

CAREER OPPORTUNITIES IN OPTICS

It's the bandwidth, stupid! That's the most concise explanation of the explosive growth in interest in optical communications. This year's Optical Fiber Communications conference drew a record 17 300 people, an astounding 70% increase over an already robust attendance last year. The number of exhibitors at the meeting, which was held in Baltimore in March, was up by 25%. More than 3400 jobs were posted for consideration by a record 300 job seekers—11 jobs per seeker. Similarly, the Photonics West conference, held in San Jose in January, drew a record attendance of 12 141, surpassing the previous year's attendance by nearly a thousand.

The trade press is gushing. According to *Lightwave*, "Last year was stellar for virtually any stock associated with optical communications. Almost without exception, every public name in this space has out-performed the broad technology indices, with stocks like SDL (semiconductor lasers and components) and JDS Uniphase (active and passive fiber-optic components) appreciating an astounding 1000% and 830%, respectively, during the year."¹

According to *Fiber Systems International*, "The market for terrestrial dense wavelength division multiplexing (DWDM) optical components will hit \$7 billion by 2003—up from \$1.4 billion in 1999. That's the conclusion of the US telecom consultancy RHK. The group's latest research says that sales of 2.5 Gbit/s devices are growing by more than 60% each year, while sales of 10 Gbit/s products are rising even faster."²

And this from *Laser Focus World*: "The worldwide market for diode lasers... grew by an unprecedented 47.2% to \$3.17 billion, far outstripping the 28.4% growth forecast at the beginning of last year. . . . Telecommunications . . . is the jewel in the crown of the diode laser market. In 1999, diode lasers used in telecom accounted for 68.7% of the overall market, or \$2.18 billion. . . . The increase over 1998 was an astounding 58.1%. . . . Surveys indicate that the number of Internet users is growing at 50% per year, while the Internet traffic due to home use is growing at more than 300% per year."³

At this year's Optical Fiber Communications conference, I ran into a former Bell Laboratories colleague, Rod Tucker, now at the University of Melbourne, who asked, "Have you joined or founded one of these new photonic startups?" "No," I replied. "Then we must be the only two academics left in this field who haven't," he quipped. Hmmm!

Have you noticed that a large fraction of radio and television commercials end in something-dot-com or refer you to a Web site for further information? Fueling this technological revolution is the speed- and bandwidth-hungry

Demand for ever faster data transmission is fueling rapid advances in fiber optic communications and a frenzied search for personnel trained in optics.

Anthony M. Johnson and C. Breck Hitz

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Internet, and at the core of the current high-speed systems and next-generation systems is the enabling technology of optics. As a recent article explains, the growing demand for more bandwidth is "enterprise-related—healthcare facilities must transmit huge files to convey medical imaging,

financial institutions have become completely dependent on electronic fund transfer all over the world, universities link students to virtual classrooms via videoconferencing. However, residential demand—especially for Internet and entertainment services—is also skyrocketing; more than nine out of every ten telephone lines in the US go to residences, creating a huge potential market."⁴ The technology to meet this demand is advancing rapidly. The amount of information that can be transmitted over a strand of glass is doubling every 9 to 12 months, outpacing Moore's famous law.

Excitement foretold

In 1994 I had the pleasure of participating in a National Science Foundation workshop on optical science and engineering, which studied new directions and opportunities in research and education. We could see then that "Research in optical science and engineering holds exceptional promise for innovation that will have impact on long-term national goals." We recommended that NSF emphasize optics research and education, because "optical science and engineering is an enabling technology—that is, a technology with applications to many scientific disciplines and with the potential to contribute in significant ways to those disciplines." (Some of the excitement that the telecommunications industry is now experiencing was also foretold in a 1994 National Research Council report entitled "Atomic, Molecular, and Optical Science: An Investment in the Future."⁵)

