Interference and diffraction - Lab report

26^{th}, 27^{th} March, 2018

1 Goal of the experiment

The first goal of this lab experience is to replicate the double slit experiment performed by Thomas Young in 1801: one of the most important experiments in the history of science. By *comparing* the theoretical predictions to the observed *interference pattern*, you will be able to calculate the wavelength of the laser beam. Also you will *carry out* an experiment about diffraction from a single slit or from a single small object.

2 Theoretical background

Interference

As discussed in class, in an experiment like the one by Young, after going through the double slit a beam of .... and .... light produces an interference pattern on the "*target*" screen. The fact that the distance between the screen with the double slit and the target screen L is much larger than the distance between the two slits d, enables us to use an approximation: we assume that two light rays passing each from one slit reach the same point on the screen by following .... paths. From Fig. 1 it is clear that the path difference between the two rays going through the two slits is simply given by $\Delta l =$ ....

If this path difference is equal to an **integer number times the wavelength** of the laser, there is **constructive interference** and a .... band appears in that spot.

$$d \sin\theta = m\lambda, \qquad \text{with } m = 0, \pm1, \pm2, \ldots \qquad \textbf{constructive interference}$$

For instance, if we call θ_1 the angle relative to the first light band close to the central band, the equation becomes

$$\ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots$$

On the contrary, if the path difference between the two rays is equal to an ***odd number*** **times half the wavelength** of the laser, there is **destructive**

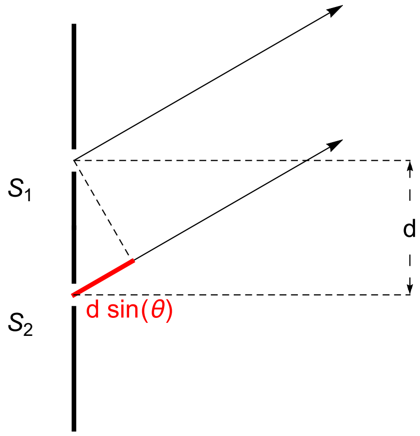

Figure 1: Path difference for two rays going each through one of the two slits.

interference and a .... band appears.

$$d \sin\theta = \left(m - \frac{1}{2}\right)\lambda, \quad \text{with } m = 0, \pm 1, \pm 2, \ldots \quad \textbf{destructive interference}$$

The two previous relations tell us if two light rays going through the slits with a certain angle θ produce constructive or destructive interference. Another formula is needed to relate the position of a band on the screen to the angle θ. A simple geometrical consideration leads to the formula

$$y = L \cdot \ldots\ldots\ldots\ldots,$$

which, for small values of the angle θ becomes simply

$$y = L\theta.$$

In fact $\lim_{\theta \to 0} \tan\theta = \theta$.

Diffraction

In Young's experiment the interference pattern was created because light passing through a slit was interfering with light passing through the other slit. In diffraction experiments light passes through a single slit, but a similar figure is created. As you learned in class this happens because light passing from one part of one slit interferes with light passing from a different part of the same slit. A theoretical discussion similar to the one carried out about the double slit experiment leads to an equation that describes the position of the diffraction minima (the .... bands) in a diffraction experiment.

If we call W the width of the slit, and θ_m the diffraction angle relative to the m^{th} dark band, the following relation is valid:

$$W \sin\theta_m = \ldots\ldots\ldots\ldots, \quad \text{with } m = 0, \pm 1, \pm 2, \ldots \quad \textbf{diffraction minima}$$

Again the formula that describes the distance of the m^{th} dark band from the central band in terms of the angle θ_m is given by

$$y_m = L \tan\theta_m.$$

3 Lab indications

Experimental tools

Every group will receive

- a laser module (with battery),
- a "black slide": a small black screen with four sets of slits.
  IMPORTANT: when you *handle* the black slide, take it by the edges and avoid leaving *fingerprints* or *scratches* on it.
- a *clothespin*,
- an A4 paper,
- a ruler.

IMPORTANT: the laser module must remain *switched off* until the experimental setup is ready into place. Before turning it on keep in mind the indications given in the "Laser safety" that you have read.

Setting up the experimental apparatus

The experimental apparatus used by Young in his experiment in the early '800 consisted of a light *source*, a screen with a small slit, a second screen with two slits, and a third target screen. See Fig. 2 for reference. The first slit S_0 was needed in order to make the light source as similar as possible to a *point-like* source. Slits S_1 and S_2 were placed at equal distances from S_0 to *assure* that the light coming out of them was coherent.
In the setup of your experiment, the requirements of a monochromatic and coherent light source are fulfilled by the use of a laser source, and you will use just two screens: the one with the double slit, and the target screen on

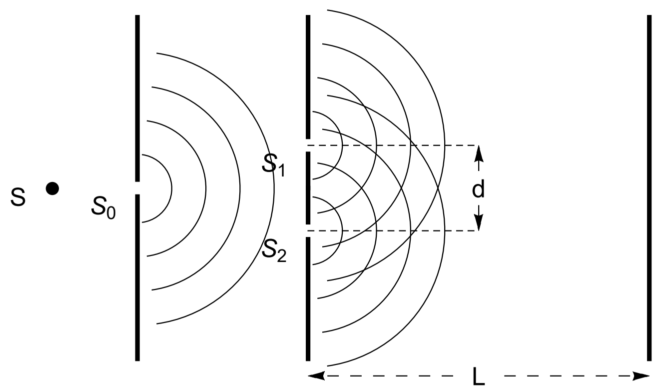

Figure 2: Schematic picture of the experimental setup used by Thomas Young in 1801.

