1-1-2016

DOC 2016-01 Creation of the Department of Electro-Optics and Photonics

University of Dayton. School of Engineering. Office of the Dean

DOC 2016-01

PROPOSAL TO THE ACADEMIC SENATE

TITLE: Creation of the Department of Electro-Optics and Photonics

SUBMITTED BY: Office of the Dean, School of Engineering

DATE: February 19, 2016

ACTION: Legislative Authority

REFERENCES: DOC 2014-04: Actions Pertaining to Degree Programs and Academic Departments

Purpose

The School of Engineering proposes a new Department of Electro-Optics and Photonics be created based on the existing Electro-Optics Graduate Program.

Background

The Electro-Optics Program is seeking to create a graduate Department in the School of Engineering. It has the only approved Ph.D. Electro-optics degree in the State of Ohio.

TO BE APPROVED BY

School of Engineering: Approved 10/28/2015

Graduate Leadership Council: Approved 12/11/2015

Academic Senate: ____________________

Provost and Provost's Council: ____________________

President: ____________________

Board of Trustees: ____________________

Since its inception in 1983, the University of Dayton (UD) Electro-Optics Graduate Program (EO) has grown steadily. With over 30 years of consistent technological advancements along with an ever-increasing academic and research reputation nationally and internationally, it is time to create the Department of Electro-Optics and Photonics (EOP).

At the start, EO was designed to be an applied program and made its home with the School of Engineering through the approval of UD faculty members from physics and electrical engineering and team members from the University of Dayton Research Institute (UDRI). Because of its unique graduate labs, the EO master's program provided students with hands-on experiences not offered in other similar programs. In 1994, Dr. Michael O'Hare, chair of the Department of Physics, wrote the proposal for an EO Ph.D. program. The proposal was accepted, and EO incorporated a doctoral program. EO faculty members were tenured in the EO program, and EO functioned as a department.

Five years ago, the EO graduate program was moved under the Department of Electrical and Computer Engineering (ECE) with an agreement that EO would (a) keep its independent entity with its own budget and director, and (b) EO would decide on its own promotions and tenure cases. In other words, both internal to the University and to the external world, EO would be seen as a separate and distinct entity. Of the six EO faculty members, two had tenure in ECE; therefore, the tenures of the remaining four were transferred to ECE.

Over the past few years, funding and recruitment tasks have become more difficult to accomplish as a "program." And, recently, confusion was created in the external academic community when EO was lost under the ECE umbrella.

The EO faculty continuously strive to increase the visibility of EO in order to enhance their academic and research presence and reputation for future funding, to recruit top faculty and students and to increase their collaboration efforts. By transitioning to a department, EO will reinforce its identity and build its visibility within the UD community as well as within the national and international academic and research ranks.

1. Rationale, focus, purpose, significance and uniqueness

1.1 Rationale

The rationale for proposing the creation of the Department of Electro-Optics and Photonics based on the current Electro-Optics graduate program is to ensure greater visibility within the national and international community of higher learning and research. EO currently has a distinctive program but need to further highlight its advanced research and technologies within the optics and photonics communities.

At UD, EO has been referred to as a flagship program, since it is one of the few across the U.S. and the world. However, to UD and to the world, including EO competitors, EO is perceived as a program under the ECE department. Confusion about EO's academic status limits its capabilities because EO does not stand out prominently. Elevating EO to a department will clarify EO's status and establish a higher ranking among other optics program competitors who have already advanced their status from department to school and then to college in optics, such as the College of Optics and Photonics (CREOL) at the University of Central Florida and the College of Optical Sciences (OSC) at the University of Arizona.

The National Research Council (NRC) ranks university departments based on information provided by faculty and their research productivity. NRC currently recognizes EO at UD as a department and highly ranks it among the top 137 ECE departments considered (see Appendix A). If NRC classifies EO as a program instead of a department, EO could lose its ranking. Or, if NRC considers EO as a program under ECE, EO's ranking could lower.

Other reasons to create the department of EOP include the positive impact on EO recruitment because prospective students will consider EOP on the same respected, specialized and advanced level as EO's competitors. Furthermore, without incurring new UD expenses, an increase in funding and research will result because funding agencies believe that departments have greater capabilities than programs when reviewing proposals. Finally, the United Nations Educational, Scientific and Cultural Organization (UNESCO) designated 2015 as the International Year of Light, so optics and photonics have been highlighted around the world. By promoting a new EOP department, EO will be acknowledged and honored for taking the initiative to advance their program during this monumental celebration (see Appendix B).

1.2 Focus

EO focuses, and will continue to focus, on providing *world-class education and research in electro-optics and photonics, while adapting and changing to successfully compete for top-notch students, funds, and prestigious awards*.

1.3 Purpose

EO thrives as a program but will soar as a department, and EO plans to build an international reputation comparable to their lofty competitors—CREOL and OSC. EO has functioned as a department for more than 30 years and tenured its faculty until a few years ago when tenure was transferred to ECE. As a department, the first step toward a greater external reputation commensurate with the growth of EO faculty activities will be accomplished.

1.4 Significance

(a) SoE predicts an increase in the recruitment of top students nationally and internationally. Recruiting the best students is critical for the EO faculty to successfully complete existing contracts and better position EO to compete for future funding opportunities. EO has lost potential top students to other institutions, such as CREOL, Virginia Tech, etc., even when they were offered assistantships, because of the greater visibility and enhanced status of the other institutions. Using CREOL as an example (see Appendix C), EO expects increased enrollment.

(b) SoE foresees a substantial increase in external funding in EO (e.g. CREOL, see Appendix C). Over the last three years, EO's average annual research expenditure has been $2M (see Appendix D). EO generates more research dollars and more overhead return of funds than any other UD academic engineering department (see Appendix D). EO's goals are to substantially increase the funding we receive, to engage in new research projects and to create other partnerships within the optics and photonics communities.

(c) SoE anticipates a high level of distinguished service to the community through supplying and refreshing the nation's workforce in key areas. Electro-optics is a growth industry with numerous applications (e.g., lasers for national security, manufacturing and medical applications, LEDs and LCDs for lighting and displays, photovoltaic cells for solar energy and optical fibers for telecommunications and Internet), and there is an urgent need to recruit the best students to fill the highly technological positions available in the our workforce.

1.5 Uniqueness

(a) EO excels in interdisciplinary research involving faculty, research scientists, research faculty, adjunct faculty and students. Grants and contracts continue to increase, the latest being one for a supercomputer cluster and another for a National Science Foundation (NSF) Major Research Instrumentation (MRI) for laser beam combining and manufacturing, over and above an existing Air Force Office of Scientific Research (AFOSR) Multidisciplinary University Research Initiative (MURI) award.

(b) EO maintains a strong connection with Air Force Research Laboratory (AFRL) Material and Sensors directorates. AFRL supports many EO students who benefit from the unique opportunity to work at world-class labs at Wright-Patterson Air Force Base (WPAFB).

(c) From research contracts such as those mentioned, EO provides full funding for most of their students, and physics funds their teaching assistant positions.

(d) EO plans to introduce an increasing number of state-of-the-art short courses and courses that expose their students to contemporary topics in electro-optics and photonics because it is a rapidly evolving area.

(e) EO employs the highest concentration of Fellows of professional organizations within any department. EO currently has over 20 Fellows of professional organizations among its faculty and research staff, such as The Optical Society (OSA), The International Society for Optics and Photonics (SPIE), the American Physical Society (APS), and the Institute of Physics (IoP), and EO expects the numbers to grow.

(f) Currently, contracts and grants fund or partially fund 100 percent of EO faculty.

(g) EO produces an exceptional amount of publications. EO's compendium includes books, book chapters, hundreds of articles in refereed journals as well as publications at conference proceedings, presentations and invited lectures. EO faculty members serve as distinguished topical editors for well-known journals, organize entire conferences and serve on numerous professional executive committees.

(h) EO has unique, entrepreneurial faculty. OPTONICUS, a small business started by one of our faculty, has been hugely successful in procuring federal contracts and was named a SPIE small business PRISM finalist last year. In the next five years, EO expects to establish another small business.

(i) EO appreciates their distinctive collaborations with world-renowned research organizations and universities such as Fraunhofer Institute in Germany, research organizations in Mexico and top-rated optics universities in China, e.g., Wuhan, etc. EO anticipates that their collaborations with universities in Mexico and China will draw top-notch students from their ranks into the department.

2. Effect on other programs/departments

With a strong department identity for EO, SoE envisions a shared spotlight and a positive impact with our physics, ECE, mechanical engineering, materials engineering, biology, mathematics and UDRI allies.

Furthermore, EO knows that their campus connections will enhance the visibility of physics faculty who specialize in electro-optics and photonics and ECE faculty who work in nanofabrication, optical information processing and imaging (an optics sub-field). Physics and ECE faculty specializing in electro-optics and photonics will have confirmed joint positions with the EOP department.

As in the past, the Department of Physics has been EO's equal partner; EO values their work and would like to expand their partnership. EO functions as the graduate program for physics. Since the establishment of EO, EO have had an agreement with physics that EO students will teach their labs. In turn, physics hires faculty with optics and photonics knowledge and experience who teach EO graduate courses. As a department, EO plans to continue this highly successful collaboration.

Indeed, physics uses the opportunity to perform EO research as one of their selling points when recruiting new faculty. Peter Powers, Andy Chong, and Imad Agha joined physics from Cornell University (where they did their Ph.D.) because of the opportunity to interact with EO. Just recently another faculty member, Chenglong Zhao, who received his Ph.D. from Peking University, joined physics from NIST (National Institute of Standards and Technology) because of EO research opportunities. Physics faculty members continue to be actively involved in independent and collaborative research with EO, teaching EO courses and advising EO students, and EO expects to expand on this in the future.

Similarly, many ECE faculty members contribute to the EO curriculum and teaching. However, the EO curriculum does not overlap ECE curriculum at UD. Therefore, inception of EOP will not have a negative effect on ECE, only a positive impact because of greater visibility.

As a department, EOP faculty and staff will continue to collaborate, campus-wide, with others who have optics and photonics interests to write proposals, recruit faculty and students, and secure funding.

