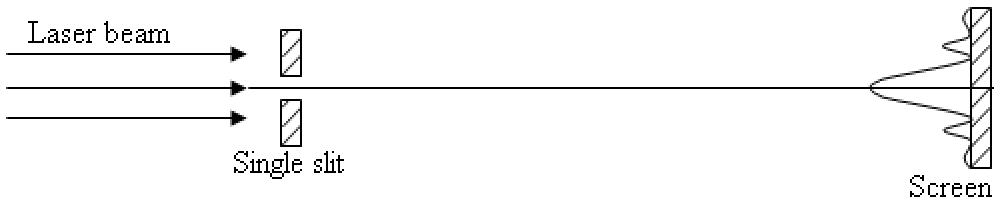
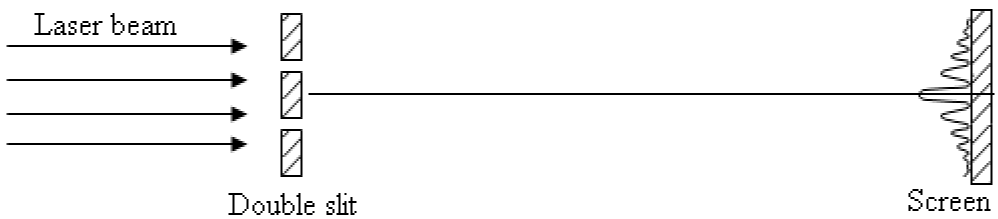
Experiment 8: Diffraction Slits and Gratings Phys 431

Fraunhofer diffraction, also called far-field diffraction, occurs when the source and the screen are large distances from the diffracting mask. In Fresnel diffraction, the source and/or screen are so close to the mask that the light incident on the mask and screen cannot be considered plane waves. In this lab, you will explore Fraunhofer diffraction by sending a laser beam through single, double, and multiple slits, as shown schematically below. Please see the appendix for a brief summary of the principles.

You are required to photograph at least one of the diffraction patterns for your write-up. You will also need to make marks on the paper screen to record the distances between minima. FYI, the wavelength of the diode laser is 651 nm. Also, please note that each mask has nominal values for slit width, separation, etc. marked right on the card. These should be compared to the results of your measurements.





Procedure:

A. Record the patterns for four different width single slits (nominally 0.02mm, 0.04mm, 0.08mm and 0.16mm). **Q1** Based on Huygen's principle, can you qualitatively explain why the central maximum gets wider as the width becomes more narrow? From the positions of the minima and the distance to the screen, compute the slit widths. Of course, you should then compare the measured values to the nominal values marked on the masks.

B. Record the patterns for four different pairs of double slits (slit width 0.04 and spacing 0.25mm and 0.5mm, and slit width 0.08mm and slit spacing 0.25mm and 0.5mm). **Q2** Can you find any empirical relations between various parts of this more complex pattern and relate that to the slit spacing and slit separation?

C. Record the patterns resulting from a four-slit or five-slit masks. From your measurements, compute the separation of the slits. **Q3** Can you deduce the number of slits from the diffraction pattern?

D. Find the square or hexagonal aperature. Both of these patterns are made up of smaller holes, as can be verified using a magnifying glass. Now shine the laser on it and record the resulting diffraction pattern. **Q4** Can you explain the qualitative appearance of the diffraction pattern?

E. Use the tick marks on a steel ruler as a diffraction grating, in reflection mode. Knowing the spacing of the marks, compute as accurately as possible the wavelength of the diode laser.

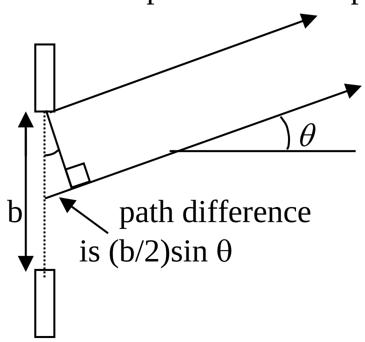
F. Use the card with 3 diffraction gratings and measure one of them. To see several spots, you may need to bring the screen much closer. How do your measurements compare to the nominal values?

