# ELECTRO-OPTICS



Partha Banerjee, Program Director

The interdisciplinary programs of study leading to the Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) in electro-optics are administered by the School of Engineering with the cooperative support of the College of Arts and Sciences.

## Doctor of Philosophy in Electro-Optics (EOP)

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 student with a graduate GPA of 3.5 out of 4, or higher, or equivalent, may be admitted.

The minimum semester-hour requirement for the doctoral degree is 90 semester hours beyond the bachelor's degree (which must include the EO core or its equivalent), or 60 semester hours beyond the EO M.S. degree or equivalent. This includes the credit for the doctoral dissertation. Doctoral candidates are required to register for two semester hours of dissertation during the semester in which the dissertation is defended.

The Plan of Study of a student seeking the Ph.D. in Electro-Optics must successfully complete a minimum of 90 semester hours beyond the bachelor's degree which must include the following:

1. Core courses as given in the EO Master's program or equivalent
2. Twelve semester hours of approved 600-level Electro-Optics courses.
3. Six semester hours of approved graduate mathematics courses.
4. Twelve semester hours of Technical Electives.
4. Thirty semester hours of Ph.D. dissertation credits in Electro-Optics.

See also the Doctoral Degree Requirements in School of Engineering section in the bulletin and consult with the director of the electro-optics program.

## Master of Science in Electro-Optics (EOP)

The individual Plan of Study will include the specific courses and all other requirements of the M.S. EO degree the student is expected to complete. The Plan of Study must be filed with the School of Engineering Office of Graduate Studies prior to registration for the tenth graduate credit hour or before registration for the third semester. The Plan of Study and any amendments thereto must be approved by the advisor, the Program Director, and the Associate Dean of the School of Engineering Office of Graduate Studies.

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|---|---|---|
| EOP 500 | Introduction to Research in Electro-Optics | 0 |
| EOP 501 | Fundamentals of Optical Design | 3 |
| EOP 502 | Light and Matter Interaction | 3 |
| EOP 505 | Introduction to Lasers | 3 |
| EOP 506 | Photonic Devices & Systems | 3 |
| EOP 510 | Contemporary Topics in Electro-Optics and Photonics | 0 |
| EOP 513 | Linear Systems & Fourier Optics | 3 |
| EOP 514 | Guided-Wave Optics | 3 |
| EOP 541L | Geometric & Physical Optics Laboratory | 1 |
| EOP 542L | Electro-Optic System Laboratory | 1 |
| EOP 543L | Advanced Electro-Optics Laboratory | 1 |
| Technical Elective | | 3 |
| EOP 599 | Thesis | 6 |
| OR | | |
| EOP 598 | Non-thesis Research Project [1] | 0 |
| Plus 6 approved additional credits of technical electives | | |
| Total Hours | | 30 |

See also Master's Degree Requirements in School of Engineering section in the catalog and consult with the Chair of Electro-Optics and Photonics.

[1.] Non-Thesis option must include EOP 598 Non-Thesis Project AND six additional, approved technical elective courses.

### Courses

**EOP 500. Introduction to Research in Electro-Optics. 0 Hours**
Introduction to research methods, laboratory safety, ethics, proposal writing, technical presentations.

**EOP 501. Fundamentals of Optical Design. 3 Hours**
Foundation of geometrical optics, Gaussian optics, paraxial raytracing, aperture stops and pupils, first-order optical design of basic optical instruments, optical materials, chromatic aberrations, third-order monochromatic aberrations, introduction to computer-based ray tracing, optical design of elementary optical components. Prerequisite(s): Acceptance into the graduate EOP department or permission of the department chair.

**EOP 502. Light and Matter Interaction. 3 Hours**
Classical and quantum mechanical description of light-matter interaction; electromagnetic waves; polarization; dipole radiation; interaction of radiation with electrons; crystal optics; electro-optic effect; Fermi's golden rule; absorption and dispersion. Prerequisite(s): Acceptance into the graduate EOP department or permission of the department chair.

**EOP 503. Optical Information Processing. 3 Hours**
2D linear systems and Fourier transforms; analysis of diffraction using transfer function, impulse response and transport of intensity; optical elements for imaging and Fourier transformation; transfer functions of coherent and incoherent systems, design of complex spatial filters and holograms; optical information processing; 3D imaging. Prerequisite(s): Acceptance into the graduate EOP department or permission of the department chair.

**EOP 504. Guided-Wave Optics. 3 Hours**
Light propagation in slab and cylindrical wave guides; signal degradation in optical fibers; optical sources, detectors, and receivers; coupling; transmission link analysis; fiber fabrication and cabling; fiber sensor system. Prerequisite(s): EOP 502 or permission of department chair.

**EOP 505. Introduction to Lasers. 3 Hours**
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. Prerequisite(s): (EOP 502 or a working knowledge of Maxwell's Equations; physical optics) or permission of instructor or department chair.

**EOP 506. Photonic Devices & Systems. 3 Hours**
Solid state theory of optoelectronic devices; semiconductor photoemitters: LEDs, optical amplifiers and semiconductor lasers; photodetectors: PIN, APD, photocells, PMT, detection and noise; solar cells; cameras and displays; electro-optic and magneto-optic devices; integration and application of electro-optical components in systems of various types. Prerequisite(s): EOP 502 or permission of instructor.

**EOP 510. Contemporary Topics in Electro-Optics and Photonics. 0 Hours**
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.

**EOP 532. Optical Thin Film Design. 3 Hours**
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. Prerequisite(s): EOP 502, or equivalent, or instructor permission.

