

Welcome to BME 495: Advanced Physical and Applied Optics

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Meeting times: Tuesday 2 - 5pm, L170

This course will provide a rigorous introduction to the theory and applications of the state-of-the-art physical optics. Coverage includes wave optics, Gaussian optics, Fourier optics, light propagation in continuous and turbid media, light scattering, statistical optics, and fiber optics. The course will consist of lectures, case studies and student presentations. The grading will be based on student presentations, homework assignments, and design projects.

Required textbooks:

Principles of Optics, Born and Wolfe (Cambridge University Press)

Fundamentals of Optics, Saleh and Teich (John Wiley & Sons)

Syllabus:

I. Fundamentals of Physical Optics

- **Lecture 1: Electromagnetic Optics** (Maxwell's equations, material equations, boundary conditions, wave equation, solutions of the wave equation, plane, spherical, and inhomogeneous waves, harmonic waves, monochromatic waves, wave groups, phase velocity, group velocity, polarization, Stokes parameters)
- **Lecture 2: Statistical Optics I** (temporal coherence, spectral composition and coherence, interference of partially temporally coherent waves)
- **Lecture 3: Statistical Optics II** (spatial coherence, interference of partially spatially coherent waves, propagation of partially coherent waves through optical systems, interferometry, partial polarization, Jones' matrix formalism, OCT as an example of the application of partial temporal coherence, enhanced backscattering as an example of the application of partial spatial coherence)

II. Light Scattering Phenomena

- **Lecture 4: Light Scattering I** (integral equation of scattering, near field and far field light scattering, Born approximation, scattering matrix formalism, scattering cross section, optical theorem, unitary and reciprocity relations)
- **Lecture 5: Light Scattering II** (Rayleigh scattering, Rayleigh-Gans approximation, Mie theory, WKB and Van de Hulst approximations)
- **Lecture 6: Light Scattering in Continuously Heterogeneous Media** (scattering coefficient and volume-averaged total scattering cross section, refractive index correlation function, Born approximation)
- **Lecture 7: Multiple Light Scattering and Propagation in Random Media** (Liouville-Neumann series, Rytov series, Transport theory, Two-flux approximation, approximations to the transport equation: diffusion approximation, delta-Eddington approximation, P-3 approximation)

III. Applied Physical Optics

- **Who Wants to Be a Millionaire I:** Gaussian Optics (Hermitte-Gaussian beams, Laguerre-Gaussian beams)
- **Who Wants to Be a Millionaire II:** Fiber Optics (step and graded-index fibers, NA, V parameter, number of modes, multimode vs. single mode fibers, attenuation and dispersion)
- **Who Wants to Be a Millionaire III:** Fourier Optics (optical Fourier transform, application of Fourier optics for light focusing, modulation, scanning and all-optical analog image processing)
- **Journal Club I:** Origin of Light Scattering in Biological Tissue
- **Journal Club II:** Application of Light Diffusion for Tissue Diagnosis, Diffraction/Diffusion Tomography
- **Journal Club III:** Advancements in Optical Microscopy
- **Everything-you-wanted-to-know-about-optics-but-were-afraid-to-ask**
- **Student Projects I & II**
- **Student Project III**

Suggested Design Projects:

Optical Computing
Negative Refractive Index Optics
Holography
Optical Biomolecular Assays
Resonance Light Scattering in Molecular Diagnostics

Student Participation:

Throughout the course, students will work in groups. Each group will

- (1) give a **talk** discussing a recent publication of student's choice,
- (2) participate in an **interactive quiz**, "Who Wants to Be a Millionaire",
- (3) complete an original **design project** and present the results.

Grading:

Design Project: 40%
Journal Club: 15%
Who Wants to Be a Millionaire: 15%
Homework assignments: 20%
Participation: 10%