LAB 3 - INTERFERENCE AND DIFFRACTION(TPL2)

Goals:

- Measure interference pattern from a double slit system

Diffraction: The bending of waves behind an obstacle into the shadow region is known as diffraction. Diffraction is easily visible only when the size of the obstacle is comparable to the wavelength of the wave. Sunlight coming though a window casts a geometric shadow of the opening without noticeable diffraction. The same sunlight passing through a very narrow slit will spread out far beyond the geometric shadow.

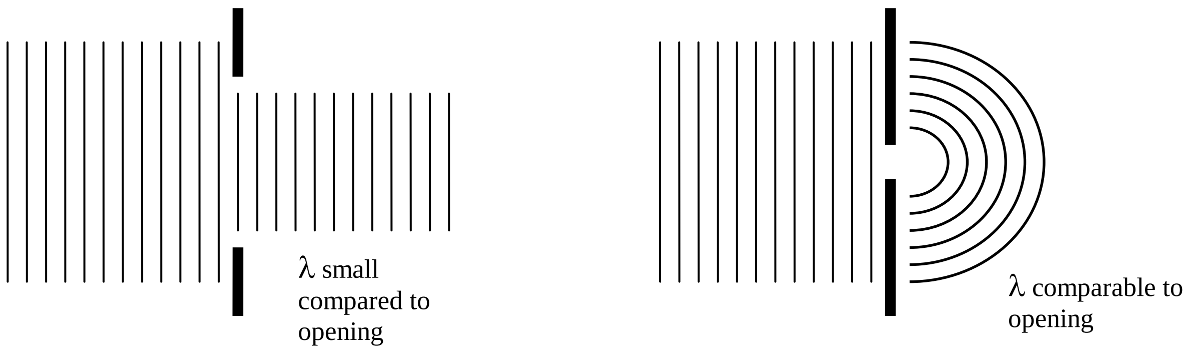


Figure 1 - Diffraction produced based on size of opening

Part 1 Interference - Double Slit

In 1801, Thomas Young obtained convincing evidence for the wave nature of light by observing the pattern of light after it passed through two narrow and closely spaced slits.

Light from each slit spreads out in all directions due to diffraction. Three specific directions are shown below which can be used to explain the light pattern observed on the screen. Light from each slit will travel the same distance to the center of the screen and will then be in phase and will result in constructive interference (a bright region). The light waves will also be in phase when the path difference is one complete wavelength, as shown in the middle figure. However, when the path difference is 1/2 λ, as in the third figure, the light waves will be out of phase and there will be a dark region. Thus, the observed light pattern should be a series of bright "fringes" separated by dark areas.

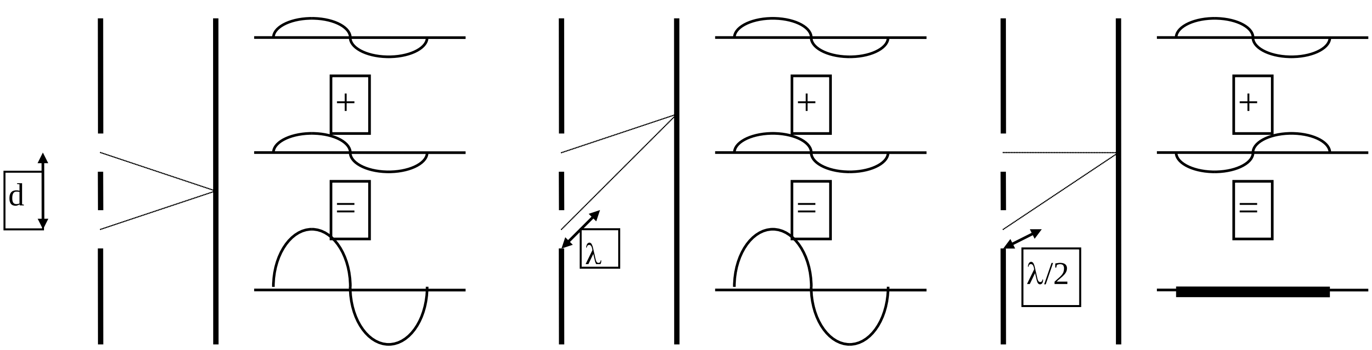


Figure 2 - Center bright region, first order bright region, and first dark region