3. Evidence of need for a new department

The need for the new EOP department, including opportunities for employment of graduates, has been evidenced during the past several years when EO lost top students to prestigious institutions such as CREOL and OSC. CREOL and OSC optics departments expanded to college levels because of the amount of funding and activities that they were supporting, which ultimately increased their visibility and further increased their students, faculty, activities and funding (see Appendix C).

Also, for funding agencies, such as NSF, a department carries more weight than a program. NSF personnel personally communicated this to the EO faculty, which is further evidence of the need to change from a program to a department to help increase EO's funding possibilities.

In light of the recent classification of EO as part of ECE, coupled with the elevated status of EO's competitors, and most importantly, to improve future funding and recruiting opportunities to better compete nationally and internationally, the proposed creation of EOP is in keeping with their changing mission and is in resonance with the rapid advances in photonics over the last couple of decades.

Moreover, EO has a long-standing, close partnership with the Department of Physics and collaboration with the Department of Electrical and Computer Engineering that would be strengthened by their independent standing. An EOP department stands out because of its unique position. There are no other stand-alone optics departments in the state of Ohio.

4. Similar programs

Two of EO's main competitors with similar programs have been elevated to colleges: the University of Central Florida's CREOL and the University of Arizona's OSC. Their elevated status brought global recognition, and along with significantly increased faculty, students and funding. A strong letter of support from the dean of CREOL, one of EO's top competitors, is attached (see Appendix E).

A comparison: In 1998, before CREOL at the University of Central Florida was elevated to a College, it had 21 faculty, five associate faculty, 29 research associates and 104 students. After the College was established, CREOL's numbers grew to 28 faculty, 16 research and associate faculty, 54 research associates or post-docs, 19 staff and 160 students. In 1987, CREOL external funding was $0.5M and grew in 2005 to $16M when the College was named (see Appendix C).

5. Curriculum

As a department, the EO curriculum will remain essentially the same as the current EO curriculum. However, an increased number of short courses and regular courses will be introduced to keep pace with this rapidly changing area. To date, EO has initiated five short courses, with more expected to follow. Appendix F shows details of the MS and PhD requirements along with a listing of the courses and the syllabi.

6. Prospective enrollment

EO averages 60-65 total graduate students. This fall, EO welcomed 18 new students, which is a new high. Recently, EO's website information was placed at the UD School of Engineering department level instead of under ECE, and applicants have increased threefold. In January, EO recruited six new U.S. students with scholarships, including one from an HBCU (Historically Black Colleges and Universities) and three BPM (bachelor's plus master's) students (two ECE, one physics). Numerous foreign students have enrolled with at least three of them funded. From WPAFB (Sensors, Materials), EO received over $500K in funding for the next two years, which will support EO students. This is over and above existing funds that support several students (>6 over last two years). The EO annual open house attracts students from ECE and physics at UD. This year, the EO open house celebrated the International Year of Light.

Currently, EO is in discussions with a Jilian University and Huazong University of Science and Technology (HUST) in China and Centro de Investigaciones en Óptica (CIO) in Mexico and expects to add 10 more M.S. students from the partnership. Thus, EO projects an average of 75 total students (60 percent M.S. and 40 percent Ph.D.) in the program for the next five years, which is about the maximum capacity that EO can enroll (see Table 1).

EO's recruitment numbers are important, and EO is cognizant of the quality and profile of the talents that it attracts. For instance, EO is in negotiations with the premier optics department in China to co-teach undergraduate courses and to introduce new graduate courses there, which should attract top graduate students to UD. EO also foresees new research connections with China Jilian University, Wuhan National Lab for Optoelectronics at HUST, and national research institutions in Mexico such as CIO.

In addition, the new departmental status will enable EO to seriously evaluate the feasibility of creating an ABET accredited undergraduate EO program.

Unfortunately, EO's recruitment capabilities may be hindered if EO does not become a department and loses its unique identity and visibility to the outside world.

Table 1: Electro-Optics Student Statistics

	2014-2015	**2015-2016**	**2016-2017**	**2017-2018**	**2018-2019**
Total Students	59	61	65	70	75
MS	29	29	35	40	40
PhD	30	32	30	30	35
Male	48	51			
Female	11	10			
Domestic	20	24			
International	39	37			
Under-represented	1	2	3	4	4

Note: Under-represented students are African Americans, Hispanic Americans or American Indians/Alaskan Natives/Native Hawaiians. We have not had any students in the last category.

7. Underrepresented groups

This fall, EO recruited a minority student from Morehouse State because of the tireless efforts of the EO physics faculty and the cooperation between the School of Engineering, the College of Arts and Sciences, the UD Graduate School, and the Department of Physics. EO predicts that more will follow because they plan to revisit Morehouse State and more HBCUs (e.g., Alabama A&M, Dillard U., etc.) to recruit minority students.

In 2015, an undergraduate female student from physics joined EO as part of the five-year BPM program. Historically, EO has graduated 8 Ph.D. and 21 M.S. female students since 2000 (Total EO alumni numbers for the period are: 41 Ph.D. and 115 M.S.).

EO's minority and female students are role models for recruitment from underrepresented groups (i.e. US citizens who are either African American or Hispanic).

8. Administrative structure

Even with the numerous positive changes that creation of a department will convey, EO's new EOP administrative structure and line of reporting will not require a reorganization effort. The process to create EOP will be seamless. The current director position will be renamed chair and will continue to report to the dean of the School of Engineering. Also, EOP personnel will continue to participate in the standing committees within the School. EOP will make up committees such as curriculum, P&T and others as deemed appropriate. The existing staff, faculty, information resources and facilities are, for now, adequate. Therefore, EO does not request additional resources.

9. Adequacy of staff, faculty, resources and facilities

EO has always had its independent budget with allocations for faculty salaries, administrative help, resources and facilities. Therefore, EO is not requesting additional resources at this time. EO faculty members now tenured in ECE have agreed to be tenured in EOP. EO will hire faculty independently in the future if required. The current admin will be the admin for the department. The current faculty list is shown below:

FTE Faculty

Electro-Optics faculty: Partha Banerjee, Joseph Haus, Andrew Sarangan, Mikhail Vorontsov, Qiwen Zhan.
All tenured faculty who are members of the Electro-Optics program, teach (or taught) courses and have EO graduate students.

Physics faculty (appointment in Physics and tenure track faculty): Imad Agha, Andy Chong, Chenglong Zhao
Physics faculty teach graduate courses in EO and have graduate students working on degrees under their supervision. They have graduate faculty status.

ECE faculty (appointment in ECE and tenured faculty): Bradley Duncan

Adjunct Faculty

EO Staff (work in EO and/or have appointments as graduate faculty): Edward Watson (UDRI), Rita Peterson (AFRL), Shekhar Guha (AFRL), David Rabb (AFRL), Matthew Dierking (AFRL), Dean Evans (AFRL), Tim White (AFRL), Thomas Weyrauch (UD), Cong Deng (UD)
The adjunct faculty teach graduate courses, as needed, for our program and supervise graduate students for both M.S. and Ph.D. degrees.

10. Additional costs

There will be NO additional costs associated with transitioning the EO program to the EOP department. Contingency funds are available to cover any unanticipated costs.

11. Advisory committee

The EO Advisory Board convened on November 20, 2015, with a new Board comprised of notable alums, top-notch faculty, administrators, researchers and company representatives. EO Board members are Bahaa Saleh (dean of CREOL), Tim Bunning (chief scientist, AFRL materials), Chris Brewer (AFRL materials and EO alum), Mike Roggeman (professor, Michigan Tech), Akhlesh Lakhtakia (Charles Binder Endowed Professor, Penn State), John Taranto (ThorLabs) and Mark Greiner (L3).

Letters of support from the Dean of CREOL, and from the Physics and ECE chairs are attached, see Appendix E.

Appendix A

NRC Rankings

From NRC report (2010 data, date of the last report)
S Rankings (for survey-based rankings) are based on how faculty weighted—or assigned importance to—20 characteristics that the study committee determined to be factors contributing to program quality. The weights of characteristics vary by field based on faculty survey responses in each of those fields. Programs in a field rank higher if they demonstrate strength in the characteristics carrying greater weights.

Research: Derived from faculty publications, citation rates, grants, and awards.

R Rankings (for regression-based rankings) depend on the weights calculated from faculty ratings of a sample of programs in their field. These ratings were related, through a multiple regression and principal components analysis, to the 20 characteristics that the committee had determined to be factors of program quality. The resulting weights were then applied to data corresponding to those characteristics for each of the programs in the field.

A layman's interpretation: for S-rank high and low numbers, for instance: one can say with 90% confidence that the true rank is somewhere between high and low [1]

Institution, program	S-Rank High	S-Rank Low	Research High	Research Low	R-Rank High	R-Rank Low
Stanford EE	**1**	**3**	**1**	**4**	**1**	**1**
UD ECE	**68**	**115**	**67**	**125**	**82**	**116**
UD EO	**18**	**62**	**9**	**50**	**38**	**86**
CREOL	**6**	**21**	**4**	**12**	**16**	**36**
Notre Dame ECE	**33**	**81**	**25**	**87**	**36**	**71**
U. Arizona Opt. Sci.*	**60**	**124**	**50**	**130**	**19**	**44**
U. Rochester Optics*	**45**	**109**	**35**	**116**	**28**	**54**

Table 1. S-rankings, research and R ranking of selected schools. UD EOp, which was polled with other ECE departments, figures higher than UD ECE and Notre Dame (a top tier Catholic research university) ECE, and compares favorably with CREOL. Stanford EE, which is one of the top rated, is listed for comparison. Total number of ECE departments is 136. *Optics programs at Arizona and Rochester are also included, although they are listed amongst PhD granting Physics departments [2]. Total number of Physics departments is 161.

[1]http://chronicle.com/article/New-Doctoral-Program/124634/%20%3Cview-source:http://chronicle.com/article/New-Doctoral-Program/124634%3E%3C/a%3E
[2] http://chronicle.com/article/NRC-Rankings-Overview-/124726/
http://chronicle.com/article/NRC-Rankings-Overview-Physics/124754/

Appendix B

The International Year of Light and Worldwide Initiatives

- The United Nations Educational, Scientific and Cultural Organizations (UNESCO) designated and sponsored 2015 as the International Year of Light.
- Europe has taken the initiative in photonics as a key enabling technology. The EU has established an Extreme Light Infrastructure with an investment of €845M.
- A National Academy of Science report has highlighted photonics, which is sponsored and supported by professional societies and government agencies. Dr. Paul McManamon, University of Dayton EO director of the Ladar and Optical Communications Institute (LOCI) and ex-president of the International Society for Optics and Photonics (SPIE), served as co-chair of the committee.
- The U.S. government has created the National Photonics Initiative and has allocated $200M toward capabilities in photonics manufacturing.

