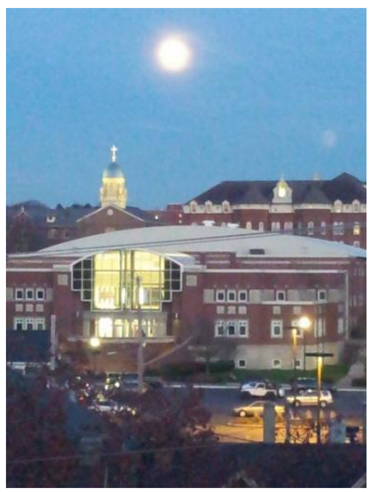
University of Dayton
School of Engineering

Department of Electro-Optics and Photonics



A joint initiative between electrons and photons

Master of Science (M.S.) in Electro-Optics

Doctor of Philosophy (Ph.D.) in Electro-Optics

Spring 2017

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

Milestones

Masters	
Thesis Route	***Non-Thesis Route***
File plan of study prior to registration for the tenth credit hour or before registration for the third semester	
Select 2 additional committee members in consultation with thesis advisor	Select a three member advisory committee before graduation semester
File application for graduation by the fourth week of the graduation semester	Propose and obtain approval for EO exam topic from advisory committee by middle of the graduating semester
Obtain advisor's approval of final thesis draft by middle of the graduating semester	Submit written report to the committee two weeks before the presentation
Submit final thesis draft to committee two weeks before the defense	Make presentation to advisory committee and pass the final examination
Request to Schedule Thesis Defense	
Present and defend the thesis to the committee	
Submit approved thesis to Graduate Office one week before the last week of semester.	

Doctorate
After M.S., select dissertation advisor during first semester
File Plan of Study before the end of the second semester (only the advisor needs to be identified).
Select two additional committee members from program and one outside committee member in consultation with dissertation advisor
Submit dissertation proposal document to committee one week prior to the proposal defense date
Present and defend the dissertation proposal within six months of passing the written exam
Submit and have at least one manuscript accepted for refereed publication during the research period
Obtain advisor's approval of final dissertation draft by middle of the graduating semester
Submit final dissertation draft to committee two weeks before the defense
Request to Schedule Dissertation Defense
Present and defend the dissertation to the committee
Submit approved dissertation to Graduate Office one week before the last week of semester.

Cover page picture: moonrise over the Chapel on the campus of the University of Dayton, as seen from the Department of Electro-Optics and Photonics, Fitz Hall.

Master's Degree in Electro-Optics

The program of study in electro-optics 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 EO Program Director 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 typically will serve as the chair of the thesis committee. The thesis defense may be oral, written, or both. The thesis must be presented to and approved by a committee of at least three members, at least two must be 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.

Text shown in blue fonts represent requirements specific to the EO program that is not in the University catalog.

Accelerated Bachelor's Plus Master's Program

This is a 5-year BS plus MS program for qualified undergraduate students from Engineering or Physics. It is anticipated that students who would normally graduate in 4 years with their BS degree would, under this program, be able to finish with both the bachelor's and the EO master's degrees in 5 years. For students pursuing the thesis option, this may require performing research over the summer following their senior year, and the summer following the fifth year.

Non-thesis Route

Senior Fall	Senior Spring	Senior Summer	MS Fall	MS Spring
EOP 501 (BS + MS dual count) EOP 502 (BS + MS dual count) 6 credit hours[1]	EOP 505 EOP 506 EOP 541L 7 credit hours[2]	EOP Technical Elective 3 credit hours	EOP 513 EOP 543L EOP Technical Elective 7 credit hours	EOP 514 EOP 542L EOP Tech. Elective Project Presentation 7 credit hours

Thesis Route

Senior Fall	Senior Spring	Senior Summer	MS Fall	MS Spring	MS Summer
EOP 501 (BS + MS dual count) EOP 502 (BS + MS dual count) 6 credit hours[1]	EOP 505 EOP 506 EOP 541L 7 credit hours[2]	Technical Elective 3 credit Thesis 6 credit hours	EOP 513 EOP 543L 4 credit hours	EOP 514 EOP 542L 4 credit hours	3 credit Thesis Thesis Defense 3 credit hours[3]

[1] The 6 credit hours will count towards the technical electives requirements of the BS degree. With the BPM election, the same 6 credits will also count towards the MS degree.

[2] These 7 credit hours will only count towards the MS degree, and do not fulfill any undergraduate requirements. Students pursuing the BPM option will have to plan their undergraduate courses to make room for these courses.

[3] The research work for the thesis will span the entire two year period regardless of when the thesis credits are earned.

Doctoral Degree in Electro-Optics

To be considered for admission to the Ph.D. program in Electro-Optics, a student must have received a M.S. degree in Electro-Optics 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

- 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.

Doctor of Engineering (D.E.)

The D.E. is granted in recognition of superior achievement in coursework and an independent project. The project will usually be broad in scope, involve more than one discipline or subdiscipline, and be closely tied to an industrial application.

