OPTICS
DISPERSION
Practical 14
STUDY OF DISPERSION OF LIGHT
WITH A GLASS PRIZM

1 Introduction

Dispersion is a phenomenon, consisting in the phase velocity of the wave depending on its frequency. In this practical you will have an opportunity to study dispersion of light in a glass prism. The refractive index of glass, the prism is made of, can be determined as

$$n=\frac{\sin\left(\frac{\varphi+\delta}{2}\right)}{\sin\frac{\varphi}{2}}, \qquad (1)$$

where φ - is the refraction angle of the prism, δ - is the angle of least deviation of rays passing through the prism. By measuring φ and δ, one can calculate the values of n for visible light of different frequencies and thus find the dependence $n(\nu)$.

2 Experimental setup

A goniometer is used (for more details see the description of practical 13), to measure the angles φ and δ. A parallel beam of light after the collimator is collected by the telescope objective (tuned to infinity) in its focal plane, forming a real image of the slit, which is observed through the eyepiece. If one places a prism between the collimator and the telescope, then the tube will need to be rotated relative to the previous position by some angle to observe the image of the slit. It can be measured on the scale of the limb with the help of the vernier. A mercury lamp is used as the source of light in the setup. The emission spectrum of the mercury lamp has a substantially linear nature in the visible region, which makes it possible to work with the emission lines of several definite frequencies. One can find those frequencies from the wavelengths of mercury emission lines in vacuum (the table of wavelengths is given below) and the speed of light in vacuum.

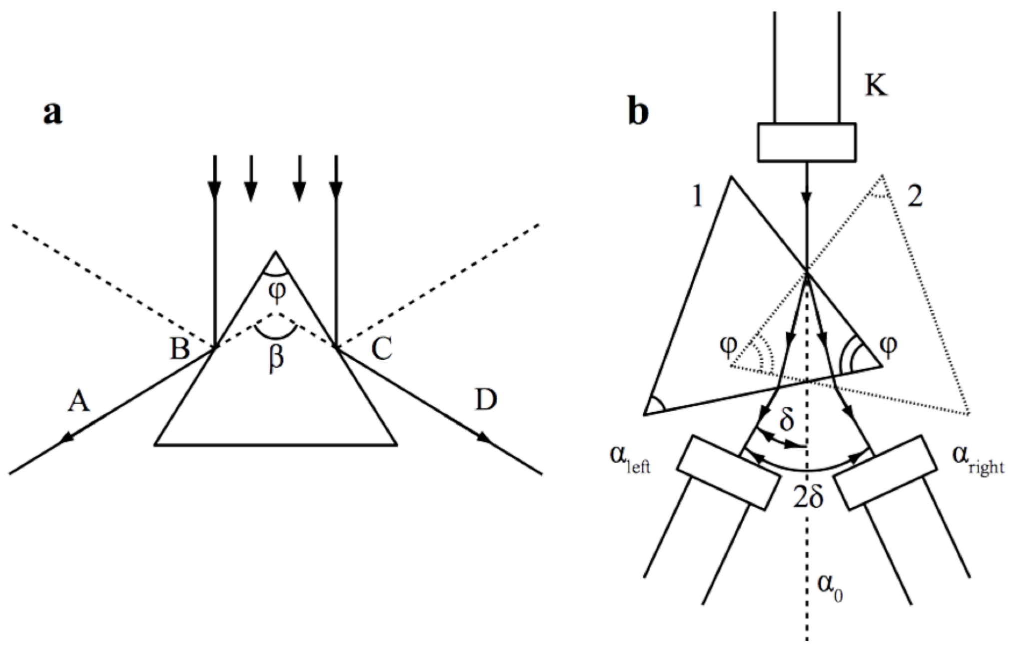

Fig. 1 A schematic of the experimental setup: a – an initial position of the prism on the goniometer relative to the incoming light; b – two positions of the prism during the measurements.

3 Measurement and data processing

Task 1. Determination of the refraction angle of the prism

Place the prism on the goniometer table so that the bisector of the angle φ coincides with the axis of the collimator (Fig.1a). The prism, which is used in this practical, has the base of an equilateral triangle. One should not forget that the angles of the prism cannot be exactly equal. Because of inequality of the prism angles, one needs to take all the measurements with the same defined refractive angle (the proper angle is marked on the prism). The beams reflected off the two faces of the prism form an angle β, as can be seen in Fig.1a. It can be shown that $\beta = 2\varphi$. The angle β is determined from the difference of measurements α_1 and α_2 corresponding to two positions of the telescope, at which the images of the slit formed by the reflected beams *BA* and *CD* are visible. Put down the results of measurements α_1, α_2, β and φ into table 1.

Task 2. Determination of the angles of minimal deviation and refraction indices for the characteristic frequencies of the radiation spectrum of a mercury lamp

To determine the angle of the least deviation of light of a particular frequency, place the prism on the goniometer table so that the refractive angle is equal to the angle, which was defined in task 1 (see Fig. 1b. - the prism in the position 1). Rotate the telescope to find a series of color images of the slit, which correspond to the individual frequencies of the mercury emission spectrum. Then, turn the table with the prism in such a direction that the images of the slit are displaced towards the undeflected beam (to the axis of the collimator). After selecting some image of the slit, continue turning the table while observing the image of the slit in the telescope. Keep turning the table until the image of the slot stops and, with the further rotation of the table in the same direction, does not begin to move back. The “stop position” of the image indicates that one has achieved the angle of least deviation for a given frequency (the angle δ in Fig.1b) by the prism. After the cross-pointer is positioned exactly at the “stop position” of the given line of the spectrum, record the angle α_{left} on the scale of the limb. To calculate the angle δ, it is sufficient to take the difference between the α_{left} and α_0 - corresponding to the undeflected beam (see Fig. 1b); however, to increase the accuracy of measurements, it is recommended to turn the prism table to the position 2 and, once again measure the angle of least deviation α_{right} for the same line of the spectrum. As shown in Fig. 1b, $\alpha_{left} - \alpha_{right} = 2\delta$. Measuring the values of α_{left} and α_{right} for five different spectral lines, calculate the angle δ and, using the refraction angle φ obtained in the task 1, find values of the refractive index n for the five characteristic frequencies of the mercury emission spectrum in accordance the the equation (1). Put down the results of measurements and calculations into table 1.

Table 1

No	Mercury spectral line	Wavelength in vacuum, nm	Frequency, 10^{14} Hz	α_1	α_2	β	φ	α_{left}	α_{right}	δ	n
1	Yellow	579									
2	Green	546									
3	Blue	492									
4	Dark blue	436									
5	Violet	405									

Task 3. Plotting of the dispersion curve and calculation of the average dispersion

Using the obtained values of n, plot the dependence $n = f(\nu)$. Find the average dispersion D_{aver} for a given glass type:

$$D_{aver} = \frac{(n_{viol} - n_{yel})}{(\lambda_{viol} - \lambda_{yel})}, \qquad (2)$$

where n_{viol} and n_{yel} are the refractive indices for the violet and yellow lines of the mercury emission spectrum.

4 Questions

1. What are the main provisions of the classical dispersion theory?
2. What type of dispersion did you observe: normal or abnormal?
3. In what cases can one speak about anomalous dispersion?
4. How can one reduce the chromatic aberration of optical instruments?
5. How can one reconcile the change in the speed of light in a medium with the fact that the speed of motion of photons is constant and always equal to the speed of light in vacuum?