G. Replace the laser with the white light of a halogen lamp. Shine the white light through the 1000 lines/mm card grating and photograph the diffraction pattern (you will probably need an aperture or iris in front of the lamp to block stray light). In this case, a single maximum can form a "spectrum" showing a rainbow of colors, as light of different wavelengths will have maxima and minima at different angles. Calculate the angular positions of the blue and red light within a single maximum and estimate the wavelength ratio of red to blue light.

Appendix: Diffraction Slits and Gratings

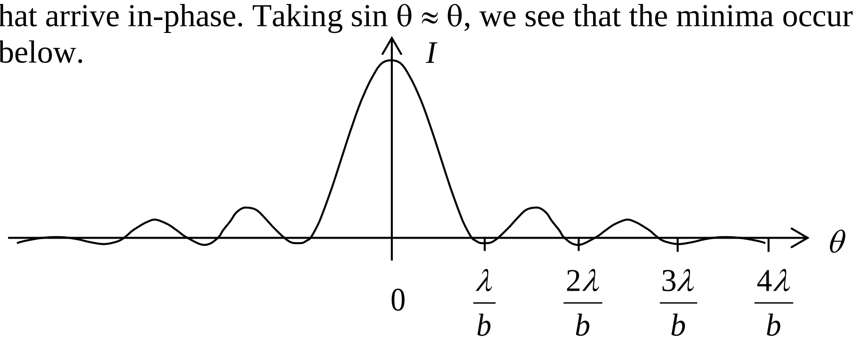
1. Diffraction from a single slit

Using Huygen's principle, we can imagine the slit to be filled with a line of point sources. Consider two point sources separated by b/2, one right at the edge and one at the center:



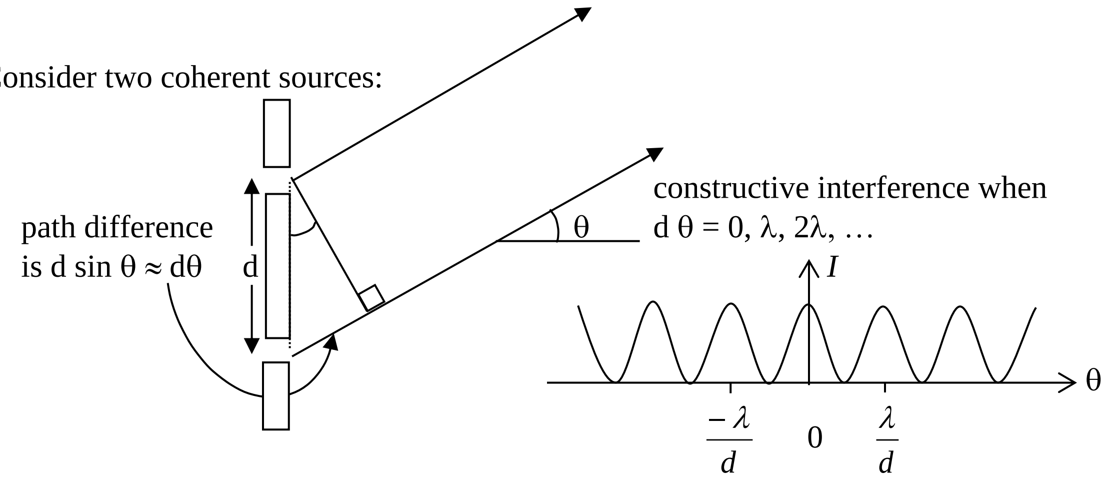
destructive interference when
(b/2)sin θ = λ/2, λ, 3λ/2, …

Now, each point sources can be paired with one b/2 away. If one pair is out-of-phase, they all will be out-of-phase. Note that a minimum does not appear at sin θ=0. This arises from the undiffracted beam, i.e. the point sources away from the edges, which produce rays that arrive in-phase. Taking sin θ ≈ θ, we see that the minima occur at the angles shown below.

