OPTICS 380A
Lab 13: Gratings

Gratings are regular arrays of periodic structures, like slits. In this week's lab, we will observe some interesting effects of gratings.

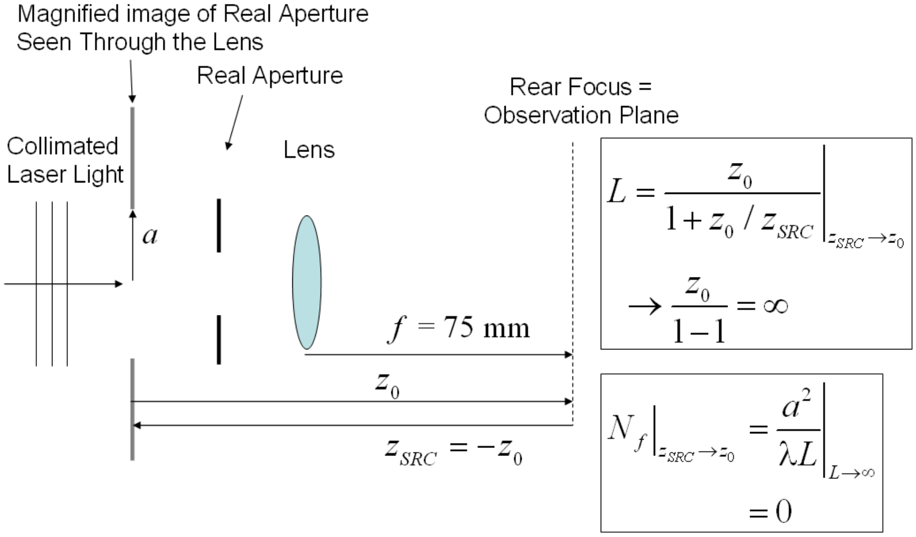
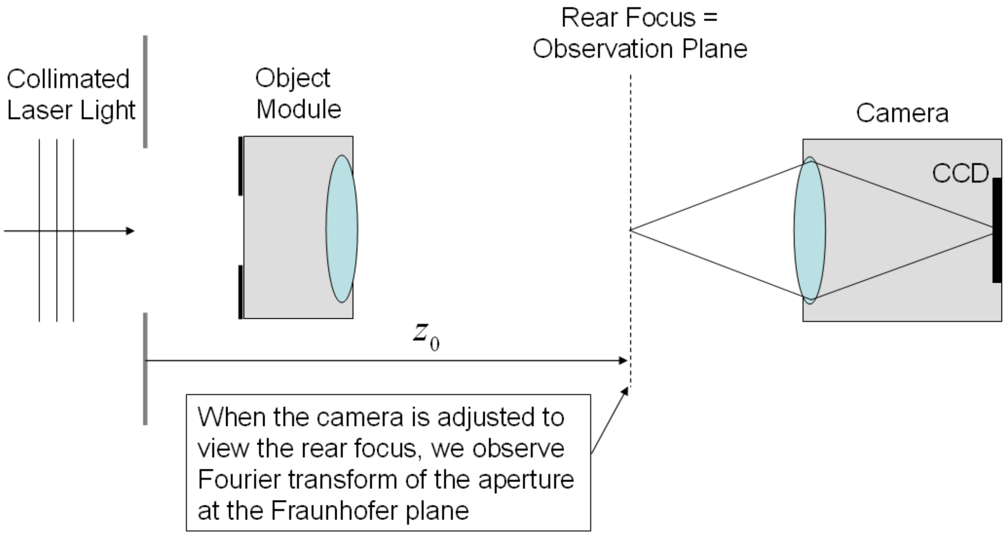


Figure 13-1. Setup used in lab with lens between real aperture and observation at the Fraunhofer plane.

The lab setup uses a collimated laser to illuminate the gratings and a lens to converge the Fraunhofer pattern at its back focus, as shown in Fig. 13-1. In this case, z_{SRC} is negative (as indicated by the backward arrow), so $L \to \infty$ and $N_f \to 0$. For the experiment, we use a camera to view the observation plane on a CCD camera, as shown in Figure 13-2. By setting the camera to image the back focus, we can view the Fraunhofer diffraction patterns of the aperture.



When the camera is adjusted to view the rear focus, we observe Fourier transform of the aperture at the Fraunhofer plane

Figure 13-2. Physical modules used in the experiments to view the diffraction patterns. The camera is adjusted to view the rear focus (Fraunhofer diffraction), where we observe the Fourier transform of the aperture.

Part A: Multiple-Slit Diffraction and Finesse

You will look at a set of diffraction patterns from multiple slits under laser illumination. Use the experimental setup to look at the following:

(A) Setup the optical system as in Fig. 13-2, with the camera imaging the rear focus of the lens. This is the Fraunhofer plane of the aperture, where we see the Fourier transform of the aperture.

(B) Verify that you have five multiple-slit apertures, containing 9, 7, 5, 3 and 2 slits spaced by 250μm. You should also have a 9-slit aperture spaced by 350μm. Look at a few of these apertures under the microscope.

(C) Describe the behavior of the diffraction patterns in the Fraunhofer zone by capturing images with the camera, saving them to the hard disk and plotting their profiles using the Matlab software. You may modify the software, if you like. As the number of slits increase, the peak power of each order also increases. You may need to adjust the brightness illuminating the camera with the crossed polarizers, as shown by your TA, so that the camera does not saturate.

(D) Does the relative spacing of the diffraction orders change with N?

(E) Measure the finesse of each pattern, and plot the finesse as a function of N. How does the finesse depend on N? Is finesse a function of the slit spacing (250μm or 350μm)?

(F) What is the relationship between the number of secondary peaks and N? What happens to the irradiance of the secondary peaks, relative to the primary peaks, as N increases?

