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solution to the problem no. 9
presented by the team of RussiaII

Alekseev Andrey
Алексеев Андрей

Woven textiles

Look at a point-like light source through different woven textiles. Describe what you see. What is the explanation of the phenomenon?

Overview

- The pattern
- Diffraction gratings
  - Maxiums and Minimums
  - Beams
- Conclusions
- Photos

1 The pattern

I shall begin the report from show you an approximate pattern, which can be seen looking at a lantern through a cloth. Instead of a lantern I shall use the laser. The laser can be taken because its beams reach a cloth practically in parallel, in the same way as from a lantern. The parallelism of beams going from a lantern is ensured because a lantern is located far off a cloth.
Let's consider the pattern, which is given by the laser beam passing through silk. In a central part there is some quantity of light spots, and these spots are located regularly. From central part four beams are going out. In this case they continuous, but if you look through other type of the cloth (synthetic), one can see that the beams can be and not continuous. The lens was set on this laser, with help of which it is possible to regulate parameters of the beam. Let's select lenses so that the image given by the laser has a view of vertical strip. We shall put a cloth on the way of the beam. The pattern, which you now see, reminds a diffraction pattern on a diffraction grating. It is obvious that here we have a diffraction phenomenon, that is the patterns, which you have seen, are made due to diffraction.

2 Diffraction gratings

Model of a cloth is two diffraction gratings, which are located so that the slits of one grating are perpendicular to the slits of other grating. Two crossed gratings give the image as the set of light spots. The cross can be seen in the observed pattern. But it does not speak that in other places of the plane there are no spots. There are spots, and they are distributed on total plane. Simply because of a small grating constant, the brightness of maximums of the deflection of nonzero order, which the diffraction grating gives, is insignificant. Here the secondary maximums are formed, too, which brightness is even less than primary ones, that is why they are not visible.

2.1 Maxiums and Minimums

Distance between fibres of a cloth much greater, than width of the slot of the diffraction grating, used in the work, and because of this at centre of the image there is no a cross, but such pattern can be seen (see photos). One diffraction grating gives system of maximums located on horizontal (vertical) strait line. The second diffraction grating gives (from each maximum of the first diffraction grating) a series of secondary maximums located on vertical (horizontal) strait line. As a result such pattern is obtained (see photo). But all the same on some distance from centre spots are not visible because of their feeble brightness. Spots remain only from the main maximum. In a cloth fibres can locate at an angle to each other. Then instead of rectangular system of spots it will be oblique-angled one.
The positions of maximums depend on distance between horizontal and vertical fibres, it can be seen from the formula of main maximums position, $X_{\text{main max}} = \frac{kL\lambda}{d}$. Here k is number of a maximum, L is distance from cloth to the screen, λ is wavelength, d is a distance between fibres of the cloth.
One can see that the greater the distance between fibres, the less distances between maximums. It can well be seen with silk. In the photo you can see that the distances between vertical maximums are greater than distance between horizontal maximums. It means that the distances between vertical fibres are greater than distance between horizontal ones (certainly, on the moment of shooting). Really, under the microscope one can see that the period of horizontal fibres differs from period of vertical fibres. For variety we shall take the photo of centre of the pattern obtained with other cloth. Distance between horizontal maximums approximately the same as between vertical ones. It testifies that for given cloth the period of horizontal fibres is the same as vertical.

2.2 Beams

Now we shall consider beams going out of centre of the image. The cloth is a diffraction grating with a varying period. Because of this a blurring will be in a diffraction pattern, which is the greater the less ideality in an arrangement of fibres. If the distances between fibres were identical, the obtained interference pattern would consist of light spots, disjointed from each other by dark gaps. If the distances between fibres in the cloth differ greatly, the blurring can become such that

the separate maximums will not be determined, and all patterns will remind a view of a continuous strip. It can be seen well in case of silk, for which distances between fibres differ greatly. In other cloth fibres are located more ideally, and because of this the separate maximums are visible in the photo. If one look through this cloth at a lantern, in place of these maximums the spectra are visible.

3 Conclusions

In my report I spoke, that the image depends on quality of a cloth. By experiment it was revealed, that the best images are obtained on thin types of cloth with thin fibres, particularly on thin silk and on different types of the thin synthetic cloth. The worse images are obtained on dense clothes such as my curtain and on clothes with very large distances between fibres such as a curtain lace. The images given by different types of clothes are very similar. The only difference how well the central area of the image, the beams and maximums on these beams are visible. The central area and the beams are visible better, when distance between fibres of a cloth is less. The maximums on beams are visible better, when the fibres in a cloth are located ideally. Thus, by means of diffraction pattern, formed on the screen, it is possible to judge about structure of a cloth. It is possible to find out, whether fibres in vertical and horizontal directions are located identically, whether fibres form rectangular or oblique-angle system, what angle are formed between fibres of the cloth. And if wavelength of light passing through a cloth is known, from the formula $d \cdot \sin\varphi = m\lambda$ $(m = 0, 1, 2, 3, \dots)$ it is possible to calculate distances between fibres of a cloth.

4 Photos