

Correlating the Curriculum to Industry's Needs

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APPLIED OPTICS AS A FIELD

The subject of applied optics encompasses several topics that are of varying levels of interest to each worker in the field. There is the traditional field of optics that includes geometrical and physical optics as the basis for applications that have found wide use in industry. Although the techniques and methods applied to solving problems are quite up to date, this aspect of optics is often referred to as "Classical Optics". Modern optics implies the addition of topics based on lasers, fibers and other electro-optical devices that have entered the field in the past two or three decades.

Optical physics is a step away from application, in that the properties of materials and the interaction of light with materials is of basic importance. Finally, engineering optics implies the comprehensive application of these principles to applications in industry.

INDUSTRIAL TRADITION FOR OPTICS

Within industry, several aspects of the application of optics need to be considered. Within the basic industry that produces optical components and devices, optics can be considered a principal activity. The structure of the company, and the expectations of the company in establishing a work pattern follows a well defined path, in which design, engineering and production are usually well understood.

In most parts of industry, the principal product is only partially optical. Optics is therefore considered a supporting activity. Optical principles are a means to an end in measurement or control in the production of an end item. In these cases, even in the largest of companies, the role of the optical engineer is not usually well structured. The evaluation of the individual as well as the ability to evaluate and participate in the development of academic ventures in the training of optical specialists is limited to a small portion of the management or engineering staffs of such companies.

The anticipated interaction of industry and academic departments is thus different with the various components of the general optical industry. The dependence and expectation of the various industrial organizations covers a very wide spectrum. However, the relative shortage of capable, trained applied-optics specialists has led to an industrial tradition of considerable inhouse training in the field of optics, with greatly varying degrees of success.

DETERMINING DIMENSIONS OF THE NEED

Surveys and scuttlebutt indicate that there is a significant backlog of need for a large number of trained optical graduates, especially at the BS level. Determination of the extent of this need, and the correlation of the need to the academic curriculum poses some difficulties. Estimates of current needs change in detail almost daily, but need to be identified, and a projection to future needs must be obtained. Since an academic curriculum is not established or terminated with the rapidity of an industrial project, this becomes an important planning activity.

While, as seen below, there are certainly parts of any applied optics program that can be considered basic elements, the extent and direction of the program vary with the intended consumer of the exiting students. For example, the needs of the optical shop are different than the needs of an aerospace company that deals with the application of optics to a wide range of products. Although the need for a product-oriented technically based company varies only mildly from that of a traditional optical company, the needs of a technical study organization differ greatly in the emphasis placed on analytic versus experimental skills. Finally the high (or low) technology manufacturing industry will place yet another set of requirements on the curriculum, as there is a premium on cost-effective engineering solutions that can be implemented with a minimum of additional capital investment.

UNDERSTANDING DIMENSIONS OF THE UNIVERSITY NEED

There are aspects of developing a curriculum that must be understood prior to the initiation of a specialized course structure in applied optics. It is not likely that most of those engineers and managers who have spent the majority of their professional life in industry will appreciate the realities of many of the academic problems. Therefore some missed communication results, and there is frustration engendered from the apparent failure of academics to respond to industrial needs in a timely manner. Some of these academic needs are real, some are merely illusory, but all have to be addressed.

First, there are academic traditions. Some of these may be archaic, but have been the result of decades of experience. None of these change easily. An obvious example is the timing of programs, with an academic year as the basic unit, and four years as the time to acquire a BS degree. Any specialized degree also requires prerequisites, which have been developed for other programs as well, and may not be completely appropriate for a degree in applied optics.

There are reasonably well-defined academic fields, such as physics, chemistry, English and so on that are established components of an education. A new program or curriculum will of necessity infringe in some manner on some or all of these traditional fields. Resistance to change can be expected in this regard. Many traditional academic subjects also bring a certain amount of centrist thought, better identified as arrogance. In the mind of a physicist, for example, Applied Optics is an outgrowth of the total field of physics, and does not receive recognition as an independent entity. It is probably not necessary to expand on this point, but it is very real.