(G) (5pts Extra Credit) If the number of illuminated slits goes to infinity, what is the peak irradiance of each order, width of each order, irradiance of the secondary peaks between the orders and finesse?

Part B: Fourier Transform Relationship for Diffraction Patterns From Gratings

(H) Setup the optical system as in Fig. 13-2, with the camera imaging the rear focus of the lens. This is the Fraunhofer plane of the aperture, where we see the Fourier transform of the aperture.

(I) Verify that you have:

- (1) Three binary 250μm pitch amplitude gratings with duty cycles of 0.25, 0.5 and 0.75;
- (2) One 250μm pitch binary phase grating with a duty cycle of 0.5; and
- (3) One 250μm pitch blazed grating.

(J) Look at these apertures under the microscope and describe their characteristics.

(K) For the gratings in (I), observe the Fraunhofer diffraction patterns with the camera, and store the images, if you like. The diffraction patterns should have some similarities and some differences. Describe and document this behavior.

(L) (5pts Extra Credit) An ideal binary phase grating with 0.5 duty cycle will not exhibit a zero order. Why?

Part C: Spectral Properties of Gratings

(M) The optical system for this lab section is shown in Fig. 13-3. We will use a 20μm wide vertical slit that is imaged by the lens and the camera onto the CCD. When a grating is placed at the object module, which is in the Fraunhofer region with respect to the slit image, we observe the Fourier transform of the grating convolved with the slit image. Our grating is a 100μm pitch binary amplitude 0.5 duty cycle grating. Our source is a multiple-color LED, which has spectral properties as shown in Fig. 13-4.

(N) Turn on the red source with the appropriate switch. Leave the green and blue switches off. Check to see that the slit is being imaged onto the camera without the grating.

(O) Install the grating on the object module, and align the grating with the slit using the red source.

(P) Note the diffraction pattern, and identify the 0^{th}, +/- 1^{st} and +/- 2^{nd} diffraction orders, if possible.

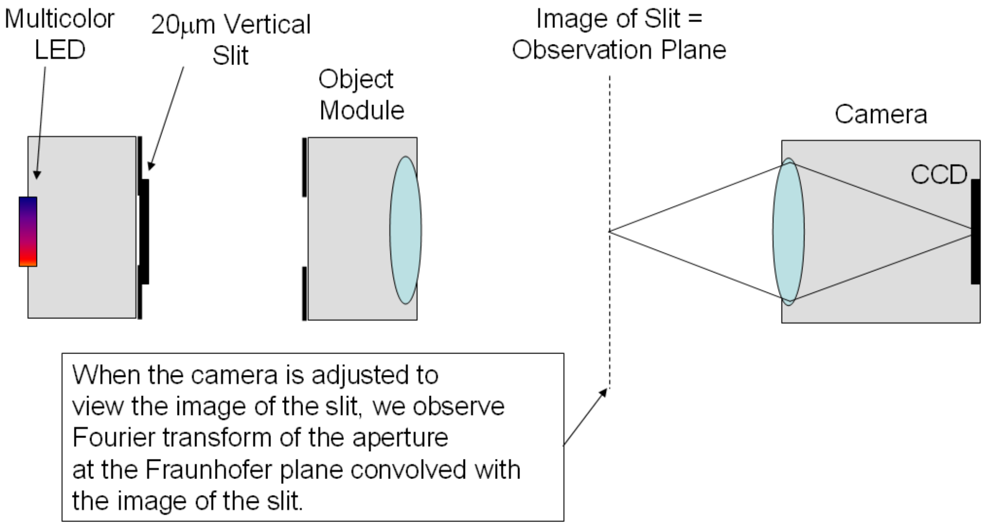
(Q) Turn on the red, green and blue sources. Describe the diffraction pattern, including properties of the zero order.

(R) Capture the diffraction pattern with the camera, saving it to the hard disk and plotting the profile using the Matlab software.

(S) Using the separation of the zero order and first order of the blue source as a calibration, calculate the expected positions of the green and red 1st orders. Use the grating equation to find the expected positions. Compare the expected positions with the experimental profiles.

(T) Use the transmission grating and the spectrometer to investigate how a grating's resolving power depends on order number, *m*. Use the sodium source and locate the yellow doublet. Measure the angular separation of the doublet as a function of order number *m*. How does the separation change with order number? Compare to the expected result.

(U) (5pts Extra Credit) – What is the difficulty in measuring both widely separated source wavelengths and finely resolved doublets with a grating spectrometer?



When the camera is adjusted to view the image of the slit, we observe Fourier transform of the aperture at the Fraunhofer plane convolved with the image of the slit.

Figure 13-3. To observe spectral properties of gratings, we will use a 20μm wide vertical slit that is imaged by the lens and the camera onto the CCD. When a grating is placed at the object module, which is in the Fraunhofer region with respect to the slit image, we observe the Fourier transform of the grating convolved with the slit image.

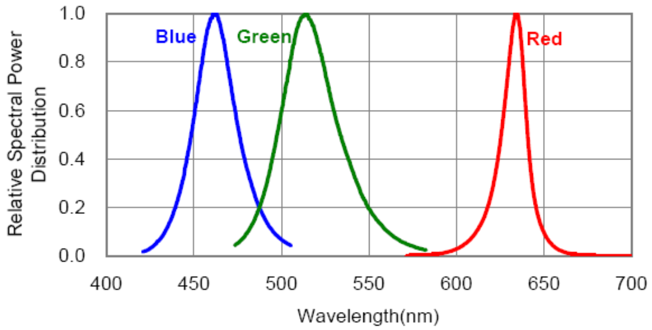


Figure 13-4. Spectral properties of the RGB LED. Peak wavelengths are: 620nm, 530nm and 465nm.