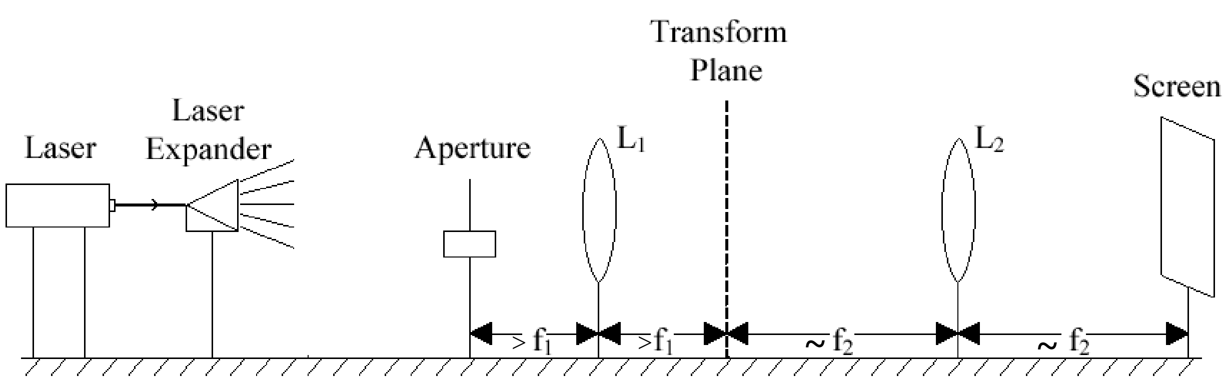
Spatial Filtering

A converging lens can be used to create a Fourier Transform (FT) of an object. In the figure below, the Fourier transform of the object (the Aperture) appears in the back focal plane of L_1 -- the transform plane. This now represents the object for L_2. Hence, the image which appears on the screen at the back focal plane of L_2 is the FT of the FT. In principle, the image should be the reconstruction of the original object. The image will not be perfect since light diffracted at sufficiently large angles is unable to enter the lens system. Large angles correspond to higher spatial frequencies, so these are filtered from the image. The result is an image with rounded or blurred edges.

In A, you will use various apertures as objects and examine their diffraction patterns and images. In B, you will place masks in the transform plane to alter the appearance of the final image. You will take two photographs; the rest of the data will consist of your observations to be recorded in your lab notebook.

Set up your optics using the diagram below as a guide. The shape of the aperture can be varied and should be placed at slightly more than the focal length from L_1. The transform plane is the point of tightest focus and L_2 should be about its focal length away. Place a mount at the transform plane. With a diffraction grating at the aperture position, position the mount to obtain the sharpest spots. Remove the grating and replace it with a parallel line mask. Adjust L_2 for the sharpest image on the screen. Do not move the mount in the transform plane when swapping masks.



Procedure:

A. Examine the diffraction pattern in the transform plane and the image on the screen for the following apertures: single slit, parallel line grid, and 100 line/mm diffraction grating. Make a sketch of the diffraction patterns and images to include in the write-up. **Q1.** Explain the appearance of the diffraction patterns and images.

B. Place a metal mask in the transform plane to selectively remove (filter) Fourier components of the image. Using the following apertures, make masks which perform the specified function. Make a sketch of the resulting images. **Q2**. Explain your results as quantitatively as possible.

Aperture	Function of Mask
(1) parallel line grid	remove the central maximum
(2) concentric squares	remove central max, vertically and horizontally
(3) spiral rays	remove central max, vertically and horizontally
(4) parallel lines + “things”	Remove all the diffraction spots, allow everything else through. The dots may be so close together that they appear as a line.

For the last item, the “things” may be blobs of tape that you can apply to the grid. For this item, take a photograph of the original object and the optically filtered image for your write-up (2 photos).

C. Spatial filters can also be applied to digital images. These are implemented using an algorithm called the Fast Fourier Transform or FFT. Use the link below and use the java applet there to load an image. The Fourier transform of the input image is displayed on the right – click “Magnitude Log” to see the detail off-axis. Then apply a line or square filter in the “Frequency Domain Operators” to remove an area around the central maximum. Click “Inverse Fourier Transform” to see the output image. Experiment with this for any picture you like and describe your results. Include one printout with your report. Start exploring with the checkerboard image che1.gif. http://homepages.inf.ed.ac.uk/rbf/HIPR2/fftdemo.htm