Interference

Purpose

Using "Borderless Lab 365" platform to observe the interference and/or diffraction patterns formed by passing laser light through varies slits (including single, double or multiple slits). In addition, the effects of the wavelength of light (λ), separation between slits (d) and distance between the slits and screen (D) on the observed pattern will be investigated.

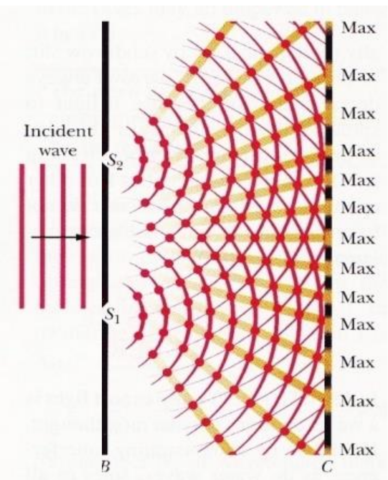
Theory

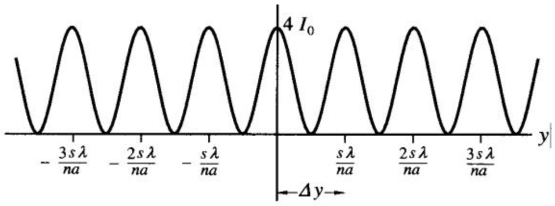
Interference

- Light waves obey principle of superposition, where their resultant amplitude is the vector sum of all composing waves.

- For interference pattern, when a homogeneous 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 (same amplitude, same phase, same 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). The waves beyond the slits transmit in ripple form, which then overlap with each other at a distance *D* from the slit plane (Fig 1).

- The distance of maxima, where constructive interference occurs, from the central maximum can be obtained by $\Delta y = n\frac{\lambda D}{d}$, for n = 0, 1, 2…
- The distance of minima, where destructive interference occurs, from the central maximum can be obtained by $\Delta y = (n + \frac{1}{2})\frac{\lambda D}{d}$, for n = 0, 1, 2…