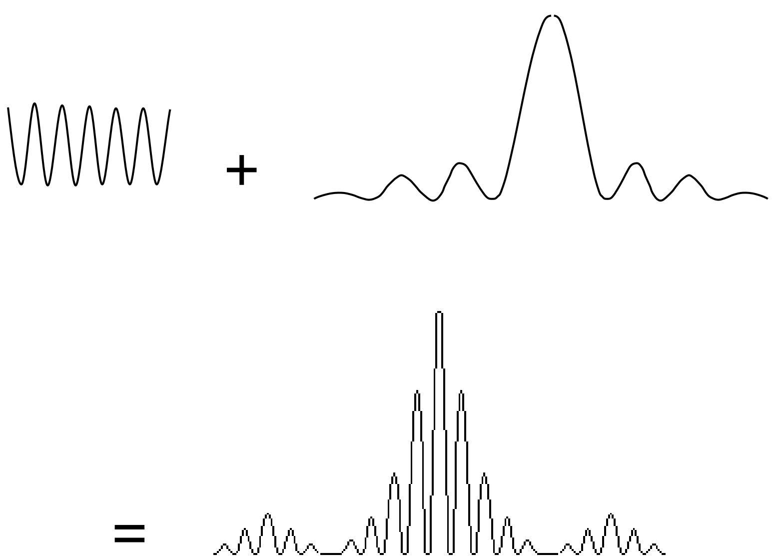


2. **Diffraction from a double slit**

Consider two coherent sources:



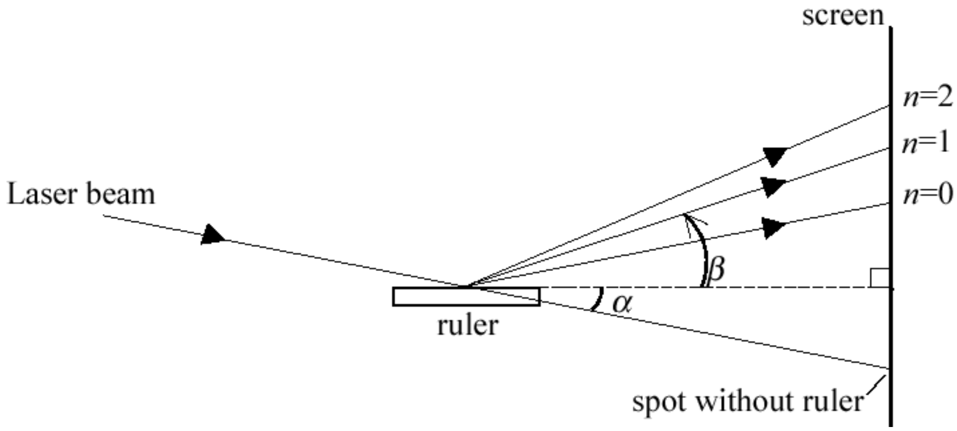
Now, let’s consider that each slit has some non-zero width, b, which would results in the single-slit pattern if the slit were isolated. The resulting pattern is



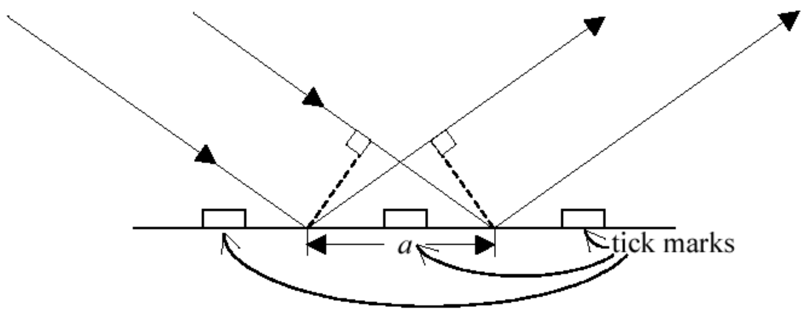
The pattern from multiple slits or a diffraction grating is calculated in a similar way.

3. Steel Ruler Diffraction Grating: Reflection Grating

Lets call the angle of the incident beam α and the outgoing beam β:



Note: *n*=0 corresponds to specular reflection, α=β.



The condition for constructive interference: a (cos β - cos α) = 0, λ, 2λ, …= $n\lambda$