Department of Physics

Optical Fourier Transforms

Summary

In this project you will be supplied with the apparatus to produce a laser based 4F optical system in which the light in the Fourier plan can be manipulated. In particular spatial filtering can be investigated.

Possible goals of the experiment include investigating how the masking of light in the Fourier plan affects the pattern formed in the image plane and deducing the nature of various masks made available.

Equipment

The experimental apparatus supplied includes (but is not limited to):

- an optical bench space, with a bread board for attaching optical elements
- A Laser source (see safety note)
- A CCD camera for collecting images
- Optical elements including lenses and filters and diffraction gratings

Safety Note:

LASER SAFETY

Used without care laser light can be dangerous. If you look directly into a laser beam the light may be focused onto your retina with a high power density. NEVER look directly into the laser beam; and ensure that you block off any stray reflections from your experiment that might otherwise be sent to other regions of the laboratory. Laser safety goggles are available if you think you need them.

Background

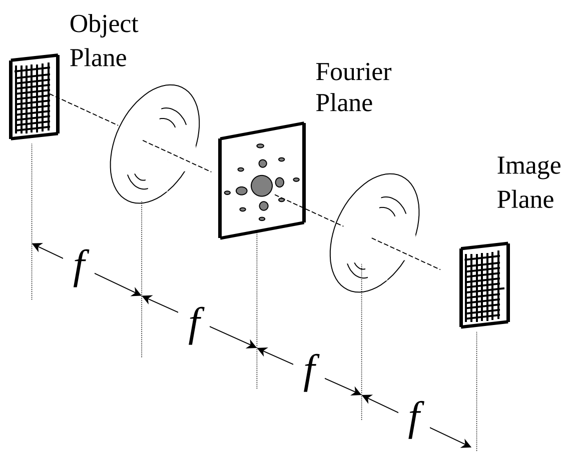
Before beginning this experiment you should familiarize yourself with the following concepts:

Fourier transforms, physics of diffraction gratings, image processing for CCD cameras. You should also write a basic python program to read in and manipulate the data from a bitmap image.

When a spatially coherent monochromatic plane wave illuminates an aperture, and the aperture is in the front focal plane of a lens, then a diffraction pattern is formed in the back focal plane of the lens that is an exact Fourier transform of the aperture's transmission function. If an object with a periodic transmission function is used, e.g. a diffraction grating, then the Fourier transform consists of discrete components, namely the fundamental frequency and its harmonics. If an identical set up of another lens placed a focal length behind the firs transform plane is used, and we look in the back focal plane of the second lens we expect to see the Fourier transform of the Fourier transform of the object, an image that is an inverted version of the object. The idea of spatial filtering is that by placing suitable masks in the transform plane it is possible to *modify* the spatial frequency components (i.e. to filter them), and consequently the object recreated is not an exact inverted version of the object anymore.

Initial experiments

Using the set up shown below with a diffraction grating in the object plane, measure the pattern in both the Fourier and object plane. Use a grating with 80 lines/mm as the object.



Spatial Filtering: an object is placed a distance *f* ,equal to the focal length, in front of a lens. The Fourier plane is a distance *f* behind the lens - the Fourier Transform of the object is obtained here. A similar set-up after the Fourier plane results in the transform of the transform - an inverted image of the initial object. Placing appropriate masks in the Fourier plane modifies the reconstructed image.

Measure the separation of the spots in the transform plane. Are they in agreement with your prediction? Now add another similar grating into the slide holder as the object, but rotated through 90° with respect to the original grating. The image formed downstream should be a coarse matrix of bright dots. Devise a **mask** that can be located in the transform plane, and can be used as a spatial filter such that the image is either a vertical or horizontal grating.

Essential reading.

Chapter 13 " Optics" Hecht (Addison Wesley 1998)
Optical Electronics by **A K Ghatak and K Thyagarajan** (CUP, 1989) Chapter 6.