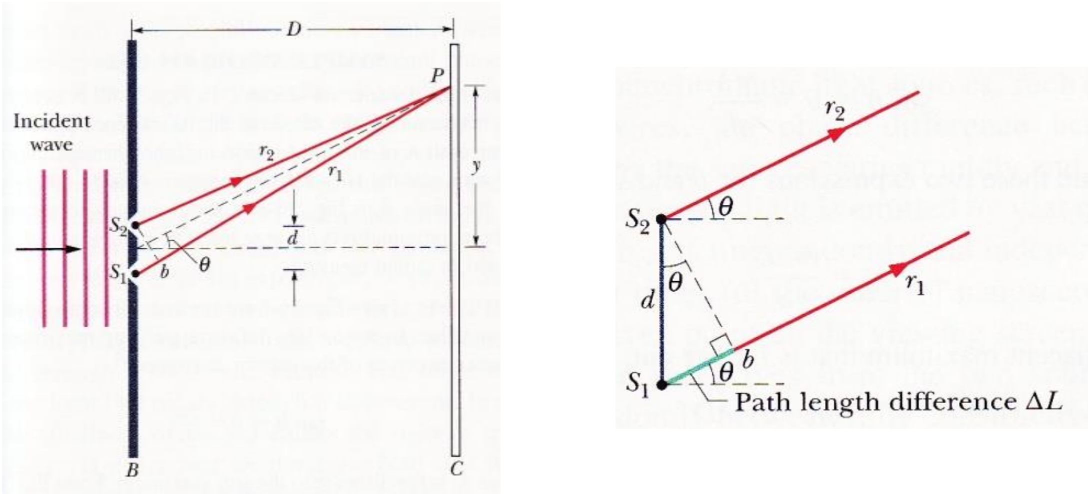


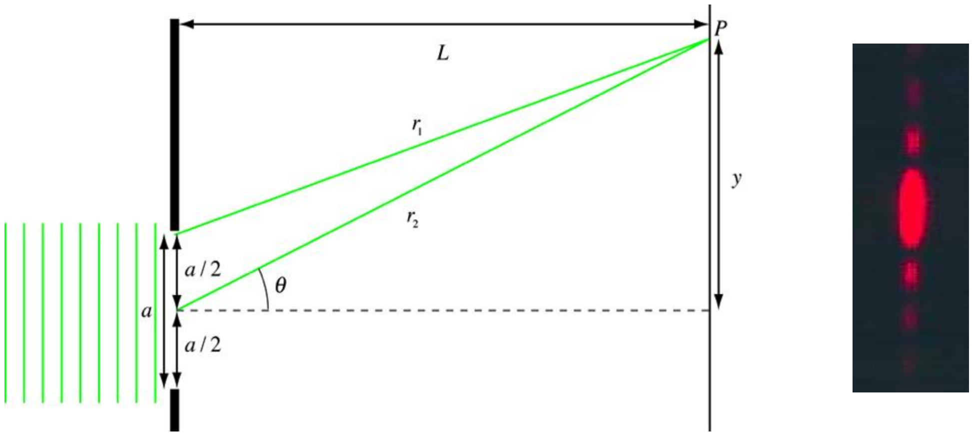
Fig. 1

<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 explain the diffraction pattern using interference. We divide the single slit into two halve, and 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. Therefore, 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 a constructive interference at point P.

- Compare to interference, where the 1st, 2nd and other maxima have the same intensity and width, the intensity and the width of the 1st, 2nd and other maxima are all different.



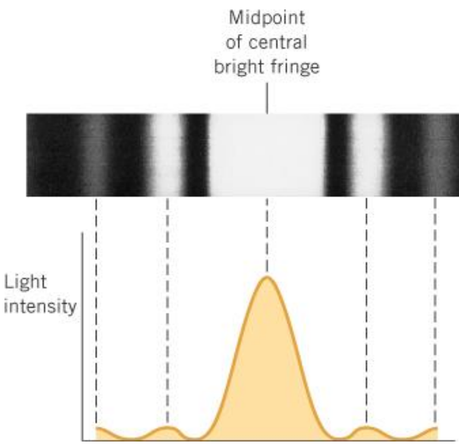
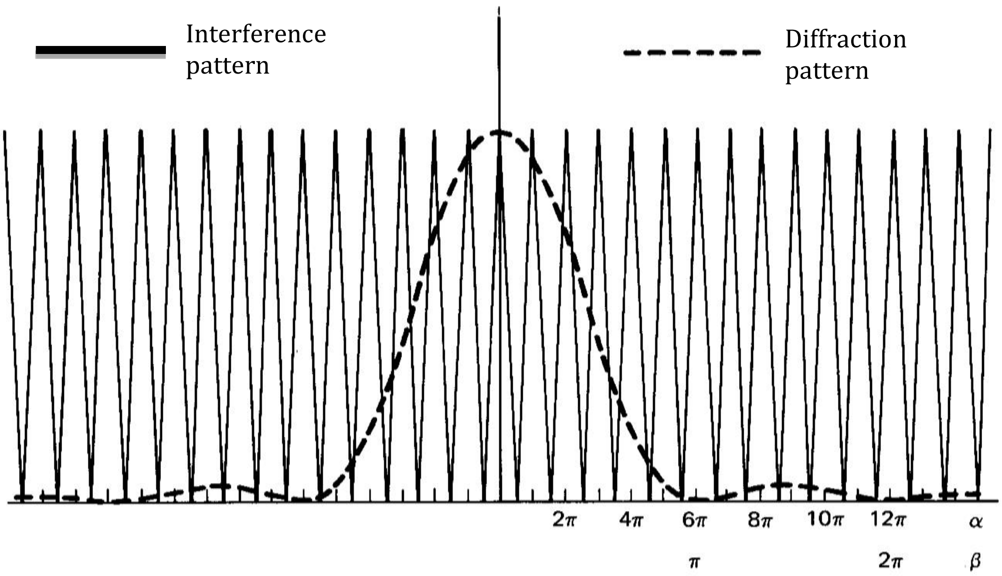
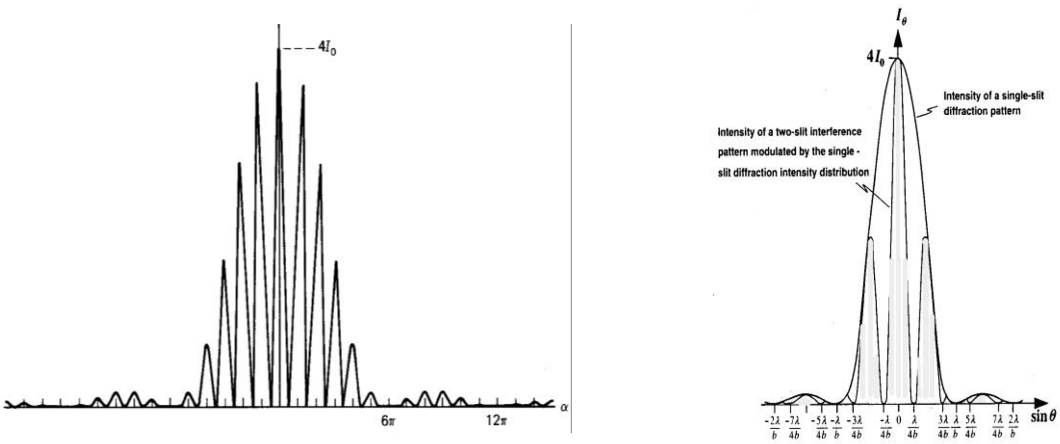


