Democratic and People’s Republic of Algerien
University of 20 August 1955-Skikda
Faculty of Science
Department of Physics

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Practical Work of wave optics

Presented by :

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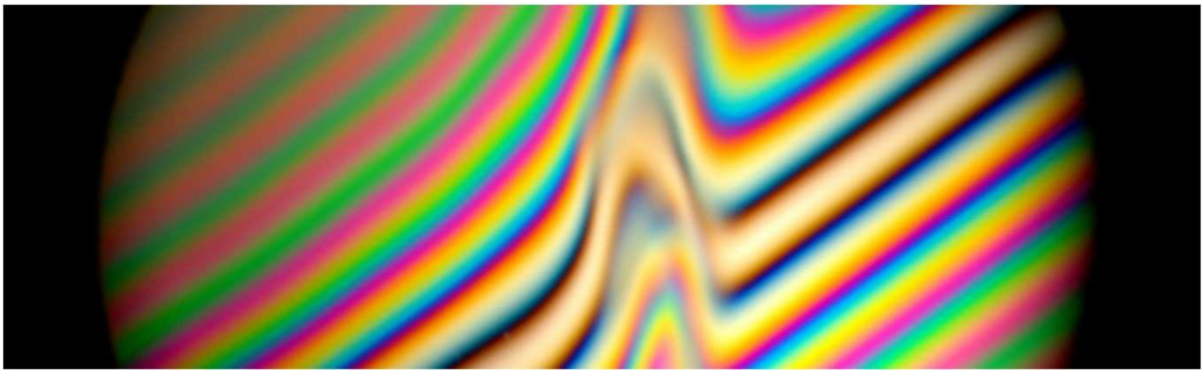
For students of 3rd LMD Fundamental physics speciality



Academic year : 2024/2025

Contenu de la matière :

Chapitre 1 : Optique physique

Principe de Huygens, Etude du phénomène d'interférences, cohérence. Interférences par division du front d'onde (Etude des différents dispositifs), Interférences par division d'amplitude (interféromètres), Etude du phénomène de diffraction, Diffraction à l'infini de Fraunhofer , Diffraction proche de Fresnel. Réseaux de diffraction (application au monochromateur, au spectroscope à réseau).

Chapitre 2 : Optique des Milieux Anisotropes

Définition d'un milieu anisotrope, tenseur de susceptibilité diélectrique, axes principaux d'un cristal, ellipsoïde et surface des indices, biréfringence et polarisation

Travaux Pratiques

TP 1 : Etude de la polarisation de la lumière

TP 2 : Interférences: Trous d'Young, Miroirs de Fresnel et Biprisme de Fresnel

TP 3 : Interféromètre de Michelson

TP 4 : Anneaux de Newton

TP 5 : Diffraction par les fentes

TP 6 : Réseaux de diffraction

Mode d'évaluation : Continu : 50% Examen : 50%

Introduction

When two or more light waves are superimposed, it is generally not possible to describe the observed phenomena in a simple way. Consider the case of two waves from a single point and monochromatic source: in the superposition region, the luminous intensity varies from one point to another between maxima which exceed the sum of the intensities of two waves taken separately and minima which may be zero. This is the phenomenon of interference.

To specify the conditions that two waves must meet in order to interfere, it is not necessary to have a precise idea of the nature of electromagnetic waves. It is sufficient to accept the following principles:

1- Monochromatic light is composed of vibrations of a single frequency.

2- The electromagnetic vibrations propagate at the speed of light v = c n, with c: speed of light and n: refractive index.

3- They are transverse to the direction of propagation.

4- They can be represented by a sinusoidal function.

5- The duration of light emission by an atomic emitter is in the range of 10^{-9} to 10^{-8} seconds, that is to say that the waves emitted have a length between 30 cm and 3 cm. In other words, each atomic oscillator emits a very fine monochromatic wave for a short time, then another without phase relation to the previous one: the source is temporarily incoherent.

6- Each atomic oscillator works independently of its neighbors. There is generally no permanent phase relationship between the radiations they emit. It is said that the source is spatially inconsistent.

7- The wavelengths of the neighbouring oscillations are generally independent, in this case all radiations are present in the continuous spectrum and the light is called white.

8- The radiation polarizations emitted by the various oscillators are independent and randomly distributed. The source is not polarized

I. Theoretical Reminders:

I.1. Wave Optics:

Wave optics is the study of light phenomena whose correct description requires a wave description of light. The electromagnetic wave is then characterized by the fields (E, B), vectors varying in time and space, solution of linear differential equations of Maxwell. There are two parts: the electric field grader and the magnetic field guarder.

- Diffraction: the amplitude of the light wave depends on the conditions at the limits imposed

by its extension. A ray of light that passes through a hole not very large compared to the wavelength, sees its amplitude modified.

- Interference: when two waves are superimposed, it is their complex amplitudes that add up and not directly the energy they carry (their intensity). For coherent monochromatic waves, a spatial modulation of their intensity results.

I.2. Objectives of the study of physical optics:

- To be able to correctly highlight the phenomenon of diffraction and interference, well distinguish the two if they coexist;

- Know how to make arrangements using the techniques of projections that give observation of figures with intense and well contrasted intensities.

In all manipulations, diffraction and interference will be observed on a screen. The distance between the objects causing interference or diffraction and the screen, marked D, shall be large in front of the characteristic dimension of this object so that one can place oneself within the framework of the Fraunhofer theory (infinite diffraction)

I.3. General conditions for obtaining interference:

When superimposing light beams, the following conditions must be verified for the observation of the interference phenomenon:

- The waves are isochrone, that is to say of the same frequency;
- The waves are consist, they present a constant phase shift in time and space;
- The waves have parallel E components.

To satisfy these conditions, the best way is to superimpose beams originating initially from a same source S having travelled different optical paths. This is achieved by an interference device:

- Either by division of the wave front (Young's slits, Fresnel's biprisms, Fresnel mirrors).
- Either by amplitude division (Michelson interferometer, Newton rings).

When the source S is point, interferences are observed throughout the region of superposition of waves, they are not localized, otherwise when the source is extended, interferences are localized.

I.4. Principle of optical interference:

Two beams (or more) of the same frequency and coherent (having a systematic phase difference) are superimposed. This can be achieved by taking two beams from the same source and following different paths.

I.4.1. Wave Front Division:

There is a division of the wave front in devices using the principle of the following figure:

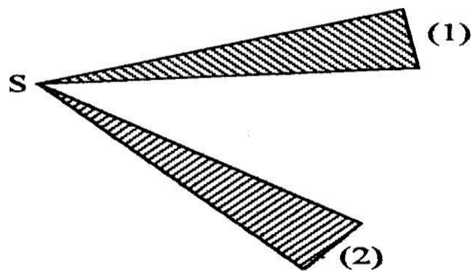


Figure 1. Principle of wave front division

The source S emits in all directions but only two separate portions (1) and (2) of the beam are used. These two beams then overlap in the region where the interference phenomena are observed.

Example: Young's Slots, Fresnel's Mirrors.

I.4.2. Amplitude division:

There is amplitude division in the case of the following figure:

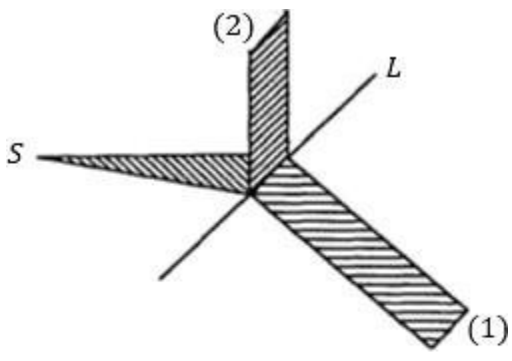


Figure 2. Principle of amplitude division

The incident beam is received on a semi-transparent blade L. One part (1) of the incident beam transmitted and another part (2) reflected. The two beams (1) and (2) are then superimposed in the region where the interference phenomena are observed.

Example: Michelson interferometer, Fabry Perot interferometer.

Practical work n⁰1: Light Wave Interference: Young's Slits Case

-**Purpose:**

1. Observation of infer fringes with the Young's slits.

2. Calculation of theoretical and practical interfringe for different slots i= f (1/a).

3. Representation of the interfringes i=f (D)

1. Interference of light rays with Young's holes:

I.1. Interference conditions:

To observe interference, certain conditions must be met:

- Sources S_1 and S_2 must be synchronous ($\omega_1 = \omega_2 = w$).

- The vibrations from S_1 and S_2 must be consistent i.e., $\varphi = \varphi_2 = \varphi_1 = Cte$ (over time)

Experimentally, these conditions are achieved when both sources S_1 and S_2 are the images of a single point source and monochromatic. The various interference systems we will see have a common characteristic: they give two S_1 and S_2 images (real or virtual) from a single point source, which then constitute coherent sources

To obtain interference, two waves of the same frequency and nature (same polarization) must be superimposed on one M point in space. The sources creating these two so-called coherent waves.

In the case of Young's slits, both sources S_1 and S_2 are consistent because they come from the same Source S.

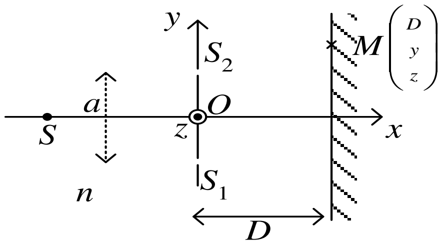


Figure 1: Interference with Young's slots

The walking difference Δ L is the difference in distance travelled by two waves before reaching point M.

$$\Delta L = S_1M - S_2M \tag{1}$$

The phase shift in this case is given by:

$$\varphi = \frac{2\pi}{\lambda}(S_1M - S_2M)\ , \ \text{avec :}\Delta L = \int nds \tag{2}$$

The amplitude of the light wave is given by :

$$\vec{E} = E_0 e^{-i(\omega t+\emptyset)} \tag{3}$$

At point M on a superposition of two light waves from the secondary sources S_1 and S_2:

$$\vec{E} = \vec{E}_1 + \vec{E}_2 = (E_{01}e^{-i(\omega t+\emptyset_1)}\overrightarrow{e_1} + E_{02}e^{-i(\omega t+\emptyset_2)}\overrightarrow{e_2}) \tag{4}$$

Calculation of light intensity at M point on the screen:

$$I = E.E^* \tag{5}$$

$$\vec{E} = \vec{E}_1 + \vec{E}_2 = (E_{01}e^{-i(\omega t+\emptyset_1)}\overrightarrow{e_1} + E_{02}e^{-i(\omega t+\emptyset_2)}\overrightarrow{e_2}) \times ((E_{01}e^{+i(\omega t+\emptyset_1)}\overrightarrow{e_1} + E_{02}e^{+i(\omega t+\emptyset_2)}\overrightarrow{e_2})$$

$$= (E_{01}e^{-i(\emptyset_1)}\overrightarrow{e_1} + E_{02}e^{-i(\emptyset_2)}\overrightarrow{e_2}) \times (E_{01}e^{i(\emptyset_1)}\overrightarrow{e_1} + E_{02}e^{i(\emptyset_2)}\overrightarrow{e_2})$$

$$= E_{01}{}^2\overrightarrow{e_1}\overrightarrow{e_1} + E_{01}E_{02}e^{i(\emptyset_2-\emptyset_1)}\overrightarrow{e_1}\overrightarrow{e_2} + E_{02}E_{01}e^{-i(\emptyset_2-\emptyset_1)}\overrightarrow{e_2}\overrightarrow{e_1} + E_{02}{}^2\overrightarrow{e_2}\overrightarrow{e_2}$$

$$\overrightarrow{e_1}\overrightarrow{e_1} = e_1e_1\cos(e_1, e_1) = e_1{}^2 = 1$$

$$\overrightarrow{e_1}\overrightarrow{e_2} = \overrightarrow{e_2}\overrightarrow{e_1} = e_1e_1\cos(e_1, e_2) = 1$$

$$= E_{01}{}^2 + E_{01}E_{02}e^{i(\emptyset_2-\emptyset_1)} + E_{02}E_{01}e^{-i(\emptyset_2-\emptyset_1)} + E_{02}{}^2$$

$$= E_{01}{}^2 + E_{02}{}^2 + E_{01}E_{02}\,(e^{i(\emptyset_2-\emptyset_1)} + e^{-i(\emptyset_2-\emptyset_1)})$$

