Academic Program Review
University of New Mexico
Optical Science and Engineering Program

Report of Review Team
An Academic Program Review (APR) visit for the Optical Science and Engineering Program (OSE) was held on Oct. 28 and 29, 2021. The meetings were held in person.
The review team consisted of:

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1. INTRODUCTION AND BACKGROUND:

All three members of this review team were already quite familiar with many aspects of optics/photonics science and technology. Additionally, the external members of the team are currently at universities that chose to form colleges in this 'field', which is considered as interdisciplinary at UNM. One of the reviewers served as the founding dean of one of these colleges. Both external members also came into this with rather extensive knowledge of the UNM OSE program (one served on the previous APR team), its faculty, its reputation, several of its graduates, as well as the research performed by its faculty. The program strongly supports research activities that structurally overlap with the Department of Physics and Astronomy, the Department of Electrical and Computer Engineering, and the Center for High Technology Materials. The program is recognized for its national and international visibility and reputation. Some of the faculty research activities also embrace the current efforts at UNM's Comprehensive Cancer Center, reflecting its broad impact on UNM's research franchise. However, the review material provided to us in preparation for this review brought into focus how the program has developed over the past many years, how its organization affects its progress, what changes in personnel have occurred and how this has/is changing the execution of the OSE program goals, how the leadership of the program has shifted to more junior members, what challenges exist, what monetary constraints exist along with much more. These findings have focused our team's energies towards what we think are the major issues moving forward. This has resulted in the present APR review team spending the majority of its effort on the primary issue holding the OSE program from expanding its achievements: i.e., its administrative organization as well as its budgetary constraints. However, we will first go through the set of "Criteria" as outlined in the package we received from the UNM administration for the APR reviews after which we will get back to the main issue toward the end of this writeup. Thus, this writeup follows rather closely the set of viewgraphs we provided to the administration at the Exit meeting on October 29, 2021.

Overall program strengths:

We will elaborate on the following:

- Faculty
- Funding
- Interdisciplinarity
- Longevity of Program
- CHTM and facilities and new PAIS space (e.g., state-of-the-art labs, excellent graduate student training lab, and user facilities)
- Local environment of government labs (i.e., Sandia National Laboratories, Los Alamos National Laboratory, and Air Force Research Laboratory).
- National/international visibility – While this program is nationally and internationally visible to many, it could greatly expand its visibility in various ways we will recommend later.
- Importance of optics as an enabling technology for 'anything' (e.g., iPhone, fiber optics/internet, astronomy, microscopy, spectroscopy, chemistry, biology, etc., etc.)!

In elaboration of the importance of optics as an enabling technology, we think it is worthwhile to give a single simple example of the pervasiveness of optics/photonics in everyday life: e.g., the i-Phone. A quick look shows multiple remarkably thin cameras (front and back) with amazingly good quality photos and movies, and a beautiful, illuminated viewing screen (of multiple technologies, including liquid crystals, organic light emitting diodes (OLEDs), quantum dots, micro-LEDs). Also, whenever a phone call is made or accepted, we all know that the information

is transmitted using optical fibers (of many varieties). This is also true of the information relayed from billions of computers around the world using the world-wide web, WWW (for good and for bad). What is often not recognized is that the internal electronics of the iPhone, computers, information storage/retrieval systems, etc., require highly sophisticated optics to produce the integrated chips. Advances in optical lithography enabled all of these and was the single foundational technology that drove most of the technological advances of the 20th century. And UNM/CHTM/OSE had a role in this advancement (e.g., still collecting royalties). The i-Phones of the future will surely have more lasers/optics internally: e.g., face recognition, image projection, or internal communication, which has already been required in the huge data centers around the world. For other examples, just think about the things you see and do every day from the grocery store to the 'electronic' (often optoelectronic) products you buy, to the lighting in your house, ubiquitous displays (on TVs, buildings, billboards,…), DVDs, laser pointers, health care, tattoo removal, surgery, cancer therapy, endoscopic imaging, eye imaging/coherence tomography, infrared cameras, temperature sensors, blood sensors (e.g., oximeter), remote sensing, TV remote, fiber sensors in bridges, etc. One can identify many others.