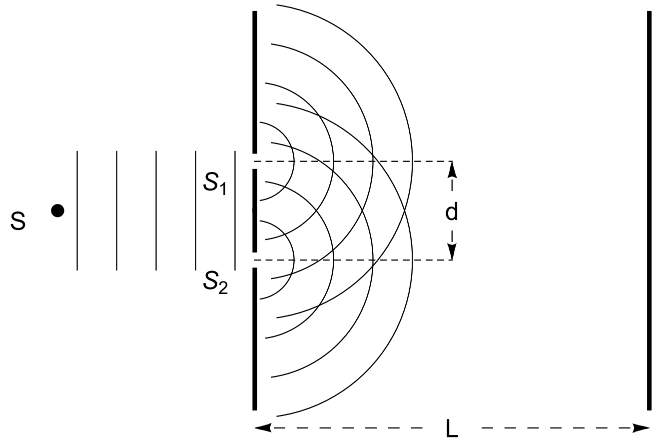

Figure 3: Schematic picture of the experimental setup that you will use in the lab.

which you will observe the interference pattern. This setup is *depicted* in Fig.3.

When doing the experiment in the lab your target screen will be a simple A4 paper. You have to set this screen around 1.5 m far from the laser module. The black slide must be around 20 cm far from the laser source: to keep it into place, you can use a clothespin as you did in the lab experience about the reflection of light. (IMPORTANT: Make sure that the reflection from the slide points towards the surface of the table!).

4 Calculations and measurements

Interference - part 1

On the black slide there are four sets of slits marked with numbers from 1 to 4. To start, direct the laser beam towards the double slit marked with number 2 on the black slide. When your setup is correctly prepared, you will see an interference pattern made of light and dark bands on the target screen.

- turn off the laser and measure the distance L between the black slide and the target screen, and note it down in the space below.
- turn the laser back on.
- with a pencil draw a small sign in correspondence to each light band on your target screen (the A4 paper).
- turn off the laser and take the target screen from the wall.
- with a ruler measure the distance between the two pencil marks that are *further away from each other* and divide by an appropriate number to obtain the distance between two consecutive light bands. We assume that all the light bands are all at the same distance from each other, therefore the number that you found can be considered equal to the linear distance y_1 between the central band and the first light band.
- Since you know y_1 and L you can calculate the value of the angle θ_1 relative to the first light band.
- The distance between the two slits in the field number 2 is $d = 200$ μm. Now you have all the data that you need and can calculate the wavelength λ.

Results

- $L = \dots\dots\dots$
- $y_1 = \dots\dots\dots$
- $\theta_1 = \dots\dots\dots$
- $\lambda = \dots\dots\dots$

Interference - part 2

Repeat the procedure carried out in the previous section but this time use the double slits marked with number 1 on the black slide. The distance between the two slits is now 80 μm.

Results

- $L = \dots\dots\dots$
- $y_1 = \dots\dots\dots$
- $\theta_1 = \dots\dots\dots$
- $\lambda = \dots\dots\dots$

Diffraction - part 1

To start, direct the laser beam towards the single slit marked with number 3 on the black slide. When your setup is correctly prepared, you will see a diffraction pattern made of light and dark bands on the target screen.

- turn off the laser and measure the distance L between the black slide and the target screen, and note it down in the space below.
- turn the laser back on.
- with a pencil draw a small sign in correspondence to each light band on your target screen (the A4 paper).
- turn off the laser and take the target screen from the wall.
- The first minima (dark bands) are not always easy to detect on the screen. To improve the accuracy of your measurement, it might be better to measure the distance between the two second order minima that are found respectively to the left and to the right of the centre, and to divide the result by 4. The value that you find can be considered equal to the linear distance y_1 between the central band and the first dark band.
- Since you know y_1 and L you can calculate the value of the angle θ_1 relative to the first dark band.
- As a wavelength for the laser you can use the one you have calculated in the interference experiments. You now have all the data that are necessary to calculate the width of the single slit.

Results

- $L =$ ....
- $y_1 =$ ....
- $\theta_1 =$ ....
- $\lambda =$ .... (value calculated in the experiment about interference)
- $W =$ ....

Diffraction - part 2

Repeat the procedure carried out in the previous section but this time use the direct the laser beam towards the thin bar number 4.

Results

- $L =$ ....
- $y_1 =$ ....
- $\theta_1 =$ ....
- $\lambda =$ .... (value calculated in the experiment about interference)
- $W =$ ....

Discussion and observations

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Glossary

While reading this report you will encounter some words or expressions that you may find difficult to understand: some of them are highlighted by writing them in *italic*, and their meaning is given here below.

- compare = confrontare
- interference pattern = figura di interferenza
- target = bersaglio
- to carry out = eseguire
- odd number = numero dispari
- handle = maneggiare
- fingerprints = impronte (digitali)
- scratches = graffi
- clothespin = molletta
- switched off = spento
- source = sorgente
- point-like = puntiforme
- assure = assicurare
- depicted = mostrato
- further away from each other = più lontani tra loro