**ECE 181**

**FRESNEL AND FOURIER TRANSFORMS**

## I. OBJECTIVES

To analyze and compare Fresnel and Fourier transform patterns generated by the following inputs: a circle, square, circle pair, grating, and letters T and A.

## II. REFERENCES

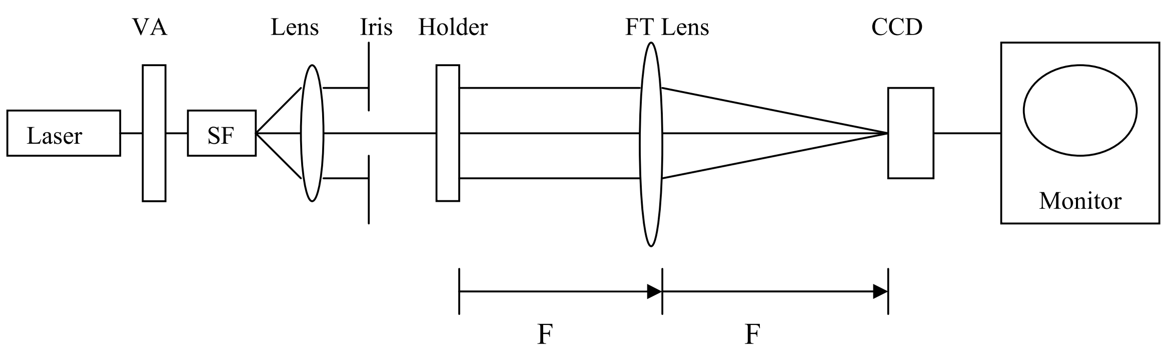
1. B. Saleh and M. Teich, *Fundamentals of Photonics,* Ch. 4, pp. 118-119, 121-134; Appendix A, pp. 924-926.
2. J. Goodman, *Introduction to Fourier Optics,* Ch. 4, pp. 63-81; Ch. 5, pp. 101-107.

## III. EXPERIMENTAL SETUP DESCRIPTION

The optical system used here is similar to the one used previously in the 'Diffraction' Lab. The system will take on two different configurations.

In the Fresnel transform section, the system is identical to the Diffraction Lab setup, with the slide holder being a free-standing unit that can be placed anywhere along the optical axis. However, the object slide must be placed at the appropriate distance from the recording system to obtain diffraction patterns in the Fresnel regime.

In the Fourier transform section, a lens will be used to place the Fourier plane in the imaging plane of the observation system (see figure below). The slide holder for the 35 mm format object slides will be fixed at one focal length in front of the lens. A CCD camera will be used in the imaging plane to view the transforms on a monitor. Monitor's video output is connected to computer and diffraction pattern generated by the object can be captured and saved.



## IV. EXPERIMENTS

For each of the two following sections, sketch the optical setup in your notebook. Label components and distances clearly.

### A. Fresnel Transforms

For this section, various slides will be placed within a specific distance Z from the imaging plane of the observation system. We will use an engineering approximation given by $Z < d^2/\lambda$, where $d$ is the aperture (opening) size of the object, and $\lambda$ is the wavelength of the laser light; for the Helium-Neon laser used in the lab, $\lambda = 0.633\mu m$.
For each slide, capture the generated image observed on the monitor and saved it as a bmp-file.

1. Place the slide with a SQUARE into the slide holder. The square has sides of 1 mm. Calculate Z for this aperture size and place the slide at the appropriate distance. Observe the Fresnel diffraction pattern generated in the image plane. Capture the image and save it.
2. Repeat (1) for the slide with a CIRCLE. The circle diameter is 1 mm.
3. Repeat (1) for the slide with a CIRCLE PAIR. Each circle's diameter is 0.5 mm.
4. Repeat (1) for the slide with a low frequency DIFFRACTION GRATING. The aperture size in each line pair is 0.25 mm.
5. Image and take a picture of the Fresnel diffraction pattern (at the appropriate distance Z) generated by the slide with the letter T. All arms of the letter are 1 mm wide.
6. Repeat (5) for the slide with the letter A.
7. Choose any object slide for this part, e.g. the letter T. Observe any changes in the diffraction pattern when the slide in the object plane is (i) rotated, and (ii) translated. Be sure that the rotation and translation occur only in the object plane. The result will indicate the variance or invariance of a Fresnel transform due to object rotation and translation.

### B. Fourier Transforms

For this section, a Fourier transform lens will be used. The lens should be placed along the optical axis such that (i) the imaging plane of the observation system is one focal length behind the lens, and (ii) the object slides are placed one focal length in front of the lens.

1. Before any object slides are used, the back focal plane of the lens must be placed in the imaging plane of the observation system. To do this, remove all object slides from the optical path, leaving just the collimated beam. Minimize the laser intensity. Place the lens in the optical path, approximately 375 mm (one focal length) away from the CCD camera. Then, while observing the output image on the monitor, adjust the position of the lens until the image shows the smallest spot possible. This means the recording system is now observing the focal point of the lens, and hence the lens is placed one focal length away. Secure the lens position with a locking screw. Position the slide holder 375 mm in front of the lens, and use a locking screw to secure its position.
2. Place the slide with a SQUARE in the slide holder. Observe Fourier transform pattern, capture and save the image.

3. Observe the Fraunhofer (far-field) diffraction pattern. An approximate distance for far-field would be ten times the Fresnel distance, which means mirrors may have to be used to increase the availability of "distance" since the optical table's length is limited.
   To see the Fraunhofer diffraction pattern use two mirrors: one placed in front of the FT lens and another one placed on the far end of the optical table. Aim and observe the diffraction pattern reflected from the mirrors on the observation screen, located on the opposite side of the optical table. (Another option to see far-field diffraction pattern is to remove the FT lens and CCD camera from their bases and see the image on the wall.)
4. Repeat (2 and 3) for the slide with a CIRCLE. Be sure to minimize the laser intensity before placing the CCD camera in the optical path, and then gradually increase the intensity for a good image on the monitor.
5. Repeat (2 and 3) for the slide with a CIRCLE PAIR.
6. Repeat (2 and 3) for the slide with a low frequency DIFFRACTION GRATING.
7. Image and take a picture of the Fourier diffraction pattern from the slide with the letter T. Compare its Fourier and Fraunhofer patterns.
8. Repeat (7) for the slide with the letter A.
9. Choose any object slide for this part, e.g. the letter T. Observe any changes in the diffraction pattern when the slide in the object plane is (i) rotated, and (ii) translated. Be sure that the rotation and translation occur only in the object plane. The result will indicate the variance or invariance of a Fourier transform due to object rotation and translation.