INSA INSTITUT NATIONAL DES SCIENCES APPLIQUÉES LYON | PC Second Year | Year 2017-2018

Physics : Test n°2 - semester 2

Monday May 7th, 2018 | Duration : 1h30

***Approximate marking scheme*: exercise 1 - 8 points, exercise 2 - 12 points.**

The subject is constituted of 2 completely independent exercises

Authorized document: one synthesis sheet recto, original and handwritten

Authorized calculator: any type but not internet connected, mobile phone not allowed

Exercise 1: Thickness control of a metal deposition

We consider the set-up of figure 1 in which a plane wave illuminates under normal incidence a mirror. On a small area of the mirror a totally reflecting material of thickness *e* has been deposited.

A very thin semi-reflecting slide (or beamsplitter) is placed in front of the mirror, building an angle $\varepsilon = 0.100°$ with the mirror.

Light is monochromatic of wavelength in vacuum $\lambda_0 = 532$ nm. We will assume that $n_{air} = 1$. Figure 1 represents a sketch of the device and Figure 2 represents a cross-section.

In the very close vicinity of the beamsplitter (at a precise location to be defined later), interference fringes are observed and they are represented on Figure 3. We denote *x* the distance counted from the edge of the corner between mirror and beamsplitter.

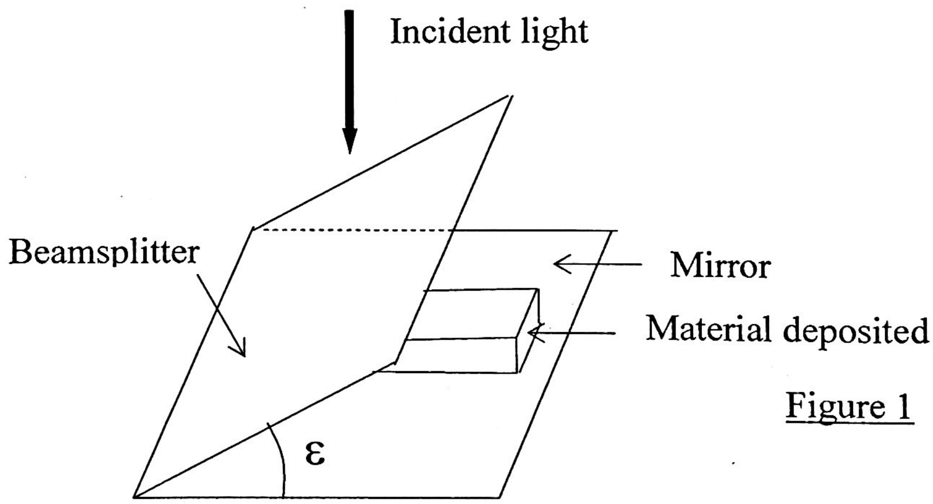

Figure 1

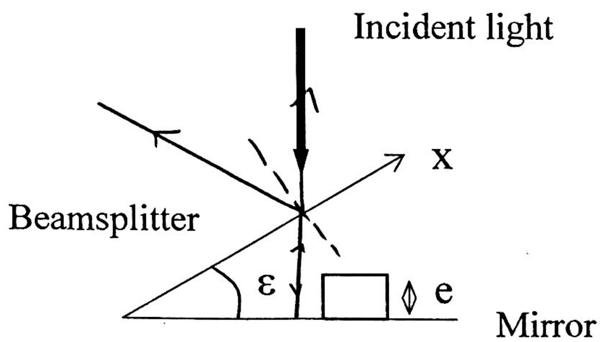

Figure 2

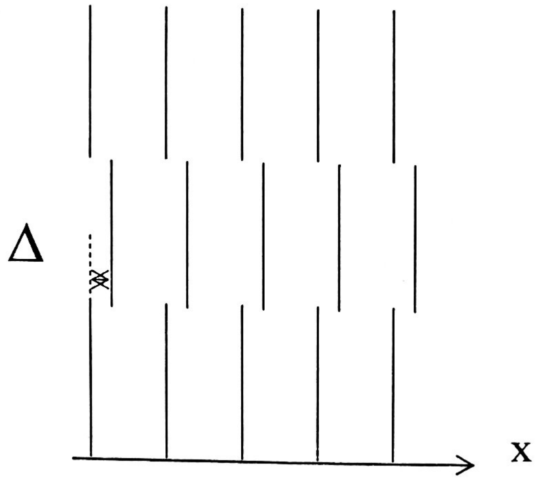

Figure 3

1) In an area without metal deposition, draw the path taken by the incident ray as illustrated in Figure 2. Show that, due to amplitude division, it splits up into 2 rays which interfere (Figure 2 needs to be redrawn in your manuscript). Where do the interferences build up for these 2 rays? Explain how they could be observed on a screen.

2) Give the expression of the optical path difference δ between these 2 rays as a function of x, n_{air} and ε in an area without metal deposition. We will consider that reflections on the beamsplitter and on the mirror do not induced any phase shift.
Explain why the interference fringes are straight lines and justify their direction.

