# Week #6 – Fourier Optics

Reminder, still practice good optics alignment and Laser Safety practices! You can use photos instead of diagrams/or drawings in your lab report where ever it is appropriate and where they can be properly labeled/understood.

◼ **1. Fourier Optics** – Goal: experimentally validate the Fourier transform and filtering of spatial frequencies.

Procedure:

(1) Setup your experiment as shown at right. You should be able to setup the beam expander quickly and accurately by now!

(2) Mount the positive 150 mm Fourier transform lens (KPX100) in the LCA about 12" from the second BSA.

(3) Mount the TA-II about 225 mm (~9") before the transform lens, this is the object plane.

(4) Place another target assembly or white board about 450 mm or about 18" past the LCA holding the Fourier transform lens. Observations at this distance should be magnified by ~2X (we learned this in previous weeks). This is the image plane.

(5) Place the square mesh target in TA-II, this is the object.

(6) Now begin observation of the following, by placing the white cards in the Fourier plane for observation, and using pinholes punched in cards, slits in cards, toothpicks, or whatever you can to perform quality filtering in the Fourier plane. These items are not shown in the diagram and right, and you are trusted to figure out the best options on your own. For each sub-experiment listed below, sketch and label the object, spatial filter, the laser pattern in the Fourier plane, and the laser patter in the image plane. Photographs are acceptable where appropriate and of sufficient quality/detail.
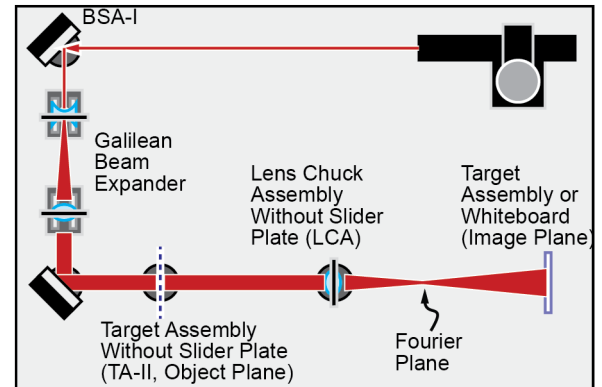
    (a) record the Fourier Transform and final image: without, and with, the mesh target. Explain/label in terms of spatial frequencies. You may need to adjust the distance of the image plane to get the clearest possible image.

    (b) for the mesh, spatially filter (one experiment each) four things: horizontal, vertical, **all** high-frequency, and the DC portions in the Fourier plane. Then record/explain what is observed in the image plane. *Hint for achieving good results: when using slits to filter vertical or horizontal components in the Fourier plane, ensure that the slits are narrow! You can cut paper, tape black tape on glass slides, whatever works best for you.*

    (c) pull out the diffractive optics cards we used for diffraction experiments, with the linear grating look at the results in the Fourier plane and the image plane. Why are their few AC components (mainly DC)? You will need to remove the beam expander for this experiment because it is too big for the small squares on the diffractive optics card. *Hint, think of how big the lens would need to be to capture the 'AC' modes… and what the zero mode represents…*

◼ **2. Setup Dismantle and Storage** – Proper care of optical components is just as important to achieving reliable results as is careful experimental setup. Improper handling, setup, dismantling, and storage will detract from your final grade in this course. Unsure about any component? Just ask. The next group should find all parts neatly stored in the optics kit. There is a card with each kit that shows where each component goes.

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◼ **3. Theoretical/Calculation Problem -** The example problem below is not exactly and optics problem, but it does get you started in using MATLAB and the Fourier transform. The code is courtesy of Mathworks:

STEP 1 : A common use of Fourier transforms is to find the frequency components of a signal buried in a noisy time domain signal. Consider data sampled at 1000 Hz. Form a signal containing a 50 Hz sinusoid of amplitude 0.7 and 120 Hz sinusoid of amplitude 1 and corrupt it with some zero-mean random noise:

```
Fs = 1000;                    % Sampling frequency
T = 1/Fs;                     % Sample time
L = 1000;                     % Length of signal
t = (0:L-1)*T;                % Time vector
% Sum of a 50 Hz sinusoid and a 120 Hz sinusoid
x = 0.7*sin(2*pi*50*t) + sin(2*pi*120*t);
y = x + 2*randn(size(t));     % Sinusoids plus noise
plot(Fs*t(1:50),y(1:50))
title('Signal Corrupted with Zero-Mean Random Noise')
xlabel('time (milliseconds)')
```
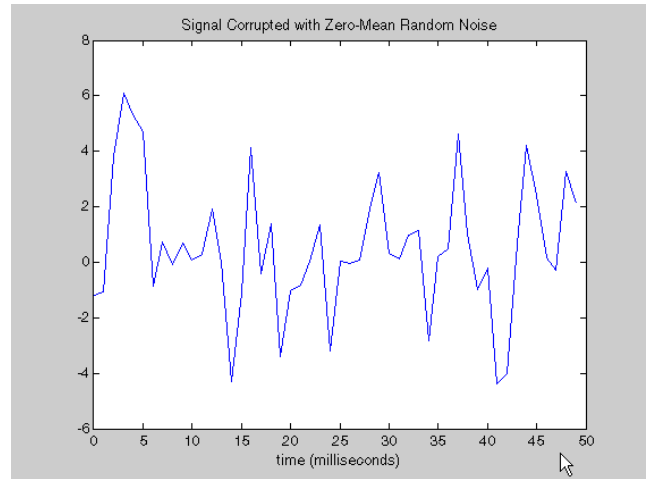

Your plot should look like this, noisy as can be, can you figure out what frequency you need to tune to (and then use that to remove all the noise from the signal)?

STEP 2 : It is difficult to identify the frequency components by looking at the original signal. Converting to the frequency domain, the discrete Fourier transform of the noisy signal y is found by taking the fast Fourier transform (FFT):

```
NFFT = 2^nextpow2(L); % Next power of 2 from length of y
Y = fft(y,NFFT)/L;
f = Fs/2*linspace(0,1,NFFT/2+1);

% Plot single-sided amplitude spectrum.
plot(f,2*abs(Y(1:NFFT/2+1)))
title('Single-Sided Amplitude Spectrum of y(t)')
xlabel('Frequency (Hz)')
ylabel('|Y(f)|')
```

STEP 3 : Code not provided. Looking at the plot (not shown above, you need to generate it) you can clearly see the strength of the 50 Hz and 120 Hz signals. Filtering them out should not be too tough, just obtain from the NFFT signal only the data right around 50 Hz and 120 Hz, and the take the inverse Fourier transform and plot the data.   Here is a link to the inverse transform in MATLAB: http://www.mathworks.com/help/techdoc/ref/ifft.html

Here is a related example: http://www.codeproject.com/Articles/317054/Simple-FFT-and-Filtering-Tutorial-with-Matlab