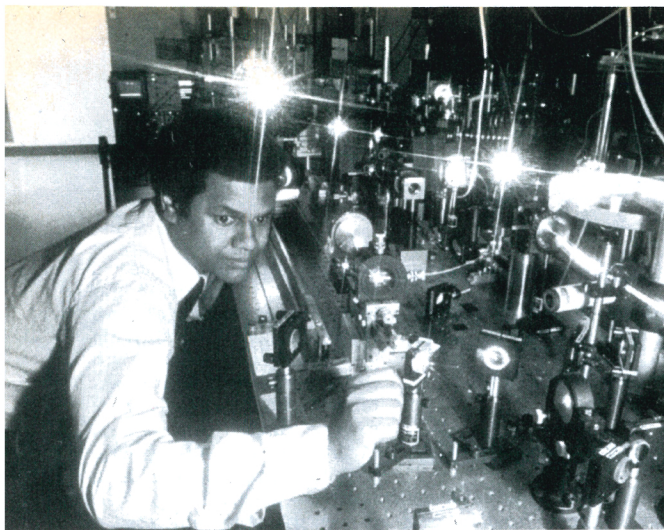
Also in 1994, an American Institute of Physics survey of initial employment of 1992 PhD recipients found that the percentage of graduates who obtained potentially permanent positions differed greatly by subfield: Only 14% of astrophysicists found permanent jobs immediately after obtaining PhDs, compared with 75% of those who studied optics or lasers. (See PHYSICS TODAY, July 1994, page 55.)

Most recently, the National Research Council committee on optical science and engineering, chaired by Charles V. Shank, director of Lawrence Berkeley National Laboratory, assessed the field by its contribution to meeting national needs.⁶ Optics is largely defined by what it enables; as a result, applications drove the structure of the NRC study and report, which is organized around seven major areas of national need:

- ▷ Information technology and telecommunications
- ▷ Health care and the life sciences
- ▷ Optical sensing, lighting, and energy
- ▷ Optics in manufacturing
- ▷ National defense
- ▷ Manufacturing of optical components and systems
- ▷ Optics research and education.

All of these areas have seen tremendous growth in research, development, and career and job opportunities. A few examples that highlight this "technology roadmap," if you will, are given below.

The surge in attendance at this year's Optical Fiber



PULSE COMPRESSION in optical fibers. The author is pictured here at an optical bench that he has dedicated to a hands-on graduate course in ultrashort nonlinear pulse propagation in fibers. The course is part of the optical science and engineering program at the New Jersey Institute of Technology, in Newark.

Communications conference reflects the explosive growth in information technology and telecommunications. On the first day of technical presentations and exhibits, the conference took on the aura of a rock concert, with registration lines running out of the convention center and down the street for nearly a city block—and Optical Society of America staff providing cold drinks to those waiting in line. There was unprecedented media coverage, with 151 press registrants, compared to 86 the previous year. The coverage included four live broadcasts by CNBC from the exhibit floor and a feature on PBS's "Nightly Business Report." This brought back fond memories of the "Woodstock of Physics," the March 1987 American Physical Society meeting in New York that highlighted high-temperature superconductivity.

Microelectromechanical systems

An area that is seeing tremendous growth, and that overlaps both the use of optics in manufacturing and the manufacturing of optical components and systems, is microelectromechanical systems. According to a National Academy of Engineering symposium report, "MEMS technology has opened up many new opportunities for optics. For the first time, reliable microactuators and 3D optomechanical structures can be monolithically integrated with micro-optical elements. This new technology will impact many applications including display, scanning, and telecommunications. . . . MEMS technology has made it possible, for the first time, to integrate an entire optical table onto a single silicon chip."⁷

According to a recent assessment of the state of the

technology, "silicon-based micromechanics is just beginning to impact industries as diverse as automaking, aeronautics, cellular communications, chemistry, acoustics, display technologies, and lightwave systems. . . . The technology continues to advance rapidly, driven by an estimated \$200 billion annual market for very-large-scale integrated circuits and [the] relentless development of related tools, techniques, and processes. . . . Although no MEMS device has yet been deployed in an active lightwave network, the wealth of new capabilities presented by such optical devices makes them certain candidates for commercial success. The optical MEMS industry is expected to become a multi-billion-dollar business in the next five years. Many companies identify MEMS as a strategic technology they cannot afford to neglect."⁸

Health care and life sciences

The use of optics in health care and the life sciences has also seen marked growth. One recent example, reported in *Optics & Photonics News*, is "a complete eradication of ocular melanoma tumors in 84% of lab animals following a single treatment with a multiphoton excitation procedure. The results are attributed to the fact that melanin precursors in melanoma tumor cells become extremely phototoxic when activated with certain light sources. . . . Human experimental trials are anticipated to begin in 2000 or 2001."⁹