Fig. 2

- For a real Young double slit experiment, we would expect the following pattern to be observed.



- Final result:



Apparatus

- "Borderless Lab 365" Platform
- Laser sources (Red λ=660 nm, Green λ=535 nm)
- A Movable track with different slit settings.
  Slits' setting on the movable track:

Slit Number (From Right to Left)	1	2	3	4	5	6	7	8	9
Type	Single	Double	Double	Double	Double	Double	Triple	Quadruple	Quintuple
Width a/mm	0.04	0.04	0.04	0.04	0.08	0.08	0.04	0.04	0.04
Separation d/mm	0	0.5	0.25	0.125	0.5	0.25	0.5	0.125	0.125

- Light sensor on movable track

Procedure

1. Log in the experiment module "Interference" on the Borderless Lab 365 platform. https://stem-ap.polyu.edu.hk/remotelab/
2. Initial setting: Set the distance between slit set and screen as 285 mm by pressing "INCREASE" button.
3. In this experiment, there are two laser sources. Switch on the laser by clicking 'Red' or 'Green'.
4. Adjust the light intensity by swiping the bar below "Power". Do not turn on the laser to its maximum power, as it will be very difficult to do the alignment when the laser spot is too bright.
5. Select a slit (single, double or multiple slits) and align with the laser by clicking "LEFT" or "RIGHT" buttons to move the movable track. You can first choose the "Large" step button for coarse alignment and then choose the "Small" step button for fine tuning until the light spot is projected correctly on the selected slit. Hint: you can observe the pattern projected on the track as shown in cam 1 to fine tuning the alignment.
6. Scan the pattern by clicking "MEASURE".
7. Wait until the end of the scan, the buttons will be enabled again. At the same time, the pattern will be show graphically in the screen.
8. Download the graph by clicking "Menu" and choose a format (.svg, .png, .csv).
9. Repeat the experiment with different light source, slit or screen distance to determine the effects on an interference pattern.
10. To obtain a good interference/ diffraction pattern, you may slowly move the screen away from the slit set by clicking "INCREASE". Observe the pattern generated on the light sensor screen, stop moving the slits until it gets dimmer.
11. Move the screen toward the slit set by clicking "DECREASE", during which the pattern becomes bright and dark again. Repeat the above two steps until the interference pattern is the brightest on the screen.
12. Turn off the laser by swiping "Power" to zero, and press "logout" button at bottom right corner.

Data

Slit separation d = ________________________m

Screen separation D = _____________________m

Wavelength of light λ = ____________________m

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

Discussion

1. Is the result of fringe separation consistent with the equation $\Delta y = \frac{\lambda D}{d}$?
2. What happens to the light intensity recorded as the order of maximum goes higher? Why?
3. What are the possible errors of the experiment?