Fourier Optics EOP 513
Second Exam (in-class) 23 July 2003

1. Give the name (if defined) and explain the significance of the following groups of constants and the circumstances in which they arise.

   (a) $\sqrt{\lambda z}$

   (b) $\frac{w^2}{\lambda z}$

   (c) $\frac{\lambda}{w}$

   (d) $\frac{\lambda z}{w}$

   (e) $\frac{w^2}{\lambda}$

   where λ is the wavelength, w is the half-width of a slit or aperture, and z is a propagation distance. (10 points)

2. Draw a diagram illustrating the definition of effective Fresnel number for a focusing lens. Identify the location of the Fraunhoffer plane and its corresponding effective Fresnel number. (5 points)

3. Given the function

$$h_{12}(x, y) = \frac{e^{jkz_{12}}}{j\lambda z_{12}} \exp\left[j\frac{\pi}{\lambda z_{12}}(x^2 + y^2)\right]$$

   where z_{12} is the axial distance from a source aperture to an observation location. Explain how the function is used in a diffraction integral, its physical significance in that context, and the domain (pupil or image) of the (x, y) coordinates. (5 points).

4. Find the analytic expression for the incoherent optical transfer function of a system with a square lens of width $2w$ and focal length f for wavelength λ and object at infinity. (5 points)

5. Define (3 points each)
   (a) fringe visibility

   (b) photographic density

   (c) Hurter-Driffield curve

   (d) Fourier-Bessel (Hankel) transform

   (e) Strehl ratio

6. Given an NeNe laser beam ($\lambda = 633$ nm) with a Gaussian beam waist of $b = 1$ mm located 150 mm in front of a 25 mm focal length lens. Find the approximate location and size of the imaged beam waist. (5 points)

7. Explain the difference between coherent and incoherent light. (5 points)

8. Compare the imaging properties of coherent and incoherent optical systems in terms of convolution. (5 points)

9. Give an expression for the mutual coherence function (or mutual intensity) used to describe partially coherent light. (5 points)

Fourier Optics EOP 513
Second Exam (Take-Home)
Due 24 July 2003

1. Given an NeNe laser beam ($\lambda = 633$ nm) with a Gaussian beam waist of $b = 1$ mm located 150 mm in front of a 25 mm focal length lens. (10 points)

   (a) Find the exact distance to and size of the imaged beam waist.

   (b) Repeat the calculation for a wavelength of $\lambda = 10.6$ μm.

2. An input function U_o, bounded by a circular aperture of diameter L and illuminated by a normally incident plane wave, is placed in the front focal plane of a circular positive lens of diameter D. The intensity distribution is measured across the back focal plane of the lens. Assume $D > L$. (10 points)

   (a) Find an expression for the maximum spatial frequency of the input for which the measured intensity accurately represents the squared modulus of the input's Fourier spectrum (free from effects of vignetting).

   (b) What is the numerical value of this spatial frequency (in cycles/mm) when $D =$ 4 cm, $L = 2$ cm, f (focal length) $= 50$ cm, and $\lambda = 0.6$ μm?

3. Use the Matlab function `quad` to numerically generate a plot of the Fourier-Bessel transform of $r^2\mathrm{Gaus}(r)$. Compare the result to the result obtained using `fft2`. (10 points)

4. Plot the point spread function versus image radius for a unit-radius circular pupil with $A = 3$ waves of fourth-order spherical aberration, that is, a multiplicative phase factor of $\exp(j2\pi Ar^4)$. Then plot the Strehl ratio of the point spread function as a function of the magnitude A of the aberration over a range of A sufficient to decrease the Strehl ratio below one-fourth. (10 points)