Appendix C

The University of Central Florida College of Optics and Photonics and the Center for Research and Education in Optics and Lasers (CREOL)

- 1986 Center founded
- 1998 21 faculty, 5 associate faculty/joint appointments in CREOL, 29 research associates, 18 staff and 104 students.
- 1999 School of Optics established
- 2004 College of Optics and Photonics established
- 2004 Florida Photonics Center of Excellence established
- 2013 B.S. in photonics science and engineering started. The College has 28 faculty, 16 research and associate faculty, 54 research associates or post-docs, 19 staff and 160 students.
- Over 50 optics-related companies are members of the Florida Photonics Cluster.

More information can be found at http://www.creol.ucf.edu/About/CreolHistory.pdf.

The University of Arizona College of Optical Sciences (OSC)

- Originally proposed by Air Force Institute of Technology
- 1964 Optical Sciences Center founded
- 2005 College of Optical Sciences
- 2014 50-year anniversary
- B.S. in optical science and engineering (housed in College of Engineering, administered by College of Optical Sciences)
- M.S. in optical sciences, photonic sciences and engineering, dual optical sciences and MBA
- Ph.D. in optical sciences
- Over 25 optics-related companies are members of the Arizona Optics Industry Association in the Arizona Optics Valley region.

More information can be found at http://www.optics.arizona.edu/about/history

Appendix D

The following excerpt is from http://engineering-schools.startclass.com/l/92/University-of-Dayton.

High-Spending Departments

In 2013, the engineering department at the University of Dayton with the highest research expenditures was **Electro-Optics**, spending $2.36M. This department spent $1.07M more than the next highest-spending department, Mechanical & Aerospace Engineering.

UD Engineering departments	Total research expenditure
Electro-Optics	$2.36M
Mechanical and Aerospace Engineering	$1.29M
Chemical and Materials Engineering	$1.16M
Electrical and Computer Engineering	$778,895
Graduate Engineering	$241,472
Civil, Environmental & Engineering Mechanics	$179,175

Appendix E

Letters of support

University of Central Florida

CREOL
The College of Optics and Photonics
Office of the Dean

July 9, 2015

Dr. Eddy Rojas,
Dean, School of Engineering
University of Dayton,
Dayton, OH 45469

Dear Dean Rojas,

I have been most impressed with the strong research and educational activities of the electro-optics program at the University of Dayton, which were sustained for more than three decades. I know that there is a current desire to make this program a department within the School of Engineering, and I am writing this letter to express my full and enthusiastic support for such action. Your website states that you are "motivated by pursuing 'Engineering that Matters' — not just doing something because it can be done, but, because it should be done." I believe that giving the electro-optics program, which has acted like a department for a long time, the weight and stature of a formal department is something that *could* and *should* be done. Here are a few reasons:

- Optics and photonics technologies have become central to modern life. Lasers are essential to precision manufacturing and metrology, and a plethora of medical applications including clinical diagnosis, surgery, and genome mapping. Optical fibers have enabled modern telecommunication and the Internet. LEDs and LCDs are essential for high-efficiency lighting and displays. Photovoltaic cells enable solar energy harvesting. Light-based technologies are needed to make and inspect the integrated circuits in nearly every electronic device we use. These technologies are here to stay, and are bound to grow and prosper. Industrial needs for optics and photonics graduates will rise.
- There has been a recent enhanced public and global awareness of the importance of optics and photonics, which will fuel strong student interest.
    - The United Nations General Assembly proclaimed the year 2015 as the International Year of Light, and Light-Based Technologies.
    - The National Academies published a 2013 report entitled "Optics and Photonics: Essential Technologies for Our Nation," which articulated the need for expansion of optics and photonics education and training programs.
    - In 2014, President Obama announced a $110M competition for the creation of an Integrated-Photonics Institute for Manufacturing Innovation, indicating that government support is strong and sustained.
    - The 2014 Nobel prizes in physics and chemistry were awarded in recognition of optics and photonics inventions (blue laser and super-resolved microscopy).

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- Job opportunities for engineers in optics and photonics have become diverse. Public companies that are focused on optics and photonics create more than 10% of all U.S. public revenue, or more than $3 trillion.

In 1987, the University of Central Florida (UCF) administration had the foresight to recognize the importance of the emerging of optics and photonics technologies by creating the *Center for Research and Education in Optics and Lasers* (CREOL), which included college of science and college of engineering photonics faculty. CREOL created a strong partnership with the laser industries and became a Florida Photonics Center of Excellence, and a world-renowned site for research and education in this field. In 2004, recognizing the emerging prominence of this program, UCF – now the second largest university in the US – elevated the Center into a college, the first graduate college in this field in the U.S., now known as CREOL, The College of Optics and Photonics. In 2013–2014, the graduate enrollment was 131, and 21 PhD degrees and 23 MS degrees were awarded. In 2013, the Board of Governors of the State University System of Florida approved the creation of a new undergraduate degree program, a BS degree in Photonic Science and Engineering. With current enrollment of over 70 students, the program will pursue accreditation next year, based on the new optics and photonics ABET criteria. CREOL is now the world's foremost institution for teaching and research in optics and photonics. The faculty are recipients of top awards and honors and are world-renowned for their contributions to fundamental and applied research in optics and photonics. In 2014, external funding was approximately $15M, the number of journal papers was 176 (including 11 in *Nature* and *Science*), and 17 patents were issued. This is a success story that UD may emulate.

I believe that electro-optics at UD has what it takes to develop a successful ABET-accredited undergraduate program within the School of Engineering. It now has a critical mass of faculty and graduate students, excellent research facilities with sustained funding, and above all an outstanding leadership; it surely deserves official recognition as its own department. The faculty and students will then have a new identity and an elevated stature within the college and the university, and this will enable the nascent department to further recruit better students and faculty, and propel its national visibility and that of the School of Engineering.

Prior to coming to UCF, I served for 13 years as Chair of the Department of Electrical and Computer Engineering (ECE) at Boston University (BU). I helped develop the BU Photonics Center. This included recruitment of faculty and support for research programs in the photonics area. Most of the photonics faculty had their homes in the ECE Department, where they constituted less than a quarter of the total number of faculty, and I believe this number has diminished since I left in 2009. A few other photonics faculty had their homes in other departments and colleges. This created some fragmentation that, in some cases, impeded collaboration. The culture at BU did not encourage a move to bring the photonics faculty to a department of their own. In contrast, I see that the faculty at CREOL are more cohesive and have a stronger sense of identity, and have more visibility within the university community, as well as at a national level. They recognize that their college is unique, and needed.

Once more, I am convinced that it is the right move to name the electro-optics program at UD as a department of its own. Please don't hesitate to give me a call if you wish to further discuss my views on this important matter.

Sincerely,

Bahaa Saleh, Dean
CREOL, The College of Optics & Photonics

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Brief biography of Dr. Bahaa Saleh

Dr. Bahaa Saleh is dean of the University of Central Florida (UCF) College of Optics and Photonics and director of the UCF Center for Research and Education in Optics and Lasers (CREOL). Prior to this, he was a professor and chair of the electrical and computer engineering department at Boston University (BU) since 1994 and co-director of its Quantum Imaging Laboratory, and deputy director of the National Science Foundation Center for Subsurface Sensing and Imaging Systems. His research interests include statistical and quantum optics, optical communication and signal processing, nonlinear optics, photodetectors, image processing and vision. He has written the books *Photoelectron Statistics* and *Fundamentals of Photonics* and numerous articles and conference proceedings. He was editor-in-chief of the *Journal of the Optical Society of America* (OSA) from 1991 to 1997 and is currently editor-in-chief of *Advances in Optics and Photonics.* Dr. Saleh is a fellow of OSA, IEEE, SPIE and the John Simon Guggenheim Memorial Foundation. He received a bachelor's degree in electrical engineering from Cairo University in 1966 and a PhD from Johns Hopkins in 1971. He was a faculty member at the University of Wisconsin at Madison from 1977 to 1994, and he has taught and conducted research at the University of Santa Catarina in Brazil, Kuwait University, the Max Planck Institute in Germany, the University of California at Berkeley, the European Molecular Biology Laboratory and Columbia University. Dr. Saleh was awarded the 1999 OSA Esther Hoffman Beller Award for his contributions to optical science and engineering education, the 2004 SPIE/BACUS award for photomask technology and the 2006 Kuwait Prize for optical science.

June 30, 2015

Eddy M. Rojas, Dean
School of Engineering
University of Dayton
300 College Park
Dayton, OH 45469-0254

Dear Dean Rojas,

I am writing a letter in support of the proposal to change the status of Electro-Optics from the Electro-Optics Program to the Department of Electro-Optics and Photonics. I have had discussions with Partha Banerjee, Electro-Optics Program Director, and other Electro-Optics faculty and staff regarding this proposed change, and I am convinced that the change in status will benefit both Electro-Optics and the Department of Physics, as well as the university as a whole.

The Department of Physics is an undergraduate department, offering only a Bachelor of Science degree. The somewhat unique relationship between the Department of Physics and the Electro-Optics Program is, however, very attractive to an individual trained in Physics and who wishes to be a member of a physics department while conducting research in electro-optics related areas. It is fair to say that the Department of Physics has been able to attract very high quality individuals to tenure track positions because of the department's relationship with Electro-Optics.

Should the Department of Electro Optics and Photonics become a reality, it is my opinion that the ability to attract excellent faculty to the Department of Physics will be enhanced. There is no doubt that the word "Department" carries a very different connotation than the word "Program." With department status, Physics and EO will be able to explore the possibility of true joint faculty appointments, which I believe will augment the Department of Physics' recruiting efforts of exceptionally strong tenure track faculty even further. It also goes without saying that the department's relationship with Electro-Optics is a two way street. Maintaining a strong faculty in physics enhances the capabilities and productivity of both the Department of Physics and Electro-Optics. If we take this positive step forward in the relationship between Electro-Optics and Physics, everyone will come out ahead.