$$= E_{01}{}^2 + E_{02}{}^2 + 2 \times E_{01}E_{02}\cos(\emptyset_2 - \emptyset_1)$$

$$= E_0{}^2 + E_0{}^2 + 2 \times E_0{}^2\cos(\emptyset_2 - \emptyset_1)$$

$$= 2\,E_0{}^2 + 2 \times E_0{}^2\cos(\emptyset_2 - \emptyset_1)$$

$$I = 2I_0 + 2I_0\cos(\emptyset_2 - \emptyset_1)$$

Thus, in point M, the following light intensity is obtained:

$$I = 2I_0(1 + \cos\Delta\emptyset) \qquad (6)$$

With :

$$\Delta\emptyset = \frac{2\pi}{\lambda}\Delta L \qquad (7)$$

Calculation of the Walk difference ΔL :

$$\Delta L = \overline{SS_1P} - \overline{SS_2P} \qquad (8)$$

$$= \overline{SS_1} + \overline{S_1P} - (\overline{SS_2} + \overline{S_2P})$$

$$= \overline{SS_1} + \overline{S_1P} - \overline{SS_2} - \overline{S_2P}$$

$$\Delta L = \overline{S_1P} - \overline{S_2P}$$

$$\overline{S_1P} = \left(x\,;\left(y + \frac{a}{2}\right);D\right), \qquad \overline{S_2P} = \left(x\,;\left(y - \frac{a}{2}\right);D\right)$$

$$= \sqrt{x^2 + \left(y + \frac{a}{2}\right)^2 + D^2} - \sqrt{x^2 + \left(y - \frac{a}{2}\right)^2 + D^2}$$

$$= D\,\left(1 + \frac{1}{D^2}\left(x^2 + \left(y + \frac{a}{2}\right)\right)\right)^{\frac{1}{2}} - D\sqrt{1 + \frac{1}{D^2}\left(x^2 + \left(y - \frac{a}{2}\right)^2\right)}$$

$$= D + \frac{1}{2D}(x^2 + \left(y + \frac{a}{2}\right)^2) - D + \frac{1}{2D}(x^2 + \left(y - \frac{a}{2}\right)^2)$$

$$= \frac{1}{2D}\ ay + \frac{1}{2D}\ ay = \frac{ay}{D} = \Delta L$$

Therefore :

$$\Delta L = \frac{ay}{D} \tag{9}$$

it was generally:$D \gg a, y, z$

As well as, $S_1M = \sqrt{D^2 + \left(y + \frac{a}{2}\right)^2 + z^2} = D(1 + \frac{1}{2D^2}\left(\left(y + \frac{a}{2}\right)^2 + z^2\right)$

And $S_2M = D(1 + \frac{1}{2D^2}\left(\left(y - \frac{a}{2}\right)^2 + z^2\right) = D(1 + \frac{1}{2D^2}\left(\left(y - \frac{a}{2}\right)^2 + z^2\right)$

Thus :

$$S_1M - S_2M = \frac{ay}{D} \quad \text{et } \varphi = \frac{2\pi}{\lambda}\frac{ay}{D}$$

Shiny fringes:

$$\Delta L = q\lambda \tag{10}$$

Dark fringes:

$$\Delta L = (q + \frac{1}{2})\lambda \tag{11}$$

Hence the interfringe:

$$i = \frac{\lambda D}{a} \tag{12}$$

The luminous intensity at point M is written:

$$I = 2I_0(1 + \cos\Delta\emptyset) = 2I_0\left(1 + \cos(\frac{2\pi}{\lambda}\frac{ay}{D})\right) \tag{13}$$

The intensity oscillates between the two extreme values, I_{max}et I_{min}

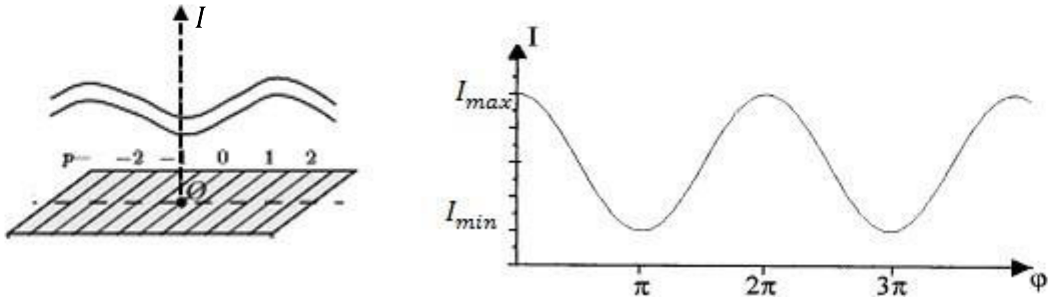


Figure 2. Intensity distribution on the screen

In the case where the vibrations have same amplitude we have:

$$E_{01}= E_{02}= E_0 \text{et} I(\varphi)= 2I_0\,(1+cos\varphi) = 4I_0\,cos^2(\frac{\varphi}{2}) \qquad (14)$$

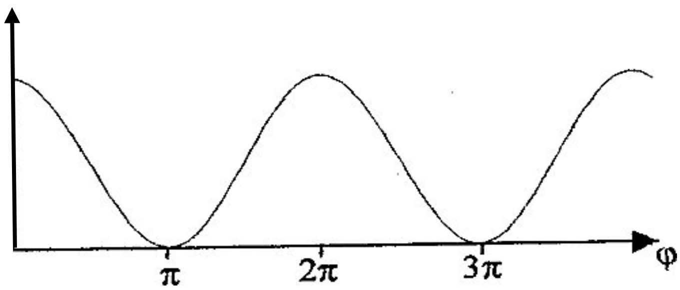


Figure 3. Intensity distribution on the screen for vibrations of the same amplitude

The shiny fringes:

$$I = 2I_0(1 + \cos\Delta\emptyset)$$

$$\cos\Delta\emptyset = 1$$

$$\cos\Delta\emptyset = \cos 2k\pi$$

$$\Delta\emptyset = 0, 2\pi, 4\pi, 6\pi, \ldots$$

So we can calculate their positions in the screen:

$$\frac{2\pi}{\lambda}\frac{ay_k}{D} = 2k\pi$$

$$\frac{ay_k}{D} = k$$

$$y_k = \frac{k\lambda D}{a} \quad (15)$$

The dark fringes :

$$I = 2I_0(1 + \cos\Delta\emptyset)$$

$$\cos\Delta\emptyset = \cos((2k\pi + 1)\pi)$$

$$\Delta\emptyset = \pi, 3\pi, 5\pi, \ldots$$

We can also calculate their positions in the screen:

$$y_{k+1} = \frac{(k+1)(\lambda D)}{a}$$

$$y_{k+1} - y_k = \frac{\lambda D}{a}$$

$$\frac{2\pi}{\lambda}\frac{ay_k}{D} = (2k+1)\pi$$

$$y_k = \frac{(2k+1)\lambda D}{2a}$$

$$y_{k+1} = \frac{(2k+3)(\lambda D)}{2a}$$

$$y_{k+1} - y_k = \frac{(2k+3)\lambda D}{2a} - \frac{(2k+1)\lambda D}{2a} = \frac{\lambda D}{a} \quad (16)$$

So the interfringe for the bright and dark fringes is given by :

$$i = \frac{\lambda D}{a} \qquad (17)$$

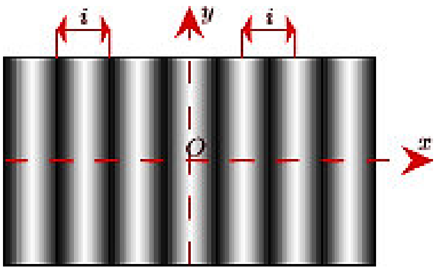


Figure 4. Image of the fringes obtained on the screen

Contrast is given by:

C : Constante

$$C = \frac{I_{Max} - I_{Min}}{I_{Max} + I_{Min}} = \frac{4I_0 - 0}{4I_0 - 0} = 1 \qquad (18)$$

I.2. Course of the experiment:

Perform the following assembly: He-Ne laser with a wavelength λ=632.8 nm, Young's slots with different value a and b (sizes defining Young's slots), screen with a blank sheet (possibility to put a lens before the slots to widen the light beam).

I.3. Requested work:

1. Know the different Young's slots (mark the values of a and b.

2. Perform your experiment for different Young's slots (4 pairs) by setting D distance between S_1S_2 and the screen, and using a pen and on the blank sheet of the screen, mark the Δ x of N fringes for different values of a and b, calculate the practical and theoretical i-interfringe, Fill in the table above (and also draw the two values of i on the same curve as a function of 1/a) (is given Δa= 0.02 mm, ΔD = 1cm, Δλ = 0.004 µm) .

a b	Δx (mm)	i (practical interfringe) (mm)	i theoretical (mm)
a=…..mm b=…..mm			
a=…...mm b=…...mm			
a=…...mm b=…...mm			
a=…...mm b=…...mm			

3. Take two Young's slots (Best measurement for both Young's slots in step 2), vary D (distance between Young's slots and screen 5, 10 or 15 cm: not suggested by your teacher). Draw i practical and theoretical according to D.

D				
i (practical interfringe) (mm)				
i theoretical (mm)				

Report from practical work n^{0}1 Young's Slots:

I. Introduction :

A screen pierced with two small holes that diffracte the light. This screen is illuminated by a monochromatic point source S. According to the laws of geometric optics, we should observe on a screen E the traces M_1 and M_2 of the rays from S_1 and S_2. Because of the small size of the holes, diffraction occurs and an interference field is obtained in the coverage of the diffracted beams.

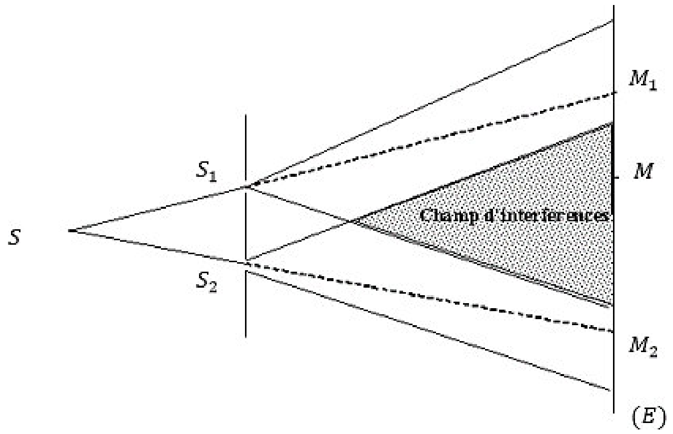


Figure 1. Image of young's holes

S_1 and S_2 are equally distant from the source S (point and monochromatic). The secondary sources S_1 and S_2 are therefore synchronous and coherent.

The screen (E) is perpendicular to the plane of the figure. It shows alternating dark and bright fringes.

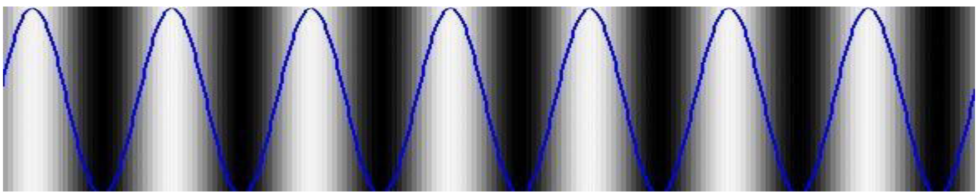


Figure 2. Fringes obtained on the screen

The interference fringes are therefore rectilinear (in first approach) the central fringe ($\Delta L=0$) corresponds to y=0 is a bright fringe.

