Interference & Diffraction

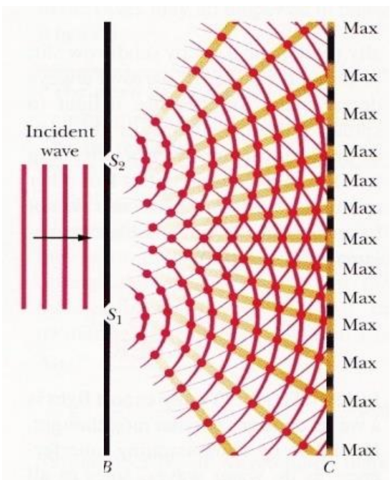
Purpose

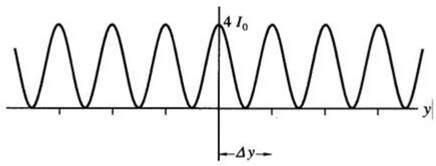
Using "*Borderless Lab365*" platform to observe **the interference and diffraction patterns** by passing laser light through single slit, double slit or diffraction grating. In addition, the effects of separation between double slits (d), wavelength of laser light (λ), slit width (a), and distance between the slits and screen (D) on the observed patterns will be investigated.

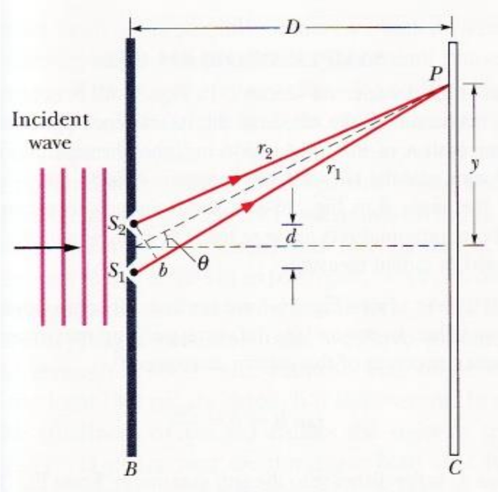
Theory

Interference

- Light waves obey **Principle of Superposition** i.e. when *two waves* meet at a particular point in space, the resultant disturbance is simply the *algebraic (vector) sum* of the constituent disturbance.
- For interference pattern, when a coherent light source goes through two distinct slits at a desired distance *d* apart, the two light waves emitted from the two slits S_1 and S_2 act as two individual point sources with identical properties (amplitude, initial phase, wavelength etc) according to **Huygen's Principle**. Here, we assume that the two slits are of *infinitely small* (if not, the interference pattern will be a combination of both interference and diffraction patterns, as shown in Fig.3). The waves beyond the slits transmit in ripple form, which then overlap with each other at a distance *D* from the slit plane (as shown in Fig. 1).
- When D >> d, where D is the distance between the slits and the screen and d is the slit separation, for constructive interference occurs, the distance of maxima from the central maximum can be obtained by $\Delta y = n\frac{\lambda D}{d}$, for n = 0, ±1, ±2… is the order of maximum.
- For destructive interference occurs, the distance of minima from the central maximum can be obtained by $\Delta y = (n + \frac{1}{2})\frac{\lambda D}{d}$, for n = 0, ±1, ±2…







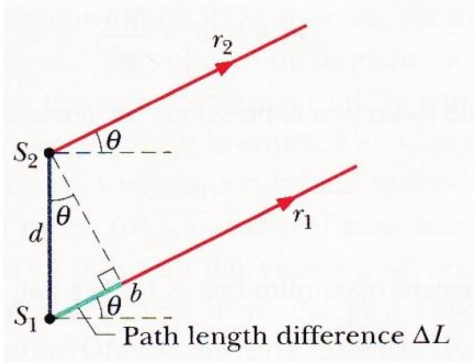
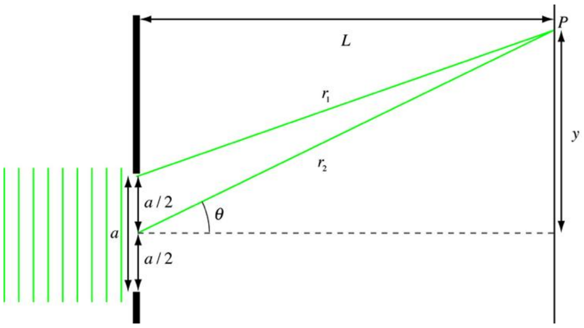