These applications fit into nearly all aspects of the modern-world life and clearly into every traditional scientific, technological, academic, as well as industrial field. The interdisciplinary nature of the technologies involved allows faculty members from many different departments to participate. Thus, participation in OSE also can result in cross-disciplinary partnerships which can drive advancements, result in new research funding, technological breakthroughs, and economic development (i.e., start-up companies, creation of high-paying jobs, and advancement/entrepreneurship/jobs). With the latest effort from the Anderson School of Management to create a MS/PhD degree program in Entrepreneurship and Technology Management, the OSE program can strongly contribute towards this effort.

Findings on Strengths: Overall, the program is doing quite well, but it has much greater potential.

Our review team spent most of our time discussing operations, since we all have significant knowledge about the quality of faculty and students and their scholarship at UNM. We see that they do a comparable level of teaching/research as at our institutions with similar results in terms of quality of technical publications, external visibility, *h*-factors/citations, etc. The faculty members are engaged, they are recruiting and graduating good students, they have an excellent reputation, they are bringing in sufficient funding for their research, they are performing and publishing good works, they have sustained this good production of graduates over a long period spanning many new chairs/deans/provosts.

Findings on Shortcomings: They have done all of the above while operating under a quite problematic organizational structure: i.e., governing/reporting structure and financing structure.

2. TEACHING AND LEARNING CURRICULUM:

Findings on Strengths and Shortcomings: the curriculum is currently good with the tracks specified; however, as suggested by a couple of faculty members, it may be useful to review these tracks to make sure they cover the needs of the diverse faculty research areas. This may include adding ***more flexibility***, having a rather small set of core courses with lots of

electives with individual tailoring of a student's set of courses with oversight by the dissertation committee with strong input from the advisor.

3. TEACHING AND LEARNING ASSESSMENT:

Findings on Strengths: The set of exams appears adequate and is similar to other academic programs (e.g., CREOL, The College of Optics and Photonics at the University of Central Florida, and the College of Optical Sciences at the University of Arizona, Tucson). We find that these are periodically reviewed and altered at many institutions including ours, in attempts to make them more useful as a gauge for evaluating the progress of students and as a means of identifying deficiencies in the students' knowledge base. Nobody has found the perfect solution.

4. GRADUATE STUDENTS:

Findings on Strengths: The program has a record of recruiting good/excellent students, and the graduate job placement is outstanding.

About retention rate – The total number of students admitted is different from the total number of students who accepted the offer and enrolled. The retention rate is higher than indicated in the self-study report, and it is healthy. Assuming the time to graduation to be 4 to 5 years, the number of newly enrolled students and the number of degrees awarded each year seems to indicate that there is no issue. Unless individual students are closely tracked from enrollment to graduation, the exact retention rate would be difficult to calculate. However, the data provided after the review visit support that the retention rate is quite high. If there is a point to raise, each year from 2013 to 2019, more students graduated with their degree than the number of newly enrolled students. This data rather points to a possibility that the total enrollment prior to 2013 might have been slightly higher than post-2013.

Findings on Shortcomings: Our team has worries about having adequate funding to support recruiting of the necessary number of good students to serve all the research needs of the faculty. It is essential that, at the time of admission, a student is offered some form of financial support (i.e., teaching assistantship and research assistantship) for at least the first year of his/her graduate studies, to entice the student to seriously consider accepting the offer. Other programs across the country that compete with the UNM for the best student recruits typically have the resources and provide this commitment, which plays a pivotal role in the student's final decision as to which program he/she will join. As an example, the College of Optical Sciences of the University of Arizona offers a full scholarship to each and every student admitted to their PhD program (typically around 30 students per year) that covers the student's tuition, medical insurance, registration fees, and a monthly stipend for the entire first year of their enrollment at the University of Arizona. In addition, at least a dozen teaching assistantships are readily available to graduate students in their subsequent years at the College of Optical Sciences in case the student fails to secure a research assistantship funded by their PhD supervisor, or if there appear unexpected gaps in the funding of their chosen research project. The College of Optics and Photonics at the University of Central Florida gives a similar commitment to their incoming graduate students (not master only).