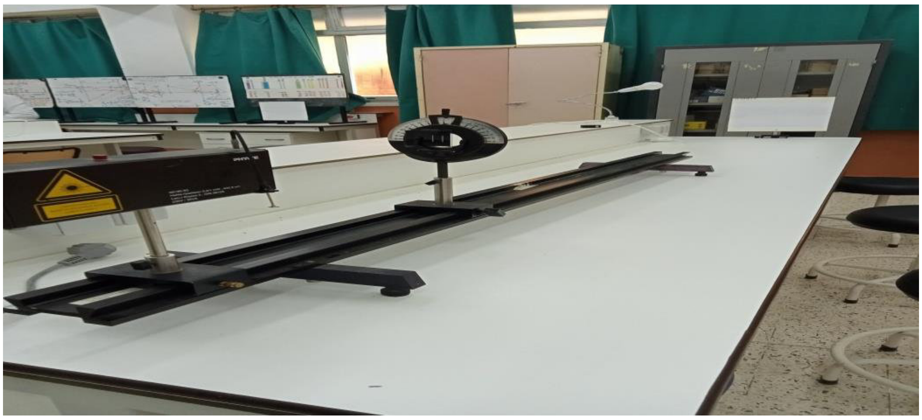


Figure 3. Actual image of the mounting of Young’s slits taken in the optical laboratory at Skikda University

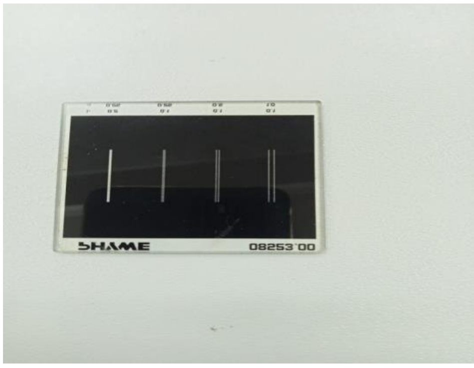


Figure 4. Real image of pairs of Young’s slits taken in the optical laboratory at Skikda University

II. History of mounting young’s slots:

In 1801, the British physicist Thomas Young envisioned a relatively simple experiment that marked a turning point in the history of science. He passes a beam of light through two slits and observes the figure formed on a screen placed behind the slits. It demonstrates the undulating nature of light.

This experiment once again played a crucial role in the history of physics when in 1961 the German physicist Claus Jönsson carried out exactly the same experiment, but with an electron beam instead of the light beam, demonstrating the wave behaviour of electrons and the particle-wave duality of matter.

Young's Slits is a famous experiment that highlights the phenomenon of diffraction of light waves Young's Slits experience. It consists in passing a beam of monochrome light through two narrow slots, located at a distance from each other comparable to the wavelength of the light used. The light that passes through the slots is projected onto a screen behind them, forming an interference pattern of bright and dark areas.

This phenomenon is explained by the fact that light is a wave which propagates by diffracting and interfering with itself. Light waves passing through the two slots interfere constructively or destructively depending on their phase shift. Areas where the waves are in constructive phase are brighter, while areas where the waves are in destructive phase are darker. The Young's slits experiment showed that light has wave properties and highlighted the phenomenon of diffraction and interference, which is the basis for many applications of modern optics such as interferometers, Holograms, etc.

Young's slits are mainly used to study the wave nature of light and quantum physics Here are some specific uses of Young's slits in physics:

1. Measurement of the wavelength of light: Young's slits can be used to measure the Indeed, Young's slits allow the historical experiment of Young which confirmed the hypothesis of the wave nature of light. This experiment involves passing a beam of light through two narrow parallel slots and observing the interference produced on a screen placed behind the slots. The observed interferences are evidence that light behaves like a wave.

2. Young's slits are also used in quantum physics to observe the phenomenon of particle diffraction, which is related to the Heisenberg uncertainty principle. Particles (for example electrons) are sent through the slits and their behaviour is observed on a detection screen. The results of these experiments show that particles can behave like waves and therefore have a wave nature as well as a corpuscular, ie particle nature.

3. In addition, Young's slits are used in the field of optics to study light propagation, image formation, interference and diffraction. These studies help to better understand the phenomena of diffraction and interference, to optimize imaging systems and optical design

a- Know the values of a and b of the Young's slots:

a **b**	**Δx (mm)**	**D(mm)**	**N**	**i (theoretical)**	**i (practical)**
a=1mm **b=0.1mm**	18.5	2445	12	1.54	1 .54
a=1mm **b=0.1mm**	17.5	2295	12	1.45	1.45
a=1mm **b=0.1mm**	19 .5	2145	14	1.35	1.39
a=1mm **b=0.1mm**	14.0	1995	11	1.27	1.26

-Calculation:

$$i_{the} = \frac{\lambda D}{a}$$

The best measurement is: N 1 for Young's Slots of **a=1mm** et **b= 0.1mm**.

-Calculation of errors :

We know that: $i=\frac{D*\lambda}{a}$ et λ=632.8mm (He Ne)

We have :

$\lambda= (\lambda_0 \pm \Delta\lambda) = (\lambda_0 \pm 0.0004)$ µm et $\Delta D= \pm 1$ cm

Too Δ a= ± 0.02 mm

$$\frac{\Delta i}{i} = \left(\frac{\Delta \lambda}{\lambda} + \frac{\Delta D}{D} + \frac{\Delta a}{a}\right)$$

$\Delta\lambda = 0$ donc :

$$\mathbf{\Delta i = \left(\frac{\Delta D}{D} + \frac{\Delta a}{a}\right) i}$$

$\Delta i_{Pra} = \Delta x/N$

Δi_{Pra}	±0,07	±0,06	±0,06	±0,06	±0,05
Δi the	±0,47	±0,47	±0,12	±0,03	±0,03

The value difference back to imperfections of light sources, the novelty of practical work for physics students, environmental disturbances, etc. Therefore, it is important to consider these factors when performing an interference experiment to obtain a precise and reliable result.

b- Drawing of the curves requested:

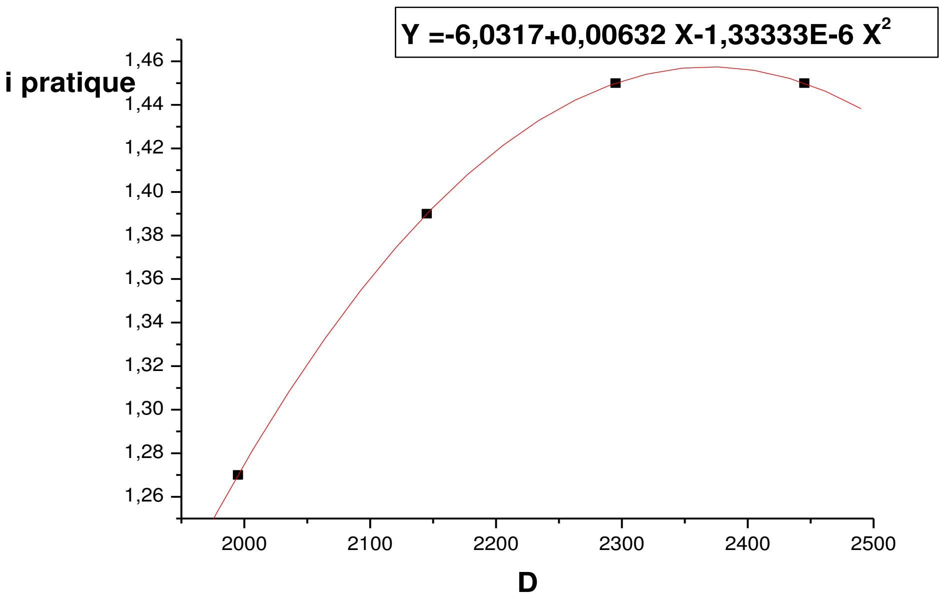


Figure 5. Variation of i_{pra} as a function of D

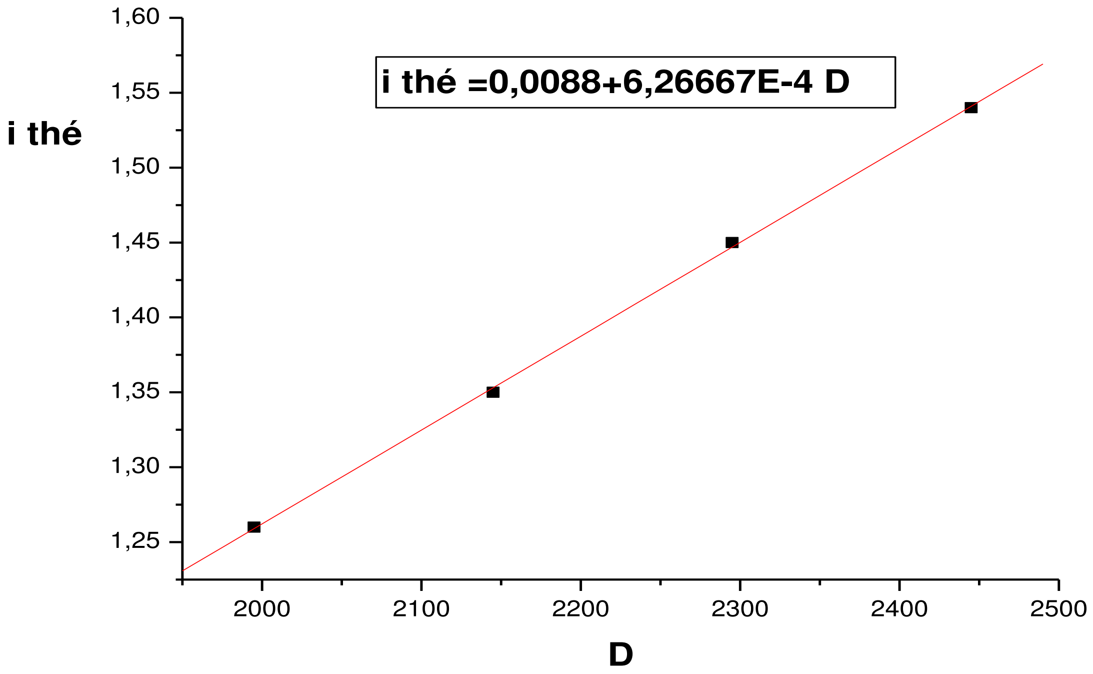


Figure 6. Variation of i_{theo} as a function of D

Note the two curves are almost congruent this is due to the convergence of theoretical and practical values

-Conclusion:

In conclusion, the Young's slits are an excellent example of the wave-particle duality of quantum physics. Experience shows that light and other particles such as electrons have wave properties and can therefore form interferences. Young's slits have helped us better understand the nature of light and how it spreads. This experiment is used in many fields today, such as spectroscopy and crystallography, to study the structure of matter using interferences. Young's slots have also inspired many theories and concepts in the field of quantum physics, such as the tunnel effect and Heisenberg's uncertainty principle. In summary, the Young's slot experiment has great significance for the development of quantum physics and continues to be studied and explored today.

Practical work n^0 2: Light wave interference: Fresnel biprism

Purpose:

1. Observation of infer fringes with the Fresnel biprism
2. Calculation of the angle at the apex A and the deviation D of the Fresnel biprism
3. See the influence of the distance d (prism-screen) on the interfrange i
4. Calculation of theoretical and practical interfrange

I.1. Interference of light rays with the Fresnel biprism:

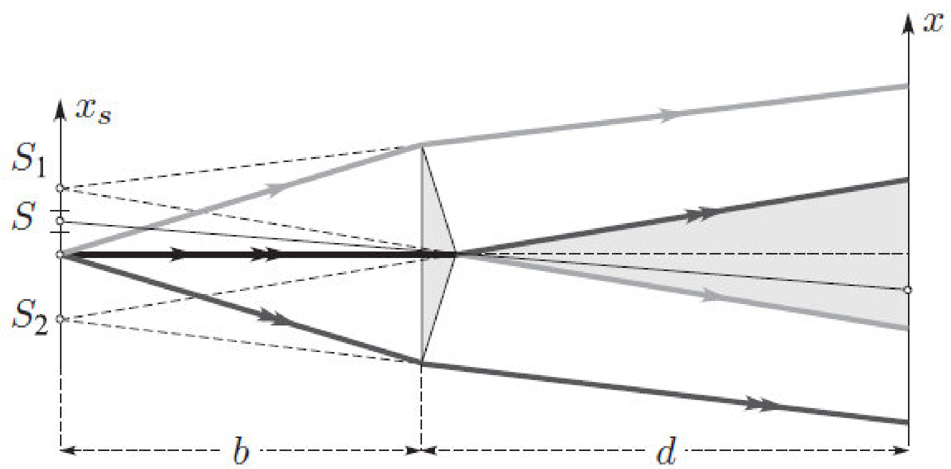


Figure 1. Descriptive diagram of the interference of light rays with the Fresnel biprism.

The Fresnel biprism consists of two identical prisms with a very small angle A (about 45'), joined by their bases. As for the Young's slits, the source slit must be parallel to the edge of the prisms.

The rays from S are deflected at an angle determined by the two prisms. The interference field is limited by the two rays (I) and (II) from S1 and S2 respectively (figure 1). The secondary sources S_1 and S_2, fictitious, are very close to the main source S.

