378.147:535.4

Methodological Notes

LECTURE DEMONSTRATION OF YOUNG'S EXPERIMENT

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THE diffraction of light from two parallel and identical slits in an opaque screen is in itself of no little practical importance (the Rayleigh interferometer, Michelson's stellar interferometer), and is at the same time of interest as a step in the transition to the important case of diffraction of light from many slits (diffraction grating). A successful lecture demonstration of this phenomenon is therefore of appreciable interest.

The realization of a lecture demonstration of this type entails well known difficulties, which are eliminated to a certain degree in the arrangement proposed below.

In this arrangement the phenomenon is demonstrated by means of an adjustable set of two slits, each having an appreciable width a, separated by an appreciable distance c. In spite of this, the pattern is observed on a nearby screen in a large enough scale and with sufficient illumination. The slits are separated by a sufficient distance, so that part of one of the slits can be covered without much difficulty by an opaque screen to produce on the screen two juxtaposed diffraction patterns (simultaneously from one and from two slits). By varying smoothly the parameters of the double slits (a, c, and accordingly $m \equiv c/a$) during the course of the demonstration, it is possible to disclose the effect of the parameter a on the width of the diffraction "maxima" from one slit, the effect of the parameter c on the width of the interference maxima, and the effect of the parameter m on the number of the latter maxima, which are produced within the confines of the principal and secondary diffraction maxima.

The experimental arrangement and the approximate distances between the elements are shown in Fig. 1.

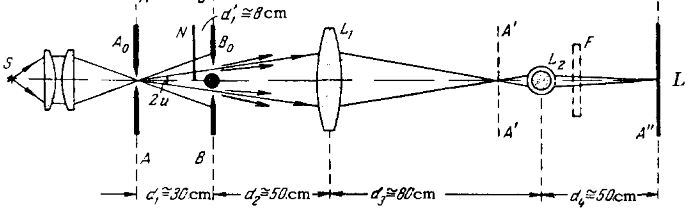

FIG. 1

The light beam from a simple variable-width slit A_0, illuminated by the source S, strikes the adjustable double slit B_0. The latter is an ordinary variable-width adjustable slit (preferably of good quality), with a piece of straight wire of diameter b fastened along its axis. The fastening is such that the wire can be displaced or tilted slightly so as to align it with the center line of the slit B_0. If the fastening is properly made, identical gaps of equal widths should be produced between the knife edges as the width of the slit B_0 is varied.

Spherical lens L_1 provides complete coverage of the light beams diffracted from the slits in the plane A′A′, which is the conjugate of the plane AA (the Fraunhofer method of observation). The parameters c and a can therefore be made sufficiently large. The primary diffraction pattern, which is produced in plane A′A′, is projected by short-focus lens L_2 onto the observation screen D, located in the plane A″A″, which is conjugate to A′A′. The cylindrical lens used in our experiments was a glass tube (outside diameter 8 mm) filled with distilled water. Lens L_2 magnifies in practice only the transverse dimensions of the primary diffraction pattern, causing an appreciable gain in illumination of the pattern on the screen D, and an appropriate increase in the light transmission of the system.

During the course of the experiments, the slits A_0 and B_0 and the axis of the lens L_2 were oriented horizontally and parallel.

To obtain a contrasty interference pattern it is necessary that the width l of the slit A_0 satisfy the coherence relation

$$l \sin 2u \leqslant \frac{\lambda}{2}.$$

If this relation is satisfied and the slits A_0 and B_0 as well as the lens L_2 are parallel, a clear picture is observed on the screen D if the center lines of the slits A_0 and B_0, the center of the lens L_1, and the axis of the lens L_2 lie on a single horizontal line.

The quality of the picture depends to no little degree on the adjustment of the elements, which is best carried out with the outer edges of slit B_0 moved considerably apart, since the illumination of the pattern on the observation screen is then at a maximum. If, as is the case in our example, $b_0 = 0.5$ mm, then the distance b between the edges can be set equal to approximately 1.5 mm. In this case c = 2a and m = 2. Consequently, three interference fringes will be located in the region of the principal diffraction pattern; the central fringe will be uncolored (zero order), and adjacent to it is one first-order spectrum on each side. When m = 2 the second-order spectra fall in the region of minimum illumination from one slot, and practically disappear from the picture.

By turning the regulator of the double slit B_0 it is possible to decrease smoothly the slit width and to observe the corresponding smooth variations of the structure and distribution of illumination in the diffraction pattern on the screen D.

To demonstrate simultaneously the patterns from one and two slits, part of one slit is covered with a small steel rule N, secured vertically at a distance d_1 such that its short edge is at the height of the wire axis.

Along with the diffraction pattern, it is possible to produce on the screen D the image of the double slit itself, using for this purpose the supplementary lens L of appropriate power, and introducing the lens when necessary in a preassigned region of the light beam from the double slit in such a way that the plane A′A′ becomes conjugate to the plane BB (and not AA).

When the screen D is moved away, the transverse dimensions of the diffraction pattern increase rapidly (almost in proportion to the distance d_4, Fig. 1), and the illumination of the picture decreases. It is therefore natural that the choice of the best screen position is determined by a combination of these two factors. If it becomes necessary to increase the longitudinal dimensions of the image, d_2 is decreased and d_3 increased accordingly.

When demonstrating the experiments to a fairly large audience, it is advantageous to project the picture on a translucent screen facing the audience, by placing between the lens L_2 and the plane A″A″ a flat mirror at an angle close to 45° to the beam axis.

To reduce the illumination of the screen from extraneous light, a light-tight partition should separate the region between the condenser and the frame of slit A from the observation screen.

Figures 2 and 3 show photographs of sections of two diffraction pattern (almost full scale), obtained at the distances between elements indicated on Fig. 1, and at the following parameters of the double slit:

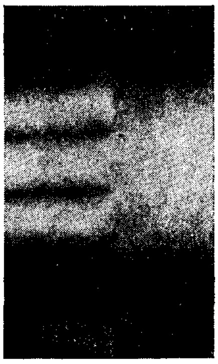

FIG. 2

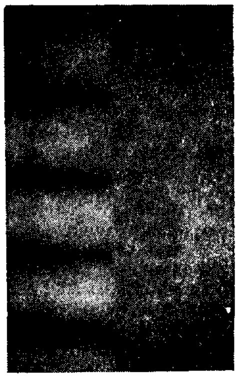

FIG. 3

$a' \approx 0.5$ mm, $c' \approx 1$ mm, $m' \approx 2$ ($b' \approx 1.5$ mm),
$a'' \approx 0.25$ mm, $c'' \approx 0.75$ mm, $m'' \approx 3$ ($b'' \approx 1$ mm);

the source S was a simple incandescent lamp. To obtain a sharper picture, the patterns were photographed through a red filter F (the exposures were 20 and 40 seconds, respectively). Figure 2 shows clearly that the second-order interference maximum coincides with the first minimum of illumination from one slit, and as a result the second-order interference fringe is split into two weakly illuminated parts.

The exposures without the filter were 2 and 5 seconds respectively (iso-panchromatic film rated 90 GOST units).

If the experiment is demonstrated in an auditorium, the use of the filter is not advised.

[1] R. W. Pohl, Einführung in die Optik, Springer, Berlin, 1940.

[2] A. B. Mlodzeevskiĭ, Lektsionnye demonstratsii po fizike (Lecture Demonstrations in Physics), No. 4., Optics, 1949.

Translated by J. G. Adashko