Recent biomedical optics research approaching commercial reality includes a handheld, noninvasive laser device that helps physicians decide whether a patient needs further testing for cancer. The device "is poised to become the first optical-biopsy system to gain US FDA clearance . . . for early detection of colon cancer. At present, colorectal cancer is primarily diagnosed by the detection and analysis of polyps identified by inserting an endoscope into the colon. . . . The SpectraScience Virtual Biopsy System uses laser-induced fluorescence through an endoscope to make contact with the polyp, optically scan it, and provide an instant analysis."¹⁰ (See also page 9 of this issue.)

Nanotechnology

In the broad area of optics research and education, one must include the National Nanotechnology Initiative announced by President Clinton in February 2000. A Sep-

GLORIA PUTNAM is a physicist at the southern California-based advanced sensors division of Pixel Vision Inc, a developer and manufacturer of scientific charge-coupled-device detectors and digital imaging systems. "It's fun," she says of her work, which often delves into fundamental physics. "The science that comes out of this work is very exciting." She received a BS in physics and math at California State Polytechnic University at Pomona in 1994 and spent several years after that teaching high school. "I always knew I wanted to wind up in industry," Putnam says. "But I had a very positive experience with an excellent teacher in high school, and I wanted to teach for a while myself to 'give back' for that experience."

Although optics and imaging are the overarching technologies of Putnam's work at Pixel Vision, she often finds herself deeply immersed in other fields such as solid-state physics. As an example, she cites a Pixel Vision study she recently became involved with to better understand the physical origin of $1/f$ noise in MOSFET amplifiers. This noise, created by trapping centers in semiconductors, currently limits the noise floor for astronomical and other scientific imaging. In the end, she and her coworkers were able to pinpoint a

location in the device where they believe the noise originates. The next step, currently in progress, is to verify their physical insights experimentally using custom-designed test amplifiers. The results may eventually lead to improved low-light-level sensitivity for the company's CCD imaging systems.

Where does Putnam see her career taking her in the future? "Right now, I'm so involved with learning the technology that I can't imagine ever going over to the management side." Still, immediately after saying that, she muses, "It might be fun to start a company someday . . ."

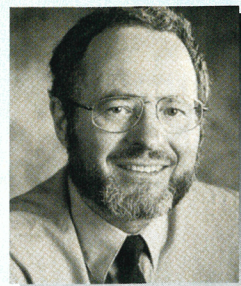


BERNARD COUILLAUD, president and CEO of Coherent Inc in Santa Clara, California, holds two PhD-equivalent degrees from the University of Bordeaux in France, one in microwave technology and the other in laser spectroscopy. He was a professor at the University of Bordeaux for several years, but during a stint as a visiting professor at Stanford University, he made the leap from academe to industry, joining Coherent in 1983 as the manager of dye-laser research.

Couillaud's background in physics and optics has served him well as a businessman, he says. "It seems like it would be difficult to run a technology company without a strong background in technology," but he acknowledges that there are many successful technology companies with non-technologists at the helm. You can do it either way if you're smart enough, Couillaud feels: Start with a background in business and learn the technology that you need on the job, or vice versa. From his perspective, though, it's easier to learn the business principles on the job. "Business is just common sense, after all," he explains. "You're in business all your life, from the first time you try

to strike a bargain with your parents."

Couillaud has observed an interesting shift in his focus as he has grown older. As a young man, he says, he was intensely interested in science and technology, and eagerly pursued the rigorous French path to becoming a professor at a leading university. It was only as he became more mature, he observes, that he found business more intriguing and challenging. Asked what advice he would offer to today's graduate or undergrad student, Couillaud pauses for a moment to reflect. "It's important to understand how the real world works," he answers. "You have to understand how technology fits into the real world, what it does. Maybe it's not enough just to understand the technology by itself."