It is easy to show that for the weak deviations of the rays we have:

$$i = nr, i' = nr', A = r + r', D = (n-1)A \quad (1)$$

The distance between the two secondary sources is given by:

$$a = 2Db = 2(n-1)Ab \tag{2}$$

Hence the interfrange in the case of the Fresnel biprism:

$$i = \frac{\lambda(b+d)}{2Db} = \frac{\lambda(b+d)}{2(n-1)Ab} \tag{3}$$

2- Theoretical reminder on the prism formulas:

Consider a triangular, transparent base right prism of refractive index n. The light rays propagated in a main section plane (perpendicular to the edge of the prism). Note At the angle of the vertex facing the base of the triangle (Figure 2).

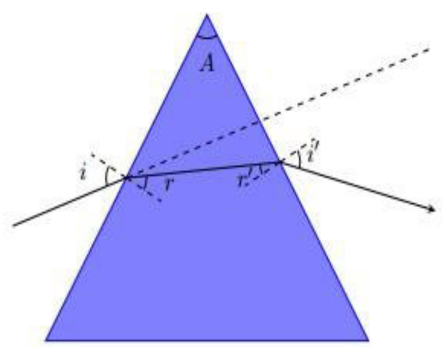


FIGURE 1.1: Le prisme. Définition des angles.

Figure 2. The prism

2.1. Formules du prisme :

The laws of refraction impose two relations between (i) and (r) then between i' and r':

$\sin i = n \sin r$ et $\sin i' = n \sin r'$

The deviation D of the incident ray is written:

$$D = (i - r) + (i' - r') \tag{4}$$

In addition, A, r and r' are related:

$$A + \left(\frac{\pi}{2} + r\right) + \left(\frac{\pi}{2} - r'\right) = \pi \qquad (5)$$

From which a new expression of D is deduced:

$$\boldsymbol{D = i + i' - A} \qquad (6)$$

If A and n are fixed, D depends only on the angle of incidence i. In the figure below, the deviation D is represented as a function of i by fixing A = 60° and n = 1, 6.

2.2. Minimum deviation and conditions of emergence:

It is noted in the previous figure that the deviation exists only if the angle of incidence exceeds a value i0. Indeed, if i is too small there is total reflection inside the prism.

For example, with a prism such as A = 60° and n = 1, 7, we have:

$$\boldsymbol{\sin i' \leq 1 \Rightarrow \sin r' \leq \frac{1}{n} \Rightarrow r' \leq 36°} \qquad (7)$$

Where do we get:

$$\boldsymbol{r \geq 42° \Rightarrow i \geq 43,7°} \qquad (8)$$

Thus, the incident beam will not be able to exit from the opposite side if it is not sufficiently tilted relative to the input face.

The figure above also shows a minimal deviation.

According to the inverse light return principle, if D is the deviation corresponding to i , then D is also the deviation corresponding to i'. There are therefore two angles of incidence giving the same deviation. When D reaches its minimum, these two angles merge (see curve):

$$i = i' \Leftrightarrow D = D_m$$

In this case, we have:

$$D_m = 2i - A.$$

The refractive laws finally give:

$$n = \frac{\sin(\frac{A+D_m}{2})}{\sin(\frac{A}{2})} \tag{9}$$

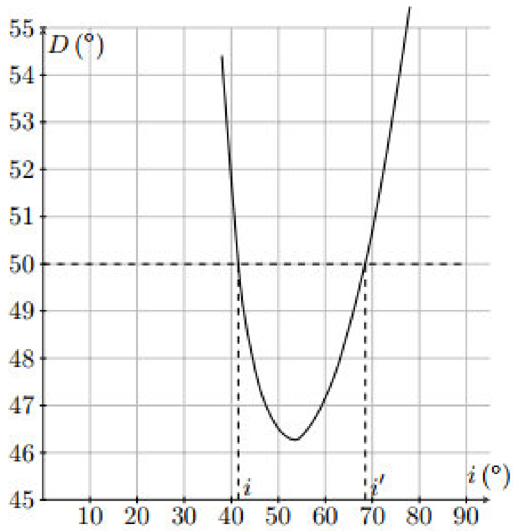


FIGURE 1.2: Evolution de la déviation D en fonction de l'angle d'incidence i pour $A = 60°$ et $n = 1,6$.

Figure 3. Variation of D=f(i)

The measurement of D_m and A allows to calculate the index of the prism.

2. How the experiment will proceed:

Perform the following assembly: He-Ne laser with a wavelength of λ=632.8 nm, convergent lens with a focal length f'=2cm, Fresnel biprism, screen with a blank sheet.

3. Work required:

1. Put the Fresnel's biprism into the goniometer (with your teacher's help); measure the D deviation and the angle at the top A that will be used in the rest of the pratical work.

2. Perform optical mounting for light interferences with the Fresnel biprism.

3. Set b, calculate the distance of N fringes Δ x and deduce the interfringe i for different values of d (not suggested by your teacher) (b=1 mm, d= 1cm, D=1', A=1').

4. Compare the theoretical and practical values of I interfringe and draw them on the same curve.

d (m)				
i (practical interfringe) (mm)				
i theoretical (mm)				

Report of practical work n^0 2: Interferences of light waves: Fresnel biprism

1-Introduction:

The Fresnel biprism is an optical device used to study light interference. It consists of two identical rectangular prisms placed side by side, with a thin groove between them. The two prisms divide the light beam into two rays, which propagate through the groove and meet at a distance of about a few millimetres. This distance is called the Fresnel zone, named after the physicist Augustin-Jean Fresnel who invented the biprism in 1819.

When the two rays of light meet, they interfere with each other, creating luminous fringes that move according to the lighting conditions and the positioning of the prisms. Interference fringes can be viewed through a screen, such as a photographic plate, silver paper or fluorescent surface. The fringes can also be photographed for more accurate analysis.

The Fresnel biprism is a useful tool for studying light properties, such as diffraction, polarization and interference, as well as for applications in holographic optics, metrology and microscopy.

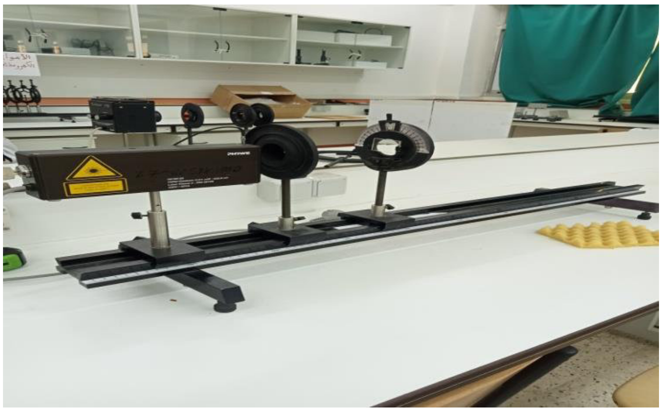


Figure 1. Real image of the Fresnel biprism mount used in our experiment

Figure 2. Real image of the goniometer used in our experiment for calculating the angle at the top of the biprism and its deviation

Figure 3. Real image of the He-Ne laser used in our experiment with wavelength λ= 632.8 nm and power of 1mwat

2. The objective :

1-Observation of infer fringes with the bi Fresnel prism

2-Calculation of the angle at the apex A and the deviation D of the Fresnel bi prism

3-See the influence of distance (prism-screen) on the interfringe i

4-Calculation of theoretical and practical intersections

3- Requested word :

3.1. Calculation of A and D :

Using the moving platform, place the biprism as shown in Figure 4 (edge facing the incident beam whose direction approximately coincides with the bisector of A.

Aim at the bezel for the two reflected images of the source slot. Measure α and β angles. The difference between the two angles measured is equal = 4A

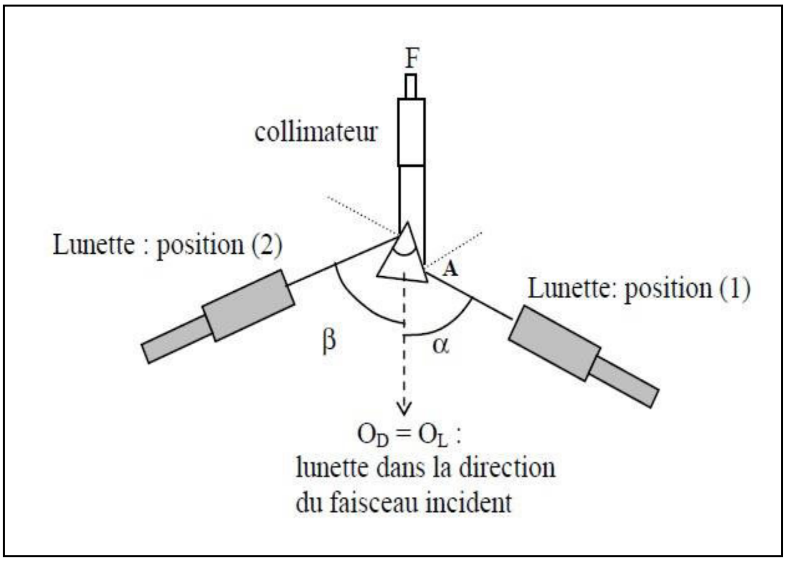
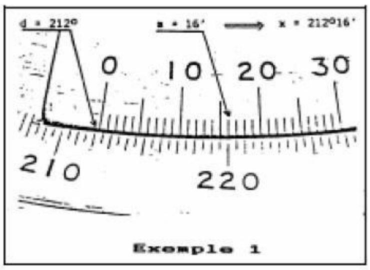


Figure 4. Mount used for calculation of angle at top of biprism used

Exemple 1	Exemple 2
Le zéro du vernier est entre les graduations 212° et 212,5° donc d = 212° ; la coïncidence donne m = 16' donc x = 212° 16'.	Le zéro du vernier est entre les graduations 212,5° et 213° donc d = 212,5° (212° 30') ; la coïncidence donne m = 10' donc x = 212° 40'



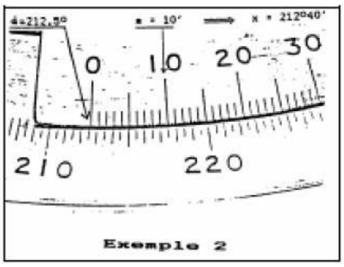


Figure 5. Vernier of the goniometer used for calculation of angles

$$A = \frac{\alpha - \beta}{4} = \frac{157'}{4} = 39.25'$$

With the help of the goniometer we calculate the deviation D which will be given by the following relation:

$$D = \frac{335.0^0\ 10' - 334.5^0}{2} = 20'$$

From this we can calculate the refractive index of our biprism:

$$(n-1)A = D \to n = \frac{D}{A} + 1$$

$$n = \frac{20}{39.25} + 1 = 1.510$$

3.2. Influence of the variation of D on the interfringe:

D(mm)	∆x (mm)	N	I theoretical	I pratical
3660	15.0±0.5	9	1.69±0.44	1.67±0.05
2380	14.5±0.5	13	1.12±0.04	1.11±0.20
2180	10.0±0.5	10	1.03±0.27	1.00±0.05
1980	8.0±0.5	10	0.90±0.25	0.80±0.05
1780	7.5±0.5	10	0.84±0.23	0.75±0.05

-Calculation :

D=366 cm, d'=12 cm

$$i_{pratical} = \frac{\Delta x}{number\ of\ fringe}$$

$$\Delta i\ theo = \frac{D+d'}{2A(n-1)d'}\Delta\lambda + \frac{\lambda}{2A(n-1)d'}\Delta D + \frac{2A\lambda(n-1)D}{[2A(n-1)d']^2}\Delta d' + \frac{2(n-1)d'[\lambda(d+d')]}{[2A(n-1)d']^2}\Delta A$$

-Presentation de D=f(i_{theo}, i_{pra}) :

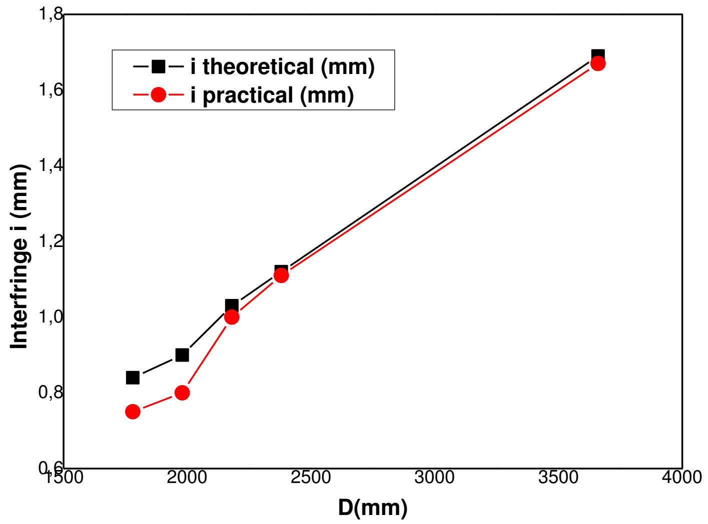


Figure 6. Representation of D=f(i_{theo}, i_{pra})

Through the values we have obtained from experience, we note that the values are theoretically and practically almost equal and also the curves identical and we notice that each time the distance decreases the value of the interfrange i decreases.

