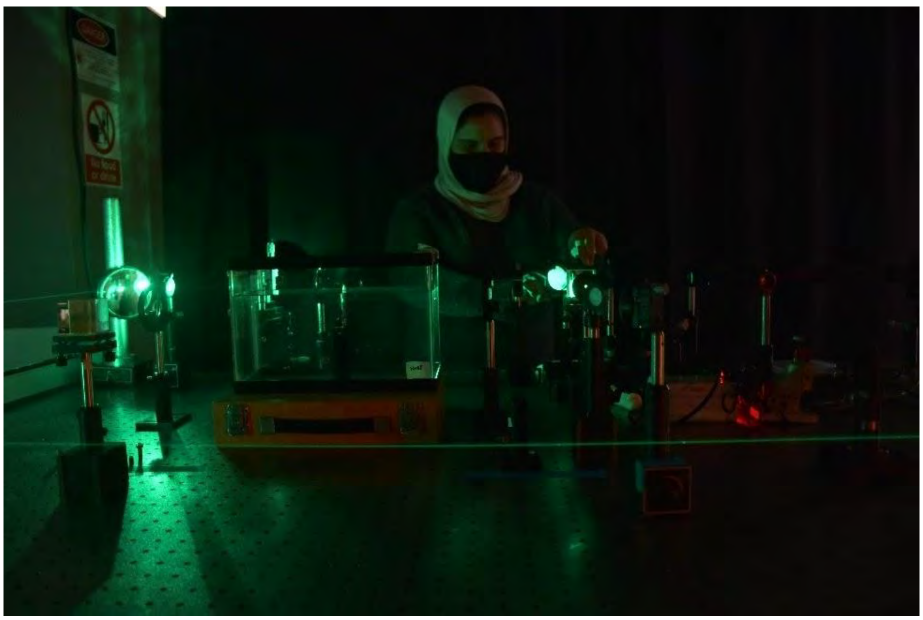
University of Dayton School of Engineering

Department of Electro-Optics and Photonics



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

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

Fall 2021

Milestones

Master's		
Thesis	***Non-Thesis***	***Remote***
Select an adviser, and submit plan of study prior to registration for the tenth credit hour or before registration for the third semester		
Plan of study must include 6 credit hours of EOP 599	Plan of study must include EOP 598	Remote students may substitute EOP 597 in place of the EOP lab classes
Select two additional committee members in consultation with the adviser		
File application for graduation by the fourth week of the graduation semester		
Obtain adviser's approval of final thesis draft by middle of the graduating semester	Obtain adviser's approval for EOP 598 presentation by middle of the graduating semester	Remote students may follow thesis or non-thesis route
Submit final thesis draft to committee two weeks before the defense	Submit written report to the committee two weeks before the presentation	
Present and successfully defend the thesis to the committee	Make presentation to advisory committee and pass the oral examination	
Submit approved thesis to Graduate Office by the deadline.	Submission to Graduate Office is not required	

Doctorate
Select dissertation adviser during first semester
File Plan of Study before the end of the first semester (only the adviser needs to be identified at this stage).
Take the EOP Candidacy Written Exam after taking all EOP core courses.
Select two additional committee members from the EOP department and one outside committee member in consultation with dissertation adviser.
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 accepted at least one refereed journal publication.
Obtain adviser's approval of final dissertation draft.
Submit final dissertation draft to committee two weeks before the defense.
Present and defend the dissertation to the committee.
Submit approved dissertation to Graduate Office by the deadline.

Accelerated Bachelor's Plus Master's Program

The Department of Electro-Optics and Photonics offers a Bachelor's Plus Master's (BPM) program for qualified undergraduate students from engineering or physics. It is anticipated that students who would normally graduate in 4 years with their B.S. 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 your senior year and the summer following your fifth year.

Non-thesis Route

Senior Fall	Senior Spring	Senior Summer	MS Fall	MS Spring
EOP 500 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 500 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.

Master's Degree in Electro-Optics

The program of study in electro-optics leading to an M.S. degree must include a minimum of 30 semester hours comprising

- Twenty-one semester hours consisting of EOP 500 (during first semester), EOP 501, EOP 502, EOP 503, EOP 504, EOP 505, EOP 506, EOP 510 (every semester) and EOP 541L, with at least two from EOP 542L, EOP 543L or EOP 595.
- **Thesis option:** six semester hours of thesis hours (EOP 599), and three semester hours of approved technical elective(s).
- **Non-thesis option:** Nine semester hours of approved technical electives, and non-thesis research project (EOP 598).
- **Remote option:** Remote students may take EOP 597 in place of the EOP lab classes with approval from the department.

