The education-training continuum: Which way optics?

By C. Yashar Ozberkmen

Educators in optics face a rudimentary dilemma. As in similar disciplines, there are basically two philosophies toward teaching: the theoretically-based path, often preferred by basic researchers and the like; and the highly-focused, task-oriented path, generally the choice of industrialists. Academics make decisions every day on how to best educate their students and how to advance their field. Schools, through the programs they offer, typically align themselves along one of these two paths. While undergraduate, graduate, and technical programs all play a part in shaping the field of optics, undergraduate education will be the focus of this article.

Are our educational institutions successfully producing graduates to meet the demands of the optics industry? Do we need more education or do we need more training? Does the program make the students or do the students make the program?

Duncan Moore, who directs the University of Rochester’s Institute of Optics, states emphatically that “there is a shortage of people who know broad optics.” He explains that there are people who know quantum optics or some other specialized area—“they’re coming out of schools like Cal Tech and Stanford and MIT, but they’re not really abreast of the whole picture.” These schools do not confer undergraduate degrees in optics and do not profess to turn out students educated broadly in optics. However, they do graduate physicists, and electrical engineers, many with substantial knowledge of various areas of optics.

There are those in industry who indicate that they are just as likely to seek undergraduate recruits for optics positions from these types of schools as from Rochester—the University of Arizona, with its strong program in electrical engineering, Cal Tech because it produces some of the best young physicists in this country, or MIT, where many of the undergraduates involved in the university’s industrial cooperative program get three summers of good work experience. Industrialists maintain that some of the individuals who learn their optics at these schools are more beneficial to them from the start.

The approach toward educating the opticist is as diverse as the various philosophies behind the individual educational systems. Rochester takes a “middle of the road” approach toward its undergraduate optics education. The goal, indicates Moore, is to produce people broadly educated in optics, well-rounded individuals who can either go into industry or academic research.

Of those schools that offer concentrations in various areas of optics, many more emphasize specifics. Arizona’s undergraduate program has grown largely out of their electrical engineering department and has concentrated on current optics applications. The University of Colorado at Boulder is home to the Center for Opto-Electronic Computing Systems and is beginning to provide undergraduate courses in this area. Rose-Hulman in Indiana focuses on applied optics. MIT has some of the best science and technically minded young people in the country and educates them formidably in physical optics. Penn State focuses on materials science.

It is no longer an issue of trying to attract the young to optics. “Optics is already becoming a ‘glamour’ industry to go into,” comments Harrison Roberts, a recent University of Rochester graduate who now works at Lincoln Laboratory. The issue now is how to train young opticians to best advance the growth of the industry. The goal of those already in this field seems to be to produce larger numbers of well trained optics graduates to fuel engineering, research, and management positions. In this light, perhaps it should not be an issue of whether to train them in theory or in applications, but rather a question of how to train them well.
Where optics students are educated

As recently as three years ago, the University of Rochester was the only school that produced graduates with bachelor's degrees in optics. The Institute of Optics at Rochester has been training scientists and engineers in optics since 1929 and is the oldest program in the U.S. The undergraduate degree there requires students to take physical and geometrical optics courses, to study radiation, detectors, lasers, and electro-optics, and allows them to dabble in entrepreneurship courses as well as the typical humanities requirements. The undergraduate “experience” at Rochester balances the theoretical with the practical engineering side of the technology. There were schools that offered bachelor's degrees in materials, imaging, and photonics, but Rochester produced the optics students.

Today, this upstate New York institution is one of five offering an undergraduate degree in optics. The recent additions are the University of Alabama at Huntsville, the University of Arizona, the Rose-Hulman Institute of Technology in Terre Haute, Ind., and the University of La Verne in La Verne, Calif. Arizona, the newest program, began last year and is expected to complement what is now the largest graduate optics school in the country with 166 students currently enrolled. The Alabama program began in 1986 and now has about 14 students. Rose-Hulman, with about 60 students, has the largest undergraduate enrollment in optics after Rochester. These newer programs are just beginning to produce their first graduates.

"As recently as five to 10 years ago," Moore notes, "Rochester was turning out all of the undergraduates with optics degrees." While many groups are accurate in labeling Rochester as America's optics hub, in terms of education, this picture is changing rapidly. Last year, 521 students were enrolled in optics courses in the five programs offering undergraduate degrees. Rochester accounted for 354 of these students, with the remainder being distributed relatively evenly between Alabama, Arizona, and Rose-Hulman. Other sources of optics specialists are engineering programs at schools like MIT, Stanford, and the University of Central Florida. Many other schools have substantial facilities for studying fields like laser energetics, precision optical engineering, or optical data processing. Taking this into consideration, Rochester's relative contribution has declined to about 60%.