Fig. 1

<u>Diffraction</u>

- On the other hand, for diffraction (with a single slit of finite size a), we would observe a diffraction pattern as shown in Fig. 2. Indeed, this observation can be explained using interference. Detailed calculation will be omitted here.
- For the first maximum to be occurred, we divide the single slit into two halve. Consider a point on the upper half and a point of the top of the lower half as shown in Fig. 2. These two points will act as the two slits (with slit distance of a/2) in the Young double slit experiment. In order to be constructive interference, the path difference (r_2-r_1) should be equal to one wavelength. Similarly, we pick two more points (one in upper half and another in the lower half) slightly below the previous two points. These two new points should have the same path difference, similar to that of the previous two points. Then, these two new points will have constructive interference again. As a result, all the small points on the upper half will have a corresponding point at the lower half to give us an overall constructive interference at point P, resulting in the 1st maximum of the diffraction pattern.
- Compare to interference, where the 1st, 2nd and other maxima have the <u>*same intensity and width*</u>, the intensity and the width of the 1st, 2nd and other maxima of the diffraction pattern are all *different* (as shown in Fig. 2). This is the main dissimilarity between the interference and diffraction patterns.



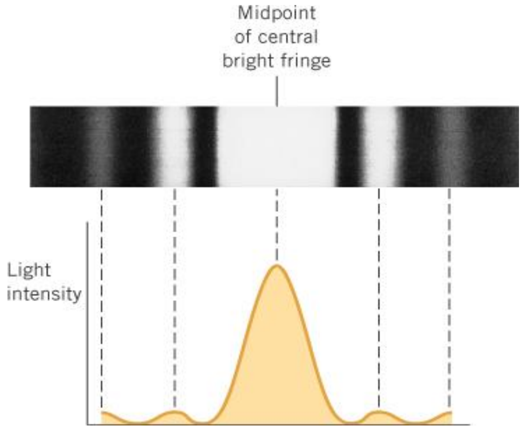
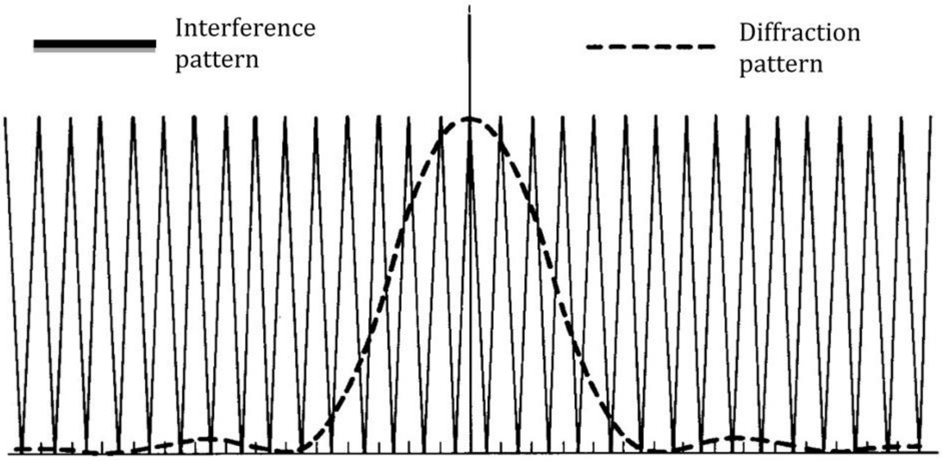


Fig. 2

- For a *real Young double slit experiment* (with two slits of finite slit width, a), we would expect the following pattern to be observed i.e. a combination of the ideal interference pattern and the ideal diffraction pattern.



Final result: The final result of the real Young double slit experiment is shown in Fig. 3. In this pattern, *make sure you can distinguish which peak is the first maximum of the interference pattern and which is the maximum peak of the diffraction pattern*!!