M.S. Thesis

For students pursuing the thesis option and/or receiving a research assistantship, the faculty research supervisor shall serve as the academic adviser. For other students, the EOP department chair or his/her designated faculty member will serve as the adviser.

Students who wish to do a thesis should select a research adviser and demonstrate satisfactory progress towards their selected topic before indicating the thesis option on their plan of study. Any thesis credits taken without the permission of the thesis adviser may not count towards the degree.

All M.S. students supported by a research or teaching assistantship, including off-site research facilitated through the efforts of the EOP department are required to take the thesis option. The research adviser typically will serve as the chair of the thesis committee.

Doctoral Degree in Electro-Optics

To be considered for admission to the Ph.D. program in Electro-Optics, a student must have received an 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 (or 60 semester hours beyond the MS) consisting of

- Typically twenty-one semester hours consisting of EOP 500 (during first semester), EOP 501, EOP 502, EOP 503, EOP 504, EOP 505, EOP 506, EOP 610 (every semester) and EOP 541L, with at least two from EOP 542L, EOP 543L or EOP 595.
- 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 (EOP 699)

Students entering the Ph.D. program with an MS in a different field or from a different institution may have to take all twenty-one EOP courses listed in the first bullet above to adequately prepare for the candidacy exam. This will require 36 total semester hours of courses (6 more than the minimum).

Research & Dissertation

For students receiving a research assistantship, the faculty research supervisor shall serve as the chair of this advisory committee.

The dissertation is expected to result in one or more manuscripts submitted and accepted for publication in a refereed journal with the student as the lead author.

EOP Candidacy Examination

The candidacy examination for the doctoral degree is generally taken when the EOP core courses as outlined on the approved plan of study, have been completed. The exam will include two parts: (1) a written examination covering the EOP 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. Passing grade is 70% with at least 50% on each question. Students receiving an overall score of 60-70%, or less than 50% in any area, will be given an oral exam. Part 2 of the candidacy exam must be completed within six months of passing Part 1.

Electro-Optics Courses and Syllabi

EOP 401: Introduction to Fiber Optics

Instructor: Miranda van Iersel
Credit Hrs: 3
Syllabus:
1. Structure and characteristics of waveguides and optical fibers
2. Optical modes
3. Propagation characteristics
4. Dispersion
5. Optical fiber communications

EOP 500: Introduction to Research in Electro-Optics

Instructor: Mikhail Vorontsov, mvorontsov1@udayton.edu
Credit Hrs: 0
Syllabus:
1. Introduction to EOP and the University of Dayton
2. M.S. & Ph.D. program overview, courses, objectives and expectations; Plan of study.
3. Library and online research resources
4. Title IX, community, inclusion
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: Fundamentals of Optical Design

Instructor: Thomas Weyrauch, tweyrauch1@udayton.edu
Credit Hrs: 3
Textbook: No formal textbook required, 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 systems.
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: Light and Matter Interaction

Instructor: Andy Chong, achong1@udayton.edu
Textbook: No formal textbook; course notes will be used as the 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 503/ECE 572: Optical Information Processing

Instructor: Partha Banerjee, pbanerjee1@udayton.edu
Credit Hrs: 3
Text: Introduction to Fourier Optics, 3rd ed., Goodman
References:

1. *Principles of Applied Optics*, Banerjee and Poon;
2. *Contemporary Optical Image Processing with MATLAB*, Poon and Banerjee;
3. Class notes

Syllabus:

1. 2D signals and systems; 2D Fourier transforms
2. Transfer function and impulse response of propagation
3. Examples of Fresnel and Fraunhofer diffraction; Gaussian beams
4. Transport of intensity and phase
5. Lenses and mirrors for imaging and Fourier transformation
6. Transfer functions of coherent and incoherent imaging systems
7. Analysis and design of complex spatial filters and holograms
8. 3D imaging using holography and transport of intensity
9. Contemporary topics in optical signal and image processing

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EOP 504/ECE 574: Guided Wave Optics

Instructor: Imad Agha, iagha1@udayton.edu
Credit Hrs: 3
Textbook: 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 505: Introduction to Lasers

Instructor: Miranda van Iersel
Credit Hrs: 3
Textbook: Christopher Davis, *Lasers and Electro-optics: Fundamentals and Engineering*, Cambridge (1996).
References:

- Amnon 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

EOP 506/ECE 573: Photonic Devices & Systems

Instructor: Andrew Sarangan, sarangan@udayton.edu
Credit Hrs: 3
Textbook: Course notes by Andrew Sarangan.
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
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. Electro-Optic Systems – CD pickup units, barcode scanners.