What should be clear is that accomplishment in optics at the undergraduate level does not necessarily require an optics degree. As Alan Huang of AT&T Bell Labs points out, "More optical converts are coming out of 'EE' programs now." The interfacing of the two fields almost demands this.

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A 1989 survey conducted by Kenneth Cupery at the Federal Systems Division of Eastman Kodak found that 957 degrees (associate, undergraduate, and graduate) were awarded in 1989 with concentrations in various areas of optics, a 14.5% increase from 1987. Not all of these degrees had the word “optics" in their title—the survey shows a large portion of these degrees awarded through electrical engineering programs and some awarded through physics programs. The two largest single contributors to the total number of people entering the optics profession were the University of Rochester and the University of Arizona with 145 and 23 graduates, respectively.

Moore spelled out a few reasons for the increasing demand at universities for optics courses. "Students are seeing more of the excitement in optics and everybody sees optics at home in CDs and 'fiber to the home,’ ” he argues. "Optics is becoming part of the folklore. Twenty years ago, high school students were interested in astronomy and photography, but today you're beginning to see lasers in the classrooms.”

Where optics students are hired

A review of The Photonics Buyers' Guide gives a good indication of where companies are flourishing. The 1988 edition indicates that there are 349 firms in the New York metropolitan area, the largest concentration of optics companies nationally. This region is followed by Los Angeles/Anaheim, Boston, San Francisco, Chicago, Philadelphia, and Rochester.

Back in the early 1980s, Hughes Aircraft would fly some 40 Rochester seniors out to California to be interviewed and would typically hire about 10 people. These kinds of mass hirings were the result of defense spending. Hughes barely hires one B.S. graduate in optics from Rochester per year now.

Stephen Fantone, president of the Optikos Corp. in Cambridge, Mass., explains that "in the past few years, the need for large numbers of optical specialists in the military sector has diminished. Many of those hired in the early '80s are now pursuing careers in commercial industry.” As Fantone observes, "The creative engineering pro-
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cesses required for commercial product development and manufacturing are often different than those for military applications. Therefore, the transition from defense to commercial projects has not always been an easy one for these individuals."

So where are undergraduate optics students going? Everywhere. As the industry is fragmented in this country, so are the places where individuals are being hired—three people here, two people there. Nobody is doing masshirings like Hughes did. Of those receiving bachelors degrees in optics at Rochester last year, MIT's Lincoln Laboratory and ITEK each took three individuals. The year before, IBM hired three. In 1986 and 1987, the big hirers were Lockheed, General Electric, MIT, Texas Instruments, TRW, and Rockwell, each hiring two recent graduates.

Increased demand, increased salaries

With the supply of opticists going into industry remaining relatively stable and the demand for them increasing, these specialists are commanding higher salaries.

An informal Optics News inquiry of the schools that produced students with bachelors degrees in optics for 1989 showed that nearly all those looking for work in optics after graduation received job offers, with an average starting salary of $30,000. In 1987, that average salary was $27,000 and in 1986 it was $25,260. This increase of about 9% in starting salaries for optics graduates is among the highest rise for all scientific and engineering vocations. New entrants into the field at the Ph.D. level command starting salaries of $50,000 in industry, equivalent to starting salaries for chemical and electrical engineers.

Cupery's survey found that in 1988, many more than 200 jobs were available for fewer than 200 job seekers with bachelor of science degrees in optics. At the masters level, 130 people were available to fill over 150 positions. At the Ph.D. level, approximately 150 job openings were available with only 65 people to fill them.

Finding jobs for young graduates in this field has not been a problem in recent years. Clearly, the demand for optical engineers, physicists, and technicians is there and seems to be rising. Starting salaries for those who go into industry are a reflection of this. Students see the higher salaries and all the exciting, new technologies in this industry, and they want to study optics.

The industry-academia connection

Even with the addition of new optics programs, schools cannot support industries' demands for optics training. Robert Shannon, director of the Optical Sciences Center at the University of Arizona, points out that increasing numbers of optical scientists will be needed to fuel this multi-billion dollar industry that makes everything from lasers and telescope mirrors to fiber optics and compact discs. Shannon, concerned with diminishing federal support for university science, warns that "the industry has grown so quickly that the nation's two leading optical sciences schools cannot keep up with student's demand for their graduate openings, despite their own efforts to expand." Shannon looks toward industry to fill this gap, hoping to develop much stronger industrial-academic relations at Arizona.

