# Acoustooptical interaction in paratellurite single crystals on a longitudinal wave with polarization reversal

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(Submitted 9 November 1989)
Pis'ma Zh. Eksp. Teor. Fiz. **51**, No. 1, 22–24 (10 January 1990)

An acoustooptical interaction on longitudinal acoustic waves with a change in light-wave polarization due to spatial dispersion has been detected in paratellurite single crystals.

We used the Sheffer-Bergman (SB) technique to study the acoustooptical (AO) interaction in paratellurite ($TeO_2$) single crystals which possess high acoustooptical characteristics and which are widely applied in laser beam-manipulating devices. The high quality of the crystals grown by us made it possible to use the method to obtain high-resolution SB diffraction patterns at sound frequencies ~13 MHz. We studied a sample measuring $10 \times 10 \times 10$ mm with oriented (100), (010), (001) planes and a sample of the same size with oriented (110), (110), (001) planes.

In the sample with oriented (100), (010), (001) planes, with the light incident along the fourfold axis, we observed the usual SB pattern of the AO interaction for paratellurite. When the crystal was rotated about the [010] axis, diffraction lines appeared, which, according to the Pockels theory and calculations of Nelson and Lax,[1] cannot be manifested in paratellurite crystals in the presence of the selected interaction geometry. Figure 1a and 1b shows the SB patterns and indicates the direction of the

0021-3640/90/010025-04$01.00

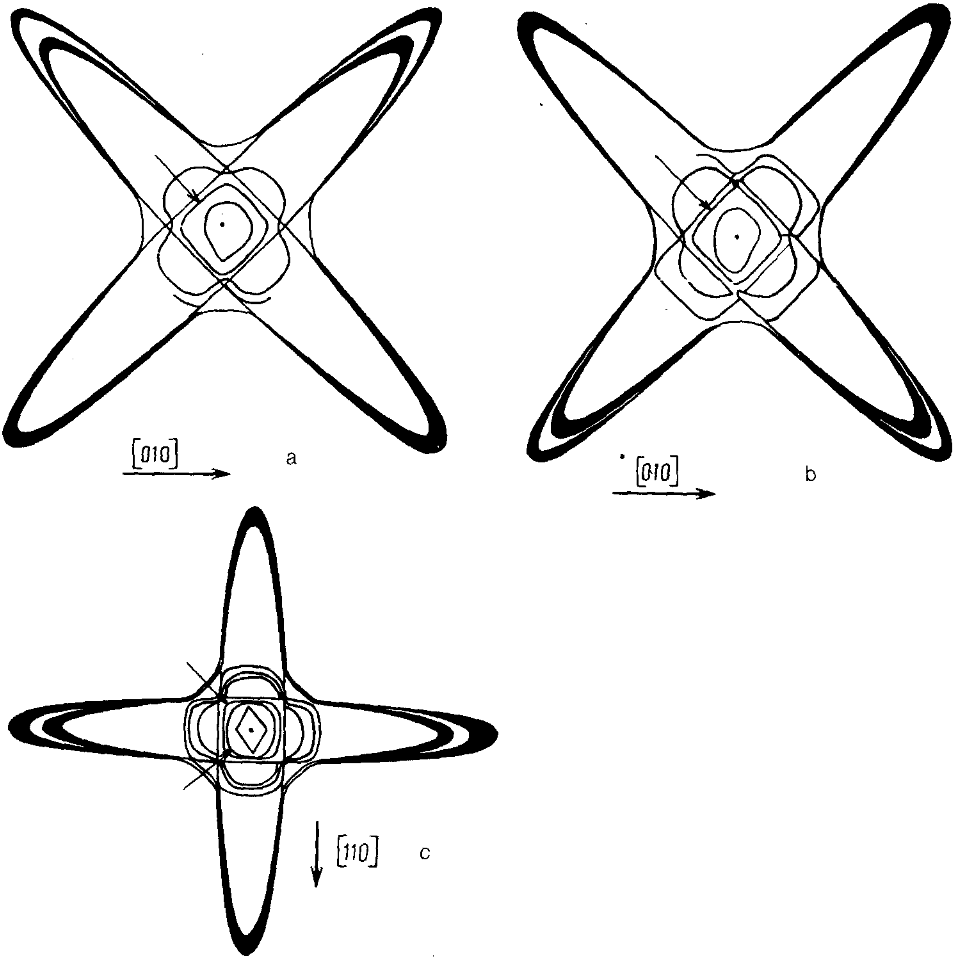

FIG. 1. Diffraction of light with a polarization reversal on longitudinal sound. The wave vector of light is perpendicular to the plane of the figure. Arrows indicate the diffraction curves. (a) Light polarized at right angles to the [010] rotation axis; (b) light polarized along the [010] rotation axis; (c) light polarized along the [110] rotation axis.

