INTRODUCTION

Solid-state materials, such as crystals and glasses, are most widely used in current acoustooptics. In these materials, the anisotropy axes, which determine the polarization of optical eigenmodes, are either predetermined by the symmetry of the crystal or appear under the action of ultrasound. However, in any case, the magnitude of the acoustooptic (AO) effect and characteristics of AO devices depend strongly on the polarization of light [1]. Thus, the proper choice of the polarization of incident light is very important in any AO experiment. Usual recommendations here can be reduced to the following: in an anisotropic medium the incident radiation should have polarization of one of eigenmodes, while in an anisotropic medium the polarization vector should be directed along one of the axis of ultrasound-induced anisotropy.

However, the problem of the AO interaction of arbitrarily polarized light is of undoubted interest from the viewpoint of both basic and applied physics. Considering this problem, Alippi [2] and Eklund, Roos, and Eng [3] showed that, in the Raman–Nath regime, upon the diffraction of linearly polarized light with an arbitrarily oriented polarization vector, the radiation at all maxima remain linearly polarized, but the polarization plane may rotate through an angle depending on the power of the acoustic wave. A similar result concerning the first order of Bragg diffraction was obtained in [4]. In an intermediate regime of the AO interaction, which is closer to reality, the situation is much more complicated. In this case, an additional phase shift appears in all diffraction orders [5–9], and this shift should be taken into account when considering polarization of diffracted light. It is shown in [10–12] that, as a result of the AO interaction, the linearly polarized light generally becomes elliptically polarized. In this case, the polarization of the diffracted light can be controlled by changing the power or frequency of the ultrasound.

In all of the papers mentioned above, only the quasi-orthogonal geometry of the AO interaction was considered. In this case, the light beam propagates nearly perpendicularly to the acoustic beam. The question on the influence of the polarization of light on characteristics of collinear diffraction remained open yet. In this paper, polarization effects upon collinear interaction are analyzed theoretically in the plane-wave approximation. Tentative experiments were conducted using a collinear AO cell made of calcium molybdate (CaMoO₄) crystal.

BASIC RELATIONS

The main distinctive feature of the collinear AO interaction is that the incident and diffracted light beams propagate along the same direction, as is shown in Fig. 1. This figure shows the actual schematic of collinear diffraction in a calcium molybdate crystal [13]. An acoustic wave excited by a piezoelectric transducer (1) first propagates along the crystallographic axis Z (the optical axis of the crystal); then, after reflection from the entrance optical face of a cell (2), it transforms into a shear mode (3), which propagates along the X axis. An acoustic absorber (4) is used to ensure the traveling-wave conditions. A laser beam (5) passes through the cell along the X axis and diffracts in the acoustic field, changing its polarization (anisotropic diffraction [1]). If a collinear AO cell is used as a spectral filter, a polarizer (6) is usually oriented such that the incident radiation has ordinary or extraordinary polarization, while an analyzer (7) is set so that its polarization plane is crossed with respect to the polarization
plane of the polarizer. Owing to this geometry, the diffracted radiation (8) is separated from the incident radiation. In this paper, we study the case of an arbitrary polarization of the incident light.

We assume that the incident radiation with the amplitude $E_i$ is polarized at the angle $\alpha$ relative to the $Y$ axis (Fig. 2). Entering the crystal, the light separates into two waves, $E_i^Y$ and $E_i^Z$, polarized along the $Y$ and $Z$ axes. These components diffract independently in the acoustic field. The ordinary wave $E_i^Y$ diffracts into the +1st order, forming the waves $E_0^Y$ (the zero order with an ordinary polarization) and $E_{+1}^Z$ (the first order with an extraordinary polarization), while the extraordinary wave $E_i^Z$ diffracts into the −1st order, giving rise to the waves $E_0^Z$ and $E_{-1}^Y$. The zero-order waves $E_0^Y$ and $E_0^Z$ have the same frequency $\omega$ equal to the frequency of the incident light, whereas the waves $E_{+1}^Z$ and $E_{-1}^Y$ have the frequencies $\omega + \Omega$ and $\omega - \Omega$, respectively, due to the Doppler effect. These frequencies differ from the frequency of the incident light by the ultrasound frequency $\Omega$. Using the well-known solutions of the diffraction problem of the collinear interaction [1], the following equations can be written for these waves at the exit from the AO cell:

$$E_0^Y = E_i \cos \alpha \left( \cos \frac{K}{2} - j \frac{R}{2} \frac{\sin \frac{K}{2}}{2\pi} \right) \times \exp \left[ j \left( \omega t - k_\alpha l + \frac{R}{2} \right) \right],$$

$$E_{+1}^Z = -E_i \cos \alpha \frac{A}{2} \frac{\sin \frac{K}{2}}{2\pi} \times \exp \left[ j \left( \left( \omega + \Omega \right) t - k_z l - \frac{R}{2} \right) \right],$$

$$E_0^Z = E_i \sin \alpha \left( \cos \frac{K}{2} + j \frac{R}{2} \frac{\sin \frac{K}{2}}{2\pi} \right) \times \exp \left[ j \left( \omega t - k_z l - \frac{R}{2} \right) \right],$$

$$E_{-1}^Y = E_i \sin \alpha \frac{A}{2} \frac{\sin \frac{K}{2}}{2\pi} \times \exp \left[ j \left( \left( \omega - \Omega \right) t - k_\alpha l + \frac{R}{2} \right) \right],$$

where $A$ is the Raman–Nath parameter proportional to the amplitude of the acoustic wave (the AO coupling coefficient); $R$ is the dimensionless phase detuning; $K = \sqrt{A^2 + R^2}$, $k_\alpha$ and $k_z$ are the wave vectors for the ordinary and extraordinary optical waves, respectively; and $l$ is the length of the AO interaction. The detuning $R$ depends on the radiation wavelength $\lambda$ and the ultrasound frequency $f$,

$$R = 2\pi l \left( \frac{f - f_0}{V} \frac{n_\alpha - n_o}{\lambda} \right) = \frac{2\pi l}{V} (f - f_0).$$