Diffraction from Single and Double Slits

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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 and double slit arrangements. 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; (sections 10.2 to 10.4).

"*Improvements in the analysis of diffraction phenomena by means of digital images*" by A. Ramil, A. J. Lopez and F. Vincitorio, American Journal of Physics, Vol. 75, No. 11, November 2007.

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 first minimas of the diffraction pattern.
2. Plot the diffraction pattern which is produced at a distance of 1 m from a slit of width 80 μm. Take the wavelength of the incident light to be 633 nm.
3. Derive and plot the diffraction pattern for the double slit with appropriate choice of the slit widths and the separation between them. 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 step 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* function.

2 The Experiment

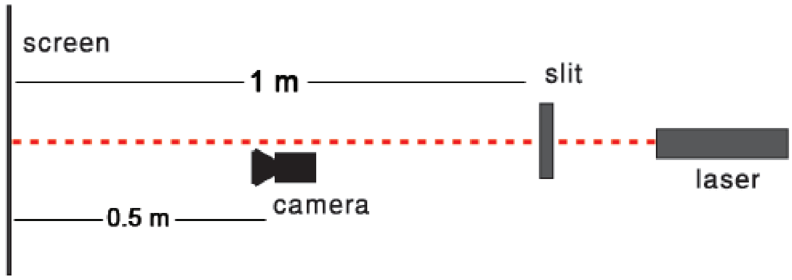

Figure 1: Schematic of the experimental setup. The red line represents the conceived path of the laser beam.

A laser beam from a HeNe laser is incident on a single slit with adjustable width. The diffraction pattern is observed on a paper screen which is placed at a distance of ≈ 1 m from the slit. A camera is placed $\approx 1/2$ m from the screen to record photographs of the diffraction pattern for quantitative analysis.

Q 1. Why have we printed a dotted pattern on the paper screen?

Turn on the laser and adjust the alignment. 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.

Connect the camera to the computer and open its software. Take photographs of the diffraction pattern at different exposures. The first one should have lowest exposure time. Increase the exposure time for subsequent photos. Note each exposure time and number the photographs i.e. name them from 1 to n in ascending order according to their exposure times. Save the exposure times in ascending order in a text file and name it *exposure.txt*. Load the first photograph by using *imshow(rgb2gray(imread('1.bmp')))*. Then type *improfile* to get the intensity pattern. You will have to mark a line along which you want to know the intensity profile. Double click to finish your selection.

Q 2. Are you able to observe the second maxima? If not, explain why?

Now open the m-file named *pattern.m* and follow the instructions in Matlab. This would combine the photographs and produce the intensity profile for the diffraction pattern.

Q 3. Why are we using multiple photographs with different exposure times?

Q 4. Find the slit width from the diffraction pattern. Does it match with the one selected by screw gauge?

Q 5. Plot the experimentally obtained intensity profile with the theoretical prediction.

Q 6. Obtain multiple diffraction patterns for different slit widths. Find the distance between first minimas for each diffraction pattern (use vernier caliper). Plot the log of this distance against the log of the slit width and find the relation between the two. Why are we taking log of both quantities?

Replace the single slit with a double slit and repeat the same process to get the intensity profile for a double slit diffraction pattern.

Q 7. Using the experimentally obtained diffraction pattern, estimate the slit width and separation for the provided double slit?

Q 8. What would have happened if we had used white light for the single slit or the double slit experiment?

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