There was previously a more decentralized graduate admissions process, which we were told worked well in the past giving the program early access to the applicants and allowing agile sharing of applications among OSE, Physics and Astronomy, and Electrical and Computer Engineering. The new centralized system has not allowed this early access or application sharing: e.g., because of incomplete applications. This impedes the program's ability to reach out at an early stage and encourage the applicants. This may be resulting in the loss of good graduate students. So, can the OSE graduate committee/Doris Williams have access to all applications (including incomplete applications) early on during the application process? Also, could the applications be sent to both physics and OSE or to both ECE and OSE? The respective admission committees could then better work together on making decisions earlier in the cycle.

5. FACULTY:

As previously described, we consider the OSE faculty members to be generally of high quality doing the things that high-quality faculty need to do in terms of teaching, research, and service. In fact, it is remarkable how successful their research as well as academic programs have been, given their limited available resources and in the face of unnecessarily restrictive and time-consuming bureaucratic hurdles.

It was unfortunate that all three reviewers did not get more chances to visit individually with more OSE faculty from the several departments – two days simply was not enough for that to occur. We are convinced that several of the OSA faculty are strongly committed to the OSE program, but the level of commitment from others we did not get to meet with was not entirely clear. For the program to advance, this commitment will be necessary. In some sense, we feel that this is a chicken and egg issue. This program has been in existence for a long time, and it has continued this way successfully with what we think are multiple problematic procedures. We all agree that a strong show of support from the administration would incentivize the OSE faculty to do more and take on more ownership of the OSE program. We want to suggest, as an example, increasing social events for students and also for faculty – some combined, some not. It only takes a few people to get these going. It would build cohesiveness between the faculties of the several departments, and it would probably spur more collaborative research programs as well.

6. RESEARCH, SCHOLARSHIP AND SERVICE:

Findings on Strengths: Excellent research is being performed with publications following in highly respected international journals: i.e., excellent record of scholarship.

Findings on Shortcomings: There are a variety of ways to increase the visibility of the OSE program in addition to the suggested re-branding. For example, acknowledging departmental, programmatic, and center affiliations on all publications would strengthen its visibility and improve academic citizenship. This is important for the departments which get ranked, e.g., by *U.S. News & World Reports*. OSE faculty could also list all these affiliations when giving conference talks, colloquia, etc. There is plenty of credit to be given, and everyone should share.

Service: Faculty members serve on various departmental/academic committees; they participate in professional societies, serve on program committees of domestic as well as international conferences, and act as conference chairs, journal referees, etc.

We should note that the OSE program has lost several senior faculty members in recent years while hiring primarily junior faculty members. Thus, they have lost professional society Fellows and renowned leaders in their fields. Future hires should not only focus on junior faculty but also on restoring the senior ranks.

7. PEER COMPARISON:

Findings on Strengths and Shortcomings: This program is much smaller than at Arizona and Florida in terms of number of graduate students, number of faculty, number of administrative staff, and annual budget. Nevertheless, excellent graduates and numerous high-quality research results, presented at conferences and published in reputable technical journals, are produced despite limited resources. For example, the OSE program has a single paid administrative staff person. In contrast, the program at Arizona is estimated to have as many as five or six persons (normalized to account for the difference in the number of enrolled students in these two programs) serving in similar roles and fulfilling similar needs.

The OSE program has great potential to grow.