A minimum of 60 semester hours beyond the master's degree is required for the D.E. degree. This includes a minimum of 21 semester hours for the dissertation and a minimum of 39 semester hours of coursework. A student seeking the D.E. is required to complete a minimum of 21 semester hours in the major area (covering the domains of at least two subdisciplines), a minimum of six semester hours in advanced mathematics, and nine semester hours in a synergistic area of engineering or science.

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.

Electro-Optics 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 chair.
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 chair.
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 Oscilators

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 the chair.
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

EOP 514/ECE 574: 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 chair.
Instructor: Dr. Imad Agha, iagha1@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 532: Optical Thin Film Design

Catalog description: Fundamental principles of optical thin film design and interference filters including: single-layer and multi-layer anti-reflection designs; High-reflection multi-layer designs; Broad band reflectors; High-pass & low-pass filters; Line filters; Bandpass filters; Metal film designs; Design methods for oblique incidence; Thin film beam splitters; Numerical methods and optimization; Thin film manufacturing methods**.**
Synopsis: Thin film coatings are ubiquitous on all optical components such as lenses, mirrors, cameras, windows etc. for achieving anti-reflection, high-reflection, spectral filtering and polarization control. This course is an introduction to the design, simulation and fabrication methods used in this field.
Instructor: Dr. Andrew Sarangan, sarangan@udayton.edu
Text: Course notes by Andrew Sarangan.
Syllabus:
1. Transfer matrix method
2. Single- and multi-layer antireflection design
3. High reflection designs
4. Equivalent index method
5. Edge filters
6. Line filters
7. Bandpass filters
8. Metal film optics
9. Thin films for oblique incidence
10. Polarization control
11. Optical thin film materials and their properties
12. Production methods

EOP 533/EOP 595: Fundamental Principles of Nanofabrication

Catalog description: Basic principles of processes used in microelectronic and photonic device fabrication: vacuum systems, plasma processes, physical and chemical vapor deposition, properties of silicon and other substrate materials, photolithography and non-optical lithography, wet chemical and plasma etching, thermal oxidation of silicon, semiconductor doping, ion implantation, metallization, electrical contacts and micro-metrology.
Synopsis: This course is designed to introduce the basic concepts and methodologies used in the fabrication of nanoscale components in microelectronics and photonics. This is a primarily lecture-based course, but may also include visits to the cleanroom laboratory.
Instructor: Dr. Andrew Sarangan, sarangan@udayton.edu
Text: "Nanofabrication: Principles to Laboratory Practice", Andrew Sarangan, CRC Press.
Syllabus:
- Cleanrooms for device fabrication
- Fundamentals of Vacuum
- Fundamentals of Plasmas for Device Fabrication
- Physical and Chemical Vapor Deposition
- Substrate Materials
- Lithography
- Wet Chemical Etching
- Plasma Etching
- Doping, Surface Modification and Metal Contacts
- Micro-metrology

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 chair.
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 chair.
Instructor: Dr. Ujitha Abeywickrema, abeywickremau1@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 amplifie

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, computer data acquisition and analysis to measurement problems electronics. 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

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

Quantum Photonics

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

Ultrafast Optics

Course description: The course is to address issues of ultrafast optics. Topics to be covered: Linear and nonlinear ultrafast pulse propagation; Generation of ultrafast pulses via mode-locking; Ultrafast pulse characterization; Ultrafast pulse applications in research and industry.
Instructor: Andy Chong achong1@udayton.edu

Practical Guide to Construction of Optical Systems

Course description: Students will learn the basic and advanced experimental skills on the construction of research-level optical system. This course will help students build experimental system for their own research project.
Instructor: Chenglong Zhao czhao1@udayton.edu

*All short courses are 1 cr. hr. each and for one 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: 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 the chair.
Instructor: Dr. Edward Watson, ewatson1@udayton.edu
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, Brillioun, 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: Thin film coatings are ubiquitous on all optical components such as lenses, mirrors, cameras, windows. This course is designed to
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.
Synoposis: 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 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 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

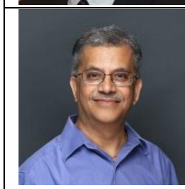
Syllabus:

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.

Associated EOP Faculty and Research Staff

Ujitha Abeywickrema, Ph.D., University of Dayton, 2015. Research Scientist, Optical processing, digital holography, nonlinear optics, photorefractive materials.

Vijayan K. Asari, Ph.D., Indian Institute of Technology, 1994. Professor of ECE. Image processing, computer vision, pattern recognition, machine learning



Monish Chatterjee, Ph.D., University of Iowa, 1985. Professor of ECE. Nonlinear dynamics and chaos, wave propagation, acousto-optics.

Cong Deng, Ph.D. University of Dayton, 2005. Research Scientist. LIDAR systems, fibers and waveguides, adaptive and active optics, THz and imaging systems.

Matt Dierking, Ph.D., University of Dayton. 2009, *Fellow, AFRL*. Graduate faculty, EOP. Technical Director, Ladar Technology Branch, AFRL Sensors Dir. Ladar, waveforms & modulation, coherent signal/ image processing, synthetic apertures.