**EOP 533. Principles of Nanofabrication. 3 Hours**
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.

**EOP 541L. Geometric & Physical Optics Laboratory. 1 Hour**
Geometric optics; characterization of optical elements; diffraction; interference; birefringence and polarization. Prerequisite(s): EOP 501 or permission of program director.

**EOP 542L. Electro-Optic System Laboratory. 1 Hour**
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. Prerequisite(s): EOP 514 or permission of program director.

**EOP 543L. Advanced Electro-Optics Laboratory. 1 Hour**
Project-oriented investigations of laser characterization, interferometry, holography, optical pattern recognition and spectroscopy. Emphasis is on the applications of optics, electronics, and computer data acquisition and analysis to measurement problems. Prerequisite(s): EOP 541L or permission of program director.

**EOP 595. Special Problems. 1-6 Hours**
Special problems in Electro-Optics.

**EOP 598. Non-thesis Research Project. 0 Hours**
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. Prerequisite(s): EOP 500.

**EOP 599. Thesis. 1-6 Hours**
Thesis in Electro-Optics.

**EOP 601. Optical Design. 3 Hours**
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(s): EOP 501.

**EOP 603. Interferometry. 3 Hours**
No description available.

**EOP 604. Integrated Optics. 3 Hours**
Review of electromagnetic principles; dielectric slab waveguides; cylindrical dielectric waveguides; dispersion, shifting and flattening; mode coupling and loss mechanism; selected nonlinear waveguiding effects; integrated optical devices. Prerequisite(s): EOP 514.

**EOP 610. Advanced Topics in Electro-Optics and Photonics. 0 Hours**
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. 3 Hours**
Optical phenomena and techniques requiring statistical methods for practical understanding and application; relevant statistical techniques for the analysis of image processing systems and the design of laser radar systems; engineering applications of statistical techniques. Prerequisite(s): Completion of the core courses of the graduate electro-optics program or permission of program director.

**EOP 624. Nonlinear Optics. 3 Hours**
Introduction and overview nonlinear optical interactions, classical and harmonic oscillator model, symmetry properties of nonlinear susceptibility tensor, coupled-mode formalism, sum- and difference-frequency generation, parametric oscillators, four-wave mixing, phase conjugation, optical solutions, stimulated Brillouin and Raman scattering, photorefractive effect, and resonant nonlinearities. Prerequisite(s): EOP 502 or equivalent.

**EOP 626. Quantum Electronics. 3 Hours**
Principles of the quantum theory of electron and photon processes; interaction of electromagnetic radiation and matter; applications to solid state and semiconductor laser systems. Prerequisite(s): (ELE 506 or ELE 573 or EOP 506) or equivalent.

**EOP 631. Nanophotonics. 3 Hours**
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.

**EOP 632. Nano-Fabrication Laboratory. 3 Hours**
This laboratory course will provide hands-on experience in state-of-the-art device fabrication technology. The course will be conducted primarily in a clean room laboratory with some classroom sessions for discussions. The students will have an opportunity to design, fabricate and test their own devices. Prerequisite(s): Permission of instructor.

**EOP 655. Optical Communications. 3 Hours**
No description available.

**EOP 656. Free Space Optical Communications. 3 Hours**
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 513, EOP 502, or knowledge of electromagnetism and radiation-matter interactions or permission from instructor.

**EOP 657. Principles of Atmospheric Optics and Applications. 3 Hours**
The course will elaborate on a foundation for the physics of atmospheric optics effects by building bridges between meteorology, computational fluid dynamics, and statistical wave optics. It provides solid theoretical knowledge of optical wave propagation through the atmosphere, and practical computational tools for realistic characterization assessment and performance prediction of various optical systems operated in the atmosphere including: laser beam projection (directed energy), laser communications, ladars, long-range laser vibrometry, active and passive imaging systems. Prerequisite(s): EOP 501 and EOP 513 or permission of the course Director. BS in physics or electrical engineering.

**EOP 658. Principles of Ladar. 3 Hours**
Survey of principals 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. Prerequisite(s): EOP 501 and EOP 513.

**EOP 659. Introduction to Atmospheric Optics. 3 Hours**
This course elaborates on a foundation for the physics of atmospheric optics effects by building bridges between meteorology, computational fluid dynamics, and statistical wave optics. It provides solid theoretical knowledge of optical waves propagation in atmosphere, and practical computational tools for realistic characterization assessment and prediction of laser beam projection and imaging in atmosphere. The students will learn about different approaches that can be applied for mitigation and exploitation of atmospheric effects including adaptive optics, engineering of stochastic and exotic laser beams with reduced sensitivity to atmospheric distortions, lucky-region fusion imaging, laser communication with turbulence-enhanced security and turbulence-induced diversity for compressive sensing and imaging. Students registering for the course should hold a BS in physics or electrical engineering, physical and/or Fourier optics, statistics and/or statistical optics.

**EOP 665. Polarization of Light: Fundamentals & Applications. 3 Hours**
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 in subwavelength structures. Prerequisite(s): EOP 502; basic knowledge of electromagnetism and linear algebra or permission of instructor.

**EOP 690. Selected Readings in Electro-Optics. 1-3 Hours**
Directed readings in electro-optics areas to be arranged and approved by the chair of the student's advisory committee and the program director.

**EOP 695. Special Problems in Electro-Optics. 1-3 Hours**
Special topics in electro-optics not covered in regular courses. Course sections arranged and approved by the chair of the student's advisory committee and program director.

**EOP 699. PhD Dissertation. 1-15 Hours**
Original research in electro-optics which makes a definite contribution to technical knowledge. Results must be of sufficient importance to merit publication.