Here, we attempt to give some information regarding the size of the administrative staff and a budget comparison for running the academic program.

Below, is information from the business manager of the College of Optical Sciences at the University of Arizona.

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COS Average Research and Admin Metrics:

- Average new annual research awards: $22,000,000
- Funding Mix: 60% Research (Including Financial & Administrative), 20% Tuition, 20% State of Arizona
- Faculty to staff ratio by dollars: 3:1. (This is the ratio of paid salaries – including benefits -- by the College to the faculty versus the staff. It does not include the salaries paid directly by the faculty to themselves, or to their RAs and post-docs.)
- Financial & Administrative (F&A) Rates On Campus 53.5% Federal; 62.5% Private (UA Public Domain)
- F&A Return to College 88% of annual differential (12% to VPR/ 88% to the College)
- Faculty & Scientist Head Count: T/TE Faculty: 35; Research Scientists; 23; Other 3 (Total = 61)

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The operating budget along with other pertinent information on the optical science and engineering program for the College of Optical Sciences is included as an appendix.

We can also look at some of the budgetary expenditures for CREOL, The College of Optics and Photonics. Dividing the CREOL budget is a bit problematic since, in addition to the graduate program, there is an undergraduate program, and CREOL also handles its own

research budget; however, the business manager for the college (his salary not included in the following) gave us the following numbers normalized by the ratio of graduate students, i.e., using 15 new students for the 1st year.

First year fellowships (TAs+RAs) – $30kx15 = $450k

Academic Staff for Grad program - (2 Grad + partial other + benefits) =$150K

Recruiting - ~$7K

This does not include $8k x15 = $120k tuition. We are not sure if this gets charged by UNM for its graduate students. This also does not include any capital equipment upgrades to teaching labs or general maintenance. We also note that CREOL charges 52% overhead on contracts and grants and gets ~34% of that returned.

8. RESOURCES AND PLANNING:

Some of this information has been given in the preceding section on peer comparisons.

Findings on Strengths: Re-branding of the OSE program by creating a new entity/name is a great idea, but the exact path may need work. The proposed IPaQT, is an example of how to re-brand as well as how to reorganize. Currently, the "program" moniker just doesn't give enough credit/attention to what is going on at UNM in optics/photonics, and also misses the more modern name "photonics".

Facilities (see next section) have greatly expanded with the completion of the PAIS building. The state-of-the-art graduate training laboratory in that building could also be used to initiate a certificate program (targeting national labs and industry as well as local colleges and even high school teachers) to generate an additional revenue stream. Perhaps senior faculty could lead this effort as a summer program. However, being mindful of young faculty's workload, some form of extra credit might be adopted: e.g., swap teaching load for contributions to a summer certificate course, outreach activities, organizing in-house symposia, seeking collaborations with the local government labs, etc.

Continue using differential tuition to generate more TAs/RAs.

Findings on Shortcomings: Even though there has been a recurring budget added for the OSE program during the last decade, this is currently an inadequate level of State funding to cover the costs of administering the program and supporting graduate students on TAs/RAs as well as covering the cost of materials and supplies for teaching laboratories. A direct funding structure (e.g., directly from the Provost's office contributing towards program funding) with well-defined allocations (e.g., TA/RAs, staff, material and supplies, etc.) would be a welcome change that would relieve some of the debilitating pressures on the faculty, staff, and administrators.

We show a summary budget below to illustrate its inadequacy.

BUDGET FY 2022:

TOTAL Operation Revenue $9,200.00
Labor Revenue Subtotal $56,323
$55,161 Labor Revenue – $54,818 Labor Expenditures = 343.00 Salary Surplus
III. Tuition Differential Index 241005
TOTAL $89,500.00

Differential Expenditures
B. Revenue
$124,727.00 Tuition Differential Total for FY22
$89,500 Tuition Differential Expenditure FY 22
$35,227.00 Reserve and Carry Forward

Carry Forward is committed for the Fall 2023 OSE Seminar, Travel, Open House, and other programmatic initiatives.