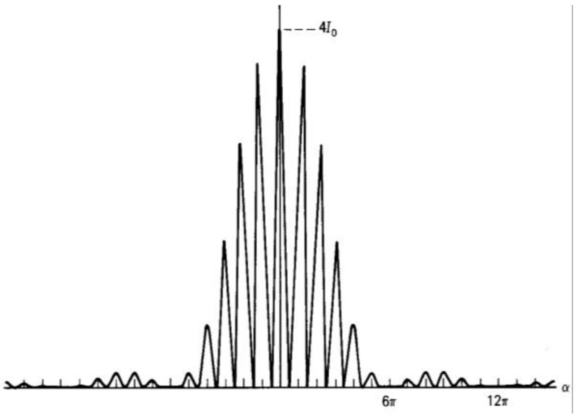
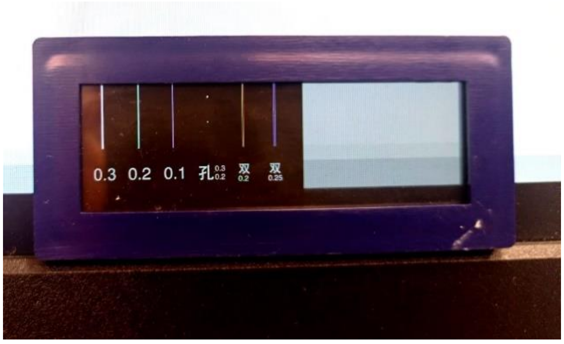


Fig.3

Apparatus

- "*Borderless Lab365*" Platform
- Laser sources (Red λ=650 nm or Green λ=520 nm)
- A movable track with different slit settings. The status of different slits is noted under each of them.



Slit (From left to right)	***Parameters***
Single Slit 0.3	Slit width:0.3mm
Single Slit 0.2	Slit width:0.2mm
Single Slit 0.1	Slit width:0.1mm
Single Point 0.3/0.2	Not in used
Double Slit 0.2	Slit seperation:0.2 mm
Double Slit 0.25	Slit seperation:0.25 mm
Grating (the white area)	300 lines/centimetre

- Light sensor on movable track
- The default and minimum value of the 'Slit-Sensor Distance' is 12cm.

Procedure

1. Log in the experiment module "Interference" on the *Borderless Lab365* platform. https://labxra.edu.hk/remotelab/platform/#/
2. Initial setting: Set the distance between slit set and screen ("*Slit-sensor distance*") as 100 mm or more by swiping the 'Slit-Sensor Distance' bar.
3. In this experiment, there are two laser sources. First select the laser by clicking 'Red' or 'Green'. Adjust the light intensity by swiping or fill in value to the bar '*Laser Power*'. (Do not choose the laser power to its maximum value for alignment, as it will be very difficult to do the alignment when the laser spot is too bright.) After adjusting the intensity to nonzero value, the laser will be turned on.
4. Select a slit (single, double or multiple slits) and align with the laser spot by swiping and fill in value to the bar '*Slit Position*' to move the movable track. (*It is suggested to use the diffraction grating for the first trail, as the pattern will have the strongest intensity and the sharpest peaks*). Tune the position until the laser hits the middle of the selected slit, you can observe the alignment through 'Camera 1', while you can observe the pattern on the screen through 'Camera 2'.
5. Adjust the position of the sensor by tuning the various parameters (such as '*Sensor Horizontal/Vertical Position*', '*Slit Sensor Distance*' and '*Scan Distance*'), check if you can

observe the pattern of the laser from the screen near the sensor from ‘Camera 2’. There will be a horizontal line for auxiliary observation.

The functions of various parameters are as following:

Slit position: allows you to select which slit (or grating) to be used in the measurement.

Slit-sensor distance: allows you to adjust the distance between the slit and the sensor (usually this parameter is set in step 2 and then fixed afterward).

Sensor horizontal position: allows you to select the starting position of the scan area of the sensor.

Sensor vertical position: allows you the adjust the height of the sensor, make sure the entrance of the sensor (same level as the horizontal line for auxiliary observation) should be on the same height of the interference/diffraction patterns.

Scan distance: allows you to select the automatic scanning range of the sensor.