-Conclusion :

In conclusion, the Fresnel biprism is an optical device used to create light interferences for the study of diffraction and polarization of light. Its principle is based on the division of a beam of light into two parts by a small prism, which create two point sources from two virtual slots. When these two sources interfere, interference fringes are observed, which allows the wavelength of light to be measured or the distance between the slots determined. The Fresnel biprism is widely used in physics and optics for applications such as spectroscopy, dispersion measurement, characterization of microscopic objects, measurement of surface shape, etc. In short, the Fresnel biprism is an indispensable tool for the study of light physics and has made many contributions to the understanding of light.

Practical work n⁰ 3: Light Wave Interference: Fresnel Mirrors

Purpose:

1. Observation of interference fringes with Fresnel mirrors

2. Goniometer angle calculation between the two mirrors

3. See the influence of distance d (center of screen mirrors) on interfringe i

4. Calculation of theoretical and practical interfringe

I. Interference of light rays with Fresnel mirrors:

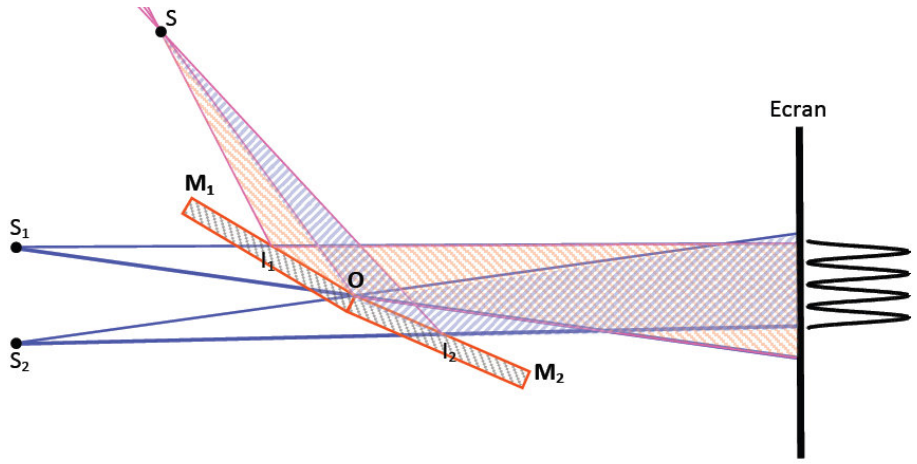


Figure 1: Schematic diagram of the interference of light rays with the Fresnel mirror.

II. Theory:

The Fresnel mirror consists of two flat mirrors M_1 and M_2 slightly tilted against each other that reflect light emitted by a monochromatic source S almost rashly.

II.1. Description of the phenomenon:

A beam from the source S (Figure 1), is reflected on both M_1 and M_2. The mirrors being tilted relative to each other, these forms two beams by division of the wave front, appearing to come from secondary sources S_1 and S_2.

The two reflected waves that appear to come from S_1 and S_2 are actually emitted by the same source (S), they are therefore synchronous (they have the same frequency) and coherent (the phase shift between these two waves is independent of time): Interference can be observed in the beam-covering area. It is therefore a division-front interferometer.

Note:

a: the distance between S_1 and S_2

α: angle formed between the two mirrors.

d' is the distance between (S_1S_2) and O center of the two mirrors.

d: distance between O center of the mirrors and screen, so the theoretical interfringe is given by:

$$i = \frac{\lambda(\mathrm{d} + \mathrm{d}')}{2\,\alpha\, d'}$$

Figure 2 shows the Fresnel mirrors which are composed of:

1. Flat mirrors
2. Micrometric screw to adjust the angle between the two mirrors
3. Framework

4. Stem

5. Parallel Displacement Device

6. Knurled screw acting on the movement.

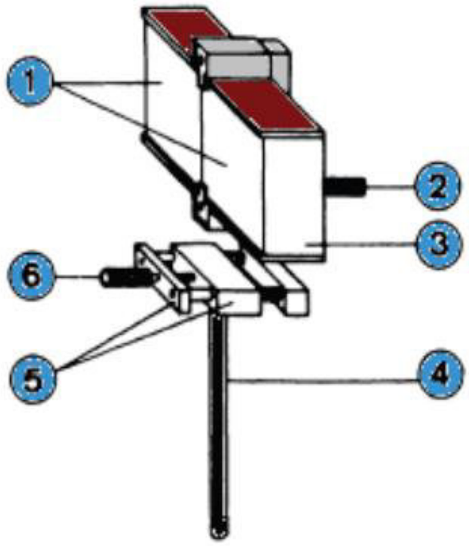


Figure 2: Fresnel mirror

2. How the experiment will proceed:

Perform the following assembly: He-Ne laser with a wavelength λ=632.8 nm, convergent lens with a focal length f'= 2 cm, Fresnel mirror, screen with a white sheet.

3. Work required:

1. Perform optical mounting for light interference with Fresnel mirrors.

2. Vary d with a suitable step. Draw a chart that gives the variation of i and d.

3. Compare theoretical and practical values of the i. interfringe (d'=1 mm, d= 1cm, α=1)

d (m)				
i (practical interfringe) (mm)				
i thoeretical (mm)				

Report of practical work n^0 3: Light Wave Interference: Fresnel Mirrors

I-Introduction:

Fresnel mirrors are flat mirrors that allow to concentrate the light in a precise point thanks to their graduated surface. These mirrors have many applications in the solar industry, power generation and telescopes. Practical works in Fresnel mirrors often consist of their multi-faceted annular surface. These mirrors are widely used in various fields, such as solar energy, optics, optical communication and medical research. In the course of practical work on Fresnel mirrors, we studied their operation, optical properties and practical use. In this report, we will present the results of our experiments, as well as the theoretical aspects related to these mirrors. This study will help us to better understand the advantages and limitations of Fresnel mirrors, as well as their importance in many fields of physics and engineering.

II-Theoretical part:

The Fresnel mirror is a type of reflective mirror that uses a series of small flat surfaces to reflect light. Unlike conventional mirrors that are smooth and perfectly reflect light, Fresnel mirrors have micro textures that distribute the light partially expel the incident light, which allows partial light transmission through the mirror. Unlike traditional mirrors, which have a continuous flat or curved surface and reflect light evenly, the Fresnel mirror uses flat surfaces in the form of prisms to deflect light forward and backward, creating alternating reflective and transparent areas.

The Fresnel mirror is named after the French physicist Augustin-Jean Fresnel, who developed this technology in 1822 to improve the quality of maritime lighthouses. Fresnel mirrors are now commonly used in movie projectors, traffic lights, solar panels, and many other optical devices.

The principle of operation of the Fresnel mirror is based on the refraction of light through prism-shaped surfaces. When light hits the flat surface of a prism, it is refracted forward and some of the light is reflected. By using multiple prismatic surfaces, the Fresnel mirror can reflect light in a specific direction while allowing partial transmission of light through the mirror.

The optical diagram of the Fresnel mirror is shown below:

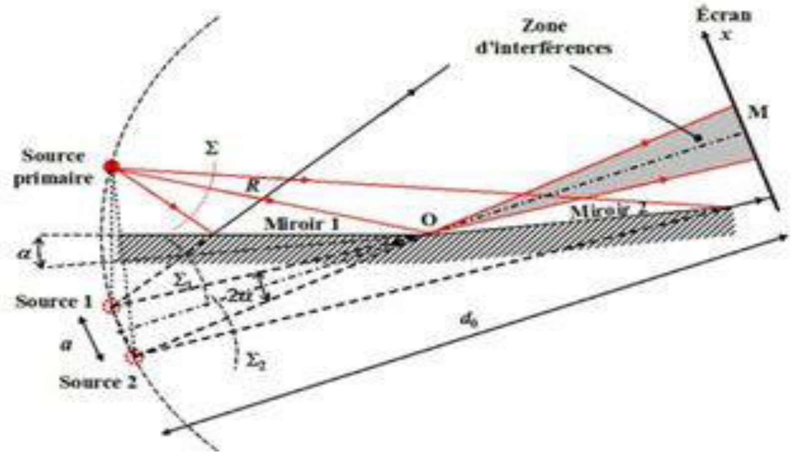


Figure 1. Fresnel mirror device

This device uses a primary source associated with two reflective plane mirrors making a slight angle α between their planes. The source is located at the distance R from the mirror stop. Each mirror gives a virtual image of the primary source and these two images behave as secondary sources. In the intersection area of the two beams, interference is observed. Figure 1 shows the Fresnel mirror arrangement. We show geometrically that the secondary sources are located on a circle of center O and radius R. The screen is placed at distance d_0 from the secondary sources, parallel to the plane of the sources. Secondary sources are distant from quantity a. We find that we have to deal with the interference between two spherical wavefronts emitted by the two secondary sources. At any point M (x , y ,d_0), the interferences s' writes:

$$I(x,y,d_0) = 4A^2(1+\cos(\emptyset(x,y,d_0))) \qquad (1)$$

and in the case of parabolic approximation where $d_0 \gg a$:

$$\emptyset(x,y,d_0) \sim \frac{2.\pi.a.x}{\lambda.d_0} \qquad (2)$$

As the angle α is small, we have in the triangle (O, S_1, S_2) :

$$2\alpha \sim \frac{a}{R} \; soit \; a \sim 2.\alpha.R \qquad (3)$$

So it came:

$$\emptyset(x,y,d_0) \sim \frac{4.\pi.a.R.x}{\lambda.d_0} \qquad (4)$$

And the interfringe is :

$$i = \frac{\lambda.d_0}{2.\propto.R} \qquad (5)$$

-Note:

To determine the geometric shape of the fringes, we look for the places of the points where the phase is constant, which results in x = Cte, the other quantities being fixed by the geometry of the assembly. The fringes are vertical, perpendicular to the plane of the figure, regularly spaced from the interfringe i.

Fresnel's mirror laws are used to describe how light is reflected on an inclined surface. The two main mirror laws of Fresnel are:

1. The law of reflection: Fresnel's first law states that the angle of incidence of light is smooth surface. The main Fresnel mirror laws are:

2. The amount of reflected light is directly proportional to the angle of incidence. This means that the smaller the angle of incidence, the larger the amount of reflected light.

3. The angle of incidence is equal to the angle of reflection. This means that if the light hits a smooth surface at an angle of 30 degrees, it will be reflected at an angle of 30 degrees.

4. Light that is not reflected is absorbed or transmitted through the surface. This means that the sum of reflected light and absorbed or transmitted light must be equal to 100%.

These laws are used to evaluate the amount of light reflected by different surfaces, such as mirrors, glass panes, metals, etc.

In summary, the Fresnel mirror is a type of reflective mirror that uses prismatic surfaces to deflect light and create alternating reflection and transmission zones. This technology is used in many optical applications, including marine lighthouses, cinema projectors and solar panels.

