

ENEE 408E OPTICAL SYSTEM DESIGN

Fall Semester 2004. TuTh 11:00 - 12:15, CSI 1115

Instructor: Professor Christopher C. Davis, davis@eng.umd.edu,
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Office Hours: TuTh 2:00 - 3:30 pm, and by appointment. I am generally available to talk with students when I am in my office.

TAs Shawn Ho (shawnho@eng.umd.edu) and Sugianto Trisno (strisno@eng.umd.edu). Both TAs are in room 2307. TA consultation hours TBA.

If you have a documented disability and wish to discuss academic accommodations with me, please contact me as soon as possible.

The purpose of this course is to teach optical analysis and design techniques by reference to the performance of many different optical components and systems. Attention will be given to real world design in terms of component selection, optimization, and integration into systems.

Most projects will require computer analysis. and graphical results presentation. I encourage the use of software such as Mathcad, Mathematica, or Matlab. Familiarity with a CAD package would be helpful, but is not required. The optical design software *Code V* will be used in the early part of the course. This software is available on selected computers on the Electrical Engineering Department UNIX network. Special training sessions will be scheduled early in the semester to make students familiar with elementary features of this software. Remote users will need to contact their local network administrator to learn how to acquire X-term access to the University of Maryland Glue network. I anticipate that some students may have local access to optical design software such as *Code-V*, *Zemax*, or *Oslo*, and others. The use of any such software will be acceptable in lieu of Code-V.

Students will be asked to design optical systems at various times during the course. They will present rationales for component selection, layout, and system analysis.

Examinations and Projects

There will be two mid-semester examinations on dates to be decided later.

The final examination is in class on Monday, December 13, from 8:00-10:00.

Examinations will test your ability to apply design techniques to simple systems, to explain these design techniques, and demonstrate practical knowledge of issues involved in overall system design.

There will be an individual project assignment approximately every two weeks. These project assignments will test your ability to use various design and analysis techniques that will be covered in the class. These projects will include component design analysis and complete system characterization and optimization using Code V.

There will be a semester-long team-based design project, which will involve research into component suppliers, prices, and overall system design. In this project each team will be required to prepare a Powerpoint poster for presentation at the Capstone Design Review Day in the Spring 2004 semester. There will be an ethics component to this project, taught by Steve Norton, which will be discussed in the class with reference to examples and based on the IEEE Code of Ethics.

Students in the class are required to honor the University of Maryland Code of Academic Integrity. Details of this code are available at the University's web site.

Anyone who misses an examination for a *valid* reason (illness or family emergency) will be permitted to take a cumulative makeup examination just before the final examination. Students should

provide notification in advance if they will have to miss an assignment or examination for reasons of religious observance.

Grading

Mid-semester examinations 20% each, Final examination 30%, Individual Projects 15%, Team Project 15%. Performance in project work will be especially important in determining your overall grade and will be the deciding factor in borderline cases.

Book

There is no single ideal book for this course but Professor Davis's book *Lasers and Electro-Optics*, by Christopher C. Davis, published by Cambridge University Press, contains much of the material for the course, together with additional material not needed for ENEE 408E. The principal chapters to be covered are: 6,14,15,16,17,18, and 22. Additional handouts will be supplied.

The trade publications Laser Focus Buyers Guide (published by Laser Focus) and the Photonics Buyers Guide (published by Photonics Spectra) will be very useful in identifying manufacturers of system components.

Course Synopsis:

Most of the following topics should be covered – not necessarily in the order indicated.

- (1) Ray Optics: Basic Design Techniques
 - Reflection, refraction and total internal reflection
 - Paraxial ray analysis: ray transfer matrices, principal planes
 - Ray tracing
 - Lenses, mirrors and prisms
 - Imaging, magnification, f/number
- (2) Wave Optics in Isotropic Media: Detailed System Analysis
 - Impedance methods
 - Anti-reflection coatings, half-wave layers, Brewster's angle
 - Polarization effects and analysis: Jones matrices
 - Interference
 - Diffraction
 - Gaussian beams
 - Focusing of Gaussian beams
 - Resonator design
- (3) Optical Instruments: Design Concepts
 - Stops, pupils and vignetting
 - Simple microscope
 - Compound microscope
 - Astronomical and terrestrial refracting telescopes
 - Reflecting telescopes
 - Periscopes
 - Zoom lenses
 - Camera lenses
- (4) Aberrations
 - Spherical aberration
 - Astigmatism
 - Chromatic aberration
 - Coma
 - Distortion