You can refer to the experimental set up diagram for a better illustration.

6. Scan the pattern by clicking “*MEASURE*”. During the automatic scanning, all the buttons will be disabled.
7. Wait until the end of the scan, the buttons will be enabled again. At the same time, the pattern will be graphically shown in the screen.
8. Download the graph by clicking the menu button at the right corner of the result bar and you can select an appropriate format (.svg, .png, .csv).
9. Repeat the experiment with different (i) light source (wavelength), (ii) slit (single slit, double slit or grating) and (iii) screen distance (D) to determine the effects of these parameters on the interference/diffraction pattern. You can design your own experiment or follow our suggested experiment (set 1, set 2 and set 3) in the Data section.
10. To obtain a good interference/diffraction pattern, you may slowly move the screen away from the slit set by swiping ‘Slit-Sensor Distance’ to larger value. Observe the pattern generated on the light sensor screen, stop moving the slits until it gets dimmer. Move the screen toward the slit set by clicking ‘Slit-Sensor Distance’ to smaller value, during which the pattern becomes bright and dark again. Repeat step 11 together with step 5 until the interference pattern is the brightest on the screen.
11. Turn off the laser by swiping “Power” to zero, and logout your account.

Data (Suggested Study)

Set 1: Double slit: Study the relationship between Δy and d

Slit separation d = ____________*(chosen from different slits)*__________m

Screen separation D = ____________________ m *(fixed)*

Wavelength of light λ = ____________________ m *(fixed)*

Maxima/Minima	Positions (m)
Central Maximum	
1st Minima	
1st Maxima	
2nd Minima	
2nd Maxima	
3rd Minima	
3rd Maxima	

For good alignment, you can observe 1st, 2nd, 3rd and 4th maximum. Then you can plot the graph with n up to 4 (i.e. 4 data points).

Set 2: Double Slit: Study the relationship between Δy and D

Slit separation d = ________________________ m *(fixed)*

Screen separation D = ______*Multiple values (selected by yourself)*______________m

Wavelength of light λ = ____________________ m *(fixed)*

Maxima/Minima	Positions (m)
Central Maximum	
1st Minimum	
1st Maximum	
2nd Minimum	
2nd Maximum	
3rd Minimum	
3rd Maximum	

Set 3: Double Slit: Study the relationship between Δy and λ

Slit separation d = ________________________ m *(fixed)*

Screen separation D = ______________________ m *(fixed)*

Wavelength of light λ = ______*Red or Green*_____________m

Maxima/Minima	Positions (m)
Central Maximum	
1st Minimum	
1st Maximum	
2nd Minimum	
2nd Maximum	
3rd Minimum	
3rd Maximum	

Discussion

1. Based on the data tables obtained in set 1, plot Δy vs n, where n is the number of maxima (i.e. n=1, 2 and 3). Is it a straight line? What is the slope and how does it compare to the theoretical value? How does the graph change if you use another d value?

2. Based on the data tables obtained in set 2, please plot Δy vs D for n =1. Is it a straight line? What is the slope and how does it compare to the theoretical value? How does the graph change if you use the data with n=2?

3. Based on the data table obtained in Set 3, as the wavelength changes, what happed to the pattern?

4. Is the result of fringe separation consistent with the equation $\Delta y = \frac{\lambda D}{d}$?

5. What happens to the light intensity recorded as the order of maximum goes higher? Why?

6. What are the possible errors of the experiment?

7. Describe how the interference pattern on the screen will change under the following situations (such changes include the position and intensity of the fringe, the separation between neighboring fringes etc.)
    i. The screen is moved away from the two slits.
    ii. The monochromatic wavelength from the point source is increased.
    iii. The distance "d" between the two slits is increased.
    iv. Two light sources are used instead and the light from different sources is forced to pass through different slits.
    v. A thin glass plate is inserted behind the slit S_2.
    vi. An ideal linear polarizer is inserted behind each slit. The transmission axes of the polarizers are perpendicular to each other.

8. What happens to the diffraction pattern when the slid width decreases?

9. Using the first maximum of the diffraction grating spectrum, estimate number of line per length for the diffraction grating. Is it the same as the theoretical value?

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