-Work required:

The experiment is carried out in the following stages:

1. The light source is lit and the condenser lens is placed in front of it to focus the light into a parallel beam.

2. The Fresnel mirror is placed at an appropriate distance from the condensing lens to reflect the parallel light beam.

3. The projection screen is placed at an appropriate distance from the Fresnel mirror to display the reflected image.

4. Obstacles may be placed along the path of light to observe the effects of refraction and reflection on the beam.

Figure 2. Fresnel mirror device

Figure 3. Image of the tool for measuring distances of the order of one metre

Figure 4. Real image of the semi-millimeter ruler

- Measures:

D (cm)	120	160	200	240
N	10	11	11	10
X (mm)	11.25	16.75	20.5	22.0
i practical(mm)	1.1	1.5	1.9	2.2
i theoretical (mm)	1.1	1.4	1.8	2.1

i practical : $=\frac{\Delta x}{N}$

Thus : i pratical$=\frac{11.25}{10}$**= 1.12 mm**

i pratical $=\frac{16.75}{11}$**= 1.52 mm**

i pratical $=\frac{20.5}{11}$**= 1.89 mm**

i pratical $=\frac{22}{10}$**= 2.2 mm**

I theoretical : On à d'après la loi suivante :

$$i = \frac{\lambda \times (d+d')}{2 \times \alpha \times d'}$$

And:

D=d+d', d' = 20 mm, λ=632 .8 nm, α= 35′=0.58^0

So when D=120 / d+d'=120

$$\mathbf{i} = \frac{\mathbf{632.8 \times 10\hat{}(-6) \times 120}}{\mathbf{2 \times 20 \times 10\hat{}(-3)}} = 1.1 \text{ mm}$$

- The uncertainty of the theoretical interfringe is given by the following relation:

$$\Delta i = \frac{d + d'}{2.\alpha.d'}\Delta\lambda + \frac{\lambda}{2.\alpha.d'}\Delta d + \frac{\lambda.d}{2.\alpha.d'2}\Delta d' + \frac{\lambda.(d + d')}{2.\alpha^2.d'}\Delta\alpha$$

- Graphical representation of experimental results:

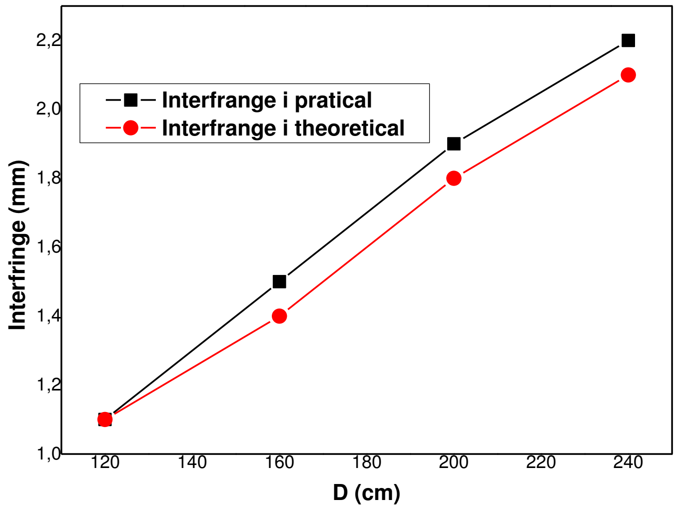


Figure 5. Representation of the practical and theoretical intersections i for different distances D

Through these results, we note that there is a slight difference between the practical and the theoretical. This suspicion is due to the external conditions that affected the success of the experiment.

-Conclusion:

Ultimately, the Fresnel mirrors are an example of how science and technology can work together to create innovative solutions to technical problems. Understanding their characteristics and limitations can help optimize their use in a variety of optical applications.

Practical work n⁰4: Interferences of light waves: Case of Newton rings

Purpose:

1. Observation of localised interference fringes (circular fringes).
2. Calculation of the radius of a convergent lens.

- Determination of the radius of curvature of the convex plane lens by measuring the Newton rings illuminated by monochromatic light:

1. Theory:

A monochromatic beam of light arrives at the plane-convex lens L with an incidence close to normal (Figure 1). At point M (amplitude division) a part of the beam is reflected (beam 1) and the other part passes through the thick air corner e and falls normally onto the plane blade where it reflects on itself (beam 2). The difference in walk between beams 1 and 2 (taking into account that our device is in the air) is:

$$\Delta L = 2(e \mp e_0) + \frac{\lambda}{2} = (q + \frac{1}{2})\lambda \qquad (1)$$

With : $e \mp e_0$: is the distance between a point on the convex face of the lens and the normal incident ray in the plane of the glass plate.

e_0 : Distance that depends on the distance or approach of the faces that build the faces of the air lacquer at the top of the lens.

$\frac{\lambda}{2}$: Quantity that depends on the reflection of a more refractive medium to a less refractive medium.

So the radius of the rings r is related to the radius of the convex lens R and the thickness e by the following relation:

$$R^2 = r^2 + (R - e)^2 \qquad (2)$$

Taking into account that: $e \ll x, R$, so :

$$r^2 \approx 2eR$$

In addition:

$$r^2 = (R\lambda)q \mp 2e_0R \qquad (3)$$

So we can calculate the R from the slope of the curve : $r^2 = f(q)$

All points at the same distance e have the same state of interference. The location of these points is a circle (ring) of radius r (fringes of equal thickness).

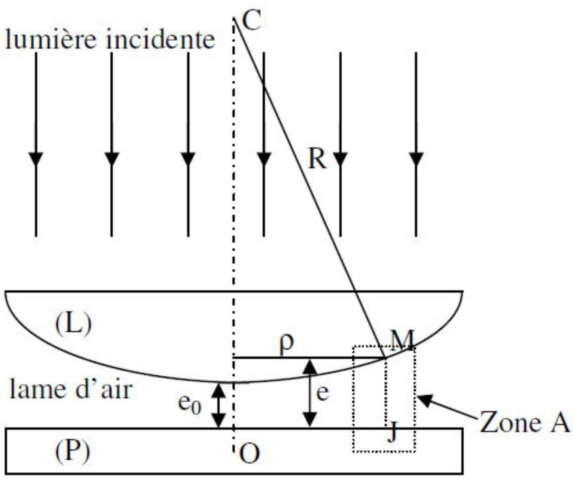


Figure 1: Descriptive diagram of the light rays.

2. How the experiment will run:

Perform the following assembly: Hg lamp, yellow wavelength filter$\lambda = 578$ nm , Convergent f'=+5 cm lens, screen with a white sheet.

3. Requested work :

1. Avec un style et sur la feuille blanche de l'écran, marquez le diamètre ou le rayon des anneaux d'inférences d'ordre q en lisant directement sur l'échelle millimétrique vertical dans l'image affichée sur l'écran et rempli le tableau suivant :

q	1	5	10	15	20	25	
D (mm)							

2. Plot the curve : $d^2 = f(q)$ on millimetre paper or microcomputer.

3. From the slope of the curve, derive the value of the radius of curvature of the convergent lens.

Report of practical work n^0 4: Interferences of light waves: Case of Newton rings

I. Introduction:

Newton's rings are a phenomenon of light interference that occurs when a flat glass lens is placed in close contact with a reflective flat surface, such as a mirror. This phenomenon is called "rings" because it creates circular patterns of colors a flat surface are in close contact. These interferences are caused by the refraction of light as it passes through the lens and is reflected on the flat surface. Variations in thickness between the lens and surface create constructive and destructive interferences that give rise to concentric coloured rings. This effect is called "light wave interference" and is a spectacular illustration of the wave properties of light. Newton's rings were first observed in 1717 by Isaac Newton himself, who used them to determine the curvature of lenses. Today, this method is still used in optics to measure the flatness of surfaces and the quality of lenses.

Figure 1. Actual image of the optical assembly for obtaining the Newton rings

Figure 2. Actual image of the Newton rings device

II. The optical assembly:

The optical assembly for practical work on light wave interference, particularly for the study of Newton rings, can be carried out in the following steps:

II.1. Equipment required:

- A 50 cm convergent lens

- A flat-concave lens

- A point light source (filament lamp)

- A flat object with a known thickness (glass, lens, etc.)

- A blank screen or sheet of paper

- A millimetric rule

II.2. Installation of the assembly:

- Place the point light source at a distance of approximately from the converging lens.

- Place the plane-concave lens at a distance of approximately from the convergent lens. The flat sides of both lenses should be facing outward.

- Place the flat object between the two lenses, for example by placing it on the plane of the convergent lens.

- Place the blank screen or sheet of paper at a distance of approximately the plane-concave lens.

- Measure the thickness of the object and note this value.

II.3. Observation of the Newton rings:

- Be careful not to move the optical assembly during subsequent handling.

- Observe the interference of light waves that occurs between the plane object and the plane-concave lens. Dark and light rings are formed on the screen.

- Measure the radius of the dark rings using the millimetre ruler. Note the distance between the object and the plane-concave lens (in this case, it is the thickness of the object).

- Repeat the measurement for different points of the object, moving it slightly each time

II.4 Analysis of results:

- Compare the radius values of the dark rings for different points on the object.

- Check if the relationship of the formula for the thickness of the Newton ring is true: $\lambda/2 = (m + 1/2)\ d$ [(m integer)]

- Deduce the wavelength of the light used (noted λ in the formula) and compare this value to that known for the light source used.

In summary, the optical assembly for practical work on Newton's rings allows to observe the interferences of light waves between a plane object and a plane-concave lens. The measurements made then allow to determine the wavelength of the light used and to check the formula for the thickness of the Newton ring.

III. Requested work :

q	5	10	15	20
d (mm)	17.3	22.7	26.6	29.3
d^2 (mm^2)	299.29	515.29	707.56	858.49

III.1. Representation of $d^2=f(q)$:

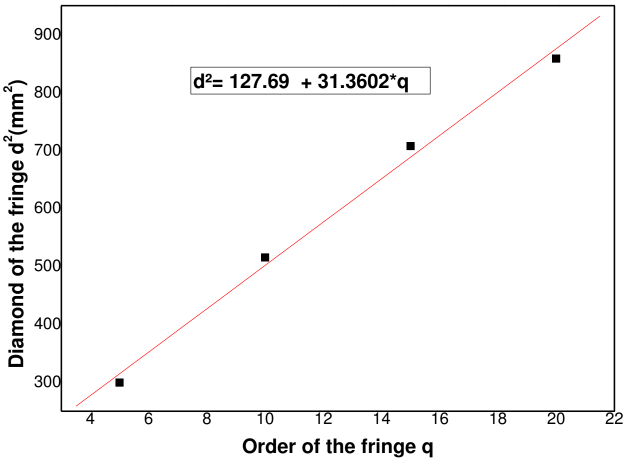


Figure 3. Representation of $d^2=f(q)$

The curve a straight line almost which passes through the origin its equation to the form:

$$d^2= 127.69 + 31.3602*q$$

In accordance with the theoretical relationship:

$$r^2 = (\lambda R)*4q$$

$$R.\lambda = 31.302/4$$

$$R=31.302/578*4$$

R= 13.53 m avec R (theoretical)=12.145 m

The theoretical value is approximately equal to the applied value, with small uncertainties in measurement due to experimental errors, calculation inaccuracies and other laboratory factors.

-Conclusion:

The concentric structure and variation of the spacing of the Newton rings are explained by the spherical curvature of the convex lens which limits the corner of air

The graph reduced the results and through the slope we determined the radius R of the lens, we usually find a value near R = 12.145 m at least

On the other hand, R = 13.53 m was obtained, this difference depends on the error which follows when the experimenter does not observe the precise value of the diameter of the rings.

So the measurement will be false by the error of reading the measurement made

Practical work n^0 5: Light wave interference: Michelson interferometer case

Purpose:

1. Observation of localised interference fringes (circular fringes).

2. Wavelength calculation

-Michelson interferometer (principle and conditions for obtaining interference):

The Michelson interferometer is a two-wave amplitude-dividing device. It can therefore lead to localized interference with large sources.

A semi-reflective blade called a separator divides a light beam into two perpendicular beams of the same amplitude. Each of the beams is then reflected by a mirror and then falls back on the separator which will give two beams propagating in the same direction. These two beams have a difference in walk which depends on the distance and angle between mirrors, so they can interfere.

By replacing one of the mirrors with its image by the separator, we see that the system is equivalent to an air blade whose thickness and angle can be varied.

Two types of interference may occur:

a-Fringes of equal inclination:

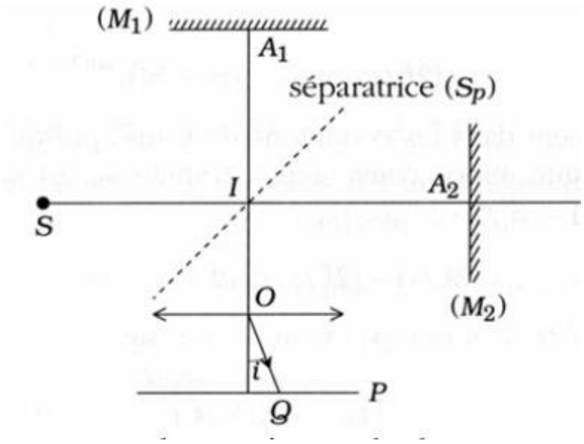


Figure 1: Obtaining equal inclination fringes with the Michelson interferometer

The mirrors are then made perpendicular to the system axes. The M'_1 image of M_1 given by the separator is parallel to the mirror M_2. Be the distance M'_1M2. Illuminate the device with an extended monochromatic source. The difference in the path between the two waves (which interfere with infinity).

