Graduate Catalog Text
See also http://cao.uah.edu/cao_home.html

OPTICAL SCIENCE & ENGINEERING PROGRAM

Degree: Doctor of Philosophy

Program Director: John O. Dimmock, Professor (PH)

400-E Optics Building
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Professors:

Adhami, R. (ECE); digital signal/image processing
Dimmock, J.O. (PH); spectroscopy
Emslie, A.G. (PH); astrophysical optics
Fork, R.C. (ECE); optical communications, lasers
Gilbert, J.A. (MAE); applied optics, solid mechanics, fiber optic sensing, panoramic imaging
Gregory, D.A. (PH); optical processing
Hillman, L.W. (PH); geometric optics, laser dynamics, radiometry, medical optics
Kulick, J.H. (ECE); computer-generated holography, medical image processing
Madarasz, F.L. (OSE); solid state optics, non-linear optics
Nordin, G.P. (ECE); diffractive optics, holography, physical optics, optoelectronics
Nayyer, J (ECE); optical communications, optical devices
Poularikas, A.D. (ECE); statistical optics, signal processing
Stensby, J.L. (ECE); statistics, communications
Vikram, C.S. (OSE); holography, speckle interferometry and metrology

Associate Professors:

Boykin, T.B. (ECE); semiconductor device modeling
Geary, J.M. (CAO); optical testing and metrology, lens design
Pakhomov, A.V. (PH); laser induced plasma, spectroscopy
Reardon, P. J. (CAO); optical design, metrology

Assistant Professor:

Sanghadasa, M. R. (PH), non-linear optics, optical materials and bio-medical optics

Adjunct Faculty:

Stahl, H.P. (MSFC); optical testing, optical metrology
Smith, S. (MSFC); optical fabrication; optical testing
In addition, there are a dozen other adjunct faculty from UAH, UA, UAB, Alabama A&M, NASA Marshall Space Flight Center, and local industry.

Overview of the OSE Program

At the dawn of the 21st century, Optics stands today as an area of major scientific and technological importance. With considerable foresight, the Optical Science and Engineering (OSE) doctoral program was formally approved at UAH in 1992. Since then the program has grown steadily. Graduates of the program have little difficulty finding employment in rewarding careers. In 2000 the OSE core curriculum was redesigned to provide students more flexibility and to accommodate those coming into the program from various disciplines.
The OSE core consists of two major parts. The first part contains the following seven courses:

1) Geometrical Optics
2) Physical Optics
3) Fourier Optics
4) Optical Testing
5) Radiometry, Detectors and Sources
6) Lasers
7) Optical Testing Laboratory

This material is normally covered in the first year of graduate study, and is the basis for the Preliminary Examination given in the fall term of the second year of study. The second part consists of three focus areas, each of which contains three courses. The student is expected to select one of these areas, and is responsible for the material contained therein. The focus areas are:

A) Optical Communications
   Communications Theory
   Optical Fiber Communications
   Optical Communications
B) Quantum Physics and Devices
   Introduction to Quantum Mechanics
   Quantum Mechanics II
   Quantum Devices
C) Optical Engineering
   Lens Design
   Opto-Mechanical Design and Fabrication
   Optical System Design

This unique program is highly multi-disciplinary and is followed by a wide variety of advanced coursework and research in both fundamental and applied subjects. This diversity is reflected by the OSE faculty, which is drawn from the expertise of optical scientists and engineers from the departments of Physics, Electrical & Computer Engineering, and Mechanical & Aerospace Engineering, and from the Center for Applied Optics.

Admission Requirements

In order to be unconditionally admitted to the doctoral program, a student must have satisfied the following set of requirements:

1. A bachelor's degree, or its equivalent, from an approved college or university, in one of the physical sciences or engineering, with an overall grade point average of 3.0 or better;
2. A minimum score of 1600 on the combined verbal, quantitative, and analytical sections of the Graduate Record Examination (for GRE tests taken after October 1, 2002 the score on the analytical portion is obtained by taking the (raw score + 2) x 100);
3. TOEFL score greater than 550 (213 computer-based) in the case of international students whose native language is not English; and
4. Three letters of reference.

All entering students will be administered a background evaluation at admission conducted by the Optics Coordinating Committee. An applicant whose scholastic record reveals a deficiency in one or more of the first two categories above, may, upon recommendation of the Program Coordinator and the approval of the Graduate Dean, be admitted on a conditional basis, as provided by Graduate School regulations. However, that student must follow the Graduate School's policies in achieving unconditional admission status prior to taking the Preliminary Examination.

Degree Requirements

Because students will come into this program with strong but diverse undergraduate and graduate training, the multidisciplinary curriculum has been structured on a common basis for all entering students, but will compensate for individual differences and provide depth in specific areas. A total of 48 semester hours of graduate coursework are required, of which 28 semester hours are in designated optics courses. An additional 18 semester hours must be in dissertation research. Students are also required to complete three semesters of Seminar in their home departments with a grade of 'S' (Note: seminar hours do not count toward the 48 course-hour degree requirement). In addition, all requirements of the School of Graduate Studies must be met in order to remain in good standing.
The student will complete three study phases, punctuated by three program examinations.