Finally there is a very subtle point regarding applied specialties that are seeking recognition as a formal engineering discipline. There are well-established accreditation programs for the "traditional" engineering fields that are represented in engineering schools. Outside committees that are made up of traditional engineers review the programs and do not, in general, look kindly toward the substitution of new topics for their established war horses. Optical engineering is not yet recognized as a branch of "legitimate" engineering, and suffers from this effect. While those of us who work in the field understand what the difference between good optical engineering and incompetent hack work may be, it is essential that the engineering world at large understand this concept.

COMPETITION WITH EXISTING NEEDS

Any new program in applied optics will of necessity compete with other university needs. Difficult and somewhat subjective judgements may well be significant in deciding whether to offer a program in applied optics or, say, polymer science. Existing science and engineering programs will be very vigorous in expanding their own areas of interest rather than striking into new areas of technology. In many cases it will be said that the provision of students taught the basics of science is sufficient, and that those desiring specific training should look to industry for on-the-job training. The university would then continue to plow a traditional course in the curriculum and avoid deviations into new areas.

SOURCES OF SUPPORT

University or institutional funding of the salaries and operational costs for an applied optics program is very important. It is only through an institutional commitment that the continued health of the program can be assured. The failure of the institution to back a program indicates that the program will be among the first to disappear should financial problems occur. However, basic institutional funding is usually squeezed to meet the needs of existing programs, and is not usually likely to provide an easy avenue for program expansion.

Public universities, because of their access to legislative funds, are the most likely to be able to initiate new programs. However this is not assured, as the political realities of obtaining state funds for new programs usually depend on a demonstration of reasonably short term economic gain for the state. History does indicate that once funding is obtained, consistency over a number of years is likely.

Federal funding would seem to be a reasonable avenue. However (again!) this is not likely to be a long-term solution. There is heavy competition for such funds, and no high priority for funding established technology. No confirmed program exists to meet the need for optical training, although it is conceded by several agencies that there is a need. Even if support is provided, the annual congressional hysteria about renewal of such programs will not lead to the necessary program stability. It is unfortunate that there is no federal job category entitled "Optical Engineer" or "Optical Engineering Specialist". This lack of job category definition diffuses the federal interest in funding programs in this area.

While the above sources of funds will be important, and will continue to be the mainstay of most of the funding supporting applied optics programs, the attention of industry will remain as the difference between success or failure of programs designed to meet the needs of a strong industrial base in optics. Industry will have to be the primary source of the capital funds for equipping student laboratories. This may be accomplished either through donations of money or up to date (not antique) surplus equipment. While University funds will probably cover the cost of building laboratories, industry must support the equipping and updating of these laboratories.

While industrial funds will continue to support a number of student fellowships and some portion of department operational funds, history indicates that industrial support of faculty salaries will not be likely or dependable. The reasons arise from the need to find a dependable budget line for salaries, plus the reluctance of industry to make long-term commitments. Some fluctuations in the operational costs can be absorbed, but salaries cannot be placed in jeopardy as various industrial sponsors change their direction of academic support.

ACADEMIC VIEW OF INDUSTRY

The understanding of industry by academics is spotty. Many faculty members have transited directly from a graduate school into their teaching positions, a minority have obtained significant industrial experience. Therefore a lack of comprehension of the goals of industry can be expected.

Under these conditions it is not surprising that many academics will consider any direction of education by industry to be a threat to scholarship and academic creativity (in the name of academic freedom...usually!). It is widely felt that industrial engineers and scientists lack experience in the methods and approach to educations. This is, of course, balanced by the desire that their students succeed in their eventual industrial jobs, and by some visions of industry brought about by participation in consulting to industry.

Industry today, in the United States at least, places major emphasis on the need to meet short term requirements in both technical and financial areas. This is perceived by academics as a threat to the long term investment of resources necessary to develop a successful curriculum. This perception is correct. It is the responsibility of academic leaders to mediate and balance this relationship.

There is another barrier to effective cooperation between academics and industrial engineers in setting up a new program. This is the well known, and largely real, effect of academic arrogance. The possession of an "earned PhD" is the academic union card. Along with this comes some degree of implied superiority of position over the "working troops" of industry. Social strata are a reality of society, and will not likely vanish overnight. Both sides of the equation have to be balanced and understood in order to achieve true cooperation. The major responsibility of carrying this through falls with the academics, who need to realize that their future depends upon the continued health of the economy and industry that produces real goods.

