Double Slit

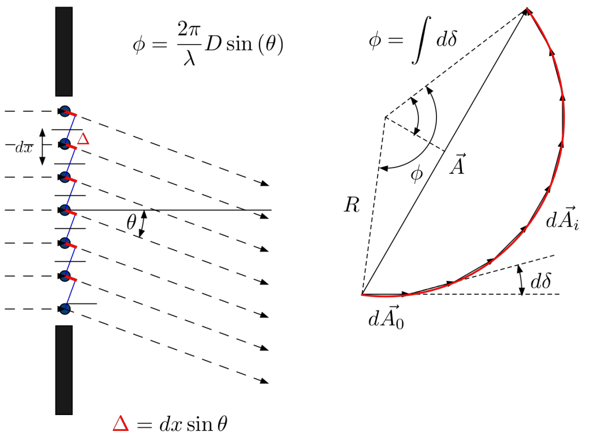
Introduction

Purpose

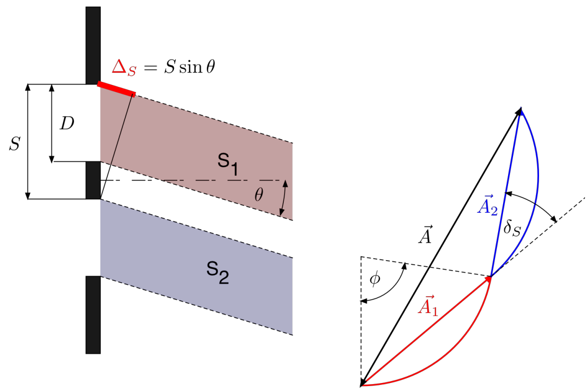
Using Fraunhofer's diffraction theory we will try to describe two slit interference by measuring the intensity peaks of the interference pattern.

Supplementary

Measuring the intensity distribution using a photodiode we should be able to see variation in a voltage signal. These values will be used to determine maxima and minimums on the data set. In the analysis of the data we will convert the micrometer readings to angles. This is done by simple geometry using the distance between slits. The observed voltages will be plotted against the angles determined and normalized such that the highest intensity has a value of one. Fitting the data will allow us to compare between double and single slit measurements



(a) Single Slit



(b) Double Slit

We are measuring the intensity and therefore need the relations,

$$\phi = \frac{2\pi}{\lambda} D sin(\theta); \quad \left|\vec{A}\right| = 2R sin(\phi/2); \quad R = \left|\vec{A}_0\right|/\phi$$

$$I(\theta) = I_0 (\frac{sin(\phi/2)}{\phi/2})^2$$

Which looks similar to Malus's law And for double slit,

$$\left|\vec{A}\right| = \left|\vec{A}_1 + \vec{A}_2\right| = 2\left|\vec{A}_0\right| \frac{sin(\phi/2)}{\phi/2} cos(\psi/2)$$

Where, $\phi = \frac{2\pi}{\lambda} D sin(\theta)$; $\quad \psi = \frac{2\pi}{\lambda} S sin(\theta)$, S is usually done center-to-center but, that's okay.

Uncertainties

σ_V

Voltage values have an uncertainty of $\pm 0.005V$ for single slit and $\pm 0.0005V$ for double slit. This will be taken through the normalization process as well to represent the uncertainty in the graphs.

σ_x

Position values have an uncertainty of $\pm 0.005mm$

Uncertainties Not Considered

We assume the beam is completely uncovered.
We assume the beam is perfectly parallel to the photodiode.
We assume the beam is perfectly coherent.
We assume the slit is large relative to the wavelength.

Calculations

θ

Using the supplementary and the micrometer readings we can calculate:

$$\tan\theta = \frac{x - x_0}{L}$$

Where x is the position of the micrometer readings and x_0 is the micrometer reading at the highest voltage (intensity). Using small angle approximations,