Phase I (the core phase) will consist of 19 semester hours of coursework. To complete this phase and become eligible for continuation in a focus area, the student must pass the Preliminary Examination (only two attempts will be permitted). After successful completion of this phase, the student should have acquired the common optics background that the program faculty believe is necessary for the doctoral program. Full-time students will normally select a dissertation advisor during their first year. Once an advisor has been chosen and the Preliminary Examination passed, a graduate committee will be appointed and a Program of Study completed.

Phase II consists of coursework in the Program of Study (which includes a Focus Area). Much of this coursework will support the dissertation research to be conducted in Phase III. This phase will be completed when the student has completed most of the formal course work as prescribed in the Program of Study and has passed the Qualifying Examination which is prepared and administered by the student's graduate committee. It will contain both written and oral parts. Questions can be drawn from part of the Program of Study (with special emphasis on the student's Focus Area). This exam will also include a proposal for dissertation research prepared by the student and distributed to the graduate committee. The proposal will demonstrate that the student is intimately familiar with the proposed research, that published research related to the proposal has been reviewed, and that the student has a clear understanding of how to proceed and can set realistic goals. If the student fails the Qualifying Examination, a second attempt will be scheduled. Students who fail in two attempts will be dropped from the program.

Phase III consists of all experimental and/or theoretical work needed to complete the student's dissertation. These activities will be directly supervised by the student's advisor. Since the Ph.D. is a research degree, recipients must demonstrate both the ability to perform independent and original research, and to clearly communicate this work both in written and oral formats. The Final Examination will consist of a public, oral presentation and defense of the dissertation.

Residence Requirement

The minimum period in which a Ph.D. in optical science and engineering can be earned is three full academic years of graduate study.

Time Limit

All requirements for the doctoral degree must be completed in no more than five years after the student has passed the Qualifying Examination. Credits earned toward a master's degree (including up to 9 hours of master's thesis) may be applied to the doctoral degree. Dated credits may be accepted if recommended by a student's committee, the Program Committee, and approved by the Graduate School. For application toward this degree, the student may be required to demonstrate competence in the dated course work.

Advisement

A student admitted to the program will have a member of the OSE Program Committee as an advisor. The student will be encouraged to consult with all faculty members in the intended area of specialization in order to develop an appropriate program of study and topic for dissertation research.

A graduate committee will be appointed for the student as soon as the student passes the Preliminary Examination and selects a research project. The committee will include an advisor and at least four other members. At least one of the committee members will be

from a department other than the student's "home department." Otherwise, the composition of the committee will follow the rules governing such committees set forth by the School of Graduate Studies. The graduate committee is charged with supervision and approval of the student's research and course of study toward the completion of all requirements for the degree.

Graduate Courses in Optical Science and Engineering (OSE)

Below are listed all the graduate courses in optics at UAH. Currently, there are 33 offerings covering the full gamut of modern optics. Graduate courses in optics are designated as OSE, PH and/or EE. This reflects the sponsorship of the course. Multiple designations indicate joint responsibility. The OSE courses are listed with full descriptions below. This is followed by a listing of courses whose full descriptions can be found in this catalog under the appropriate department heading.

Part I - Core

541 Geometrical Optics **3 hrs.**

Foundations and physics of geometrical optics, Fermat's principles and Huygen wavelets, refraction and reflection. The many forms of Snell's Law. Optical path lengths, geometrical wavefronts and rays. Ray tracing, ynu-chart and matrix methods. Gaussian imagery and paraxial optics, conjugate elements, cardinal points, and image-object relations. Stops and pupils, chief and marginal rays, vignetting, and the optical or Lagrange invariant. The y-y bar diagram, design of common systems: objectives, magnifiers, microscopes, collimators and detectors. Optical glasses and chromatic aberrations, wavefront and transverse aberrations, spot diagrams and ray fan plots. (Same as EE 541, PH 541.)

542 Physical Optics **3 hrs.**

Scalar and electromagnetic waves, polarization, coherence, reflection and refraction; two beam and multiple beam interference, interferometers, Fabry-Perots, thin films, diffraction, and absorption and dispersion. (Same as EE 542, PH 542.)

546 Radiometry, Detectors, & Sources **3 hrs.**

Theory and practice of radiometry and photometry. Blackbody radiation and Lambertian sources. Propagation of radiant energy in free space and through optical systems. Detector classes, responsivity, bandwidth and noise, power spectral density, properties of sources, photon noise. Prerequisite: PH 342 or equivalent. (Same as PH 546.)

632 Fourier Optics **3 hrs.**

Introducing the optical system as an invariant linear system, convolution, Sommerfield's diffraction integral, Fourier Transform, angular spectrum, coherent & incoherent imaging, optical transfer function. (Same as EE 632, PH 632.)

645 Lasers **3 hrs.**

Resonant optical cavities. Atomic radiation. Laser oscillation and amplification. General characteristics of lasers. Laser excitation. Semiconductor lasers. Gas discharge phenomenon. Transition rates. Spectroscopy of common lasers. Detection of optical radiation. (Same as EE 613.)

