الجامعة المستنصرية – كلية العلوم

قسم الفيزياء

Mustansiriyah Univ. – College of Science

Physics Department

Optics 2

Third Class (B.SC.)

2022-2023

Lecture (4)

Fresnel Biprism

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1- <u>Coherence Sources:</u>

Coherence sources are the sources which either have not phase difference or have always a Constant phase difference them.

Light from conventional sources is characterized by **two important parameters**, namely **coherence time** and **coherence length**

1. **Coherence time:** It is the average time during which the wave remains sinusoidal and phase of the wave packet can be predicted reliably.
2. **Coherence length:** It is the length of the wave packet over which it may be assumed to be sinusoidal and has predictable phase.

2- <u>Conditions for Interference</u>:

We may now summarize the conditions that are to be fulfilled in order to observe a distinct well-defined interference pattern.

A- Conditions for sustained interference:

1. ***The waves from the two sources must be of the same frequency.*** If the light waves differ in frequency, the phase difference fluctuates irregularly with time. Consequently, the intensity at any point fluctuates with time and we will not observe steady interference.
2. ***The two light waves must be coherent.***

If the light waves are coherent, then they maintain a fixed phase difference over a time and space. Hence, a stationary interference pattern will be observed.

3. ***The path difference between the overlapping waves must be less than the coherence length of the waves.***

We have already learned that light is emitted in the form of wave trains and a finite coherence length characterized them. If we consider two interfering wave trains, having constant phase difference, as in Figure (1), **the interference effects occur due to parts QR of wave 1 and ST of wave**

2. For **the parts PQ and TU interference will not occur**. Therefore, the interference pattern does not appear distinctly.

When the entire wave train PR overlaps on the wave train SU, interference pattern will be distinct. On the other hand, when the path difference between the waves 1 and 2 becomes very large, the wave trains arrive at different times and do not overlap on each other. Therefore, in such cases interference does not take place. **The interference pattern completely vanishes if the path difference is equal to the coherence length**. It is hence required that

$$\Delta < I_{coh} \quad (1)$$

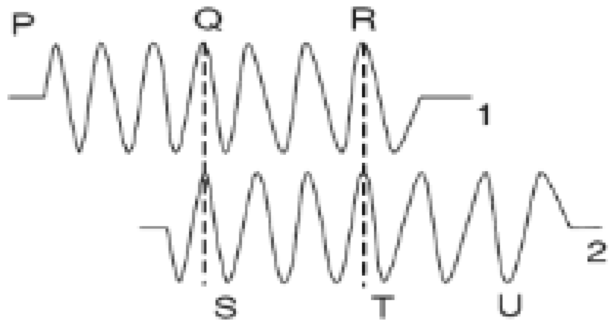

Fig. (1) Partial overlap of the wave train

4. ***If the two sets of waves are plane polarized, their planes of polarization must be same.***

Waves polarized in perpendicular cannot produce interference effect.

B- Conditions for formation of distinct fringe pattern:

1. ***The two coherence sources must lie close to each other in order to discern the fringe pattern.*** If the sources are far apart, the fringe width will be very small and fringes are not seeing separately.
2. ***The distance of the screen from the two sources must be large.***

3. ***The vector sum of the overlapping electric field vectors should be zero in the dark regions for obtaining distinct bright and dark fringes.*** The sum will be zero only if the vectors are antiparallel and have the same magnitude.

3- Fresnel Biprism

Fresnel used a biprism to show interference phenomenon. The biprism consists of two prisms of very small refracting angles joined base to base. In practice, a thin glass plate is taken and one of its faces is ground and polished till a prism (Fig. 2-a) is formed with an obtuse angle of about 179° and two side angles of the order of 30'.

When a light ray is incident on an ordinary prism, the ray is bent through an angle called the angle of deviation. As a result, the ray emerging out of the prism appears to have emanated from a source S' located at a small distance above the real source, as shown in Fig. (2-b). We say that the prism produced a virtual image of the source. A biprism, in the same way, creates two virtual sources S1and S2 , as seen in Fig. (2-c). These two virtual sources are images of the same source S produced by refraction and are hence coherent.