Beyond recruiting faculty, I believe potential graduate students will look more favorably on a department than a program as they begin their post-baccalaureate educational searches. Clearly, the student's final choice will be based upon what Electro-Optics has to offer to a graduate

DEPARTMENT OF PHYSICS
300 College Park Dayton, Ohio 45469-2314
(937) 229-2311 FAX (937) 229-2180

student. Right now, it is clear that Electro-Optics has a great deal to offer to graduate students, but as students make their initial searches, I think a Department of Electro-Optics and Photonics stands out far more than a Program. As with faculty, strong graduate students benefit the Department of Physics as well as Electro-Optics, since some Electro-Optics graduate students conduct their research within Department of Physics laboratories. Advancing the program to a department will ensure that we will be competitive with other departments for the best students nationally and internationally.

I have spoken with faculty in the Department of Physics regarding this proposal and have asked specifically if they feel that there will be a positive impact on the department if this change is made. The strong feeling is that the Department of Physics will gain an advantage in the recruiting of faculty if Physics is associated with a graduate department rather than a program. Becoming an academic department will potentially open new avenues for external funding, even stronger graduate students, and possible true joint faculty appointments between Physics and Electro-Optics. We currently have a strong and nationally recognized Electro-Optics Program. However, this is a good time to have an eye toward the future and move forward, rather than maintaining the status quo. As Chair of the Department of Physics, I strongly support the proposal to change the Electro-Optics Program to the Department of Electro-Optics and Photonics.

Sincerely,

John E. Erdei, Chair
Department of Physics

June 9, 2015

To:

Dr. Eddy Rojas,
Dean, School of Engineering
University of Dayton

Subject: Letter of Support for the formation of Electro-Optics and Photonics Department

Dear Eddy:

I am writing a letter in support of the proposal to change the status of Electro Optics from the Electro-Optics Program to the Department of Electro-Optics and Photonics (henceforth EOP). My letter of support is based on Electrical and Computer Engineering (ECE) Department faculty's input to the proposal. ECE faculty were presented the new proposal by Partha Banerjee on May 13th, 2015.

The ECE faculty endorse the proposal for the formation of the Department of Electro-Optics and Photonics in the hope that the ties between the ECE faculty and EOP faculty will continue without any change. Faculty in ECE could have joint appointment with EOP and vice-versa to strengthen both programs. ECE faculty welcome EOP faculty for teaching undergraduate courses in ECE. The ECE faculty agree that the word "Department" carries a very different connotation than the word "Program." We have several of our ECE students pursuing MS degree in Electro-Optics each year. Potential graduate students will look more favorably on a department than a program as they begin their post-baccalaureate educational searches. ECE faculty do believe that the experiment in forming the Electro-Optics graduate program has been successful, and to get to the next level, formation of the department seems to be the logical step. ECE faculty also agree that advancing the program to a department will ensure that we will be competitive with other departments for the best students nationally and internationally. By elevating EOP to be a department, ECE faculty benefit from a strong academic and research partner. The ECE faculty also support the formation of the new department in the "Year of Light", which will bring good publicity to our School of

Engineering and to the University. In summary, ECE faculty enthusiastically support the proposal to change the Electro-Optics Program to the Department of Electro-Optics and Photonics.

If you have any questions, please feel free to contact me any time at (937)-229-3188 by phone, or gsubramanyam1@udayton.edu via email. Thank you for your consideration.

Sincerely Yours,

Guru Subramanyam, PhD

Professor & Chair

Department of Electrical and Computer Engineering

University of Dayton, 300 College Park, Dayton, OH 45469-0232

Phone: 937-229-3611, Fax: 937-229-4529

UNIVERSITY *of* DAYTON

November 9, 2015

Eddy Rojas, Ph.D., Dean
School of Engineering
University of Dayton
KL 565 +0254

Dear Dean Rojas:

On behalf of the College of Arts & Sciences, I am writing in support of the proposal for a Department of Electro-Optics and Photonics. I believe that converting the Electro-Optics Program to the Department of Electro-Optics and Photonics will benefit the School of Engineering, the Department of Physics, and importantly the Ph.D. students in the program.

Sincerely,

Jason L. Pierce, Ph.D.
Dean

UNIVERSITY of DAYTON

November 5, 2015

Paul Benson, Provost
University of Dayton
300 College Park
Dayton, OH 45469

Dear Provost Benson:

This letter supports the elevation of the Electro-Optics Program to departmental status. Dr. Partha Banerjee, Director of the Electro-Optics Program and Dr. John Erdei, Chair of the Physics Department have discussed potential academic impacts of this change and found them to be positive. The close cooperation between the Physics Department and the new Electro-Optics and Photonics Department will be maintained and both feel that this change will enhance their ability to attract quality faculty and students.

The faculty of the Electro-Optics Program have been attached to the Electrical and Computer Engineering Department for the purpose of tenure. Dr. Guru Subramanyam, the Chair of the Electrical and Computer Engineering Department, has also indicated his support as well as the support of the faculty who will remain in the Electrical and Computer Engineering Program.

I have personally contacted Deans of the other campus units and they have indicated their support for such an organizational change. In addition, I have received a unanimous vote in favor of this change from the School of Engineering Academic Leadership Committee.

Also, we have received a very positive letter of encouragement from Bahaa Saleh, Dean of the College of Optics and Photonics at the University of Central Florida. In 1987, the University of Central Florida established a Center for Research and Education in Optics and Lasers. The success of this center resulted in the elevation of the center to a College in 2004. By establishing the Electro-Optics and Photonics Department, we are hoping to achieve a growth profile similar to that of Central Florida.

Since 2015 has been designated the International Year of Light, it seems appropriate to enhance the status of our Electro-Optics program by creating the Department of Electro-Optics and Photonics. I enthusiastically endorse this proposal and respectively request that we proceed with establishing this important department within the School of Engineering.

Sincerely,

Eddy M Rojas, Ph.D., M.A., P.E.

Dean

SCHOOL OF ENGINEERING
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Appendix F

UNIVERSITY of DAYTON

University of Dayton
School of Engineering

Electro-Optics and Photonics

Master of Science (M.S.)

Doctor of Philosophy (Ph.D.)

https://www.udayton.edu/engineering/departments/electrooptics_grad/index.php

Master's Degree in EOP

The program of study in EOP leading to a M.S. degree must include a minimum of 30 semester hours comprising

- Twenty-one semester hours of core courses in electro-optics: EOP 500, EOP 501, EOP 502, EOP 505, EOP 506, EOP 513, EOP 514, EOP 541L, EOP 542L and EOP 543L.
- Nine semester hours of technical electives.
- Students taking the thesis option may substitute six credit hours of the technical electives with thesis hours.

Unclassified Status
Students anticipating acceptance into a degree-granting program may register for only six semester hours of graduate coursework without approval of the associate dean of engineering. There is no guarantee that any hours taken before acceptance will count toward a degree. An application for graduate study should be submitted as soon as possible to ensure that courses taken are compatible with degree requirements. Performance in graduate courses taken before acceptance to a graduate program does not change admission requirements.

Advising
For students pursuing the thesis option and/or receiving a research assistantship, the faculty research supervisor shall serve as the academic advisor. For other students, the EOP Chair or his/her designated faculty member will serve as the advisor. A change of academic advisor is permissible upon request of the student. The academic advisor shall be a member of the program faculty and be approved by the department chair or program director, and the associate dean of engineering. The academic advisor will assist the student in preparing a plan of study.

Plan of Study
A student must complete a minimum of 30 semester hours of graduate work. The specific courses should be itemized and approved on a Plan of Study form to be submitted to the Office of the Dean of Engineering, prior to registration for the tenth graduate semester hour (excluding transfer credits), or before registration for the third semester. It is the student's responsibility to obtain approval from the academic advisor for any changes made to the plan of study and to submit to the academic advisor all deletions and additions in writing before the fourth week of the student's final semester. The plan of study and any amendments must be approved by the student's academic advisor, the department chair or program director, and the associate dean of engineering.

Transfer of Credit
Up to six semester hours, or the equivalent, of graduate studies outside the University of Dayton may be accepted toward the master's degree. The transfer credit must be of B or higher grade level, cannot have been used to satisfy the requirements of an undergraduate degree, and must be verified by an official transcript from the granting institution. It is the responsibility of the student to have the transcript(s) sent to the Office for Graduate Admission and Processing.

Thesis Option
Enrollment in the thesis option is not automatic. Thesis credits should not be taken prior to enrolling in the thesis option. Students who wish to write a thesis should select a research advisor and demonstrate satisfactory progress towards their selected topic before indicating the thesis option on their plan of study.

Thesis
Each student whose plan of study requires a thesis must prepare it in accordance with the format outlined in the University of Dayton's guide to creating and submitting a thesis or dissertation. This guide can be found at http://libguides.udayton.edu/etd. The thesis must be based on the student's own work. Joint authorship is not permitted. The thesis advisor is responsible for supervising and approving the work, and assisting in forming the thesis committee and scheduling a defense. The thesis advisor will typically also serve as the chair of the thesis committee. The thesis defense may be either oral or written or both. The thesis must be presented to and approved by a committee of at least three members, at least two of whom are on the graduate faculty. The committee must receive the thesis at least one week prior to an oral defense. No student shall be allowed to defend the thesis more than twice.

A pass/fail grade will be assigned to the quality of the work. A final approved copy of the thesis is due in the Office of the Dean of Engineering no later than one week before graduation.

Academic Standards
Master's degree students are required to maintain a minimum cumulative grade point average of a B (3.0) in coursework, with no more than six semester hours of C. Grades received from a thesis are Pass/Fail, and do not count toward the minimum grade point average of 3.0. Students who fail to meet these standards are placed on academic probation or dismissed from the program.

Time Limit

All requirements for a master's degree must be satisfied within seven calendar years from the time of matriculation.

Doctoral Degree in EOP

To be considered for admission to the Ph.D. program in EOP, a student must have received a M.S. degree in EOP or equivalent. Only the most promising students with a graduate GPA of 3.5 out of 4 or higher, or equivalent, may be admitted.