tember 1999 report by the administration's National Science and Technology Council and the Interagency Working Group on Nanoscience, Engineering and Technology, summarizes the prospects for nanoscale science and engineering (NS&E): "By using structures at the nanoscale . . . it is possible to greatly expand the range of performance of existing chemicals and materials. Scientists can already foresee using patterned monolayers for a new generation of chemical and biological sensors; nanoscale switching devices to improve computer storage capacity by a factor of a million; tiny medical probes that will not damage tissues; entirely new drug and gene delivery systems; nanostructured ceramics, polymers, and metals, and other materials with greatly improved mechanical properties; nanoparticle reinforced polymers in lighter cars; and nanostructured silicates and polymers as better contaminant scavengers for a cleaner design and fabrication of complex nanoscale assemblies."¹¹

Key to many of these NS&E prospects is the ability "to see and rearrange atoms and molecules with the help of varieties of scanning probe microscopes, optical tweezers, and high-resolution microscopes. . . . The administration's FY 2001 budget for NS&E includes \$495 million distributed around six different agencies, led by NSF. This is an increase of \$227 million, or 84%, over FY 2000."¹² The National Nanotechnology Initiative is clearly a huge and exciting research thrust, and at the core of this prospective nanotechnology is the enabling technology of optics.

Career path options

The six sidebars that Breck Hitz wrote for this article serve

as examples of the career and job prospects for students with backgrounds in optics. I can also cite the success of our relatively small, four-year-old, NSF-sponsored optical science and engineering (OPSE) program at the New Jersey Institute of Technology. Over the last three years, three students have completed PhDs. One of them is now doing research at Lucent Technologies, one is a postdoc at the Naval Research Laboratory, and one is on the faculty at Manhattan College. Three of our BS graduates work in the local optics industry—Edmund Scientific, JDS Uniphase, and Optics for Research. Eight of our students are interns at Edmund Scientific, JDS Uniphase, and Lucent Technologies. The sample of students who have graduated with OPSE training is fairly small, but I believe that our experience is indicative of the vibrancy of optics-related training. One thing is absolutely clear—we have not been able to fill the strong demand of local industry for OPSE-trained students, and the demand is at all levels—BS, MS, and PhD.¹³

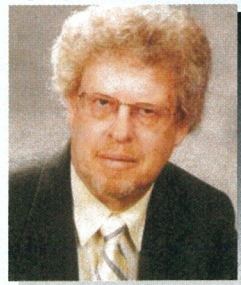
Thus there are a tremendous number of career path options for individuals with a solid background in optics and optical technology at any academic degree level. Optics is truly an enabling technology that runs the gamut from the physics of semiconductor quantum-well lasers, four-photon parametric mixing, and optical solitons in fibers, to multilayer mirror coatings and liquid-crystal displays. Two of the plenary speakers at the Optical Fiber Communications conference said that physicists and engineers will solve the linear and nonlinear optical problems necessary to satisfy or appease the thirst for bandwidth in fiber-optic communication systems. The problem will be people-

DAVID HARDWICK is vice president and general manager of IPG Photonics in Sturbridge, Massachusetts, a manufacturer of active fiber optic telecommunications components. His career illustrates the spectrum of professional opportunities available to physicists in photonics. Hardwick earned a dual BS in physics and English from St. Johns University in Minnesota and went to work in 1960 at the Honeywell Research Center with Paul Kruse, Jack Ready, and other photonics pioneers. During his initial job interview, when Hardwick admitted he hadn't studied optics in school, Kruse handed him a copy of Born and Wolf,¹⁴ along with the advice, "Read this." Hardwick got the job, and was soon at work building ruby and helium-neon lasers for Honeywell.

When Herb Dwight and Bob Rempel, founders of a new company called Spectra-Physics, visited Honeywell several years later, they recruited Hardwick to California. Half a decade after that, Hardwick left Spectra-Physics to join Jim Hobart at a Spectra-Physics spin-off called Coherent Radiation Laboratories. Since then, Hardwick has worked in scientific or management positions in a handful of pho-

tonics companies, including Lasertron, Polytec PI, Valtec, and Melles Griot.

"I've been reading Born and Wolf ever since Kruse gave it to me in 1960," Hardwick says today. From his perspective, the dual degree in physics and English has been an invaluable tool. "You have to be able to communicate with many people" to function well in both management and technology, he says, and he believes that the English and liberal arts side of his formal education has assured him of that capability. His physics training, on the other hand, has enabled him to understand the ever-changing technology around him. "Just knowing that calculus works" has given him a significant advantage over colleagues whose background is in non-technical fields.



