюг, контур, схема
collimator	коліматор
compare	порівнювати
compression	стиснення
conversion	перетворення
converter	перетворювач
correction	виправлення
correlator	корелятор
counter	лічильник
current	струм

D

damp	вносити затухання, ослаблювати
dasar	оптичний атенюатор
definition	чіткість (зображення), роздільна здатність
deflection	відхилення
defocus	дефокусувати
degree	степінь
density	щільність
design	проектування, розроблення
detection	реєстрація (випромінювання)
detector	детектор, сенсор
optical	фотоелектричний сенсор, фотоприймач
deviation	відхилення
device	прилад, пристрій
diffraction	дифракція
diffusion	розсіювання (світла)
digital	цифровий
diode	діод
laser	лазерний діод
light-emitting	світлодіод
optical	оптрон, оптопара
photoemissive	фотоелемент
discrimination	розпізнавання, роздільна здатність
dispersion	дисперсія
display	дисплей, пристрій відображення, індикатор

distortion	спотворення
distribution	розподіл
disturbance	завада, збурення
division	розподіл

E

echo	відбитий сигнал
edge	край, межа
effect	ефект, вплив, явище
emission	емісія, випромінювання
emissivity	коефіцієнт випромінювання
engineering	техніка, технологія
expansion	розширювання

F

film	плівка
filter	фільтр
flow	потік
fluorescence	флуоресценція
flux	потік, щільність потоку
focus	фокус
force	сила
frame	система відліку, кадр
frequency	частота

G

gain	коефіцієнт підсилення
gate	логічний елемент
glass	скло, скляна оптика
grating	гратка, дифракційна гратка
guide	хвилевід, світловід

H

hologram	голограма

I

identification	ідентифікація, розпізнавання
illuminance	освітлюваність
illuminant	джерело світла
illumination	освітлення
image	зображення
imaging	формування зображення
immersion	імерсія
impedance	опір
intelligence	інтелект
intensity	інтенсивність, сила світла

J

junction	з'єднання, перехід

L

ladar, lidar	лазерний локатор
lambda	довжина хвилі
laser	лазер
lasing	лазерна локація
layer	шар, плівка
LED	світлодіод
lens	лінза
level	рівень
liquid crystal displays	рідинно-кристалічні дисплеї
light	світло, світлове випромінювання
link	лінія зв'язку, канал зв'язку, ділянка
loss	втрата
luminescence	люмінесценція

M

matrix	матриця
measurement	вимірювання
memory	пам'ять
mirror	дзеркало, відбивач
mixing	змішування

N

nanoelectronics	наноелектроніка

network	мережа, схема
noise	шум

O

objective, **object glass**	об’єктив
optical axis	оптична вісь
operation	робота, режим
oscillation	коливання

P

package	блок, вузол, модуль
pattern	зображення, структура
photocell	фотоелемент
photodiode	фотодіод
photon	фотон
photoresistor	фоторезистор
photosensor	фотоелемент
phototransistor	фототранзистор
pipe	хвилевід, магістраль
point	точка, контакт
pulse	імпульс

Q

quality	якість
quantity	величина, кількість
quantization	квантування
quantum	квант

R

radiance	енергетична яскравість
radiation	випромінювання, радіація
range	діапазон
rate	швидкість, частота, інтенсивність (відмов)
ratio	відношення
ray	промінь, пучок
real-time	у реальному масштабі часу
receiver	приймальний пристрій
receptor	приймач (біон.)
recognition	розпізнавання, ідентифікація
recording	запис, реєстрація
recovery	відновлення, повернення
reduction	зменшення, послаблення
reference	еталон, взірець
reflection	відбиття
reflectivity	коефіцієнт відбиття
reflector	відбивач, дзеркало
refraction	рефракція, заломлення
refringence	заломлення
region	ділянка, зона
registration	реєстрація
rejection	ослаблення, відбиття, режекція
relation	відношення, зв’язок
relay	трансляція, передача (сигналів)
reliability	надійність
repair	ремонт, відновлення
reradiation	перевипромінювання, розсіювання
research	дослідження
resistance	опір, резистор
resolution	роздільна здатність
retrieval	пошук (інформації)
return	відбивання (відбивати)
rotation	обернення, поворот
route	шлях, траса

S

safety	безпека
sample	взірець, відлік
sampling	дискретизація
saturation	насичення
Scale	*(n)* масштаб, шкала, *(v)* змінювати масштаб

scan,	*(n)*	сканування,
scanning	*(v)*	сканувати
Scatter	*(n)*	розсіювання,
	(v)	розсіювати
screen		екран
search		пошук (шукати)
selection		селекція, вибір
semiconductor		напівпровідник
sense		знак, напрямок, орієнтація, розпізнавання, зчитування
sensitivity		чутливість
sensor		вимірювальний перетворювач, сенсор, детектор
separation		розділення
set		набір, множина, пристрій. апарат
sheet		шар, діаграма, графік, таблиця
sigh		знак, символ, ознака,
simulation		моделювання, імітація
solid-state		твірдотільна
source		джерело
space		простір, ділянка, зона
speckle		спекл-структура
spectroscopy		спектроскопія
spectrum		спектр
speed		швидкість, швидкодія
split		розчеплення, розбиття
splitter		світлоподільний елемент
spot		пляма, ділянка. точка
stage		стадія, етап, каскад
standard		еталон, взірцева міра
state		стан, положення
storage	*(n)*	пам'ять,
	(v)	запам'ятовувати
strength		інтенсивність, сила
surface		поверхня

T

technology		техніка, технологія
test	*(n)*	випробування,
	(v)	випробувати
trace		слід, спостерігати
transducer		перетворювач
transfer		передача, передавати
transform		перетворення
transparency		транспарант, прозорість

U

unit	одиниця (фізичної) величини, елемент, прилад, апарат, блок, вузол, модуль

V

value	(числове) значення
velocity	швидкість
vertex	вершина, вузол (схеми, графа)
vertex of a refracting surface	вершина заломленої поверхні
Video	відеосигнал
voltage	напруга

W

wave	хвиля
waveform	форма хвилі
waveguide	хвилевід
wavelength	довжина хвилі

Z

zone	зона, ділянка

Навчальне видання

Багнюк Г.М., Павлов С.В., Плиненко В.О.

ЗБІРНИК ВПРАВ І ТЕКСТІВ АНГЛІЙСЬКОЮ МОВОЮ З ЛАЗЕРНОЇ ТА ОПТОЕЛЕКТРОННОЇ ТЕХНІКИ

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