EOP 510: Contemporary Topics in Electro-Optics and Photonics (CTOPS)

Instructor: Mikhail Vorontsov, mvorontsov1@udayton.edu
Credit Hrs: 0
Syllabus:

- Discussion, inquiry and feedback of research progress towards a thesis in electro-optics and photonics
- review of background research literature
- discussion of experimental or computation methods and results
- presentation of research progress reports
- review of laboratory safety protocols
- participation in technical conferences and professional workshops and/or Stander Symposium

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EOP 532: Optical Thin Film Design

Instructor: Andrew Sarangan, sarangan@udayton.edu
Credit Hrs: 3
Textbook: *Optical Thin Film Design*, Andrew Sarangan, CRC Press
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. Phase change materials
13. Production methods

EOP 533/ECE 580: Fundamental Principles of Nanofabrication

Instructor: Andrew Sarangan, sarangan@udayton.edu
Credit Hrs: 3
Textbook: *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

Instructor: Cong Deng, cdeng1@udayton.edu
Credit Hrs: 1
Textbook: There is no formal textbook required for this course. The laboratory exercises are based on the set of notes developed by Gordon Little, 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

Instructor: Andrew Sarangan, sarangan@udayton.edu
Credit Hrs: 1
Text: There is no formal textbook required for this course. The exercises are based on the set of notes developed by Andrew Sarangan and Ighor Idenehre.
Syllabus:
1. Optical Fibers: multimode fibers, single mode fibers, cleaving, inspecting, splicing, numerical aperture and light coupling,, V numbers, Erbium doped fiber amplifier.
2. Optoelectronic/electronic devices and systems: photocells, photodiodes, LEDs, laser diodes, biasing and sensing circuits, PCB assembly.
3. Diffraction gratings: Review of basic principles, measuring the grating periods of grooved gratings, applications in spectroscopy
4. Gratings and Spectrometry: fiber bragg gratings, spectrometry, diffraction gratings, quantum dots.
5. Liquid crystal devices

EOP 543L: Advanced Electro-Optics Laboratory

Instructor: Swapnajit Chakravarty
Credit Hrs: 1
Textbook: There is no formal textbook required for this course. The project manuals 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: 1-Week Summer Short Courses

Introduction to LiDAR

Instructors: Paul McManamon, paul@excitingtechnology.com, Edward Watson, ewatson1@udayton.edu
Credit Hrs: 1 (2 CEU)
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.

Practical Guide to Construction of Optical Systems

Instructor: Chenglong Zhao czhao1@udayton.edu
Credit Hrs: 1 (2 CEU)
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 systems for their own research project.

Digital Holography

Instructor: Partha Banerjee, pbanerjee1@udayton.edu
Credit Hrs: 1 (2 CEU)
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.

Design of Optical Thin Films

Instructor: Andrew Sarangan, sarangan@udayton.edu
Credit Hrs: 1 (2 CEU)
Course description: Fundamentals of thin film design; antireflection and optical filter design; numerical methods; metal film optics; fabrication methods; design exercise.

Introduction to Optical Project Design w/ Zemax

Instructor: Cong Deng, cdeng1@uayton.edu
Credit Hrs: 1 (2 CEU)
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 the course with follow-up discussions.

Quantum Photonics

Instructor: Imad Agha, iagha1@udayton.edu
Credit Hrs: 1 (2 CEU)
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.

Ultrafast Optics

Instructor: Andy Chong achong1@udayton.edu
Credit Hrs: 1 (2 CEU)
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.

EOP 595: Special Problems

The objective of this course is to provide an opportunity and flexibility for a student to study a topic of their choosing in a depth appropriate for the MS level under the guidance of an instructor.
Credit Hrs: 1-6
Prerequisite(s): Permission of instructor.

EOP 597: Capstone Project

Instructor: Student's adviser.
Credit Hrs: 2
Syllabus:
Students are expected to design, build and demonstrate an independent project that falls within the scope of Electro-Optics and Photonics. The project must include elements that demonstrate a practical understanding of the course material contained in EOP 541L. Successful completion of this course also meets the requirements of EOP 598.
Prerequisite(s): Permission of chair

EOP 598: Non-thesis Research Project

Instructor: Student's MS research (non-thesis) adviser.
Credit Hrs: 0
Syllabus:
The objective of this course is to ensure that MS students who choose the non-thesis route have the opportunity to demonstrate the skills necessary to write professional documents and make technical presentations on a chosen research topic.