- Curvature of field
- Non-spherical lenses and mirrors
- Quantification of aberration coefficients
- Reduction of aberrations
- (5) Wave Optics in Anisotropic Media
 - Birefringence
 - The indicatrix
 - Wave-plates and polarizers
 - Faraday effect and optical isolators
 - Electro-optic devices: amplitude and phase modulators
 - Designing with crystals
- (6) Fiber Optics: Selection and Utilization
 - Numerical aperture
 - Single and multi-mode fibers
 - V-number
 - Coupling to fibers
- (7) Optical Sources: Selection and Evaluation
 - Radiometry and Photometry: units and definitions
 - Point sources, extended sources, Lambertian sources
 - Characterization by spectrum and coherence
 - Black-body sources for absolute calibration
 - Incandescent lamps
 - Discharge lamps
 - LEDs
 - Lasers
- (8) Optical Detectors: Selection and Evaluation
 - Figures of merit, NEP, D^* , Responsivity, speed of response
 - Vacuum tube devices: photodiodes, photomultipliers, channeltrons
 - Semiconductor detectors: photovoltaic and photoconductive detectors
 - Thermal detectors: thermopiles, Golay cell, bolometer
 - Hot carrier detectors
- (9) Optical Systems: Design Concepts
 - Design Examples: Spectrometers; Interferometers: Michelson, Mach-Zehnder, Fabry-Perot;
 - Optical Communication Systems
 - Optical Design Software
 - Opto-Mechanical Design
 - Project Feasibility
 - Manufacturability, Cost Estimation
- (10) Safety Issues Related to Laser Radiation
- (11) Design Documentation

GENERAL REFERENCES

Comprehensive (General) Optics Texts

M. Born and E. Wolf, Principles of Optics, 7th edition, Cambridge University Press, Cambridge, 1999.

E. Hecht, *Optics*, 3rd Edition, Addison-Wesley, Reading, Massachusetts, 1998

R. W. Ditchburn, *Light*, 3rd edition, Academic Press, New York, 1976.

F. A. Jenkins and H. E. White, *Fundamentals of Optics*, 4th Edition, McGraw-Hill, New York, 1976.

M.V. Klein and T.E. Furtak, *Optics*, 2nd Edition, Wiley, New York, 1986.

R. S. Longhurst, *Geometrical and Physical Optics*, 3rd. Edition, Longman, London, 1973.

F. G. Smith and J.H. Thomson, *Optics*, 2nd Edition, Wiley, Chichester, 1988.

J. Strong, *Concepts of Classical Optics*, Freeman, San Francisco, 1958.

Applied Optics

W.J. Smith, *Modern Optical Engineering*, 2nd Edition, McGraw-Hill, New York, 1990

Applied Optics and Optical Engineering, R. Kingslake, Ed., Academic, New York, Vol. 1, 1965; Vol. 2, 1965; Vol. 3, 1965. Vol. 4, 1967; Vol. 5, 1969.

L. Levi, *Applied Optics*, Wiley, New York, Vol. 1, 1968; Vol. 2, 1980.

Lens Design

W.J. Smith, *Modern Lens Design: a resource manual*, McGraw-Hill, New York, 1992.

R.R. Shannon, *The Art and Science of Optical Design*, Cambridge University Press, Cambridge, 1997.

M. Laikin, *Lens Design*, Marcel Dekker, New York, 1991.

J.H. Moore, C.C. Davis, and M.A. Coplan, *Building Scientific Apparatus*, 3rd Edition, 2002, Perseus Books Cambridge, Massachusetts.

Fiber Optics

J. Hecht, *Understanding Fiber Optics*, 3rd Edition, Prentice-Hall, Upper Saddle River, New Jersey, 1999.

A. Ghatak and K. Thyagarajan, *Introduction to Fiber Optics*, Cambridge University Press, Cambridge, 1998.

J. C Palais, *Fiber Optic Communications*, 4th Edition, Prentice-Hall, Upper Saddle River, N.J., 1998.

Other Useful Reference Books

Handbook of Chemistry and Physics, 81st. edition, David R. Lide, Ed., CRC Press, Boca Raton, Fla., 2000.

G. W. C Kaye and T. H. Laby, *Tables of Physical and Chemical Constants*, 15th edition, Longman, London, 1986.