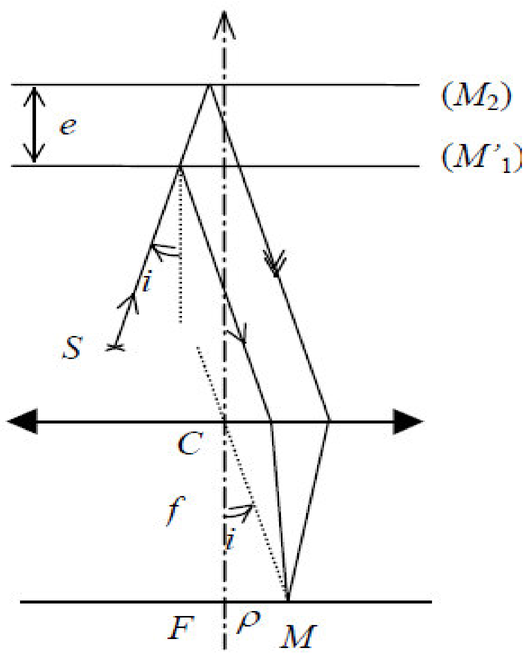


Figure 2 : Descriptive diagram

For an incidence i is given by the relation:

$$\Delta L = 2e.\cos i$$

b- Air corner fringes:

The length of the two interferometer arms is equalized and M2 is tilted by a small angle α. The equivalent of an air corner of thickness e = α X is obtained. We observe fringes of equal thickness (straight fringes parallel to the edge of the corner). With an interfringe in normal incidence (i = 0) is λ/ 2α.

2. How the experiment will proceed:

Perform the following assembly: λ= 632.8 nm wavelength He-Ne laser, Michelson interferometer, f'=+5cm convergent lens, screen with blank sheet.

3. Work required:

1. With a style and on the blank sheet of the screen, mark the diameter or radius of the inference rings of order q.

2. Calculate the wavelength.

Report of practical work n^0 5: Interferences of light waves: Case of the Michelson interferometer

I. The constituent elements of the Michelson interferometer:

1. The Separator (Sp) or semi-reflective blade, fixed, essential element of the Michelson because it divides the beam into two waves of the same amplitude.

2. The Compensator (Cp) and its two orientation settings V_{01} and V_{02}. A Palmer, shown here, allows to locate the vertical adjustment. The Equalizer is used to compensate for the path of light in the glass of the Divider.

3. Mirror M_1, and these two coarse orientation settings V_{11} and V_{12}.

This mirror is carried by a trolley which can be translater with V_{13} and whose movement is marked by a Palmer, which allows a reading at 0.002 mm.

4. The M_2 Mirror, as well as these two fine-tuned orientations V_{21} and V_{22}.

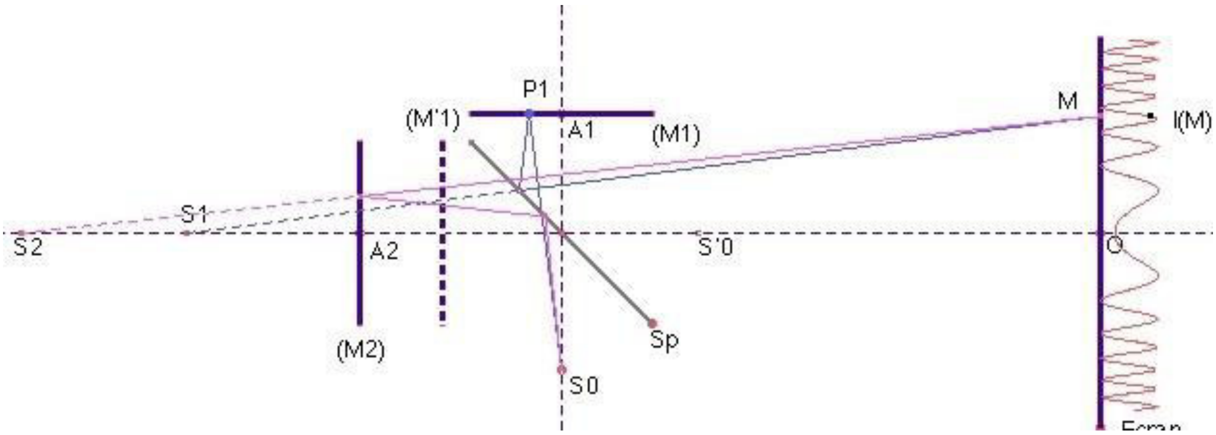
Figure 1. Real image of Michelson interferometer device

II. Reminder of the essential results on the air-slide Michelson:

When the two mirrors M_1 and M_2 are orthogonal, the Michelson is said in air blade. To understand this name, the Michelson must be unfolded (figure.2). M'_1 is the image of mirror M_1 by the separator (axial symmetry). S'_0 is the image of point source S_0 by separator. S_1 is the image of source image S_0 by mirror image M'_1 . S_2 the image source image S_0 by the mirror M_2. The situation is then analogous to that of the air slide, formed by the slide M'_1 and M_2. The thickness e is then the distance separating M'_1 and M_2. In the case of an infinite observation, the difference in gait is then:

$$\Delta(M) = S_1M - S_2M = 2.e.\cos(i)$$

$$I_{tot} = 2.I_0(1 + \cos\left(\frac{2.\pi}{\lambda}.(2.e.cosi)\right)$$



Figure

Figure 2. Michelson interferometer in air slide

The figures of equal illuminance are the equiphase surfaces, so unlike constant walking, which in this case imposes an angle of incidence i = cste, which is shown on the screen gives concentric circles. The fringes of equal illuminance are then called fringes of equal inclination, as shown (figure 2).

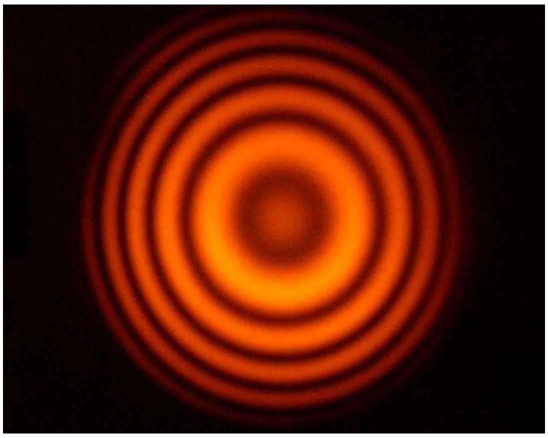


Figure 3. Air blade sloping fringes

III. Reminder of key findings on the Michelson in the air corner:

The air corner Michelson is equivalent to an air corner formed by mirror M_2 and image M'_1 of mirror M_1 by the separator (Figure 4).

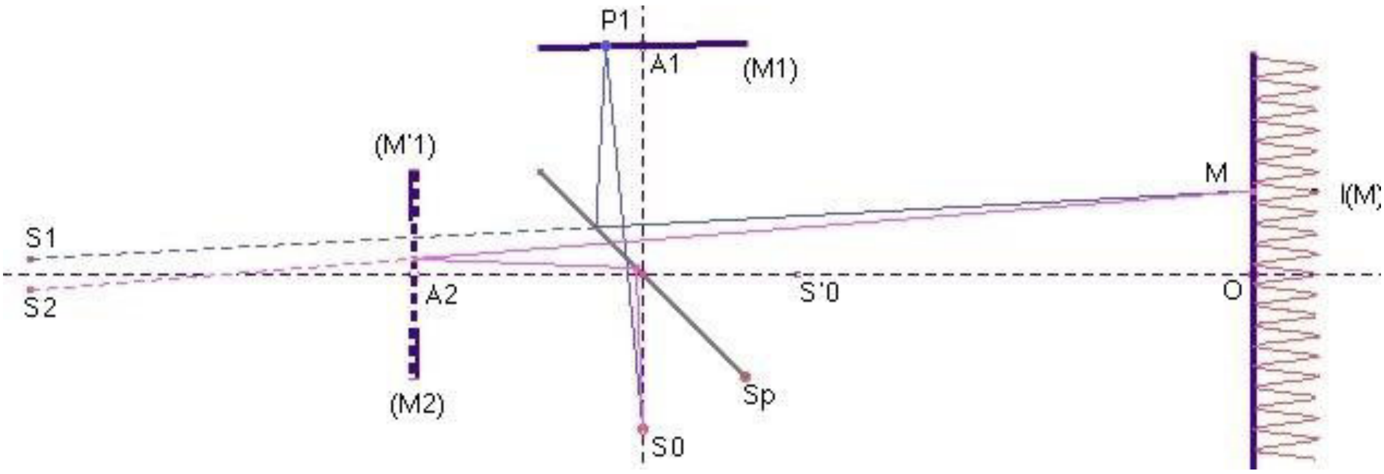


Figure 4. Michelson interferometer in air corner

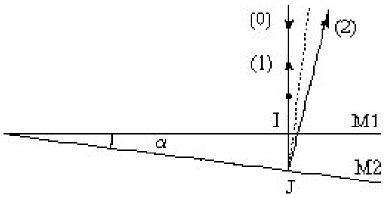


Figure 5. The corner of air

In the case of a mirror observation, the difference in gait is then:

$$\Delta(M) = S_1M - S_2M = 2.\alpha.x$$

$$I_{tot} = 2.I_0(1 + \left(cos\frac{2.\pi}{\lambda}(2.\alpha.x)\right))$$

The figures of equal illuminance are the equiphase surfaces, therefore, unlike constant walking, which in this case imposes that x = cste, which is carried over to the screen gives straight fringes equidistant. The fringes of equal illuminance are then called fringes of equal thickness as shown in figure 6.

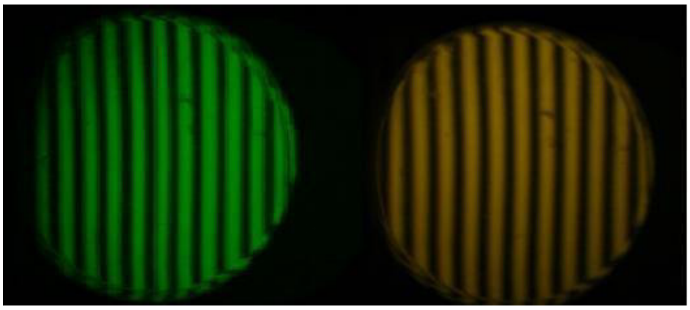


Figure 6. Fringes of equal thickness

-Requested work:

In our practical work we used the Michelson interferometer for the calculation of the wavelength of the He-Ne laser using the equal thickness fringes.

We focus on a bright fringe and then use the micrometric screw for the change of optical path, after scrolling 200 brilliant fringes the micrometric screw shows a value of :

We have : $\Delta l = 2.e = k.\lambda$ for an angle i=0

k=200 fringes

Therefore: $\lambda = \frac{2.65}{200} = 0.65\mu m = 650\ nm$

$$\lambda \text{ theo} = 632.8 \text{ nm}$$

Thus $\Delta\lambda$= 650 – 632.8 = 17.2 nm, The Michelson interferometer is therefore the most suitable device for calculating the wavelength of a light beam.

Practical work n^0 6: TP Study of light diffraction

Objective:

• Perform an experimental approach to study or use diffraction in light waves

I. Diffraction:

In addition to interference, waves also have another property – diffraction, which is the bending of waves when they pass by objects or through an opening. The diffraction phenomenon can be understood by using the Huygens principle which states that Every unobstructed point on a wave front will act as a source of secondary spherical waves. The new wave front is the surface tangent to all secondary spherical waves. Figure 1 shows the wave propagation according to the Huygens principle.