- Research project on a selected topic for non-thesis MS students. Review of relevant research literature.
- Preparation of a written project report and an oral presentation to the student exam committee.

EOP 599: M.S. Thesis

Instructor: Student's M.S. thesis adviser
Credit Hrs: 1-6
Thesis credits can be taken in any increment up to the required 6 credit hours. However, students are advised that 6 credit hours of research work by itself will normally be insufficient to meet the standards of the MS thesis. The students should remain enrolled in EOP 510 throughout their MS program of study.

EOP 601: Optical Design

Instructor: Cong Deng, cdeng1@udayton.edu
Credit Hrs: 3
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 603: Optical Interferometry and Metrology

Instructor: Partha Banerjee, pbanerjee1@udayton.edu
Credit Hrs: 3
Textbook: *Introduction to Optical Metrology*. R. Sirohi, CRC 2016. ISBN 9781482236101
Syllabus:

1. Interference and diffraction; Fourier optics
2. Review of digital signal and image processing
3. Holography: classical, digital; transmission, reflection
4. Interferometers, fringe analysis, Moire patterns
5. Phase shifting, holographic and speckle interferometry
6. Fiber-optic interferometers: gyros and bio-sensors
7. Optical metrology; thickness, velocity, pressure measurements
8. 3D nondestructive testing: optical imaging of surfaces and phase objects
9. Contemporary applications in semiconductor processing, LiDAR and astronomy

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EOP 604/ECE 674: Integrated Optics

Instructor: Andrew Sarangan, sarangan@udayton.edu
Credit Hrs: 3
Reference Material: Course notes by Andrew Sarangan
Syllabus:

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.

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

EOP 610: Advanced Topics in Electro-Optics and Photonics

Instructor: Mikhail Vorontsov, mvorontsov1@udayton.edu
Credit Hrs: 0
Syllabus:

- Discussion, inquiry and feedback of research progress towards a dissertation in electro-optics and photonics
- review of background research literature
- discussion of experimental or computation methods and results
- presentation of research progress reports
- review of laboratory safety protocols
- participation in technical conferences and professional workshops
- preparation, submission and acceptance of a technical article, with student as lead author, in a peer-reviewed journal in Electro-Optics and Photonics.

EOP 621: Statistical Optics

Instructor: Edward Watson, ewatson1@udayton.edu
Credit Hrs: 3
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

Instructor: Shekhar Guha
Credit Hrs: 3
Text: Powers and Haus. *Fundamentals of Nonlinear Optics*. Boca Raton, CRC Press.
References: *Nonlinear Optics*, Boyd; *Handbook of Nonlinear Optics*, Sutherland; Nonlinear Optics, Banerjee.
Syllabus:

1. Linear and Nonlinear Materials
    a. Homogeneous isotropic media
    b. Crystals: Isotropic, Uniaxial, Biaxial
2. Nonlinear Optics
    a. Microscopic origin of the nonlinearity – classical picture
    b. Heuristic model of nonlinearity
    c. Nonlinear wave equation
        i. Introduction to various processes (SHG, Raman, Brillioun, etc)
        ii. Phase matching and quasi-phase matching
    d. $\chi^{(2)}$ effects and devices
        i. Sum frequency generation
        ii. Second harmonic generation
        iii. Phase matching and quasi-phase matching
        iv. Optical parametric generation
    e. $\chi^{(3)}$ effects and measurements
        i. Nonlinear index of refraction
        ii. Nonlinear Schrödinger equation
        iii. Solitons
        iv. z-scan
        v. Numerical techniques
        vi. Four wave mixing and phase conjugation

EOP 626/ECE 676: Quantum Electronics

Instructor: Andrew Sarangan, sarangan@udayton.edu
Credit Hrs: 3
Textbook: *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

Instructor: TBD
Credit Hrs: 3
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 657: Principles of Atmospheric Optics and Applications

Instructor: Mikhail Vorontsov, mvorontsov1@udayton.edu
Credit Hrs: 3
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.