Bradley D. Duncan, Ph.D., Virginia Polytechnic & State University, 1991. Professor of ECE. LADAR imaging, waveguides; EO sensors; and Fourier optics.

Dean Evans, Ph.D. University of Georgia, 2000. Fellow, OSA, SPIE, APS. Graduate faculty, EO. Research Leader, Hardened Materials and Processing Research Team, AFRL Materials Directorate. Photorefractives, liquid crystals, hybrids, ferroelectric nanoparticles.

Shekhar Guha, Ph.D., University of Pittsburgh, 1981. Fellow. OSA. Graduate faculty, EOP. Project leader, IR optical materials, AFRL. Nonlinear optics, IR materials, lasers

Russell C. Hardie, Ph.D., University of Delaware, 1992. Professor of ECE. Signal/image processing; pattern recognition; remote sensing.

Keigo Hirakawa, Ph.D., Cornell University, 2005. Assistant Professor of ECE. Color image processing, digital camera processing pipeline, 3D image reconstruction and display.

Paul McManamon Ph.D. Ohio State University. 1977, *Fellow IEEE, SPIE, OSA, MSS, AFRL, AIAA*. Graduate faculty, EO. Laser radar, electro-optical countermeasure systems, optical phased-array beam steering.

Rita Peterson, Ph.D. University of Central Florida, 2000. Graduate faculty, EOP. Senior Research Physicist at AFRL Sensors Directorate. Nonlinear optics and lasers.

David Rabb, Ph.D., Ohio State University, 2008. Graduate faculty, EOP. Senior Electronics Engineer, Ladar Technology Branch (RYMM). LIDAR, synthetic aperture systems, holography.

Guru Subramanyam, Ph.D., University of Cincinnati, 1993. Professor of ECE. RF and microwaves, nanobiomaterials for sensor applications, micro- and nano-fabrication.

Ed Watson, PhD. University of Rochester. 1991, *Fellow, OSA, SPIE, AFRL*. Research scientist, UDRI. Laser radar, optical phased array technology, statistical optics, low light level imaging & pattern recognition, speckle characterization of objects in optical and millimeter wave domains.

Thomas Weyrauch, Ph.D., Darmstadt University of Technology, 1997. Senior Research Scientist, EOP. Light propagation through atmosphere: distortion characterization, mitigation; beam control and coherent combining.

Timothy White, Ph.D., University of Iowa, 2006. Graduate faculty, EOP. Senior Research Engineer (DR-III), Agile Filters Group Leader, Photonic Materials Branch (AFRL/RXAP), ACS POLY Program Chair. Liquid crystals, polymer, nanomaterials.

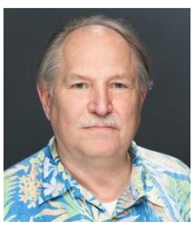
Perry P. Yaney, Ph.D., University of Cincinnati, 1963. *Fellow, APS*. Professor emeritus of Physics and EOP. Laser spectroscopic optical probe techniques including linear and nonlinear Raman scattering.

EOP Faculty

Imad Agha, Ph.D., Cornell University, 2009. Assistant Professor of Physics. Quantum optics, quantum communication, nonlinear optics, nanophotonics.

Partha P. Banerjee, Ph.D., University of Iowa, 1983. *FInstP, Fellow, OSA, SPIE*. Chair, EOP, Professor, EOP and ECE. Metamaterials, holography, nonlinear optics, photorefractives, acoustooptics.

Andy Chong, Ph.D., Cornell University, 2008. Assistant Professor of Physics. Nonlinear optics, ultrafast fiber lasers and amplifiers, arbitrary optical wave packet generation.



Joseph W. Haus, Ph.D., Catholic University of America, 1975. *Fellow, OSA, SPIE, APS*. Professor of EOP and Physics, LOCI Director. Nonlinear optics, quantum optics, metamaterials.

Jay Mathews, Ph.D., Arizona State Univ., 2011. Assistant Professor of Physics. Si photonics, optical properties of semiconductors for IR optoelectronics.

Andrew M. Sarangan, Ph.D., University of Waterloo (Canada), 1997. Professor of EOP. Photodetectors, nano-fabrication, thin films, integrated optics, semiconductor lasers.

Mikhail Vorontsov, Sc.D., Physics and Mathematics, Moscow State University, 1989. *Fellow, OSA, SPIE, ARL*. LADAR Endowed Chair Professor of EOP. Imaging thru' turbulence, Laser beam control, non-linear spatio-temporal dynamics.

Qiwen Zhan, Ph.D., University of Minnesota, 2002. Fellow, OSA, SPIE. Professor of EOP; Managing Director, UD-Fraunhofer joint research center. Physical optics, nanoscale imaging with applications in metrology, nodestructive evaluation and biophotonics.

Chenglong Zhao, Ph.D., Peking University, 2011. Assistant Professor of Physics. Nanophotonics, plasmonics, metamaterials, graphene, plasmofluidics, optical trapping, imaging and sensing

Administrative Assistant

Meghan Brophy