The program of study in electro-optics leading to a Ph.D. degree must include a minimum of 90 semester hours beyond the bachelor's degree consisting of the following:

- Twenty-one semester hours of core courses in electro-optics: EOP 500, 501, 502, 505, 506, 513, 514, 541L, 542L and 543L, or equivalent.
- Six semester hours of approved graduate mathematics courses.
- Twelve semester hours of approved 600-level electro-optics courses.
- Thirty semester hours of doctoral dissertation in electro-optics.

Doctor of Philosophy (Ph.D.)

The Ph.D. is granted in recognition of superior achievement in independent research and coursework. The research must demonstrate that the student possesses the capacity for original thought, talent for research, and ability to organize and present findings.

The minimum credit hours required for the Ph.D. degree are 60 semester hours beyond the master's degree. This includes a minimum of 30 semester hours for the dissertation and a minimum of 30 semester hours of course-work. A student seeking the Ph.D. is required to complete a minimum of six semester hours in advanced mathematics.

The dissertation must either add to the fundamental knowledge of the field or provide a new and better interpretation of facts already known. It is expected to result in one or more manuscripts submitted for publication in a refereed journal.

The dissertation must address an integrated industrial project. It is expected to result in a manuscript submitted for publication in an applied engineering journal and/or to documentation leading to a patent.

Temporary Advisor

Immediately upon admission into the doctoral program, a student will be assigned a temporary advisor. This temporary advisor will assist the student in the initial selection of courses for the first semester of enrollment.

Doctoral Advisory Committee

Before the student completes the second enrolled semester or 12 credit hours, the student, in consultation with the department chair or program director, selects a major professor to serve as the chair of the doctoral advisory committee. The chair of the doctoral advisory committee will be a member of the graduate faculty. For students receiving a research assistantship, the faculty research supervisor shall serve as the chair of this advisory committee. An advisory committee consisting of the chair and at least two other graduate faculty members from the program will then be recommended for approval to the department chair or program director and to the associate dean of engineering. Appointment of one additional member of the committee from outside the student's program (i.e., other university faculty, adjunct professors, and prominent researchers in industry or government) is required. One additional graduate faculty member may be appointed by the associate dean of engineering. The composition of the committee will generally reflect the student's area of study and research interest. The duties of the doctoral advisory committee include advising the student, assisting the student in preparing the program of study, administering and reporting the candidacy examination, assisting in planning and conducting research, approving the dissertation, and conducting and reporting the results of the dissertation defense. A dissertation advisor other than the chair of the doctoral advisory committee may be appointed by the doctoral advisory committee.

Plan of Study

The plan of study shall include all the specific courses beyond the master's degree that the student is required to complete. The plan shall indicate the time and manner in which these requirements will be met. The preliminary Plan of Study is to be completed and approved by the doctoral advisor, the department chair or program director, and the associate dean of engineering, before the beginning of the third semester of the student's enrollment. The final Plan of Study should be completed once the committee is formed and prior to the presentation of the dissertation proposal.

Candidacy Examination

The candidacy examination for the doctoral degree is generally taken when the EO core courses as outlined on the approved plan of study, has been completed. Its purpose is to determine the student's eligibility to become a candidate for the doctoral degree. It will include two parts: (1) a written examination covering the EO core courses; and (2) an oral examination on the dissertation proposal. Part 1 is offered twice a year, at the beginning of the Fall and Spring semesters. Part 2 must be completed within six months of the completion of Part 1.

The proposal outlining in detail the proposed area of dissertation research should clearly show the review of the literature in the area, the need for and the uniqueness of the research, the general approach, expected results, the laboratories and/or other facilities needed, and a schedule of work. No more than 12 semester hours of dissertation can be taken prior to successful presentation of the dissertation proposal. The student must make a copy of this proposal available to each doctoral advisory committee member at least one week prior to the Part 2 examination.

The student must pass all parts of the examination to be admitted to candidacy. The student is considered to have passed only when the decision of the doctoral advisory committee is unanimous. All members must sign the examination report form with an indication of their decision noted prior to it being submitted to the associate dean of engineering. If any part of the examination is unsatisfactory, the student will be notified in writing of the conditions for another examination. No student will be permitted to take any part of the examination more than twice. A second examination may not be given earlier than four months after the submission of the examination report.

A student must pass the candidacy examination at least six months prior to the dissertation defense.

Dissertation

A single author dissertation is required of each doctoral candidate who has passed the candidacy examination. The dissertation topic will be selected by the student in consultation with the advisor and the doctoral advisory committee. The dissertation topic must be approved by the doctoral advisory committee. A manuscript prepared for an appropriate journal and an acknowledgment of receipt by the editor must also be submitted along with the dissertation.

The student must obtain approval from the doctoral advisory committee to undertake all or part of the dissertation in absentia. A letter requesting such permission, signed by the chair of the doctoral advisory committee, must be submitted to the associate dean of engineering. This letter should outline in detail the relationship between the advisor and the candidate and the name and background of the person who will directly advise the candidate during the accomplishment of this independent research. This person will be added to the advisory committee.

The University of Dayton's guide to creating and submitting a thesis or dissertation can be found at http://libguides.udayton.edu/etd.

Dissertation Defense

No earlier than six months after the successful candidacy examination, the candidate shall defend the doctoral dissertation in a public forum to demonstrate to the committee that all the preparation for which the doctoral degree is awarded has been met. The defense is open to all members of the University of Dayton faculty, student body, and interested outside parties. The members of the doctoral advisory committee, with the advisor acting as chair, will conduct this dissertation defense.

Before the announcement of this defense, the doctoral advisory committee must agree that the dissertation is ready for public defense. At least two weeks prior to the date of the defense, the candidate must provide the committee with copies of the nearly final dissertation and also submit "Request to Schedule Dissertation Defense" form to their advisor. For the defense to be satisfactory, the advisory committee members must agree that the dissertation defense has been successfully completed. If the candidate's defense is deemed unsatisfactory by only one member, the case will be referred to the associate dean of the engineering for appropriate action.

In addition to defending the dissertation, the candidate must verify that a paper based on the dissertation has been submitted and accepted to a refereed journal for publication.

Additional Requirements

The student must satisfactorily complete the courses listed in the doctoral plan of study with a 3.0/4.0 or better cumulative GPA. One grade of "F" or more than six semester hours of "C" grade may be grounds for dismissal from the program by the Dean, pending recommendation of the doctoral advisory committee. Grades received from a dissertation are Pass/Fail, and do not count toward the GPA.

Two thirds of the semester hours required beyond the master's degree should be earned at the University of Dayton. Generally, this is 40 semester hours beyond the master's degree.

Candidates must complete a minimum of 30 semester hours of dissertation. Candidates are required to register for two semester hours of dissertation during the semester in which the dissertation is defended. Students are expected to complete the dissertation requirements for the doctoral degree within nine years from matriculation.

Any other specific requirements and sequences leading to these degrees are described in the following sections or in departmental and program documents.

EOP Courses and Syllabi

EOP 500: Introduction to Research in Electro-Optics

Catalog description: Introduction to research methods, laboratory safety, ethics, proposal writing, technical presentations. 0 cr. hr.
Prerequisite(s): Acceptance into the EO program or permission of the director
Instructor: Dr. Joseph Haus, jhaus1@udayton.edu
Syllabus:

1. Introduction to EOP and the University of Dayton
2. MS & PhD program overview, courses, objectives and expectations; Plan of study.
3. Library and online research resources
4. Literature review
5. Laboratory safety
6. Technical writing
7. Copyright issues, plagiarism and academic honor code
8. Intellectual property, disclosures and rights
9. Research funding
10. How to make effective technical presentations

EOP 501: Geometrical Optics

Catalog description: Wavefronts and rays; Fermat's principle; Gaussian optics of axially symmetrical systems; aperture stops; pupils and field lenses; Lagrange invariant; angular and visual magnification; optical systems; plane mirrors and prisms; aberration theory; introduction to computer ray tracing. 3 cr. hrs.
Prerequisite(s): Acceptance into the EO program or permission of the director
Instructor:
Dr. Thomas Weyrauch, tweyrauch1@udayton.edu
Text: There is no formal text book required for this course, but the course follows roughly and uses the notation and nomenclature of *Geometrical Optics and Optical Design* by Mouroulis and Macdonald.
References:

- P. Mouroulis and J. Macdonald, *Geometrical Optics and Optical Design*, Oxford University Press, New York, 1997.
- J. E. Greivenkamp, *Field Guide to Geometrical Optics*, SPIE Press, Bellingham, 2004
- W. J. Smith, *Modern Optical Engineering*, SPIE Press, Bellingham, 2008.

Syllabus:

1. Foundation of Geometrical Optics: Waves, wavefronts, and rays; Propagation of Wavefronts, Reflection, Refraction; Fermat's Principle; Basic Postulates of Geometrical Optics
2. Elementary Ray Optics: Reflecting and refracting plane surfaces; Graphical ray tracing for thin lenses and mirrors
3. Imaging by Single Surfaces and a Thin Lenses: Sign convention; Paraxial approximation; Conjugate equation, power, and focal length of surfaces, spherical mirrors, thin lenses; Imaging of extended objects, lateral, longitudinal, and visual magnifications
4. Gaussian Optics: Paraxial height & angle variables; Paraxial ray tracing for systems of many surfaces; Matrix methods; Power and focal length of a general system; Cardinal points (principal planes, focal and nodal points); Thick lenses; Two-component systems; Afocal sys.
5. Optical System Pre-design: Aperture stop, entrance and exit pupils; Numerical aperture and F-number; Depth of focus and depth of field; Paraxial marginal and principal rays; Locating stops and pupils; Telecentricity; Delano diagrams; Lagrange invariant; Etendue; Vignetting
6. Gaussian Optics of Optical Instruments and Components: Visual telescopes; Field lenses; Microscope, Visual magnification, magnifying power and resolution; The eye; Reflecting prisms
7. Chromatic Effects: Optical glass; Dispersion; Sellmeier equation; Abbe V-number; Dispersing prisms; Chromatic aberration; Achromatic doublet.
8. Monochromatic Point Aberrations: Wavefront and ray aberrations; Image quality and Strehl ratio; Wavefront expansion; Spot diagrams; Classical aberration types
9. Monochromatic Field Aberrations: Wave aberration polynomial for rotationally symmetric systems; Seidel aberration coefficients; Aplanatic meniscus; Astigmatism and Field Curvature; Petzval theorem; Aberrations of a thin lens in air: shape factor, stop-shift effects; Landscape lens
10. Computer-based ray tracing: Introduction to OSLO software; Paraxial Setup and ray analysis; Seidel coefficients; Through-focus spot diagrams; Introduction to optimization: landscape lens and achromatic doublet.