EOP 658: Principles of Ladar

Instructor: Paul McManamon, pmcmanamon1@udayton.edu
Credit Hrs: 3
Text: *Lidar Technologies and Systems,* Paul McManamon, SPIE press
References:

- Field Guide for Lidar – Paul McManamon
- National Academy of Sciences, NAS, Report
- Laser Radar: Progress and Opportunities in Active Electro-Optical Sensing (2014)

Syllabus:

1. Introduction to Lidar
2. History of Lidar
3. Lidar Range Equation
4. Types of Lidar
5. Lidar Sources and Modulations
6. Lidar Receivers
7. Lidar beam steering and optics
8. Lidar processing
9. Figures of merit, testing, and calibration
10. Lidar performance metrics
11. Significant Applications of Lidar

EOP 695: Special Problems in Electro-Optics

The objective of this course is to provide an opportunity and flexibility for a student to study a topic of their choosing in a depth appropriate for the Ph.D. level under the guidance of an instructor.
Credit Hrs: 1-3
Prerequisite(s): Permission of instructor.

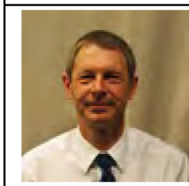
EOP 699: Ph.D. Dissertation

Instructor: Student's Ph.D. dissertation adviser
Syllabus:
Dissertation credits can be taken in any increment up to the required 30 credit hours. The students should also remain enrolled in EOP 610 throughout their Ph.D. program of study.

Associated EOP Faculty and Research Staff

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; joint faculty, EOP. Nonlinear dynamics and chaos, wave propagation, acousto-optics.



Gary Cook, Ph.D., University of Hull, England, 1998. FInstP. AFRL Sensors Directorate. Graduate faculty. Lasers, photorefractives, nonlinear optics.

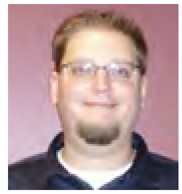
Cong Deng, Ph.D. University of Dayton, 2005. Research Scientist. LIDAR systems, fibers and waveguides, adaptive and active optics, THz and imaging systems.

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

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

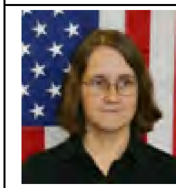
Shekhar Guha, Ph.D., University of Pittsburgh, 1981. Fellow. OSA. Graduate faculty. Project leader, IR optical materials, AFRL. Nonlinear optics, IR materials, lasers

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



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

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



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

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

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

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

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

Partha P. Banerjee, Ph.D., University of Iowa, 1983. *FInstP, Fellow, OSA, SPIE. Holoknight.* Professor, EOP. Metamaterials, dynamic and digital holography, nonlinear optics, acousto optics.

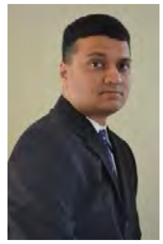
Miranda van Iersel, Ph.D., Vrije Universiteit (the Netherlands), 2004. Assistant Professor of EOP. Atmospheric optics.

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.

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

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

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



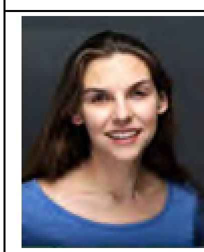
Swapnajit Chakravarty, Ph.D., University of Michigan, 2007. Associate Professor of EOP. Photonic integrated circuits.

Andrew M. Sarangan, Ph.D., University of Waterloo (Canada), 1997. Chair and Professor of EOP. Director, Nanofabrication Laboratory, Photodetectors, lithography, thin films, integrated optics, semiconductor lasers.

Imad Agha, Ph.D., Cornell University, 2009. Associate Professor of Physics; joint faculty, EOP. Quantum optics, quantum communication, nonlinear optics, nanophotonics.

Bill Plick, Ph.D., Louisiana State University, 2010. Assistant Professor of Physics; joint faculty, EOP. Quantum Optical Metrology and Devices

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



Meghan L. Brophy, Administrative assistant, EOP

EOP Advisory Board

Tim Bunning: Chief Technology Officer, AFRL, Air Force Materiel Command, Wright Patterson AFB
Chris Brewer: Chief, Photonics Branch, Materials Directorate, AFRL, Wright Patterson AFB
Akhlesh Lakhtakia: Professor of Engineering Science and Mechanics, The Pennsylvania State University
Nasser Peyghambarian: Professor, College of Optical Sciences, University of Arizona
John Taranto: Advanced Imaging Research Engineer, Thorlabs
Mike Spicer: Director and General Manager, L-3 Communications
Michael Valley: Senior manager, Materials Science R&D group, Sandia National Laboratories