Collaborative efforts between industry and academia are becoming paramount. James E. Pearson, general manager of United Technologies Optical Systems, sees industry's role in optics education as vital. Describing the symbiotic relation between industry and academia, Pearson said that "those in industry are more than observers, promoters, and users of optics education. They are an integral part of the definition and delivery of optics education and training." Universities, he suggests, should provide industry with graduates and technology that will enhance the production of goods and services. And industry should compensate educational institutions by providing them with funding, students, faculty, and technological advances.

Currently, according to Pearson, a much more superficial relationship between academia and industry exists. While universities continue to provide industry with graduates, the reciprocation of industry is less evident. Shannon, like many academic leaders, would welcome a larger industrial commitment toward optics. A better relationship needs to be developed between universities and small businesses, particularly in optics. Schools that offer the hands-on training need to invest substantially in the kinds of equipment currently used in industry. The problem here is that equipment becomes outdated very quickly. Many schools teach with outdated equipment. Providing state-of-the-art equipment, or the chance for students to use it, is a substantial role industry could play. Rochester, Arizo-
na, MIT, and many other schools have such agreements and they augment them with cooperative programs.

**Education vs. training**

Employers want employees who know how to use simple tools. They look for students who understand what they are being offered before they begin work, workers with a sense and an appreciation for the industry and for themselves. The complaint heard most often is that you get students right out of school who simply cannot come into industry and produce. As one optical engineer working in industry commented, “They’re useless if they don’t know what a Phillips-head screwdriver is.”

Students should not be surprised if at an interview they are straightforwardly asked if they think they can do the work, if they think they’re smart, and what they want to be doing in five or 10 years. Employers are interested in people who work on their own cars, who have industrious hobbies, or like to build things on weekends. Typically, these are individuals who know what it means to be an engineer or a scientist. A successful academic career is persuasive, but an understanding of the discipline, knowing what it means to be an optical engineer or a scientist, is more critical. Pursuing an education that fosters this sort of understanding is a valuable approach for any individual. Students who have worked in the types of industrial cooperative programs offered by schools like MIT have an enormous head start.

Fantone refers to MIT, Berkeley, Stanford, and Cal Tech as having a “critical mass,” implying that schools like these produce the kinds of individuals needed to drive an industry. They start out with some of the best students and are among the most competitive schools in the world. They balance the theoretical with some practical experience. Moreover, their students may play a much more substantial role in their own education than they are given credit for.

Fantone, who has degrees from both MIT and the University of Rochester, argues that, “undergraduates can take laser physics courses at MIT and Rochester, and the MIT course will be more rigorous. However, Rochester
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offers students a broader range of optical engineering courses.”

It is not necessarily the person who does best in school who gets hired, nor is it the person who goes to the best school or what is perceived as the best school. Rochester produces first rate optical engineers and optical physicists with its broad approach toward optics. However, AT&T’s Huang observes, and other seem to agree, that companies do not go to Rochester as much as they used to for new employees. Employers have other options, with other schools producing knowledgeable students. “We’ll typically go to Arizona or Cal Tech for people who know solid state physics or circuit design,” Huang said. Both fields are relevant to optics research and development.

A broad education may not mean as much for new entrants into industry. Those planning to enter the optics job market with a new undergraduate degree might ask themselves if they can go into a lab and build a heterodyne interferometer with some given specs if all the equipment needed is in the lab. Or manage the production and distribution of a new type of spatial light modulator. Those doing the hiring note that most recent graduates do not “make the grade” in this respect. Companies spend years getting people up to speed and this is not cost effective, particularly for small companies. The typical optics “rookie” is considered a sort of “glorified technician.”

Duncan Kennedy, a critical legal studies scholar at Harvard, once described the difference between the exceptional Class of 1983 and the “truly extraordinary” Class of 1963. He said that good instructors are abundant and they always will be, that the difference between a bright class and one that may create change and profound advancement is in the quality of students and how active they are in the learning process. Poor students hold back the educational process, good students maintain the status quo, while extraordinary students foster depth and impact their peers as well as their teachers, he explains. These kinds of students affect the process of education. No matter what the curricula, no matter who the instructors are, an institution’s strength is founded in its students’ achievements, regardless of the educational approach.

Kennedy’s thesis may best describe what Fantone means by “critical mass.” Having great students in a good program, indicates Fantone, is more crucial than having good students in a great program. Rather than expanding a theoretically based optics program or concentrating on one promising area of R&D, institutions might focus on new methods for attracting the best students, thus assuring the “critical mass” necessary for a solid optics education. Fantone believes that increasing competition for available optics positions at schools that offer good programs may accomplish this.