EOP 502: Optical Radiation and Matter

Catalog description: This course discusses the interaction of light with matter by modeling atoms as classical oscillating dipoles. Important topics to be covered are

electromagnetic waves, polarization, dipole radiation, interaction of radiation with atomic electrons, phenomena related to the interaction of optical radiation with matter, crystal optics, electro-optic effect, and nonlinear dielectric effects. 3 cr. hrs.
Prerequisite(s): Basic knowledge of electromagnetism and vector calculus or permission of instructor.
Instructor: Dr. Andy Chong, achong1@udayton.edu
Text: No formal textbook is required. Course notes will used as a textbook.
References:

- D. J. Griffith, *Introduction to electrodynamics 4th edition*, Addison-Wesley, Boston, MA, 2012.
- G. R. Fowles, *Introduction to modern optics 2nd edition*, Dover, Mineola, NY, 1989.
- B. E. A. Saleh and M. C. Teich, *Fundamentals of photonics 2nd edition,* John Wiley & Sons, New York, 2007
- A. Yariv and P. Yeh, *Optical waves in crystals*, John Wiley & Sons, New York, 2003

Syllabus:

1. Review of electromagnetic wave: Maxwell's equations, Plane wave solution, Phase and group velocity, Poynting theorem
2. Polarization of light: State of polarization, Jones matrices, Stoke parameters, Poincaré's sphere, polarization devices
3. Radiation and Scattering: Potential theory of electromagnetism, Radiation from dipole, Scattering by a dipole
4. Absorption and line broadening: Extinction by a dipole, Propagation in a dilute medium, Broadening
5. Macroscopic electrodynamics: Macroscopic Maxwell's equations, Dielectric tensor, Electromagnetic wave equation, Reflection and transmission at an interface
6. Crystal optics: Polarizer, Birefringence, Optical activity, Faraday effect
7. Electro-optic effects: EO effects, EO retardation, EO amplitude modulation, EO phase modulation
8. Optical properties of metals: Drude model

EOP 505: Introduction to Lasers

Catalog description: Laser theory; coherence; Gaussian beams; optical resonators; properties of atomic and molecular radiation; laser oscillation and amplification; methods of excitation of lasers; characteristics of common lasers; laser applications. 3 cr. hrs.
Prerequisite(s): EOP 502 or a working knowledge of Maxwell's Equations and physical optics, calculus and linear algebra, or permission of instructor.
Instructor: Dr. Qiwen Zhan, qzhan1@udayton.edu
Textbook: Christopher Davis, *Lasers and Electro-optics: Fundamentals and Engineering*, Cambridge (1996).
References:

- Ammon Yariv, *Optical Electronics in Modern Communications, 5th Edition,* Oxford Univ. Press (1997)
- William Silfvast, *Laser Fundamentals, 2nd Edition,* Cambridge University Press, (2004)

Syllabus:

1. Introduction and laser safety
2. Analysis of Optical Systems
3. Optics of Gaussian Beam
4. Optical Resonators
5. Optical Frequency Amplification
6. Optical Resonators Containing Amplifying Media
7. Characteristics of Laser Radiation
8. Control of Laser Oscillators
9. Practical Laser Systems

EOP 506/ECE 573: Electro-Optical Devices and Systems

Catalog Description: Solid state theory of optoelectronic devices; photo-emitters; photodetectors; solar cells; detection and noise; displays; electro-optic, magneto-optic, and acousto-optic modulators; integration and application of electro-optical components in electro-optical systems of various types. 3 cr. hrs.
Prerequisite(s): EOP 502 or permission of instructor
Instructor(s): Dr. Joseph Haus, jhaus1@udayton.edu
Recommended Text: Fundamentals of Photonics – by Bahaa Saleh and Malvin Teich
Syllabus:

1. Optical properties of materials
2. Basic semiconductor properties
3. PN junction diodes
4. Light emitting diodes and fiber coupling
5. Semiconductor optical amplifiers and fiber amplifiers
6. Diode Lasers – Fabry-perot, DFB, VCSELs
7. Photodetectors – junction detectors, photoconductors, avalanche detectors, PMT
8. Noise in detection systems
9. Solar photovoltaic devices
10. Image Sensors – CCD & CMOS sensors, IR imagers
11. Electro-Optic Devices – Mach-Zehnder modulators
12. Liquid crystal devices – displays, spatial light modulators
13. Diffraction Grating
14. Acousto-Optic Devices
15. Electro-Optic Systems – CD pickup units, barcode scanners.

EOP 513/ECE 572: Linear Systems and Fourier Optics

Catalog description: Mathematical techniques pertaining to linear systems theory; Fresnel and Fraunhofer diffraction;

Fourier transform properties of lenses; frequency analysis of optical systems, spatial filtering, application such as optical information processing and holography. 3 cr. hrs.
Prerequisite(s): Acceptance into the graduate EO program or permission of program director.
Instructor: Partha Banerjee, pbanerjee1@udayton.edu
Text: Introduction to Fourier Optics, 3rd ed., Goodman
References: *Principles of Applied Optics*, Banerjee and Poon; *Contemporary Optical Image Processing with MATLAB*, Poon and Banerjee; Class notes
Syllabus:

1. 2D signals and linear systems
2. Scalar diffraction theory: transfer function and impulse response for propagation
3. Fresnel and Fraunhofer diffraction
4. Lenses for imaging and Fourier transformation
5. Frequency analysis of coherent and incoherent imaging systems
6. Optical recording systems
7. Spatial filtering and holography; examples of image processing
8. Contemporary topics in image processing

EOP 514: Guided Wave Optics

Catalog Description: Light propagation in slab, cylindrical, and rectangular wave guides. Signal dispersion and attenuation in optical fibers. Perturbation and effective index techniques will be also discussed. Coupled mode theory and its applications as well as Beam propagation method (BPM) will be introduced. 3 cr. hrs.
Prerequisite: A good background in: Calculus, MATLAB, ODEs, EOP 502 or permission of the director.
Instructor: Dr. Andy Chong, achong1@udayton.edu
Text: C. R. Pollock, *Fundamentals of Optoelectronics*, Richard Irwin Inc., 1995. (out of print but an electronic copy will be given to the class), or
C. R. Pollock, and M. Lipson *Integrated Photonics*, Springer; Softcover reprint of hardcover 1st ed. 2004 edition.
Text Notes: Will be handed out in class.
Reference Texts:

- Gerd Keiser, *Optical Fiber Communications*, 4th Ed., McGraw Hill, New York, 2011.
- Amnon Yariv and Pochi Yeh, *Photonics*, Sixth Ed., Oxford University Press Inc. 2007.
- Dietrich Marcuse, *Theory Of Dielectric Optical Waveguides*, 2nd Ed. Academic Press Inc. 1991.
- A. Snyder, and J. Love, *Optical Waveguide Theory*, Springer; 1st Ed. 1983.
- A. H. Cherin, *An Introduction To Optical Fibers*, McGraw Hill, New York, 1983.

Syllabus:

1. Introduction
2. Review of Maxwell's equations
3. Planar slab waveguide
4. Dispersion in waveguides
5. Graded index waveguides and the WKB method
6. Step index circular waveguides
7. Dispersion in step index and graded index fibers
8. Attenuation in optical fibers
9. Rectangular dielectric waveguide
10. Coupled Mode theory and applications
11. Coupling between optical sources and waveguides

EOP 541L: Geometric and Physical Optics Laboratory

Catalog description: Geometric optics; characterization of optical elements; diffraction; interference; birefringence and polarization. Audit is not permitted. 1 cr. hr.
Prerequisite(s): EOP 501 or permission of program director.
Instructor: Dr. Cong Deng, cdeng1@udayton.edu
Text: There is no formal text book required for this course. The laboratory exercises are based on the set of notes developed by Dr. Gordon Little, Dr. Bradley Duncan, and Nick Miller.
References:

- Born and Wolf, *Principles of Optics,* Cambridge University Press, 1999.
- Goodman, *Introduction to Fourier Optics,* Roberts and Company Publishers, 2004.
- Hecht, *Optics*, Addison-Wesley, 2001.
- Miller, *Geometric and Physical Optics Laboratory Course Documentation and Lab Manual.*

Syllabus:

1. Modulation transfer function (MTF) of a pinhole camera.
2. Focal length of lenses: Investigate and evaluate several techniques for determining the focal length of a lens with emphasis on experimental measurement uncertainty and error analysis.
3. Simple Optical Systems: Investigate the properties of a Gaussian beam expander and an optical relay system.
4. The Airy disc and Fraunhofer Diffraction: Study the Airy disc, the diffraction limit of lenses and Fraunhofer diffraction from slit apertures.
5. Fresnel diffraction: Study the Fresnel diffraction irradiance pattern from an opaque line stop.
6. Polarization: Study several aspects of polarization including: linear polarizers, retarders, birefringent materials, Fresnel reflection, and Brewster's Law.
7. Interferometry and temporal coherence: Study the temporal coherence of conventional and laser sources using two-beam interferometers.