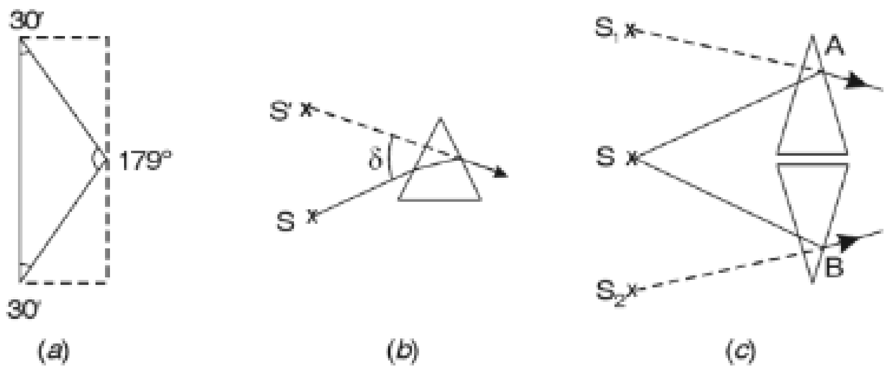

Fig. (2) Fresnel biprism and formation virtual sources

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3-1 Experimental Arrangement

A monochromatic light source such as sodium vapour lamp illuminates a vertical **slit S**. Therefore, the slit S acts as a **narrow linear monochromatic light source**. The **biprism** is placed in such a way that its **refracting edge is parallel to the length of the slit S**. A single cylindrical wavefront impinges on both prisms. The top portion of wavefront is refracted downward and appears to have emanated from the virtual image S_1. The lower segment, falling on the lower part of the biprism, is refracted upward and appears to have emanated from the virtual source S_2. The virtual sources S_1 and S_2 are coherent (see Fig.(3), and hence the light waves are in a position to interfered in the region beyond the biprism. If a screen is held there, interference fringes are seen. In order to observe fringes, a micrometer eyepiece is used.

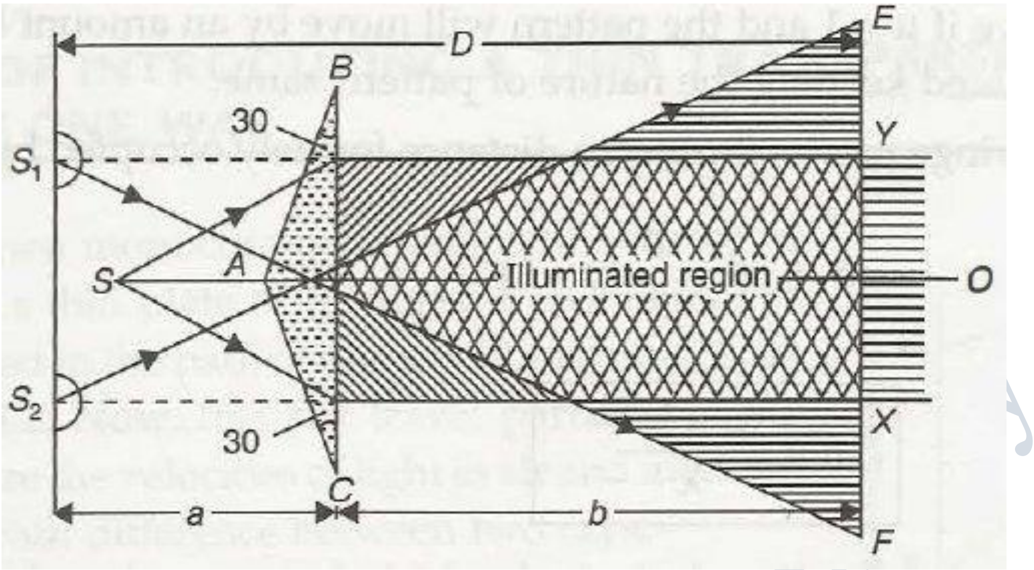

Fig. (3) Fresnel biprism

3-2 Theory:

The theory of the interference and fringe formation in case of **Fresnel biprism is the same as described for the double-slit**. As the point O is equidistant from S_1 and S_2, the central bright fringe of maximum intensity occurs there. On both sides of O, alternate bright and dark fringes are produced. The **width of the dark or bright fringe** is given by eq.(2).

$$\boldsymbol{\beta = \frac{\lambda D}{d}} \qquad \textbf{(2)}$$

Where (**D= a + b**) is the **distance of the sources from the eyepiece**.

3-3 Determination of wavelength of light

The wavelength of the light can be determined using equation (2). For using the relation, the values of β, D and d are to be measured. These measurements are done as follows.

