

Diffraction from Single Slit *

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Diffraction is one of the remarkable consequences of the wave nature of light. In this experiment, you will study diffraction patterns for single slit arrangement. You will also understand the relation between the shape of the diffraction pattern and that of the slit arrangement that creates it. Furthermore, you will explore techniques in image analysis for quantitative evaluation of the phenomenon.

Essential pre-lab reading: “*Physics of Light and Optics*” by Justin Peatross and Michael Ware, Brigham Young University, 2013; (Chapter 10: Diffraction; Sections 10.2 to 10.4).

“*A Student’s Guide to Fourier Transforms*” by J. F. James, Cambridge University Press, 2011; (Chapter 1: Physics and Fourier Transforms).

1 Test your understanding

1. Derive the Fraunhofer diffraction pattern for a single slit of width Δx . Calculate the slit width as a function of the distance between the central maximum and the first minimum of the diffraction pattern.
2. Plot the diffraction pattern which is produced at a distance of 1 m from a slit of width $80 \mu\text{m}$. Take the wavelength of the incident light to be 633 nm.
3. Understand the dependence of diffraction pattern on the slit width and the separation. Derive a formula for calculating these two from the diffraction pattern itself.

You can use the provided simulation *diffraction.m* to further understand the dependence of diffraction pattern on the slit width, the wavelength of incident light and the distance between the slit and the screen

The diffraction pattern is the Fourier transform of the slit shape. For example, the shape of the single slit is a *Rect/Top-hat* function where solid part is considered zero and slit opening is taken to be one. Its Fourier transform is a *Sinc* function. As you perform the experiment, you will notice that the intensity profile in the diffraction pattern is also a *Sinc* squared function.

*No part of this document can be used without the explicit permission of Dr. Muhammad Sabieh Anwar. We would like to thank Zahra Tariq, Mah Para Iqbal and Muhammad Hamza for helping improve this experiment and the associated write-up in 2018.

2 The Experiment

Turn on the laser and adjust the setup as shown in Figure 1. The laser beam should pass straight through the variable slit and fall on the paper screen. The slit contains a micrometer screw; rotate it to completely close the slit. The screw gauge has a least count of 0.01 mm. Now open it to a desired width and observe the diffraction pattern.

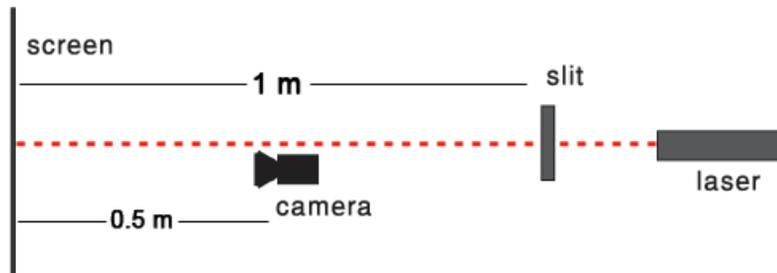


Figure 1: Schematic of the experimental setup. The red line represents the conceived path of the laser beam.

Connect the camera to the computer and open the software *uc480 Viewer*. Click on *Live video* icon. Now click on *Open camera* icon. You should now be able to see the image viewed by the camera. Adjust the intensity and focus of the camera using two knobs on it to achieve a clear result.

Turn off the lights and take an image of the diffraction pattern at such an exposure time where you observe bright fringes on a black background. For adjusting the exposure time, click on *uc480* menu and follow the path *Properties... -> Camera -> Exposure time*.

Click on *Save Image* icon to save the image in *.jpeg* format. Now, you have to convert it into an intensity graph using *ImageJ*. After opening the picture on *ImageJ*, use the mouse to select the area for which you want the intensity plot. Click on the *Analyze* menu and select the *Plot Profile* option. You will get an intensity plot with x-axis in pixels and y-axis in greyscale magnitude. Convert the pixels to cm and plot again the normalized intensity profile using *MATLAB*.

Q 1. How would you find out the pixel-to-cm conversion factor? (*Hint* : The grid on the screen can be helpful.)

Q 2. Find the slit width from the diffraction pattern. Does it match with the one selected by screw gauge?

Q 3. Plot the experimentally obtained intensity profile with the theoretical prediction.

Q 4. Obtain multiple diffraction patterns using different slit widths and perform the above steps for all of these.

Remember to print your diffraction patterns and pasting these on your notebooks. They will be a nice take-home souvenir.