MASSACHUSETTS INSTITUTE OF TECHNOLOGY

2.997 Optical Engineering **Fall '99**

Assignment #8 Posted Nov. 24, 1999 — Due Dec. 1, 1999

1. **Diffraction gratings.** Describe in detail a procedure that allows the measurement of the amplitude (*i.e.*, magnitude and phase) of the diffracted orders generated by a thin transparency with periodic modulation.

2. **Dot pattern generator.** We wish to generate an arbitrary pattern composed of small dots on a screen. The dots are constrained to lie on a regular grid of periodicity d in either direction, and the brightness of the dots is arbitrary but specified as a design parameter. Describe a design procedure that will accomplish that goal. Discuss possible difficulties that may arise in your implementation.

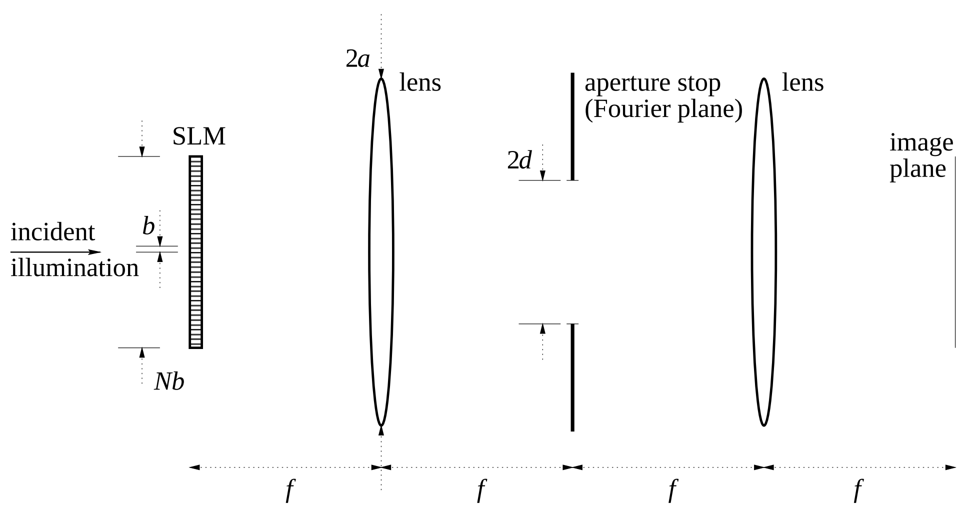
3. **Computational spatial filtering.** In this problem we will explore the consequences of spatial filtering on images using MATLAB. Consider a single-lens imaging system with lens focal length $f = 5$cm, lens radius $a = 2$cm, and object and image distances $z_1 = z_2 = 10$cm, respectively.

   3.a) Plot the transfer function and impulse response of the imaging system.

   3.b) Download an arbitrary image from the Web. Import the image in MATLAB (e.g., using the function `imread` or equivalent), convert it to square shape (e.g., truncate the longer side), remove colors (e.g., add together all the three color components), and add an empty (black) strip surrounding the image. Then pass the image through the spatial filter you computed in part (1). State clearly how many pixels your image had, and the pixel size that you selected in order to perform the simulation.

   3.c) Explain the significance of the pixel size and number of pixels and how they affect your results.

4. **Space-bandwidth product of a 4F imaging system.** Consider the system shown below, where a pixelated spatial light modulator (SLM) is illuminated by a plane wave at normal incidence. The size of each pixel is b, and there are N pixels in total. The resulting optical field is input to a 4F imaging system. The lenses composing the 4F system are identical with radius a and focal length f.



   4.a) Argue that the first diffracted order with highest spatial frequency which can be modulated on the beam by the SLM is $u_{\max} = 1/(2b)$. Assume $N \gg 1$ so that you can ignore edge effects in your justification.

   4.b) Require that the first diffracted order generated by a grating of spatial frequency $u_{\max}$ be transmitted by the lens over the entire lateral extent of the SLM; show that the requirement results in an upper limit $N_{\max}$ on the number of pixels N, and calculate $N_{\max}$. (Again, ignore edge effects).

4.c) Ignoring edge effects still, calculate the lateral extent of the field on the Fourier plane of the system (*i.e.*, calculate the stop size d). Can you now justify the designation of $N_{\max}$ as the *"space-bandwidth product"* of the imaging system?

4.d) Describe qualitatively what the image looks like when the system operates at its space-bandwidth product limit. Which of the above assumptions are critical for your conclusion?

4.e) (optional) Which fundamental physical principle does the upper limit on the space-bandwidth product remind you of? Discuss how the analogy comes about from both mathematical and physical perspectives.

5. JG problem 6-1, pp. 165-166.

6. JG problem 6-3, pp. 166-167.

7. JG problem 6-10, p. 169.

8. JG problem 6-11, p. 169.