1. **Determination of fringe width β**: When the fringes are observed in the field view of the eyepiece, the vertical cross wire is made to coincide with the center of one of the bright fringes. The position of the eyepiece

is read on the scale, say $\mathbf{x_o}$. The micrometer screw of the eyepiece is moved slowly and the **number of the bright fringes N** that pass across the cross-wire is counted. The position of the cross-wire is again read, say $\mathbf{x_N}$. The fringe width is then given by

$$\boldsymbol{\beta = \frac{x_N - x_o}{N}} \quad \textbf{(3)}$$

2. **Determination of (d)**: The value of d can be determined as follows. The deviation δ produced in the path of a ray by a thin prism is given by

$$\boldsymbol{\delta = (\mu - 1)\alpha} \quad \textbf{(4)}$$

Where α is the refracting angle of the prism. For the figure 9, it is seen $\boldsymbol{\delta = \theta/2}$. Since d is very small, we can also write $\mathbf{d = a\,\theta}$

$$\delta = \frac{\theta}{2} = \frac{d}{2a} = (\mu - 1)\alpha$$

$$\boldsymbol{d = 2a(\mu - 1)\alpha} \quad \textbf{(5)}$$

3-4 Interference Fringes with white light

In the biprism experiment if the slit is illuminated by **white light** the **interference pattern** consists of a **central white fringe** flanked on its both sides by a few colored fringes and general illumination beyond the fringes. **The central white fringe is the zero-order fringe**. **With monochromatic light** all the bright fringes are of the **same color** and **it is not possible to locate zero- order fringe.** Therefore, ***in order to locate the zero-order fringe the biprism is to be illuminated by white light.***

3-5 Lateral Displacement of Fringes

The biprism experiment can be used to determine the thickness of given thin sheet of transparent material such as glass or mica. If a thin transparent sheet is introduced in the path of one of the two interfering beams, the fringe system gets displaced towards the beam in whose path the sheet is introduced. By measuring of displacement, the thickness of the sheet can be determined.

Suppose **S_1 and S_2 are the virtual coherent monochromatic sources**. The **point O** is **equidistan**t from **S1 and S2**, where we obtain the **central bright fringe**. Therefore, the **optical path $S_1O= S_2O$**. Let a transparent plate G of **thickness t** and **refractive index μ** be introduced in the path of one of the beams (see fig. (4). **The optical path lengths S_1O and S_2O are now not equal** and the **central bright fringe shits to P from O**. The light waves from **S1 to P travel partly in air and partly in the sheet G**: the distance travelled in air is (S_1P – t) and that in the sheet is t.

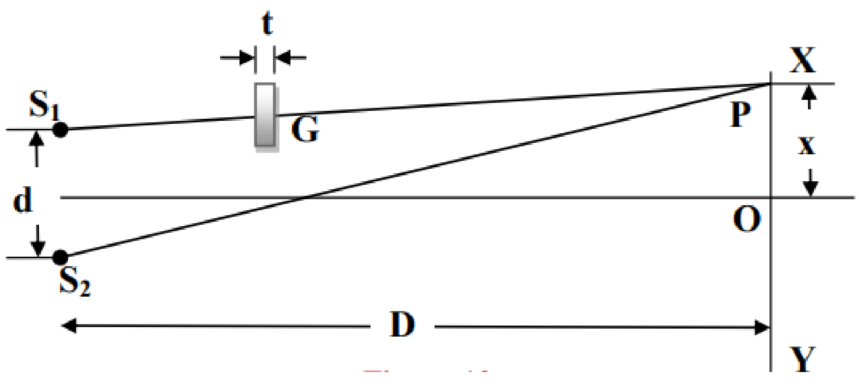

Fig. (4) Measurement of thickness of thin sheet

The optical path $\Delta_{s_1 p} = (s_1 P - t) + \mu t = s_1 P + (\mu - 1)t$

The optical path $\Delta S_2P = S_2P$

The optical path difference at P is , $\Delta_{\boldsymbol{S_1 P}} - \Delta_{\boldsymbol{S_2 P}} = \mathbf{0}$, since in the presence of the thin sheet, the **optical path lengths S_1P and S_2P are equal** and **central zero fring**e is obtained at **P**.

$\Delta_{\boldsymbol{S_1 P}} = \Delta_{\boldsymbol{S_2 P}}$

$[S_1P+(\mu-1)t]=S_2P$

$S_2P-S_1P=(\mu-1)t$

But according to the relation, $S_2 P - S_1 P = \frac{xd}{D}$

Where **x is the lateral shift of the central fringe** due to the introduction of the thin sheet.

$$(\boldsymbol{\mu} - \mathbf{1})\boldsymbol{t} = \frac{\boldsymbol{xd}}{\boldsymbol{D}} \qquad \mathbf{(6)}$$

Hence, the **thickness of the sheet** is

$$\boldsymbol{t} = \frac{\boldsymbol{xd}}{\boldsymbol{D}(\mu - \mathbf{1})} \qquad \mathbf{(7)}$$