The budgets for optics/photonics programs at Arizona and Florida are several times larger. See Peer Comparisons above and appendix.

9. FACILITIES:

Findings on Strengths: With the completion of the PAIS building, much needed (and long awaited) access to excellent research and training space is now available. This building (and installed equipment) along with CHTM and its facilities are outstanding and can greatly help student/faculty recruiting as well as enhancing research and teaching activities.

STRATEGIC PLANNING:

Findings on Strengths and Shortcomings: The Self-Study Report outlined a proposed restructuring under the IPaQT umbrella organization (or perhaps *Institute of Optics and Photonics*). We think this merits consideration with multiple possible changes/additions. However, we strongly agree that a reorganization of the administrative structure is required to simplify the governing structure. Specifically, have a single layer of reporting (e.g., Provost's office, Associate Provost of Student Affairs, Graduate Studies, University College, or another that the university administration feels would allow OSE to best flourish).
THIS IS A VERY BIG DEAL FOR THE CONTINUING FUTURE SUCCESS OF THIS PROGRAM.

Further Discussion and Recommendations/Conclusions:

"The OSE program was informed on April 16, 2021 that the School of Engineering (SOE) cannot support the program with its normal allocation for FY22." This is a quote from the self-study report, and it is indicative of the problems with the current administrative structure.

The university must decide if the OSE program merits growth or a continuation of its current status as a "grass roots" program. Without a major change in structure, it cannot properly compete with other established optics programs in the US. Currently, the program has very little budget, little control over future Optics hires for its program, and relies on the good will and dedication of a few scientists and engineers. The administrative structure is the biggest challenge, requiring these few dedicated individuals to go begging for nearly every needed resource with the requirement to continually reeducate new academic administrators every time there is a change – and there are a LOT of administrators! This really is not sustainable.

The program needs a high-level champion!

We would argue that UNM has a unique advantage given its local environment of national labs along with the diversity of its local student base. Great advantage in recruiting could be obtained

with the right strategy and organization. The College of Optical Sciences at the University of Arizona (Tucson) began as a government-funded program to educate the armed services in optics. This need has grown since that time, and the Southwest is a/the center of that activity. **However, the view from outside UNM is of a university that views optics as a sideline effort with token support for those interested faculty**. There appears to be no organized effort to, e.g., bring in heavy hitters in the field to boost the program (note that Carlton Caves and Steve Brueck are both emeritus, JC Diels is close to retirement, and the School of Engineering has lost optics faculty and not replaced them – for the obvious reason that these engineering departments are not the beneficiaries of such hires – they go to work at CTHM which gets much of their overhead, and given the geographical separation, they are out-of-sight and out-of-mind. Physics & Astronomy seems to be doing better, but this may be due to the combination of proximity within CHTM, the local push by 'optics' faculty, and the current administrator's experiences.

The OSE self-study proposes an institute;

". . . we propose to establish an interdisciplinary educational "Institute" that aims at bringing OSE degree programs, ECE's OE concentration, and P&A's Bachelors of Science degree with Photonics concentration, as well as the Biophotonics program (in Physics) under a single, visible and prominent umbrella with a distinctive name, the Institute for Photonics and Quantum Technologies (IPaQT)."

Our team appreciates the current difficulties and the need for reorganization including well-defined budget lines and a single, direct, high-level reporting structure.

However, we are not sure that just granting the rather minimal requests outlined in the self-study and strategic plan (as necessary as they are) will be enough to greatly advance the robustness and national competitiveness of the OSE program: i.e., minimal budget, and still no real control over academic hires and their careers, and who they report to for annual evaluations, etc., along with the lack of overhead return.

