OPTI 512R- Linear Systems, Fourier Transforms

Course Description:
Mathematical background, convolution, the Fourier transform, linear filtering and sampling, two-dimensional operations, diffraction, image formation. Prerequisites: MATH 223, PHYS 142 & PHYS 241.

Learning Outcomes:
At the conclusion of this class, the student will be able to

- Write the formulae for 1D and 2D convolution and Fourier transform and apply these to common examples found in optics.
- Apply theorems such as the convolution theorem, the shift theorem and the scaling theorem to broaden the application of and simplify the solving of common problems in optics.
- Use Fourier theory to analyze sampled systems such as digital image sensors to understand the implications of finite pixel size and finite spacing.
- Use Fourier theory to filter signals to extract useful information such as edges and patterns.
- Use Fourier theory to perform beam propagation for both free-space and systems with lenses.

Textbook:
Recommended
Tyo, JS, Alenin A. Field Guide to Linear Systems in Optics. SPIE Press. 2015.
Gaskill, Jack D. Linear Systems, Fourier Transforms, and Optics. Wiley Interscience 1978.
Goodman, Joseph W. Introduction to Fourier Optics. 4th ed. Freeman & Company. 2017.

Outline
Mathematical Background and Linear Systems Theory
1. Complex numbers
2. Special functions, the impulse function and functions based on the impulse
3. Harmonic Analysis and the Fourier Series, truncated Fourier series
4. Operators and Linear Shift-Invariant Systems
5. Convolution and its properties
6. Fourier Transform and its properties
7. Convolution Theorem and other special theorems for the Fourier transform (Rayleigh energy, moment, Wiener-Khinchine)
8. Two-dimensional functions, Fourier transforms, and convolution. The Hankel transform and the Radon transform.

Signal Processing and Sampling
9. Filters: Low Pass, High Pass, Band Pass; Amplitude and Phase Filters
10. Signal processing, noise reduction, equalization
11. Sampling and Reconstruction; Aliasing
12. Discrete Fourier Transform and Discrete Convolution

Linear Systems applied to Electromagnetic Wave Propagation and Diffraction

13. Plane waves, the plane wave spectrum
14. Gaussian beam propagation
15. Spherical waves and Fraunhofer diffraction
16. Fresnel Diffraction, the Fresnel transform
17. Fresnel diffraction from circular apertures, Fresnel zone plates