$$\tan\theta \approx \theta$$

$$\theta = \frac{x - x_0}{L}$$

Uncertainty

$$\frac{\partial\theta}{\partial x_0} = \frac{x}{L}$$

$$\frac{\partial\theta}{\partial x} = \frac{-x_0}{L}$$

$$\frac{\partial\theta}{\partial L} = \frac{-(x - x_0)}{L^2}$$

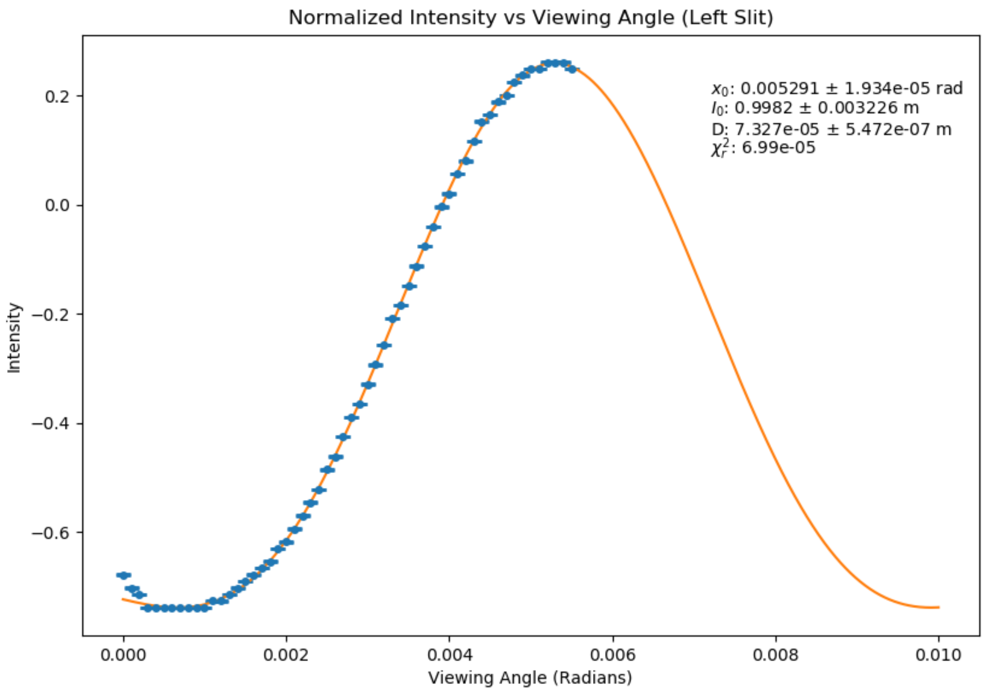
Per usual,

$$\sigma_\theta = \sqrt{(\frac{\partial\theta}{\partial x_0}\sigma_{x_0})^2 + (\frac{\partial\theta}{\partial x}\sigma_x)^2 + (\frac{\partial\theta}{\partial L}\sigma_L)^2}$$

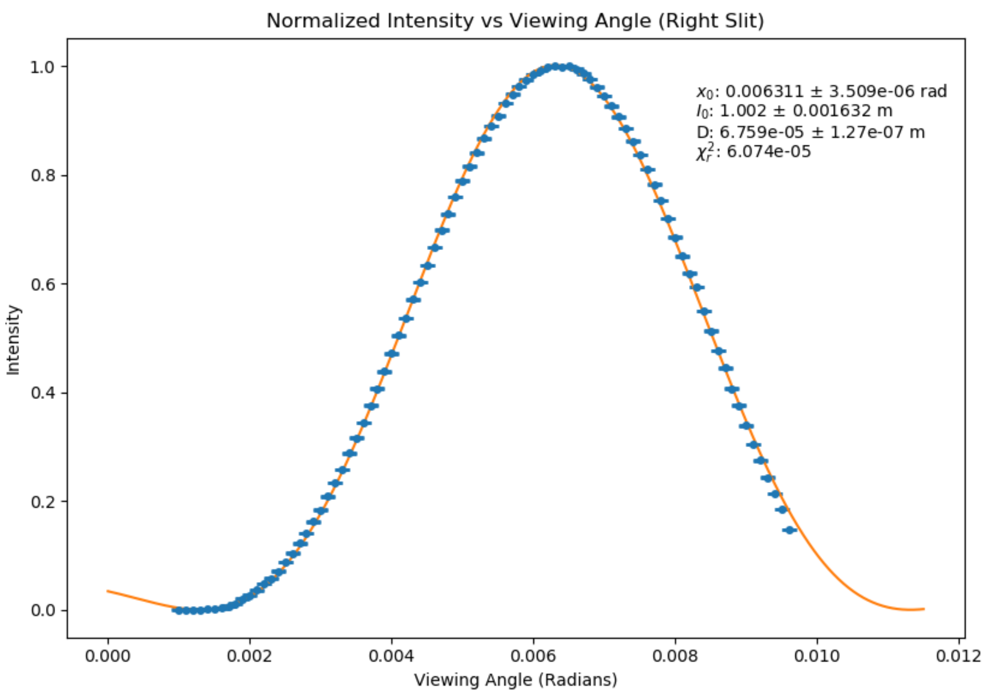
For the graph uncertainty if we divide the value of the data before the normalization with the value after the normalization we will get the ratio of each data point, if we multiply this by the uncertainty discussed previously, we will get the normalized uncertainty for the data.