The separation of the slits, d, is measured from the center to center, and is much larger in the picture than it really is. The rays from each slit to the screen are basically parallel. The angle they make with respect to the horizontal is θ, and the path difference is given in terms of that angle:

$$\text{Path difference} = d\sin\theta$$

Whenever this path difference is equal to an integral number of wavelengths, there will be a bright region.

$$d\sin\theta = m\lambda \quad \text{for constructive interference} \quad m=0,\ \pm 1,\ \pm 2\ \ldots$$

Suppose we look at two adjacent fringes as shown in the figure below:

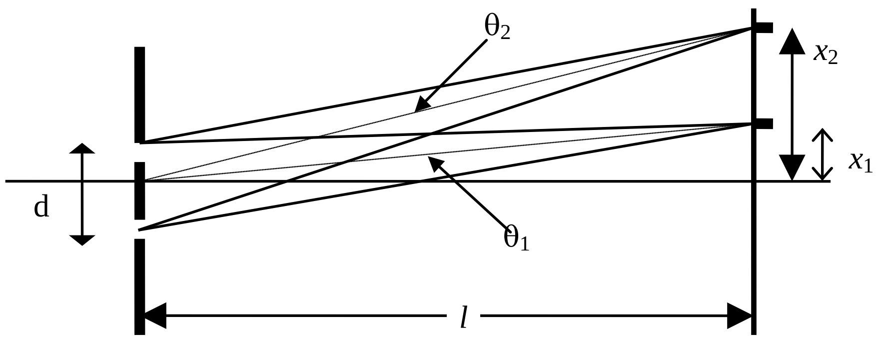


Figure 3 - Adjacent interference fringes

The two angles in the diagram can be calculated as follows:

$$\sin\theta_1 \cong \tan\theta_1 = \frac{x_1}{l} = \frac{m\lambda}{d}$$

$$\sin\theta_2 \cong \tan\theta_2 = \frac{x_2}{l} = \frac{(m+1)\lambda}{d}$$

The separation between the two fringes on the screen can also be calculated (this is like m=1):

$$(x_2 - x_1) = \Delta x = \frac{\lambda l}{d}$$

Thus, the variables d, Δx, *l*, and λ, are what we will measure or calculate.

1. <u>Double slit setup.</u> On the projector slide there are four sets of slits marked (**A**) 0.04, 0.25; (**B**) 0.04, 0.50; (**C**) 0.08, 0.25; and (**D**) 0.08, 0.50 (the pairs of slits are NOT labeled as **A, B, C, D** on the disk). For each pair of slits, the values are for '*a*', '*d*', where '*a*' is the slit width and '*d*' is the separation of the two slits. Mount the disk holder on the optical bench at the 7.5 cm mark (this puts the slits at the 10.0 cm position), the laser at the 0 position, and the screen at the 110 cm position. This should allow l = 1000mm for all measurements. See diagram below and on the **on-line help page**:

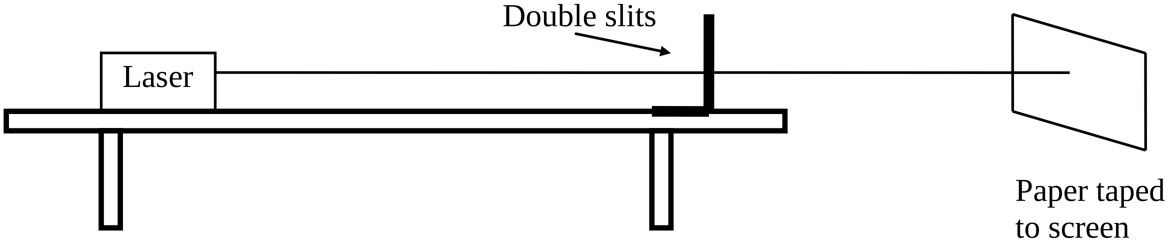
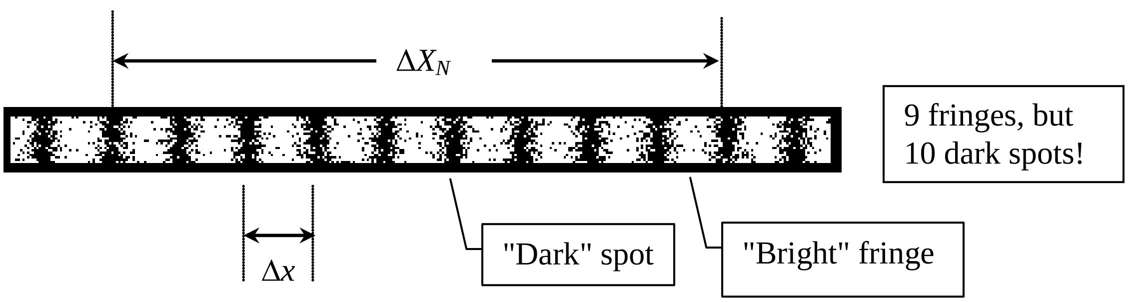


Figure 4 - Double-slit setup

2. <u>Image on paper.</u> Tape a piece of paper to the screen where the pattern shows up. Calculate the separation of the fringes by measuring the distance across several fringes and divide by the number to get the average (remember, the Δx is measured). Consider the sample pattern below (the "white" parts will be laser-red on your image). For the double slit, it will be easier to measure the average distance between the "spaces" rather than the "brights". For example, consider the measurement across several fringes as shown:



Then we can calculate the **average width of a fringe** (**Δx**) to be:

$$\Delta x = \frac{\Delta X_N}{N} \quad \text{where N= number of fringes}$$

$$\text{in this case :} \quad \Delta x = \frac{\Delta X_N}{9} \quad \text{(note there are 10 darks, though!)}$$

For each of the 4 double slit patterns, record the calculations on the Data/Question sheet and answer the questions there.

DATA/QUESTION SHEET FOR LAB 3 - INTERFERENCE AND DIFFRACTION

Part 1 Interference - Double Slit

2. Image on paper. (All values are in mm)

Double	*l*	ΔX_N	N	Δx	d_{exp}	d_{given}	% diff
A	1000					0.25	(d_{exp}, d_{given})
B	1000					0.50	(d_{exp}, d_{given})
C	1000					0.25	(d_{exp}, d_{given})
D	1000					0.50	(d_{exp}, d_{given})

Slit widths for **A** & **B** are a=0.04mm and for **C** & **D** are a=0.08mm

Use l = 1000mm and $\lambda = 6.50\text{x}10^{-4}$mm

Use $\Delta x = \frac{\Delta X_N}{N}$ and $d_{exp} = \lambda * l / \Delta x$ and % diff $\frac{|x_1 - x_2|}{\left((x_1 + x_2)/2 \right)} x100$

(For %diff, use $x_1 = d_{exp}$ and $x_2 = d_{given}$)

Question Discuss the % differences from the chart for this section. What measurement do you think is the factor that contributes most to the uncertainty for each one?

Question The **A** and **C** slits in the above table are separated by 0.25mm and the **B** and **D** slits are separated by 0.5mm

a) Did you see any difference in the interference patterns from these two pairs? (think in terms of number of fringes, widths of fringes, clarity, etc.)?

If there is a difference (and there is), can you think of any reason why changing the separation of the slits from 0.25mm to 0.5mm would cause it?

Questions/Suggestions -> James Nolta – jnolta@LTU.EDU