3) Establish the expression of the interfringe distance i in an area where the metal deposition is missing as a function of λ_0, n_{air} and the angle ε. Give its numerical value.

4) Give the expression of the path difference δ' in an area where there is a metal deposition as a function of x, ε, n_{air} and e.

5) Starting with the position x of one given bright fringe of order p without metal deposition and with its position x' with metal deposition, explain the presence of a shift $\Delta = |x-x'|$ of the fringes (corresponding to the area where the metal has been deposited). Establish its expression as a function of the thickness e of the metal deposited.
We measure $\Delta = 1.000$ µm: give the numerical value of the metal thickness e.

6) We increase the angle ε. How does the interference pattern change on the screen?

Exercice 2 : Diffraction

A monochromatic plane wave (wavelength in vacuum λ_v = 633 nm) illuminates under normal incidence a metallic plate containing 4 identical apertures (the 4 apertures have the same shapeand the same dimensions). The optical axis of the setup is the *(Oz)* axis. The diffraction pattern at infinity is observed on a screen using a lens of focal distance f' = 100 mm (see black and white photograph on figure 4). We will assume that n_{air} = 1.

Data : For a plane wave of wavelength λ arriving on a circular aperture of diameter ϕ, the diffracted intensity is nil for angles whose sinuses equal to $\pm 1,22\lambda/\phi$, $\pm 2,23\lambda/\phi$, $\pm 3,24\lambda/\phi$... For a rectangular slit of width d, the diffracted intensity is nil for angles whose sinuses equal to $\pm\lambda/d$, $\pm 2\lambda/d$, $\pm 3\lambda/d$...

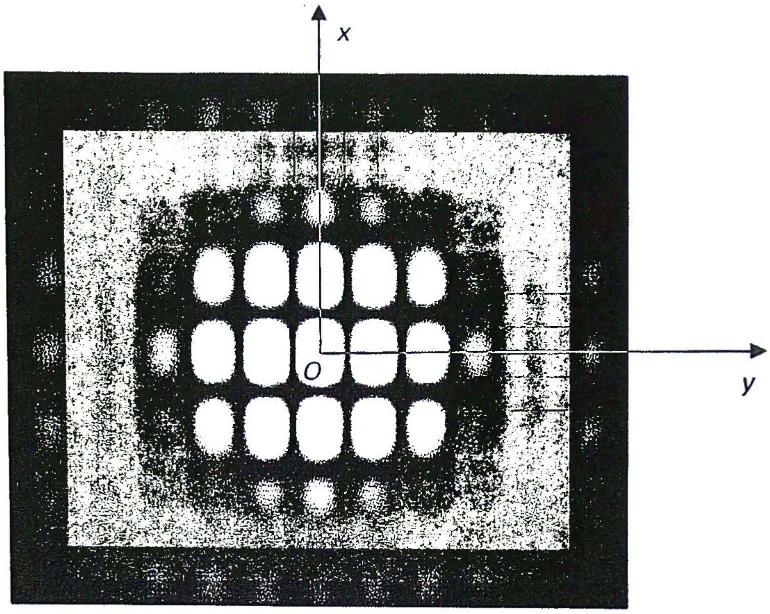

Figure 4 : Diffraction pattern observed on a screen, scale 2:1 (image enlarged twice).

1) Recall Huygens' principle.
2) Make a sketch of the setup in the (O, x, z) plane, indicating the position of the screen with respect to the lens. Draw 2 different diffracted rays from one aperture reaching the same point M (x not nil, $y = 0$) on the observation screen.
3) What is the geometrical shape of the apertures giving this diffraction pattern? Explain briefly.
4) Give the characteristic dimension(s) of these apertures. You'll first explain and give the literal expression(s) and then do the numerical application(s).
   Explain how you can determine the uncertainty(ies) on your value(s), and give its(their) literal expression(s) and numerical application(s).
   For simplification, you'll consider that $\sin\theta \approx \tan\theta \approx \theta$ and that the uncertainties on n_{air} and λ_v are nil.
5) Draw the metallic plate indicating the relative position of the 4 apertures with the associated distances in direction(s) x and/or y between the apertures. You'll explain carefully your reasoning and demonstrate the relation(s) you use in your justification.
6) Explain (with a short justification) how the figure evolves if :
   - the metallic plate is translated by 1 cm in the x direction ?
   - the metallic plate is rotated by an angle $+\pi/2$ (trigonometric orientation) around the *(Oz)* axis (so staying in the *(x,y)* plane) ?
   - the wave now arrives with an incident angle $\alpha = +10°$ (trigonometric orientation) in the (x, z) plane ?
7) Assuming that the intensity in the center of the screen is I_0 if we have just one aperture, give the values (as a function of I_0) of the minimum and maximum intensities I_{min} and I_{max} on the screen if using the 4 apertures. Justify briefly.