EOP 542L: Electro-Optic System Laboratory

Catalog description: Fiber optic principles and systems: numerical aperture, loss, dispersion, single and multimode fibers, communications and sensing systems. Project oriented investigations of electro-fiber-optic systems and devices in general: sources, detectors, image processing, sensor instrumentation and integration, electro-optic component, display technology, nonlinear optical devices and systems. 1 cr. hr.
Prerequisite(s): EOP 514 or permission of program director.
Instructor: Dr. Andrew Sarangan, sarangan@udayton.edu
Text: There is no formal text book required for this course. The laboratory exercises are based on the set of notes developed by Dr. Andrew Sarangan.
References:

- Saleh & Tiech, *Fundamentals of Photonics*, Wiley-Interscience, 2007.
- Andrew Sarangan, "*EOP-542L Laboratory Exercises*," downloadable lab manual

Syllabus:

1. Multimode fibers: basic fiber handling, cleaving, inspecting, measuring the numerical aperture and coupling light
2. Multimode fibers: fusion splicing techniques, measuring splice losses of multimode fibers, light coupling and coupling efficiency calculations
3. Single mode fibers: examining the mode patterns of different diameter fibers, light coupling, calculating V numbers and cut-off wavelengths.
4. Diffraction gratings: Review of basic principles, measuring the grating periods of grooved gratings, applications in spectroscopy
5. Fiber Bragg Gratings: properties of FBG, measuring the reflection spectrum using a tunable laser, applications as a temperature or strain gauge, working with an optical spectrum analyzer.
6. Photodetectors, Laser Diodes and LEDs: measuring the I-V and L-I curves, measuring responsivity and quantum efficiency, bandgaps of materials.
7. Project based on Erbium doped fiber amplifier

EOP 543L: Advanced Electro-Optics Laboratory

Catalog description: Project-oriented investigations of laser characteristics, ellipsometry, holography, optical pattern recognition and spectroscopy. Emphasis is on the applications of optics, electronics, computer data acquisition and analysis to measurement problems. 1 cr. hr.
Prerequisite(s): EOP 541L, or permission of instructor.
Instructor: Dr. Qiwen Zhan, qzhan1@udayton.edu
Text: There is no formal textbook required for this course. The project manuals developed by Dr. Qiwen Zhan will be distributed to the students electronically at the beginning of the semester.
Syllabus:

1. Optical spectroscopy
2. Laser and laser characterization
3. Computer generated holography
4. Spectroscopic ellipsometer
5. Optical pattern recognition

EOP 595: Selected Short Courses*

Digital Holography

Course description: Basic principles of holography, digital holography (DH), holographic interferometry, holographic microscopy and tomography, multi-wavelength DH, phase-shifting holography, compressive holography, dynamic holography, transport of intensity imaging, etc. with selected applications to real-world problems. Lab demos.
Instructors: Dr. George Nehmetallah, Dr. Partha Banerjee, pbanerjee1@udayton.edu

Thin-film Engineering

Course description: Fundamentals of thin film design and depoition; PVD & CVD; optical properties of thin film materials; numerical methods & optimization; metal film optics; thin film metrology; lab demonstrations of selected optical coating processes.
Instructor: Dr. Andrew Sarangan, sarangan@udayton.edu

Introduction to Ladar

Course description: Survey of principles of direct detection and coherent detection ladar systems, ladar sources and receivers, effects of illumination path and object scattering, basic ladar range equation, elements of detection theory as applied to direct detection ladar systems. 1 cr. hr.; 1 week
Instructors: Dr. Paul McManamon, Dr. Edward Watson, ewatson1@udayton.edu

Free-space Laser Communications

Course description: Laser communications systems, atmospheric channels, propagation in turbulent and scattering media, fluctuation statistics, horizontal uplink and downlink; system performance, link analysis, bit-error-rate analysis; mitigation of atmospheric effects; UAV and mobile platforms, retro-modulators, adaptive optics, hybrid optical/RF communications. Lab demos.
Instructor:Dr. Arun Mazumdar arunk.majumdar@gmail.com

Introduction to Optical Project Design with ZEMAX

Course description: Introduction to ZEMAX, fundamental skills for designing practical optical systems, project design with ZEMAX, use of ZEMAX database of sample files, including three real typical design projects. Full access to ZEMAX for 60 days after course with follow-up discussions.
Instructor: Dr. Cong Deng, cdeng1@uayton.edu

Applied Quantum Photonics and Quantum Information Processing

Course description: Review of quantum mechanics and density matrix methods, qubits and qubit operations, quantum logic gates and quantum circuits, quantum states of light, quantum theory of measurement, introduction to measurement based linear optics quantum computing, quantum communications and cryptography.
Instructor: Dr. Imad Agha, iagha1@udayton.edu

* All short courses are 1 cr. hr. each and for 1 week.

EOP 601: Optical Design

Catalog Description: Chromatic aberrations: doublet lens; telephoto, wide-angle, and normal lenses; triplet lens design and variations; optimization methods and computer lens design; optical transfer functions; telescopes and microscopes; two-mirror telescope design: aspheric surfaces; prism and folded optical systems, rangefinders; gratings and holographic optical elements; anamorphic optical systems; zoom systems.
Prerequisite: EOP-501
Instructor: Dr. Cong Deng, cdeng1@udayton.edu
References:

- Robert E. Fischer, Biljana Tadic-Galeb, and Paul R. Yoder, *Optical System Design*, Second Edition, SPIE Press and McGraw-Hill, 2008. ISBN 978-0-07-147248-7.
- Michael J. Kidger, *Fundamental Optical Design*, SPIE Press, 2002. ISBN 9-8194-3915-0
- Milton Laikin, *Lens Design, 2nd Ed.*, Marcel-Dekker, Inc., 1995.
- Robert R. Shannon, *The Art and Science of Optical Design*, Cambridge University Press, 1997.
- Warren J. Smith, *Modern Optical Engineering*, 3rd Ed. McGraw-Hill, 2000. ISBN 0-07-135360-2
- Warren J. Smith and Genesee Optics Software, Inc., *Modern Lens Design: A Resource Manual*, McGraw-Hill, 1992.

Syllabus:

1. Ray tracing and image evaluation
2. Introduction to ZEMAX
3. Optimization methods and computer lens design
4. Telephoto, wide-angle and normal lenses
5. Optical transfer functions
6. Aspheric surfaces
7. Telescopes and microscopes
8. Optical tolerancing
9. Prism and folded optical systems, rangefinders

Course Requirements
This course mixes lectures on geometrical optics and lens design with computer lab sessions using ZEMAX and Matlab.

EOP 604/ECE 674: Integrated Optics

Catalog description: Asymmetric dielectric slab wave-guides; cylindrical dielectric wave-guides; multi-layer waveguides; dispersion, shifting and flattening; mode coupling and loss mechanisms; selected nonlinear waveguiding effects; integrated optical devices.
Synopsis: Monolithic integrated optical circuits (IOC) have transformed the field of optics just as integrated circuits have transformed electronics. This course will cover the fundamental principles of integrated optics that are of practical interest to scientists and graduate students in the area of optoelectronics.

Instructor: Dr. Andrew Sarangan, sarangan@udayton.edu
Reference Material: Course notes by Andrew Sarangan
Syllabus:

1. Review of electromagnetic principles
2. Optical waveguides – slab, ridge
3. Coupled mode theory for waveguides
4. Coupled mode theory for periodic structures
5. Numerical methods in integrated optics
   Optical Shooting Method
   Transfer Matrix Method
   Beam Propagation Method (BPM)
   Finite Difference Time Domain Method (FDTD)
6. Integrated optic devices:
   AO, AWG, directional couplers, MZ, FBG, ring resonators, add/drop filters, DBR lasers, DFB lasers, VCSEL's
7. Design project

EOP 621: Statistical Optics

Catalog Description: Optical phenomena and techniques requiring statistical methods for practical understanding and application; relevant statistical techniques for the analysis of image processing systems and the design of laser radar systems; engineering applications of statistical techniques. Prerequisite(s): Completion of the core courses of the graduate electro-optics program or permission of program director.
Instructor: Dr. Edward Watson, ewatson1@udayton.edu
Prerequisites: Introductory course in physical optics
Text: *Statistical Optics* by J. W. Goodman
Additional references:
J. W. Goodman, *Speckle Phenomena in Optics*
E. Wolf, *Introduction to the Theory of Coherence and Polarization of Light*
A. Papoulis, *Probability, Random Variables, and Stochastic Processes*
Syllabus:

1. Random variables

2. Stochastic processes (moments, power spectral density, Wiener-Khinchin Theorem)
3. Modeling of optical waves
4. Thermal light (unpolarized, polarized, and partially polarized)
5. Noise and statistics of detection
6. Temporal coherence of optical fields (degree of coherence, coherence time)
7. Spatial coherence of optical fields (mutual coherence, cross spectral density, van Cittert – Zernike Theorem, imaging as an interferometric process)
8. Speckle (fully and partially developed, speckle in laser radar, extracting information from speckle)
9. Photoelectron statistics (if time allows)

EOP 624: Nonlinear Optics

Catalog description: Nonlinear optical interactions, classical anharmonic oscillator model; symmetry properties of nonlinear susceptibility tensor; coupled-mode formalism; sum- and difference-frequency generation; parametric oscillators; four-wave mixing; phase conjugation; optical solitons; stimulated Brillouin and Raman scattering; photorefractive effect; resonant nonlinearities.
Prerequisite(s): EOP 502 or equivalent.
Instructor: Dr. Joseph Haus, jhaus1@udayton.edu
Text: Powers, P. E. 2011. Fundamentals of Nonlinear Optics. Boca Raton, CRC Press.
References: Nonlinear Optics, Boyd; Handbook of Nonlinear Optics, Sutherland
Syllabus:
1. Linear and Nonlinear Material Characterization
   a. Homogeneous isotropic media (gases, glasses, liquids, etc)
   b. Crystals: Isotropic, Uniaxial, Biaxial
2. Nonlinear Optics
   a. Microscopic origin of the nonlinearity – classical picture
   b. Nonlinear wave equation and the coupled wave equations
      i. Introduction to various processes (SHG, Raman, Brilloun, etc)
      ii. Phase matching and quasi-phase matching
   c. $\chi^{(2)}$ effects and devices
      i. Sum frequency generation
      ii. Second harmonic generation
      iii. Optical parametric generation
   d. Optical parametric oscillators
   e. $\chi^{(3)}$ and nonparametric effects
      i. Microscopic classical picture
      ii. Spontaneous and stimulated Raman processes
      iii. Brillouin effects
      iv. Four wave mixing and phase conjugation
      v. Two-photon absorption
      vi. Nonlinear index of refraction
      vii. z-scan
      viii. Nonlinear Schrödinger equation
      ix. Numerical techniques