Data

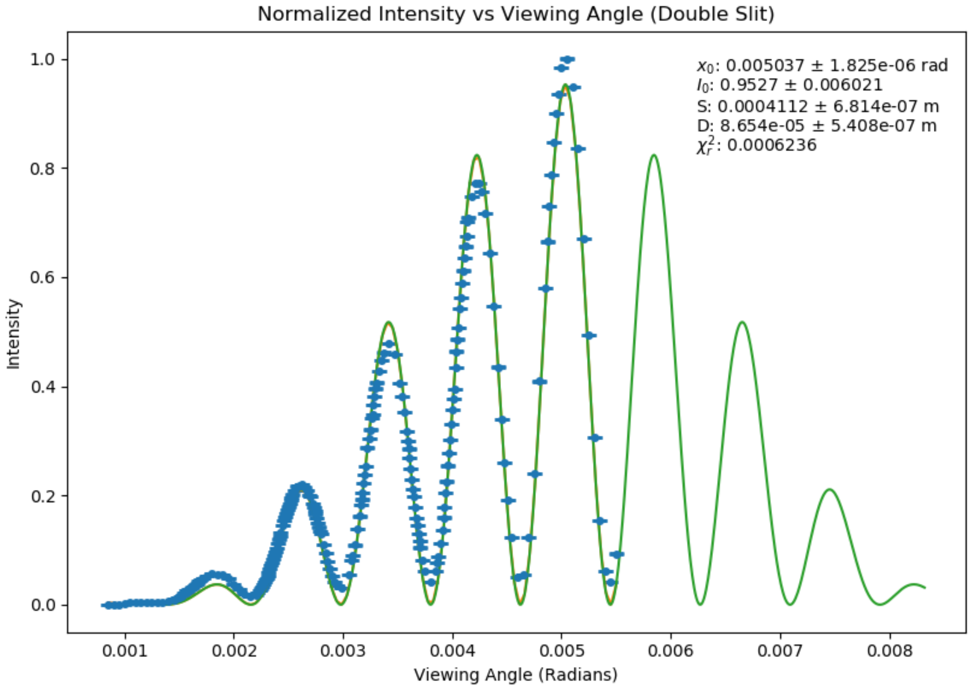
For the single slit experiment; using the supplementary, a fitting function was generated and used to fit the data. The parameters are shown on the top right of the graphs. I_0 represents the maximum intensity, because we normalized our data the intensity is now unit-less. Otherwise, we would represent the y-axis as a voltage which would be directly proportional to the intensity. x_0 represents the micrometer position at I_0 in radians D represents the slit width χ_r^2 represents the reduced chi squared, an indicator of how good a fit is.



Due to time constraints, most of the data was collected and the rest was fitted.



For Double slit we introduce one more parameter which is S and it represents the slit separation. This fit was discussed in the supplementary.



Analysis

Both single slits should give the same value for D however, they are about $\frac{7.327-6.759}{7.327} = 7.75\%$ off from each other. If we analyse the data we can see that the maximum voltage for the left slit before being normalized is 0.823V while the maximum voltage for the right slit was 0.604V. This indicates that one let more of the beam through than the other one.

Comparing the slit separation to the closest given value,

$$\frac{0.411 - 0.406}{0.406} \cdot 100 = 1.23\%$$

This is not covered by our relative uncertainty of 0.1657%

Conclusion

We were able to calculate the values of x_0,S,D and I_0 by using a fit given to us by the theoretical equations discussed in the supplementary. The voltage recorded was normalized to represent relative intensity values. For the double slit, a reduced chi-squared value of 0.0006236 represents very good correlation between the fitted line and the data points.