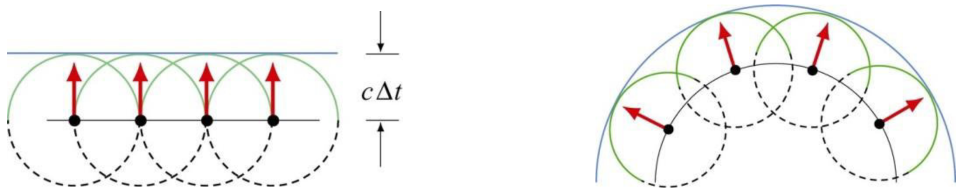


Figure 1. Huygens' principle

According to the Huygens principle, light waves that occur on two slits spread out and present an interference pattern in the region beyond. The pattern is called a diffraction pattern. If no bending is observed and the light wave continues to move in straight lines, no diffraction pattern will be observed (Figure 2).

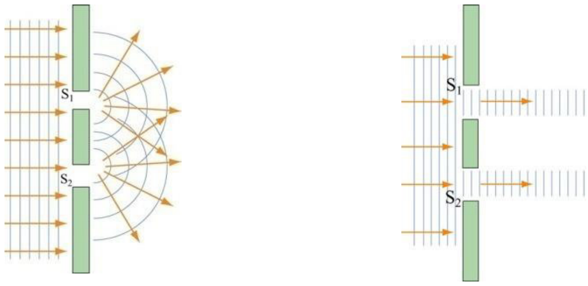


Figure 2. Diffraction of light

In addition to interference, waves also have another property: diffraction, Figure 2. Propagation of light leading to a diffraction pattern. No diffraction pattern if the paths of the light wave are straight lines.

We will limit ourselves to a particular case of diffraction called the Fraunhofer diffraction. In this case, all the light rays coming out of the slit are approximately parallel to each other. To make a diffraction pattern appear on the screen, a convex lens is placed between the slot and the screen to ensure convergence of light rays.

II. Single-slot diffraction:

In our study of the Young double-slot experiments, we assumed that the width of the slots was so small that each slot is a point source. In this section, we will take the crack width to be finished and see how Fraunhofer diffraction occurs.

In addition to interference, the waves also have another property: diffraction, let a monochromatic light source be incident on a finite width slot a, as shown in Figure 3.

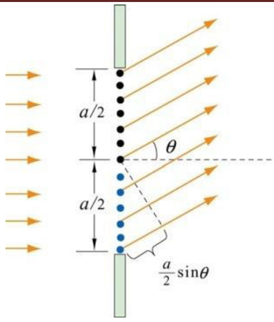


Figure 3. Diffraction of light through a width gap a.

In Fraunhofer-type diffraction, all the rays passing through the crack are approximately parallel. In addition, each part of the slit will act as a light wave source according to the principle of Huygens. For simplicity, we divide the slot into two halves. At the first minimum, each ray of the upper half will be exactly 180 out of phase with a corresponding ray of the lower half. For example, suppose there are 100 point sources, with the top 50 being in the lower half and 51 to 100 in the upper half. Source 1 and source 51 are separated by a distance a/2 and are out of phase with a path difference a/2. A similar observation applies to source 2 and source 52, as well as any pair that is at a distance of a/2. Thus, the condition for the first minimum is:

$$\frac{a}{2}\,sin\theta = \frac{\lambda}{2}$$

$$sin\theta = \frac{\lambda}{a}$$

Apply the same reasoning to four-point equidistant wavefronts at distance a/4, the path difference would be a sin a/4 , and the condition for destructive interference is:

$$sin\theta = \frac{2.\lambda}{a}$$

The argument can be generalized to show that destructive interference will occur when

$$a.sin\theta = m.\lambda$$

III. Single-slot diffraction intensity:

To calculate this, the total electric field is found by adding up the contributions of each point. Divide the simple slot into N small areas of width y a/N, as shown in Figure 4. The convex lens is used to bring the parallel light rays to a focal point P on the screen. We will assume that all the light of a given area is in phase. The relative phase shift is given by the ration:

$$\Delta L = \frac{2.\pi}{\lambda}.\Delta y.sin\theta$$

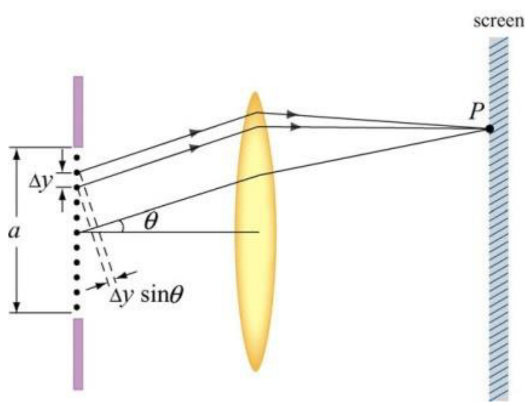


Figure 4. Single-slit Fraunhofer diffraction

Suppose the wavefront from the first point (counting from the top) arrives at the point *P* on the screen with an electric field given by:

$$E_1 = E_{01}.sin\theta$$

With a phase shift it will be:

$$E_1 = E_{01}.\sin(wt + \acute{\emptyset})$$

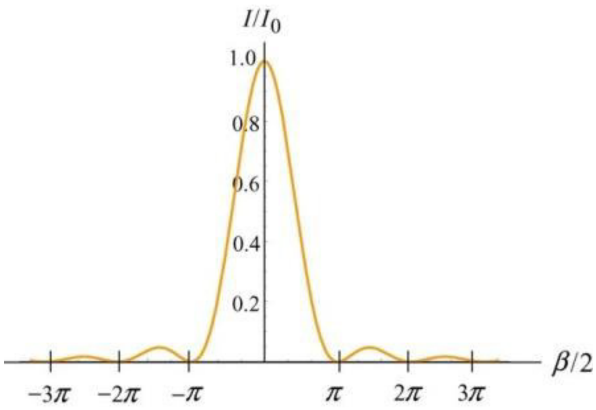
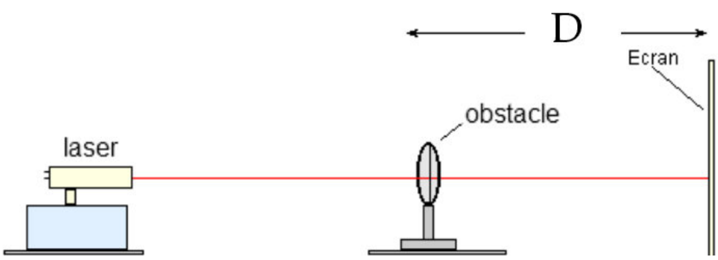


Figure 5. Intensity of the single-slit Fraunhofer diffraction pattern.

I- Qualitative study of the phenomenon:



A laser beam emitting monochromatic light of red color and wavelength $\lambda = 632.8$ nm is used. The laser beam is directed to a screen at D in meters. An opaque plate with a vertical slot is inserted between the laser and the screen.

- What is observed in the absence of a crack?
- Conclude on the nature of light in this experiment

II- Quantitative study of the phenomenon:

1.The parameters to be taken into account:

The width of the central spot, noted d, is measured between the midlands of the first two extinctions.

The width of the central spot d on the screen varies when the distance D between the slot and the screen, the color of the light characterized by its wavelength λ , or the width a of the slot is varied. First calculate the width of the slot by calculating the interfringe i.

2. Influence of the distance D between slot and screen:

The screen is moved and the width d is measured by varying the distance D.

a. Record your results in a table:

D en m				
i en mm				

b. Plot the graph i = f(D). Describe this graph.

Appendix 1: Diffraction by a circular aperture

-Circular aperture diffraction :

The calculation of diffraction by a circular pupil is based on the same principle as that of a rectangular pupil. However, it is important to use pupil symmetry to perfect the calculation. Starting from the general relation:

$$E(u,v) = KA \iint t(x,y) e^{-2i\pi(ux+vy)}\, dxdy$$

We enter the cylindrical coordinates, to describe the position of the point so that:

$$x = rcos\alpha \quad y = rsin\alpha$$

So we have :

$$E(u,v) = KA \int_0^{\rho} \int_0^{2\pi} e^{-2i\pi(urcos\alpha + ursin\alpha)}\, rdrd\alpha$$

The diffraction figure having the cylindrical symmetry of the pupil we consider the calculation only in the y direction which leads to:

$$E(0,v) = KA \int_0^{\rho} \int_0^{2\pi} e^{-i2\pi vrsin\alpha}\, rdrd\alpha$$

We then use the definition of the Bessel function of order 0 given by:

$$J_0(q) = \frac{1}{2\pi} \int_0^{2\pi} e^{iqsin\theta}\, d\theta$$

Which brings us to:

$$E(0, v) = 2\pi KA \int_0^{\rho} J_0\,(2\pi vr)rdr$$

The integral of the zero-order Bessel function is then obtained by using the following property of this function:

$$qJ_1(q) = \int_0^{q} J_0(u)udu$$

Either by posing: $u = 2\pi rv$

$$\int_0^{\rho} J_0(2\pi vr)rdr = \frac{1}{4\pi^2 v^2}\int_0^{2\pi\rho v} J_0(u)udu = \frac{2\pi\rho v\, J_1(2\pi\rho v)}{4\pi^2 v^2} = \rho^2\,\frac{J_1(2\pi\rho v)}{2\pi\rho\vartheta}$$

It follow that :

$$E(0, v) = KA\; 2\pi\rho^2\,\frac{J_1(2\pi\rho v)}{2\pi\rho v}$$

With :

$$v = \frac{x}{\lambda D}$$

The intensity observed on the remote screen of D of the circular pupil is thus written:

$$I(v) = \left|KA\; 2\pi\rho^2\,\frac{J_1(2\pi\rho v)}{2\pi\rho v}\right|^2$$

The Bessel functions are tabulated and the first zero of the function $J_1(S)$ is located in S=3.83.

It follows that the intensity is cancelled in X_z :

$$\frac{2\pi\rho X_z}{\lambda D} = 3.83 \rightarrow X_z = \frac{0.61\ \lambda D}{\rho} = \frac{1.22\ \lambda D}{2\ \rho}$$

One can write according to the diameter of the pupil a and the wavelength λ:

$$1.22\ \frac{\lambda}{a}$$

The diffraction figure is then cancelled for the rays: 2.23, 3.23, 4.24, 5.24....

The luminous rings have as ray, in the same unit: 1.63, 2.68, 3.70, 4.71, 5.71...

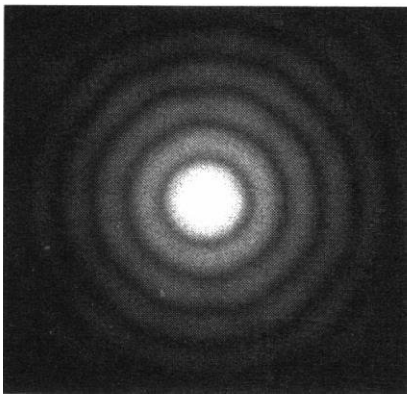


Figure 1. Fringes obtained by a circular opening

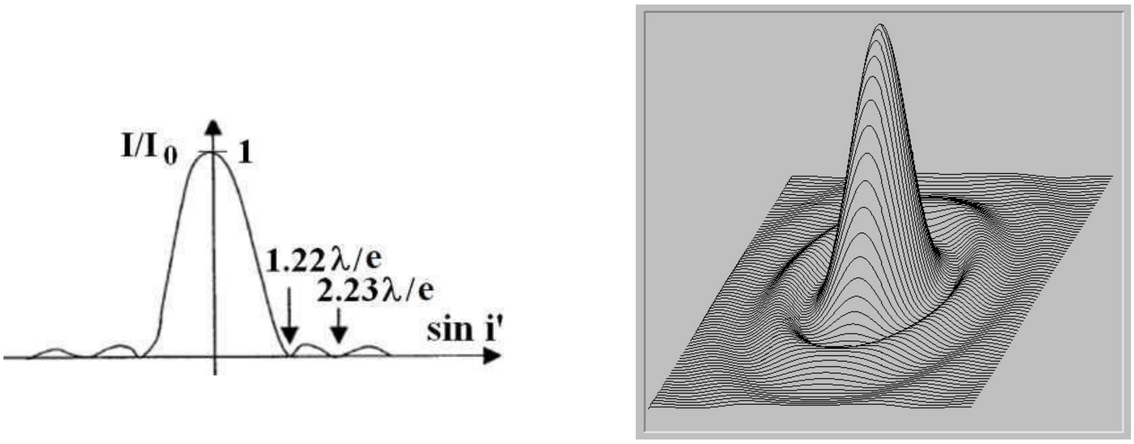


Figure 2. Diffraction intensity by a circular aperture

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