## EEE 428/551 Optics: Learning Objectives Haldun M. Özaktaş October 2005

- 1. To understand the behavior of light rays travelling in free space and incident on reflective surfaces and refractive index discontinuities. To be able to trace rays through optical systems involving such features. To understand the concept of ABCD matrices and to be able to use them to analyze and design simple optical systems. To understand Fermat's principle, the ray equation, and the eikonal equation as three equivalent statements of the laws of geometrical optics.
- 2. To understand the scalar wave model of light and elementary solutions of the wave equation and its paraxial approximation. To understand the concept of a wavefront and to be able to visualize waves in terms of their wavefronts. To understand geometrical optics as the small wavelength limit of wave optics and the relationship between rays and wavefronts. To understand the effect of thin transmissive components on optical waves. To understand the interference of two or more optical waves.
- 3. To understand Gaussian and Hermite-Gaussian beams as solutions of the paraxial wave equation. To understand the interpretation of the beam diameter and wavefront radius in physical terms and by observing how these parameters vary along the optical axis. To be able to visualize Gaussian beams in terms of their intensity envelopes and wavefronts. To be able to determine the beam diameter and wavefront radius of a beam at one axial location in terms of those at another axial location, upon passing through thin lenses, and upon passing through more general systems characterized by ABCD matrices.
- 4. To understand the relationship between the direction of propagation of a plane wave and the spatial frequencies of its two-dimensional transverse profile. To understand how arbitrary propagating waves can be decomposed into plane waves. To be able to determine the optical field at a given plane in terms of that at another plane parallel to it in terms of the formulation of propagation as a linear shift-invariant system. To be able to analyze arbitrary optical systems consisting of thin lenses and sections of free space using the linear system formulation. To be able to design linear shift-invariant spatial filtering systems. To understand and be able to estimate the resolution and spatial frequency filtering characteristics of simple optical systems. To understand the fundamental principles of holography and synthesis of complex spatial filters.
- 5. To understand how absorption and dispersion in optical media can be characterized. To understand the propagation of temporal pulses in dispersive media through a linear systems approach and concepts such as group velocity and pulse broadening.
- 6. To understand the characterization of polarization and the effects of systems on polarization through the Jones vector formulation. To be able to analyze and design systems composed of simple polarization altering devices. To understand the optics of anisotropic media in terms of the index ellipsoid and to be able to analyze the propagation of waves in arbitrary directions in such media.
- 7. To understand how the wave equation is solved in waveguide geometries and how arbitrary solutions can be composed in terms of modes. To be able to determine parameters such as the cut-off frequency, number of modes, propagation constant, group velocity, fraction of energy in core for mirror and dielectric waveguides and be able to physically interpret them. To understand the physical origins and different kinds of attenuation and dispersion in optical fibers and their effects on propagating pulses.

- 8. To understand light as a random process and its characterization in terms of space and time correlation functions. To understand the effect of degree of correlation, known as coherence, on interference and diffraction for simple optical experiments.
- 9. To complement theoretical, analytical, and design capabilities in optics with hands-on experience in the optics laboratory, and developing the basic skills essential for experimental work in optics, such as learning elementary techniques such as aligning laser beams. To understand the importance of laser safety and to habitually internalize safety precautions. To learn to respect and care for equipment. To become familiar with both opto-mechanical equipment and optical components and instruments,
- 10. To observe experimentally the laws of geometrical optics and to measure optical power. To experiment with imaging systems based on mirrors and lenses and observe aberrations. To observe interference in various elementary configurations and interferometers. To be able to measure parameters of Gaussian beams. To demonstrate Fourier transforms in the far field and with a lens, and to be able to perform spatial filtering in the Fourier domain. To observe the results of classical diffraction experiments involving edges, apertures, gratings and to reconstruct a hologram. To observe the effects of linear polarizers, the relation between reflection and polarization, and to verify the Fresnel equations of reflection. To observe the effects of quarter-wave and half-wave plates and measure the optical activity of a medium.