INDUSTRY VIEW OF ACADEMICS

The industry view of education and academics is inevitably weighted by the views and attitudes obtained while the industrial scientist, engineer or manager was obtaining his (or her) own education. It is probably a fine nostalgic feeling to view the academic process as unchanged from the time of obtaining one's own degree, but the reality is that the world has changed. The economic and social forces facing academic departments have changed, and the obligation of those departments to produce graduates that will strengthen a particular industry has markedly changed. In this respect, the average industrial engineer is not fully in touch with the realities of today's academic needs.

A strength of this position is that the industrial engineer has developed a strong view of what is required to carry out his job. Conveying this to the academic can greatly enhance the ability of the academic to be responsive. The difficulty is that each industrial engineer has a slightly different perception of the needs of industry. Thus, a cross section must be developed of these needs and requirements. The result is that no program will ever be completely satisfactory to all industrial engineers who will benefit from hiring the graduates. The result is the need to recognize and respect the balance of basic and directed education that is required.

Another problem with some industrial engineers and managers is the view of the university as a hiring hall. One relatively large optical company (left nameless here) once approached us after a three year absence from recruiting with a statement "we have three lens design openings that just were approved, and we want to come out Tuesday and fill them." The company recruiters came, interviewed students, made offers, and were rejected by the students. I, personally, received much criticism from that company about our failure to meet their instant need. Obviously, their criticism is unjustified, but the existence of the attitude is real.

Other misconceptions arise in the view that summers are a guaranteed time off for faculty. This attitude on the part of industry is a nostalgic hangover from the distant days of the industrial engineer's own education. In today's competitive research environment, the faculty job is a full-year job. The fact that academics are the predominant attenders of professional meetings and seminars is not a result of their having nothing to do, but is a reflection of a professional lifestyle that differs from that of the industrial engineer. It should be obvious that greater participation in professional society activities by the industrial engineer would expand his capabilities, and most likely enhance the capabilities of his company.

A contradictory and difficult problem in the view of industrial engineers and managers is that academic institutions are possible competitors for research funds with industry. The contemporary approach to much government funding does encourage this speculation. Unfortunately much applied research falls into the development rather than the basic research guideline and indeed this competition does occur. The basic research, as supported by NSF and AFOSR does fall into a category in which Universities are preferentially supported, but much pertinent work that could be used in supporting applied optics MS or PhD students does not.

BASIC NEEDS IN OPTICS TRAINING

ACADEMIC FUNDAMENTALS

Any graduate can be expected to have mastered a certain number of academic skills. The number of these depends, of course, on the level of the degree. I will discuss the minimum and optimum expectations for a BS level graduate with a degree in Optics or Optical Engineering. Associate degree holders can be expected to be far less complete in the support requirements, such as mathematics, social sciences and language skills. Graduate degree holders can be expected to be more proficient in the speciality. Over the years the BS graduate has been considered to be a well educated person, with a sufficiently broad level of knowledge to be of direct use to a prospective employer, and with sufficient breadth to be able to grow in the field.

The ability to write and communicate on a satisfactory level seems to have become the responsibility of the Universities. The ability to critically examine one's own writing (in English) and to understand the subtleties of written communication is presumed to be required. Sufficient background to examine social and historical issues with some perspective is also assumed to be required at the BS level.

Scientific and technical skills encompassing a year of chemistry, two years of physics and mathematics through differential equations, numerical analysis and Fourier analysis is also presumed to be required. Needless to say, the ability to comprehend the use of computers is essential.

The difference between the specializations then begins to be evident in technical skills that are required. For an optical engineer, courses in engineering design, materials, mechanics and basic circuit theory and practice are appropriate and necessary to the background of the student. These courses also provide the knowledge necessary to communicate with other engineering specializations.

