Lab # 9 - Diffraction I

The purpose of this lab is to observe and quantify Fresnel and Fraunhofer diffraction patterns of various objects and to observe the transition between the two regions.

Preparation:

Review notes on diffraction, Fresnel number, and Babinet's principle. See Siegman Chapter 18. Be familiar with Talbot imaging. Do part (2) under the Straight Edge experiment. You may use the software in the lab to calculate the Fresnel pattern from a straight edge. Also, please look on Jim Wyant's web page at http://wyant.opt-sci.arizona.edu/math.htm for some fun diffraction calculations.

Fresnel Diffraction

Straight Edge:

1) Have the lab TA place a clean razor blade in the aperture plane. Focus to obtain a crisp image of the edge.

2) (*Do before class.) Use a software package to graph the diffraction pattern observed for λ = 670 nm at a distance of 50 mm from the edge. You may use the computer in the lab for this purpose.

3) Defocus to obtain 4 to 6 fringes on the bright side of the edge. Obtain a line profile and compare the result with part (2).

4) Observe the fringe pattern as the focus is changed.

5) Have the lab TA remove the razor blade.

Circular Aperture:

1) Place one of the circular apertures in the aperture plane. Focus to obtain a crisp image of the aperture.

2) Observe the diffraction pattern at several focus positions toward the Fraunhofer region.

3) Set the focus for a Fresnel Number (N) of 5. Obtain a line profile of the pattern, and compare with theoretical graphs from Siegman, Ch. 18, as shown in accompanying pages. Now focus at N = 4 and repeat.

4) Adjust focus to observe the Fraunhofer region. Obtain a line profile and compare your result with theory.

Central Circular Obscuration:

1) Place the circular obscuration in the aperture plane. Focus to obtain a crisp image.

2) Adjust the focus until you observe a bright spot in the center of the obscuration. This is Poisson's Spot.

3) Adjust the focus slowly toward the Fraunhofer plane and observe the characteristics of the spot. It may be necessary to adjust the beam attenuator several times.

Single Slit:

1) Place the single slit in the aperture plane. Focus to obtain a crisp image of the aperture.

2) Observe the diffraction pattern as focus is changed to the Fraunhofer region.

Double Slit:

1) Place the narrow double slit in the aperture plane. Focus to obtain a crisp image of the aperture.

2) Observe the diffraction pattern as focus is changed to the Fraunhofer region. Comment on differences between single-slit experiment.

3) Place the wide double slit in the aperture plane. Focus to obtain a crisp image of the aperture.

4) Repeat part (2).

Angled Slits:

1) Place the angled slits in the aperture plane. Focus to obtain a crisp image of the aperture.

2) Slowly adjust the focus toward the Fraunhofer region. Sketch images of the pattern observed in the Fresnel region and note the orientation of the pattern with respect to the slits.

3) Adjust focus into the Fraunhofer region and observe the diffraction pattern. Note the orientation of the pattern with respect to the slits.

Talbot Imaging:

1) Place the middle-sized circular aperture and the fine grid in the aperture plane. Focus to obtain a crisp image of the aperture.

2) Slowly move focus toward the Fraunhofer region. Observe the first plane of contrast reversal.

3) Change focus to obtain the first Talbot image of the grid. Compare this image with the image obtained in part (1).

4) Move the focus toward the Fraunhofer region and observe how the diffracted orders grow. Explain the pattern observed in the Fraunhofer region.

Rectangular Aperture: (Collimated HeNe Illumination)

1) Observe the Fraunhofer pattern of the rectangular aperture at a distance of 2.0 m from the aperture.

2) Estimate the size of the aperture in both directions by measuring the diffraction pattern. Compare your results with the dimensions given you by the lab TA.

Questions:

1) How does the fringe pattern observed behind the straight edge vary as we change focus, which is essentially the observation distance? How does it change with λ?

2) Why don't we observe smooth rings in the Fresnel diffraction pattern of the circular aperture?

3) Plot qualitatively the on-axis irradiance observed in the diffraction pattern of a circular aperture versus observation distance.

4) With the central obscuration, does the central bright spot in the Fresnel diffraction region oscillate in intensity in the longitudinal direction? Why or why not?

5) Qualitatively explain the pattern you observed in the Fresnel and Fraunhofer regions of the angled slits.

6) What is the distance from the object to the first Talbot image for a grid spacing of 0.25 mm and λ = 670 nm? Assume collimated illumination.

7) Comment on how closely your observations matched theoretical results.

8) What are some effects that could be present in optical systems due to improper design of edges and apertures?

9) How could you reduce the effects of the problems encountered in Question 8?