We think more needs to be requested and more needs to be done. Without a paid leader (administrative leader even if only part time – but permanent and dedicated) who will push for advancement, work on recruiting top faculty, the best students, this program could simply languish or have modest growth or possibly modest decline. That would depend on keeping the dedicated faculty member's interest and hard work.

Additionally, the possibility of an undergraduate program could then be explored. The national need for optics-educated bachelor degreed students is high and growing rapidly. That program will not happen if only because the currently involved faculty will never have the energy to push for it given their need to push the graduate program. In comparison, both the University of Arizona and University of Central Florida have undergraduate optics/photonics degree programs jointly operated with their Electrical & Computer Engineering (ECE) departments, and these programs are highly successful. The review committee recommends exploring an undergrad program with a collaboration with the ECE department. This would probably help spur the School of Engineering to more heavily support the graduate program as well, considering that some of their undergrads would be looking for higher degrees. The committee recognizes that starting a new undergraduate program is a lengthy and time-consuming process that requires ABET accreditation. The undergraduate degree program need **not** start as a full-blown program. Instead, the ECE department could start by offering a **minor** in Optical Sciences/Engineering, with an eye toward future expansion of the effort to a BS degree in Optics.

We hope this is THE BEGINNING of an exciting new era for the OSE program, its talented and highly motivated students, and its dedicated and hard-working faculty.

Sincerely,

Eric W. Van Stryland

Masud Mansuripur

Sang M. Han

Appendix: Operational Budget of the College of Optical Sciences at the University of Arizona.

Operating budget for academic programs: $132K/year + $10K/year for teaching labs. (Does not include staff salaries.)

TA funding: $400K / year. Supports about 32 students per semester, in ¼ and ½-FTE (full-time equivalent) positions.

Applicants: About 80-85 domestic PhD applicants, and about 100 international, per year. We take about 30-35 into our PhD program, with all of them being (for the first year) on full scholarships (30 Friends of Tucson Optics (FoTO) scholarships, privately funded) or RA positions (a few) or other funding such as national fellowships or employer supported (a few).

MS applicants: about 70-110 per year. Most (90%) are accepted. About 70% of the applicants end up matriculating and starting our program. Our Master of Science degree program has **Distance Learning** as well as **on-Campus** options. In any given semester, we may have as many as 20-25 distance learning students (typically professionals working in the Optics industry around the Country).

Undergraduate degree program is joint with Electrical & Computer Engineering department. Average number of students enrolled in this four-year program: 120, of whom ~ 25% are female. About 35% of undergraduates in our program are US minority. (**Note:** 120 is the **total** number that includes sophomores, juniors, and seniors. Students typically choose Optics as their major in their 2nd year on campus.)

Friends of Tucson Optics (FoTO) Scholarships: These are privately funded by individuals such as current/former faculty members and alumni, as well as corporations and the optics & photonics society (SPIE). The total endowment (~$17M) is kept in perpetuity at the University of Arizona's Foundation, with guaranteed minimum interest rate that is paid annually to cover the stipends for 30 PhD students in their first year. The College matches these donations by covering the students tuition, medical insurance, and other registration fees.

The College also offers a **Professional Graduate Certificate** in Optical Sciences, which requires 15 units (5 classes) of graduate coursework in Optics.

2021 Graduate Student Statistics: 175 PhD (32% female), 195 MS (21% female), 27 Certificate (22 online, 5 on-campus).

Areas of research are broadly divided into four categories: Optical Engineering, Image Science, Photonics, Optical Physics.

PhD degree requirements: A total of **45-54 units** of coursework is required, including **2 lab courses**. 8 core curriculum courses (5 required courses in Electrodynamics, Geometrical Optics, Diffraction & Interferometry, Optical Physics, and Solid-State Optics; 2 other courses from Quantum Mechanics, Fourier Optics, Mathematical Optics, and Statistical Optics; 1 specialty core course from Image Science, Optical Design, Optical Resonators, and Photonics), **Qualifying exam** (written), **Comprehensive exam**.