The courses that differentiate the Optical Engineering student from the other engineering categories include extensive courses in Geometrical and Physical Optics, laboratory practice in these subjects, as well as optical measurements and testing, radiometry and imaging. Specific courses in engineering of optical systems, including the optomechanical parts of the subject are important to the eventual industrial employer. It is obvious that these skills will also be of importance to those BS degree holders who eventually proceed to graduate education.

Other courses would be appropriate in technically related subjects. I do not believe that one can "teach management" at the BS level. But a course involving some business practices, cost accounting and professional ethics would be appropriate, if it can be fitted into the curriculum. Another neglected area is the realistic one of languages. The world of U.S. industry would be quite different if a reasonable proportion of the working engineers had a working knowledge of Japanese, for example.

SPECIFIC NEEDS IN OPTICAL TRAINING

The training at both the graduate and undergraduate levels in optical engineering would rapidly go out of date if the curriculum did not cover the current developments in the field. For example, the use of visible diode lasers will be an essential part of the teaching program, although these sources have only barely appeared on the market in 1988. The faculty involved in teaching these courses will have to be always revising the curriculum to keep up with this fast-moving field.

Blending this rapid change of electro-optical technology with traditional engineering is important. The problems of aligning, mounting and testing optical components remain as technology advances. A curriculum responsive to the needs of industry must have this content. In the advanced optical engineering courses, integration of a variety of optical, mechanical and electronic components must be studied.

FINDING INDUSTRY'S NEEDS

While the above comments are respond to the basics, and the need for a comprehensive education for the students, tapering the curriculum to any specific needs of industry requires the obtaining of information about these needs. The usual exhortation is "just ask". The actual problem of obtaining information is quite a bit deeper.

Surveys could be used, but generally are not adequately responded to by industry. Even when a good return is obtained, the credentials of the respondents within a company may not be defined, and the response can lack credibility.

Visiting committees from industry also sound good, but they only meet occasionally. Often the inputs can be the reflection of an individual point of view rather than a reflection of a balanced industrial point of view. Discussions with corporate affiliates can also be useful, and perhaps have more tangibility to the program, as the industry has a financial stake in the outcome.

The credibility of such inputs does get a bit frayed by some experiences. For example, we invested in establishing national video courses leading to an National Technological University degree with all course work being essentially identical to our MS degree. This was done at the urging of several of our affiliates, especially by one very vociferous company. Several companies have taken advantage of this, but the loudest company has not supplied any students as yet.

The best, and most time-consuming, approach is direct visits to industry. A wider variety of responses can be obtained and coordinated with the history of employment by each company in the industry. When this input is coordinated with the other companies, and with the general faculty awareness obtained from consulting contacts, a useful picture will begin to emerge. Such contacts are time consuming and expensive, however, and cannot be repeatedly carried out.

MATCHING TO FACULTY CAPABILITIES AND INTERESTS

No course or curriculum is useful if it does not reasonably match the abilities and interests of the faculty involved in carrying out the curriculum. Sometimes this can be affected by acquiring new faculty. Most times economics plus other factors require that existing faculty adapt to changes in the curriculum. Several factors are operative here in making the curriculum follow at least some of the needs of industry.

Credibility of the faculty member with the student depends on the background and interests of the teacher. Success in the course is very dependent upon the interest of the teacher in the material he has to cover in the course. A match in this regard is important. If faculty are not interested in developing curriculum material that is responsive to industrial needs, and the faculty member's training does not parallel these needs, the resulting curriculum will not cover the desired material. Finally, of course, not all faculty are qualified by experience or inclination to teach all courses.

MATCHING TO STUDENTS INTERESTS

No curriculum is of value unless an adequate number of the right students take the courses. Therefore the content of the curriculum must also appeal to the interests of the prospective student. The apparent "sex appeal" of the subject is important. This is influenced by the nature of the work done in optics, the ability to prosper professionally and economically, and the probable expectations in stability of future employment in the field.

Once in the program, the student's basic technical curiosity and interests must be met. This is accomplished by faculty responsivity to current topics in the field, as well as creative and competent teaching. Obviously the quality and interest of the faculty is a major component.

Research appropriate to applied optics degrees is a problem. There are many research problems that are of interest. However, finding support from federal sources for these topics is likely to be very difficult. Joint programs with industry are beneficial, and provide priority in the students attitude regarding possible future employment by the supporting company.

