MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Mechanical Engineering

2.71/2.710 Optics
Spring 2014

Quiz 2

(Take Home, Open Book and Notes)

Posted: Wednesday, April 23, 2014

Written part Due: Wednesday, April 30, 2014
Please schedule a 30 minute individual meeting on April 30 and May 1

Estimated time: 90min

TOTAL PAGES: 3

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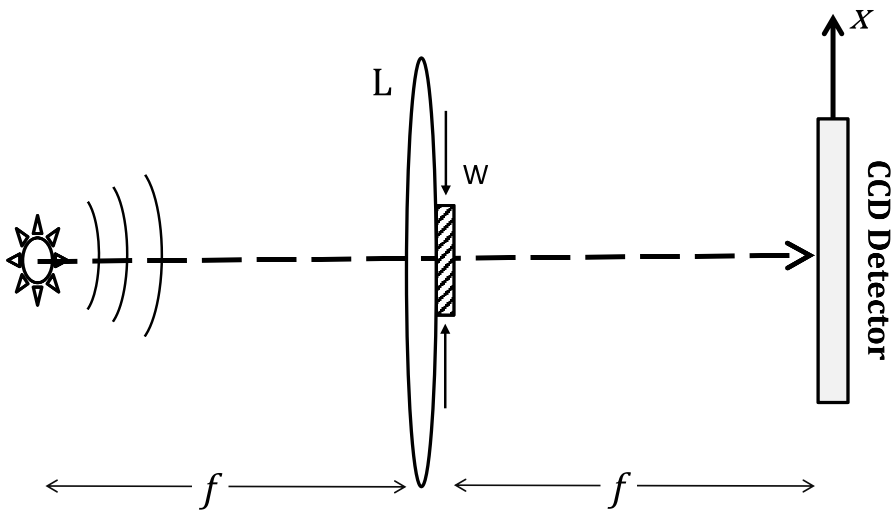
1. The following figure illustrates a simplified Billet's split lens setup for interference. A point source is placed at the front focus of a convex lens with a diameter D. On the back for the convex lens, a thin, totally opaque block of width W is used to separate light passing through the upper and lower half of the lens. On the back focal plane, alternating dark and bright fringes are collected using a CCD detector. For simplicity, please assume a 2D problem (i.e., y=0).



Let's assume the lens is is placed at the plane $z = 0$ and illuminated by a spherical wave originating on–axis at location $z = -f$ (where $f > 0$.) Using the paraxial approximation for the spherical wave (y=0),

$$E(x, z = 0) = \left\{ E_0 \frac{\exp[ik(z + f)]}{i(z + f)} \exp[ik \frac{x^2}{2(z + f)}] \right\}\Bigg|_{z=0}$$

a) Derive an expression of the total E field that arrived at CCD detector;

b) Argue that the expression that you derived can be regarded as a coherent superposition of three spherical waves;

c) Discuss the origins (source position) of these spherical waves;

d) Explain how this diffraction pattern would change if the illumination were to move off–axis by a distance x_0, *i.e.*

$$E(x, z = 0) = \left\{ E_0 \frac{\exp[ik(z + f)]}{i(z + f)} \exp[ik \frac{(x - x_0)^2}{2(z + f)}] \right\}\Bigg|_{z=0}$$

2. We are given a 4F imaging system consisting of two identical lenses L_1, L_2 with focal length f =10cm. As an experiment, you attached a square mesh grid as amplitude mask at the pupil plane of the imaging system. In all questions below, the illumination is assumed to be at wavelength λ = 0.5µm. Assume spatial period Λ = 10μm, stripe size d = 2μm, and edge lengths a = 5mm, b = 3mm.

   Hint: First calculate the Fourier transforms of the grid and the aperture individually. Then use the convolution theorem.

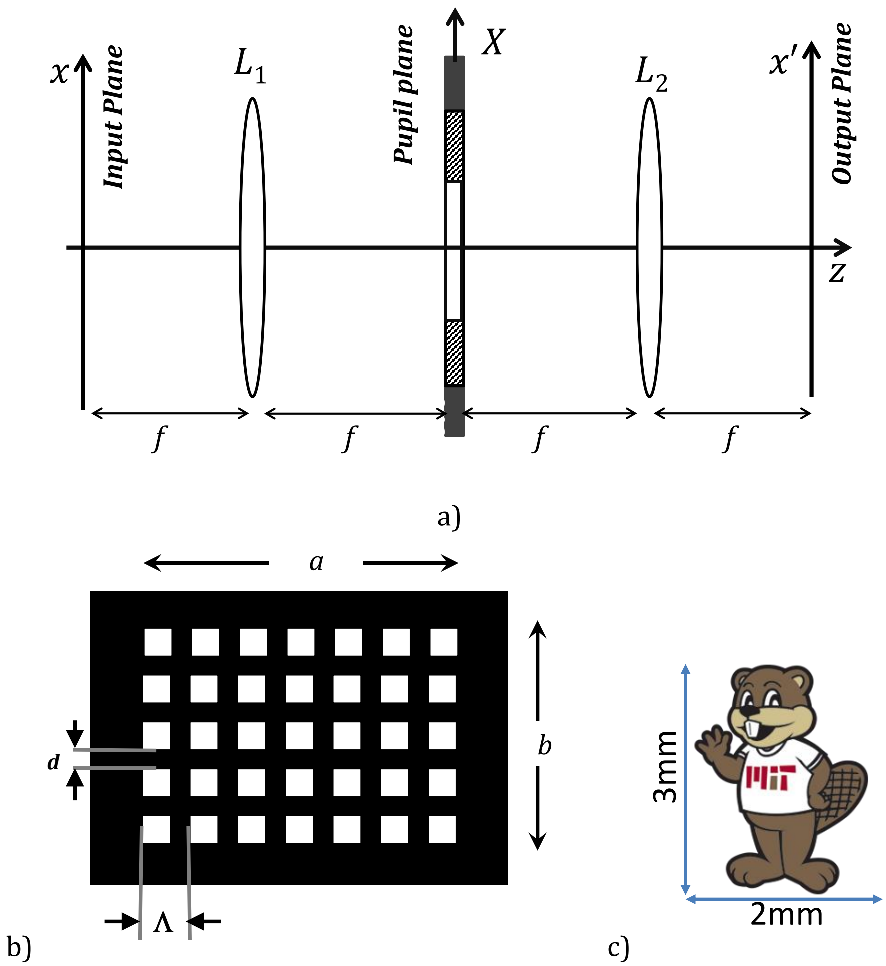


Figure 2. 4F imaging system with a square mesh grid as amplitude mask (dark area is completely opaque, and white area is transparent) placed at pupil plane(X, Y).

a) Let's consider a coherent plane wave illuminating the input plane. Please calculate the output field and sketch the intensity pattern.

b) Now coherent a point source is placed at the origin of the input plane(x=0), please calculate and plot the light intensity at the output plane with actual size of your image.

c) (**2.710 only**) Let's put a transparent stamp of the Tim the beaver at the input plane. The stamp measures 2mm wide and 3mm tall. What is the image at the output plane? Feel free to download one online and use Matlab to plot the resulting image.

GOOD LUCK!

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