WILLIAM GORNALL is vice president of technology at Burleigh Instruments in Fishers, New York, a firm he joined 23 years ago after a stint in academe. He earned a PhD in physics at the University of Toronto, doing his thesis on laser spectroscopy, and subsequently did a postdoc at Harvard University under Nicolaas Bloembergen. He then embarked on what he thought would be an academic career by joining the physics faculty at Brandeis University.



"But I became really interested in designing optical instruments," Gornall says, and he decided to leave Brandeis to join Burleigh, which was then a young company with several exciting new products. "The transition from academia to industry wasn't difficult," he says. He was initially in charge of developing Burleigh's line of Fabry-Perot interferometers. "They had a lot of respect for my opinions, because I'd been building Fabry-Perots for some time in my lab at Brandeis." When the company became interested in developing wavelength-measurement instrumentation, Gornall

led the development of a scanning Michelson interferometer that the company dubbed the "Wavemeter." The instrument remains one of Burleigh's leading commercial products.

Today, Gornall says he spends a lot of his time on strategic planning. "I'm trying to figure how our existing products can evolve to best serve future markets, especially markets in fiber optic telecommunications," he says. He wants the company to develop instruments that can measure the real-time performance of optical networks, not just measure static wavelengths. He is also spending time looking at the company's intellectual property, trying to understand how and if the company's existing patents apply to new products.

"I've become something of an IP lawyer, something of a product engineer; I've become a lot of things," Gornall says of his current responsibilities. But the foundation on which it is all based, he insists, is his physics background. That background has made it easy to communicate with a variety of engineers and scientists, to understand their needs, and to develop products to suit those needs.

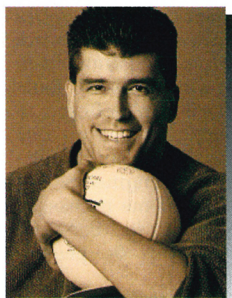
LINDA LINGG was called back to the physics workforce sooner than she had planned after interrupting her career for seven years to start a family. Responding to the surging demand for optical physicists in the telecommunications industry, Lingg has been designing thin-film filters since May 1999 for Spectra-Physics, a photonics and laser company in Mountain View, California. "So much of my work is proprietary that there's not much I can talk about," she says. "But I'm really enjoying being back in the game. It's very exciting being in such a dynamic technology, and I'm learning a lot more about it every day."

Lingg earned a PhD from the Optical Sciences Center at the University of Arizona in 1990, and worked for several years developing infrared fibers at the Naval Research Laboratory before starting her family. "My dad was an engineer at DuPont," she explains. "I remember being fascinated by the holograms he used to show me." She was leaning toward specializing in optics even during her undergraduate years, she says, but didn't really confirm that decision until well into graduate school.

The seven-year hiatus hasn't been much of an impediment to getting back into the thick of things, Lingg says. One reason is that much of the technology of high-bandwidth fiber optic communication has developed during the past several years. It has also been helpful, she notes, that Spectra-Physics has been willing to help her fill in the missing technology. When interviewed for this article, Lingg was in the UK taking a refresher course from Angus MacCloud, her thesis adviser in Arizona.



"My physics background has been enormously helpful to me," Lingg says. "My advice to anybody would be to stay in physics as long as possible, don't specialize too early." Lingg feels that her physics background has given her great flexibility in choosing the direction of her career. "When you understand physics, you can go off and do a lot of things."



SALVADOR TISCARENO earned a BS in physics at the University of California, Santa Cruz, in 1995, and immediately accepted a job as an electro-optical engineer with New Focus in Santa Clara, California. The favorable impression he had gained of New Focus while working there as a summer employee several years earlier was a major factor in his accepting the company's offer after he graduated.

"I wish I'd studied more optics in college," he laments now. While the basic physics and math of his formal education have been invaluable, he says, he had to learn most of his optics on the job, and through several optics courses he took at nearby San Jose State University.

Tiscareno is currently the project manager for one of New Focus's telecommunications products, a fiber optic Faraday isolator. Although one of the company's senior engineers suggested the concept, Tiscareno designed the device and has overall responsibility for its manufacture. With some support from the company's marketing department, he is also heavily involved in marketing and selling the device.

power—will we be able to produce enough optics-trained individuals to keep this roller coaster on track?

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