REVIEWING THE PROGRAM

No curriculum is static, but must develop with time. Furthermore, the content of the curriculum must provide the training that is expected by the students, the faculty and the eventual employer. Thus a method of reviewing the curriculum on a regular basis is important.

In any competent academic department there is always a faculty committee reviewing the curriculum on a regular basis. This provides most of the development of new ideas in courses, and should be relied on as the mainstay of the curriculum.

A broader review can be obtained by an occasional external review. In the engineering profession there is an established ABET committee review in order to bestow accreditation upon the program. Such a review is really a check-list of competence, and does not directly develop an innovative program. In fact, too much innovation can place the accreditation of a program in some jeopardy. There is as yet no established procedure for accreditation of a program in Optical Engineering. Perhaps there will be in the future.

PAYING FOR IT

It is true that economic balance is a fundamental to industrial survival. It is no less true for an academic endeavor. There are several basic costs involved in running an academic department. Salaries are, of course, the largest single component. Academic salaries have, of necessity, reached about 80% of the equivalent industrial salary level.

Additionally, overhead and operation costs must be applied. Fortunately these are usually lower than an industrial average, being of the order of 50%. However, faculty in academic institutions have achieved tenure, which greatly reduces flexibility in responding to changes in economic fortunes. Since a teaching program must be permanent in form, this is appropriate, but does mandate that economic stability is very important.

The training of a BS level graduate costs from \$50,000 to \$100,000. A graduate student will cost up to twice or even three times as much, if experimental laboratory costs are included. Since a graduate student is by nature a part-time employee, the apparent benefit of lower stipends or salaries is not as great as might be expected on an industrial basis. Thus a major investment in training has been made prior to a graduate entering an industrial position. The resource to continue this must be found, and the availability of resources will affect the nature of the curriculum that can be developed.

Universities must remain solvent, just as much as industries need to maintain a competitive position. The options available to academic departments are not as broad as those available to industry, and the limits within which the department chairman can maneuver are seriously limited by such concepts as tenure. Income is desirable, and faculty are judged partly on their ability to obtain research funding. There is an obvious competition between research interests and teaching interests. The university is no longer the "Ivory Tower" envisioned by many industrial engineers and managers.

Nevertheless, there are obligations that must be met. The University has an obligation to provide a quality education. The faculty has an obligation to provide the most enthusiastic teaching of students possible. Students have the obligation to work

hard and excel in their course of study. The graduate has an obligation to lobby sources of funding and support to continue the academic base upon which his, or her, own career is built.

All parties, including the government and the potential employer share the responsibility of paying for the quality education needed for the development of a strong technical base. The depth and the limit of these responsibilities needs to be seriously examined in the next few years, with the goal of enhancing the stability of the U.S. technical resource and the U.S. industrial establishment.

SUMMARY

There is a live and growing need for optically trained personnel. The greatest unfilled need is in the engineering or applied optical area. It is possible for the academic world to respond to this need, but the assistance of industry is required.

There are problems in funding and continuity that must be addressed, in addition to developing an appropriate description of the curriculum to be followed. A partnership between industry and the academic world needs to be built on a continuing basis. The need can be expressed by the professional societies and individual engineers, but the creation of a continuing program must be sold to the academic administrative establishment. Once a program is initiated, continuity is relatively easy to maintain, as long as a demonstrated need for the students exists.

RECOMMENDATIONS

In order to move forward in the training of competent engineers a realistic partnership of industry and academics is required. Each side needs to be able to treat the other as an available resource that can be counted on to be available on a long term basis.

Optical engineering itself must be recognized as a field with reasonable qualifications and degree requirements. The pursuance of degree programs of marginal merit as a byproduct of other degree programs needs to be discouraged by industry, and the pursuance of excellence endorsed. A basic curriculum needs to be devised and developed through experience that reflects the reality of working in the field. A tradition of support of optical programs by industry does exist, but needs to be strengthened.

Finally, a common goal of the development of a self-sufficient U. S. Optical industry, with a goal of greater commercial and practical product development is required. It is not difficult to achieve leadership if a quality education for those entering the field is provided.