EOP 626/ECE 676: Quantum Electronics

Catalog description: Principles of the quantum theory of electron and photon processes; interaction of electromagnetic radiation and matter; applications to solid state and semiconductor laser systems.
Synopsis: Recent advances in nano-technology have made quantum-engineered devices a reality. This course will cover selected topics in quantum electronics of current and practical interest to scientists and graduate students in the area of optoelectronics.
Instructor: Dr. Andrew Sarangan, sarangan@udayton.edu
Text: *Quantum Wells, Wires and Dots: Theoretical and Computational Physics, 3rd Ed. Paul Harrison,* 2009, Wiley.
Syllabus:
1. Semiconductors and Heterostructures
2. Numerical solutions to Schrodinger's Equation
3. Strained Quantum Wells
4. Quantum Wires and Dots
5. Carrier Scattering - photons and phonons
6. Electron Transport
7. Optical Properties of Quantum Wells
8. Quantum well infra-red photodetectors (QWIP)
9. Superlattice detectors
10. Quantum cascade lasers (QCL)

EOP 631: Nanophotonics

Catalog description: The fundamentals of nanoscale light-matter interactions, basic linear and nonlinear optical properties of photonic crystals and metals; nanoscale effects in photonic devices; computational and modeling techniques used in nanophotonics; nanofabrication and design tools; nanoscale optical imaging; principles of nanocharacterization tools.
Prerequisite(s): EOP 501, EOP 502, knowledge of electromagnetism and radiation-matter interactions or permission from instructor.
Synopsis: This course provides students a comprehensive understanding of the key issues of optics on the nanometer scale. Students are expected to learn the fundamental properties of novel materials such as photonic crystals, quantum dots, plasmonics, and metamaterials and their applications. They will develop numerical modeling skills to investigate the properties of these materials and design nanophotonic devices based on these novel materials. Students are expected to explain selected fabrication and synthesis techniques in order to realize certain nanophotonics devices designs. They will learn the principles of various nanocharacterization

techniques necessary during the fabrication process and understand the capabilities and limits of these techniques.

Instructor: Dr. Joseph Haus, jhaus1@udayton.edu
Syllabus:
1. Materials and modeling
   - Introduction to Nanophotonics
   - Photonic Crystal Basics
   - Photonic Crystal Intermediate Topics
   - Photonic Crystal Advanced Topics
   - Photonic Crystal Fibers
   - Plasmonics
   - Metamaterials
   - Quantum Dots
2. Nanofabrication
   - Thin Film Technology
   - Nano-lithography
   - Pattern Transfer and Micromachining
   - Epitaxial growth of nanostructures
3. Nanocharacterization
   - High Numerical Aperture Imaging
   - Far-Field Optical Characterization Techniques
   - Microscopes: Scanning, e-beam, near-field, etc.

EOP 632/ ECE 682: Nano-Fabrication Laboratory

Catalog description: This laboratory course will provide hands-on experience in state-of-the-art device fabrication technology. The course will be conducted primarily in a clean room lab with some classroom discussion sessions.
Prerequisite(s): Permission of instructor; there is an enrollment limit.

Instructor: Dr. Andrew Sarangan, sarangan@udayton.edu
Text: No formal text; reading material will be assigned from various articles and book chapters.
Syllabus:
1. Cleanroom operations
2. Vacuum systems and plasma processes
   a. Vacuum systems, measurements and diagnostics
   b. Basic plasma theory - DC, RF, parallel plate and magnetron, ICP configurations
3. Thin film deposition techniques
   a. PVD methods: RF & DC sputter deposition, filament and e-beam evaporation
   b. CVD methods
   c. Optical properties of thin films and multi-layer optical filters
4. Substrate properties
   a. Properties of silicon and crystal orientations
   b. Quartz, fused-silica, III-V substrates
5. Photolithography
   a. Basic photoresist chemistry, Dill parameters
   b. Photomask design
   c. Contact and projection printing techniques
6. Plasma & wet chemical etching
   a. Etch chemistries and thermodynamics
   b. Plasma etching and ion beam milling
   c. Bulk micromachining for MEMS devices
7. Microfluidics and Lab-on-a-Chip Technology
   SU8 master and PDMS molding techniques
8. CMOS technology
9. Optoelectronic fabrication technology – waveguides, detectors, image sensors and diode lasers
10. Bulk micromachining for MEMS devices
11. Micro-metrology – surface profilometry, scanning electron microscopy
12. Device packaging in electronics and photonics, wire bonding and flip-chip bonding

EOP 656: Free-space Optical Communications

Catalog description: Laser beam propagation, random processes, wave propagation in turbulence, turbulence spectra, structure function, coherence length, anisoplanatism, Strehl ratio, scintillation index, long-time and short-time spot size, and beam wander, bit-error rates, adaptive optics corrections, performance analysis.
Prerequisite(s): EOP 502, 513, or knowledge of electromagnetism and radiation-matter interactions, or permission from instructor. In addition, knowledge of optics of lenses and mirrors, apertures, and diffraction fundamentals; Random processes basics, including autocorrelation and autocovariance functions, and power spectra; Gaussian beam propagation fundamentals, including ABCD ray matrices; and Matlab programming ability are required.
Synopsis: This course provides students with a fundamental understanding of beam propagation through a turbulent atmosphere with applications to free space optical communications. The students get an in-depth presentation of stochastic methods for weak and strong turbulence and are able to describe to Gaussian beam propagation characteristics. They will analyze impairments caused by the atmospheric channel, especially fade statistics and scintillation effects and examine techniques to ameliorate atmospheric effects. Adaptive optics methods will be introduced and discussed. Applications to free space optical communications issues are emphasized.
Instructor: Dr. Joseph W. Haus, jhaus1@udayton.edu
Prerequisites:
- Optics of lenses and mirrors, apertures, and diffraction fundamentals
- Random processes basics, including autocorrelation and autocovariance functions, and power spectra

- Gaussian beam propagation fundamentals, including ABCD ray matrices
- Matlab programming ability.

Syllabus:

1. Random Processes and Random Fields in a nutshell
2. Optical Turbulence in the atmosphere
3. Gaussian Beams Review
4. Propagation Through Random Media
5. Second-order statistics
6. Weak and strong fluctuation theory
7. Fourth-order statistics
8. Weak and strong fluctuation theory
9. Sources and detectors fundamentals
10. Free space Optical Communication Systems
11. Fade Statistics
12. Laser Satellite Communications
13. Computer Usage: MATLAB is used for homework and/or demonstrations.

Project format

The projects will be conducted individually or in small groups (2 students). Each student is expected to submit a formal well-documented report for each project and each group is expected to give in-class oral presentations.

EOP 665: Polarization of Light: Fundamentals and Applications

Catalog description: The fundamentals and applications of the polarization properties of light; description of state of polarization; propagation of state of polarization; polarization devices; polarization in guided waves; polarization in multilayer thin films; ellipsometry and polarimetry; birefringent filters; spatially variant polarization; polarization and subwavelength structures.

Prerequisite(s): EOP 502, basic knowledge of electromagnetism and linear algebra or permission of instructor.

Instructor: Dr. Qiwen Zhan, qzhan1@udayton.edu

Text: There is no formal text book required for this course. The course package is based on the set of PowerPoint notes developed by Dr. Qiwen Zhan.

References:

- Huard, *Polarization of Light*, Masson, Paris, 1996.
- Q. Zhan, "*High Resolution Microellipsometry*," chapter in *Nondestructive Materials Characterization with Applications to Aircraft Materials* (Eds. Meyendorf, Nagy, Rokhlin), Springer, Berlin, 2003
- Pochi Yeh, *Optical waves in layered media*, John Wiley & Sons, New York, 1988

Syllabus:

1. Representation of state of polarization: Vector nature of light, Polarization ellipse, Main states of polarization, Trigonometric representation, Jones vector, Complex representation, Stokes parameters and Poincaré's sphere, Partially polarized light and coherence matrix
2. Propagation of state of polarization: Polarization devices, Jones matrices, Evolution of state of polarization in complex plane, Geometrical representation, Muller matrices
3. Polarization devices based on anisotropic dielectric materials: Anisotropy, Index ellipsoid, Light in linear anisotropic medium, Induced anisotropy, Electro-optical effects, Photoelastic effects, Magneto-optical effects, Devices using optical anisotropy
4. Polarization in guided waves: Mode theory for waveguide and optical fiber, Induced anisotropy in waveguide and optical fiber, Devices using polarization in waveguide and optical fiber
5. Polarization in multilayer thin films: Polarization in isotropic multilayer thin films, Polarization in anisotropic thin films, Metal thin films and surface plasmon resonance
6. Advanced microellipsometry and polarimetry: Introduction to ellipsometer, polarimetry, Microellipsometer, Imaging microellipsometer, Scanning microellipsometer with rotational symmetry, Solid immersion nano-ellipsometer, Scanning nearfield ellipsometric microscope, Biomedical applications
7. Birefringent filter: Principles of birefringent filters, Types of birefringent filters, Applications of birefringent filters
8. Spatially variant polarization: Berry's phase, Cylindrical Vector beams, Polarization gratings
9. Polarization and subwavelength structures: Effective medium theory, Rigorous diffraction theory, Nano-optic devices

EOP 695: Introduction to Atmospheric Optics

Catalog description: Foundation for physics of atmospheric optics effects using meteorology, computational fluid dynamics, and statistical wave optics. Fundamentals of atmospheric physics, global and macro optical effects, atmospheric optical turbulence and its impact on imaging systems, atmospheric optical systems modeling and performance analysis, laser beams propagation in atmosphere, mitigation and exploitation of atmospheric effects.

Prerequisite(s): BS in physics or electrical engineering, physical and/or Fourier optics, statistics and/or statistical optics.

Instructor:

Dr. Mikhail Vorontsov, mvorontsov1@udayton.edu

Text: class notes

Syllabus:

1. Polarization of beams
2. Laser communication link performance

3. ABCD matrices
4. Numerical techniques for atmospheric optical effects
5. Numerical wave optics propagation basics
6. Turbulence simulations and applications
7. Elementary optical feedback control systems
8. Multi-dithering wavefront control principles
9. Phase and field conjugate adaptive optics
10. Adaptive systems based on stochastic parallel gradient descent techniques
11. Wavefront correctors
12. Wavefront sensing and phase reconstruction
13. Wavefront control and turbulence mitigation in phased fiber arrays
14. Exploitation of turbulence effects.