653 Optical Testing Laboratory **1 hr.**

Provides students with hands-on experience via the in-depth testing of an aerial reconnaissance photographic lens. The main measurement tools are a 168-inch Collimator/T-Bar nodal slide for image plane measurements, and a Fizeau phase shifting interferometer for exit pupil measurements. Measurements include: effective focal length, F-number, axial color, spherical aberration, field curvature, distortion, astigmatism,

transmission, relative illumination falloff, resolution, modulation transfer function, on-axis interferometry, fringe analysis. Co- or Pre-requisite: OSE 654.

654 Optical Testing **3 hrs.**

Spherometry; refractive index measurements; optical bench measurements of imaging systems via T-bar nodal slide (effective focal length, f-number, axial color, field curvature and distortion, transverse ray aberrations); illumination falloff; image resolution tests (finite object); modulation transfer function; star image testing; knife edge tests; Hartmann tests; Fizeau interferometer and testing configurations; null lens testing of aspheres; wavefront measurements (point diffraction interferometer, radial shear interferometer); Prerequisites: OSE 541, 542. (Same as PH 654.) Spring.

Part II - Focus Areas

A. Optical Communications

Communications via free-space, and guided-wave light signals.

506 Communication Theory **3 hrs**

Review of elementary signals and systems including the Hilbert transform, cross and auto correlation, power density spectrum, and the Wiener-Khintchine theorem. Butterworth and Chebyshev lowpass filters. Bandpass signals and systems. The lowpass equivalent of a bandpass signal/system. Commonly used forms of linear and nonlinear modulation. Demodulation methods and circuits. Phase lock and frequency feedback techniques. Prerequisite: EE 382 (Same as EE 426/506.)

534 Optical Fiber Communications **3 hrs**

Introduction to optical fibers and their transmission characteristics, optical fiber measurements, sources and detectors, noise considerations for digital and analog communications, optical fiber systems. (Same as EE 534.)

634 Optical Communications **3 hrs**

Optical communication systems; counting statistics; the optical detector response process; direct detection; heterodyne detection parameter estimation in optical communications; pointing, spatial acquisition and tracking. Prerequisite: EE 506. (Same as EE 634).

B. Optical Physics & Devices

Foundation and basis of operation of solid state opto-electronic devices.

555 Introductory Quantum Mechanics I **3 hrs.**

Waves and particles; Bohr's model of the atom; de Broglie waves, wave packets and the uncertainty principle; postulates of quantum mechanics; Schroedinger's equation; simple systems in one, two and three dimensions; the hydrogen atom. Prerequisites: PH 113, PH 351 or CH 343, MA 244, 324. (Same as PH 451, PH 551, CH 553, MTS 651.) Fall.

655 Applied Quantum Mechanics **3 hrs.**

Application of quantum mechanics in solid state, electronics, materials science and optics. Topics to include: Hydrogen atom and molecule, excitons, phonons, Bloch's theorem, periodic boundary conditions, electrons and holes, band structure of simple semiconductors, dipole transitions, optical constants, absorption and emission processes, introduction to device physics. Prerequisite: PH 551 or OSE 555, spring of odd numbered years (Same as PH 652.)

755 Quantum Devices **3 hrs.**

Quantum aspects of optical, electronic, and semiconductor devices approached from a phenomenological/physical point of view. Topics will include: Quantum well devices,

optical modulators, optical detectors, quantum Stark effects, electrooptic devices, high speed optical devices, frequency chirping in high speed devices and system applications. Prerequisite: PH 652 or OSE 655. Fall of odd numbered years. (Same as PH 733.)

C. Optical Engineering

Multi-disciplinary application of optics to the controlled propagation of light, imaging systems, and optical instrumentation.

656 Lens Design **3 hrs.**

Design of refractive imaging systems. Skills acquired include thin lens pre-design, first and third order analytical methods, and computer-based design using Zemax. Designs include: Wollaston and Chevalier landscape lenses, a 10X microscope objective, the Rapid Rectilinear and Celor lenses, Cooke triplet and Petzval portrait lenses, and a telephoto lens. Prerequisite: OSE 541. Fall.

670 Optomechanical Design and Fabrication **3 hrs.**

Practical aspects of optomechanical design, material selection, fabrication and integration of precision optical components and systems for commercial, space, and military application. Topics include: fixture design, tolerance analysis, machining methods, thermal stabilization, integrated computer-aided design and analysis, diamond machining, finishing and plating techniques. Prerequisite: OSE 541. (Same as PH 670.)

710 Optical System Design **3 hrs.**

Integrated view of what it actually takes to build a real optical system. All the tools of the "trade" are utilized, including conceptual design and computer modeling (optical and mechanical), control system design, fabrication issues, cost/schedule and system testing. Use of geometric and physical optics, radiometry, sources and detectors, electro-optics controlled positioning and feedback, environmental influences, optical systems architecture, opto-mechanical design, precision optics fabrication technologies, optical metrology, and operational and survivability testing. Prerequisite: OSE 670.

690/790 Selected Topics in Optical Science & Engineering **3 hrs.**

Sample topics include optical thin films and optical instrument systems analysis.