Physics 570
Physical and Fourier Optics
Spring 2014

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Class: Berthoud 204 11-12:05
Office hours: TBD

Summary:
This course will address topics related to the propagation of light through optical systems. Such an understanding is essential to being able to work with modern optical technology. Diffraction theory shows that the field distribution at the focal plane of a lens is the 2D Fourier transform of the field transmitted through the lens. This enables the use of linear systems theory (transfer functions, convolution) to describe imaging systems: microscopes, spectrometers, holography. We will also cover topics in ultrafast optics, waveguides, and beam propagation. To increase the utility of the course, we will use some numerical methods to be able to calculate beam propagation in complex systems.

Text and resources:
The books we are using are *Introduction to Fourier Optics* by Goodman (3rd edition).
Several others that can be useful:
Griffiths: *Introduction to Electrodynamics* (3rd edition) (text from PHGN462)
Hecht: *Optics*
Lipson: *Optical Physics*
Guenther: *Modern Optics*
Siegman: *Lasers* especially (good for beam propagation and ABCD methods)
Born and Wolf: *Principles of Optics* (this is the classic reference text)
Gaskill: *Linear Systems, Fourier Transforms, and Optics* (good basic intro to Fourier methods in optics, on reserve in library).
Yariv: *Quantum Electronics* (more of a lasers book, but has good sections on Gaussian beam propagation and nonlinear optics).
Bracewell: Fourier Transforms and Applications (on reserve in library).

Course website:
The course website will be on the Physics Wiki page. See this for notes, Mathematica demos, journal references.

Computation:
Most of the modeling and calculations will be done with Mathematica. Some of you who know the raytracing program Zemax may find that useful.

Homework:
The homework will be most every week. You will be able to pick up the homework assignment from the course website.

Class participation:
This will include attendance, participation in classes and in-class exercises. I also encourage you to post journal references to add to the bibliography on the website.

Project:
Instead of a final, you will do a mini-research project that will involve some literature research and calculations. You will need to write it up, and give a ~10 min presentation to the class on your findings. In the spirit of making sure the project is useful, we can coordinate with your advisor to identify a calculation that is relevant to your research.

Grading proportions:

The proportions to the grades will be subject to change

Homework	35%
Class participation	5%
Midterm	25%
Final project	35%

Syllabus (subject to change. *italicized* items are special topics that we may not have time for)

- 1D Fourier techniques with applications to ultrafast optics (t-ω domain)
  - Fourier transform techniques
    - Shift, scale, modulation, convolution, etc.
    - Application to intuitive analysis
    - Fourier transform spectrometers (FTIR)
    - Temporal coherence
  - Linear systems theory
    - impulse response and transfer functions
    - amplitude and phase filters
    - Dispersive propagation, pulse compression
  - Numeric techniques
    - Sampling theory, FFT and numeric convolution
    - Fourier split-step method applied to pulse evolution
  - Advanded applications topics:
    - *Pulse shaping/synthesis, Gerchberg-Saxton optimization*
    - *Pulse characterization*
    - Alternative representations of t-ω space – *Wigner transforms*
    - *Modeling nonlinear pulse propagation: pulse compression, soliton dynamic*s
- Physical optics and wave propagation
  - 2D Fourier transforms (spatial/spatial frequency domain)
    - Cartesian coordinates: angular plane wave spectrum
    - Cylindrical coordinates: Fourier-Bessel transforms
  - Scalar diffraction theory
    - Fresnel and Fraunhofer diffraction
    - Fresnel calculation of propagation of Gaussian and arbitrary beams
    - Wavefront characterization techniques
  - Modal decomposition
    - Hermite-Gauss and Laguerre-Gauss beams
    - Vortex beam
    - *Bessel and Bessel-Gauss beams*
    - Waveguide modes: index guiding, *surface plasmons*
    - *Leaky modes*
  - Fourier split-step method applied to beam propagation
    - Free-space propagation
    - Applications: integrated optics, *resonators*, *nonlinear beam propagation*
    - Spatio-temporal methods
- Imaging and holography
  - Abbe imaging theory
    - Frequency analysis of imaging systems (MTF, OTF)
    - Spatial filtering and optical processing
  - Microscope and imaging systems using Fourier techniques
  - Beam shaping
    - Spatial light modulators and deformable mirrors
    - *Diffractive optics and phase plates*
  - Holography and spectral interferometry