axis along which the crystal was rotated. The direction of the light wave vector was perpendicular to the planes of the figures, and the polarization of the incident light in Fig. 1a was perpendicular to the rotation axis, and in Fig. 1b it was parallel to the rotation axis. The angle of rotation was 13°. The figures show diffraction lines due to AO interaction on a longitudinal wave with polarization reversal. The longitudinal waves produce deformations with the components $u_{11}$, $u_{22}$, and $u_{33}$. The polarization of the incident light has the components $E_1$ and $E_3$ in the first case and $E_2$ in the second. In order for the AO interaction to occur on longitudinal waves in the case of such geometry, the nonzero components of the photoelasticity tensor $P_{3111}$, $P_{3211}$, $P_{2311}$, $P_{1311}$, $P_{2111}$, $P_{1211}$, $P_{3122}$, $P_{3222}$, $P_{2322}$, $P_{1322}$, $P_{2122}$, $P_{3133}$, $P_{3233}$, $P_{2333}$, $P_{1333}$, $P_{2133}$,

$P_{1233}$, and $P_{1222}$ must be present. In the classical Pockels theory of elastooptics, these components are zero. They also are zero in the calculations of Nelson and Lax,[1] who showed the contribution of the AO interaction from rotations of volume elements and from the indirect AO effect—the piezoelectrooptical effect which consists in the successive action of the piezoelectric and electrooptical effects. This action stems from the fact that longitudinal waves do not rotate the volume elements, and in class 422 crystals, to which paratellurite belongs, longitudinal waves do not produce a piezoelectric effect.

The presence of diffraction patterns can be explained in terms of the Nelson-Lax theory which was developed by the authors with allowance for spatial dispersion.[2,3] Spatial dispersion is responsible for the appearance of nonzero components of tensor functions with the enumerated indices. Inclusion of spatial dispersion and vibrations of the center of mass of the volume elements gives rise to new additions to the elastooptical tensor. These additions are associated with direct and indirect AO effects. The indirect effects, which consist in the successive action of the piezoelectric effect and electrogyration effect, as well as the piezoelectric effect and electrooptical effect in an inhomogeneous field, cannot take place here because their manifestation requires the presence of the piezoelectric effect.

It is evident from an analysis of the calculations of Ref. 3 that the nonzero components of the tensor functions for the geometry in question are provided for by two imaginary additions to the photoelasticity tensor. One of these additions describes the contribution to the AO interaction from the indirect flexoelectrooptical effect, which consists in the successive action of the flexoelectric effect and electrooptical effect. This tensor function, which appears in the form of an increment to the photoelasticity tensor in the expression describing nonlinear polarization due to the AO interaction,[3] has the form

$$id_{ijr}\, a_r a_s g_{sklm} k_m^A / (a_p k_{pq} a_q).$$

In our geometry, in particular, we have the component of the flexoelectricity tensor $g_{1111}$ and the component of the electrooptical tensor $d_{321}$. The acoustic wave vector has the component $k_1^A$, i.e., the unit vector $a = k^A/|k^A|$ has the component $a_1$. As a result, we have the component of the tensor function $i\widetilde{P}_{3211}$. Other components are similarly manifested.

The second increment is due to the direct AO effect, which is attributed to the fact that the inhomogeneity of the interacting waves in a medium of slight nonlocality is taken into account. The wave vectors of these waves are the inhomogeneity parameter. In our case this means that one of the interacting waves rotates its polarization vector, while the other wave "senses" this gyration. Both increments are found in crystals without an inversion center.

In the case of propagation of light along the fourfold axis, we do not see this interaction, i.e., the optical waves diffracted with the polarization reversal strike almost the same points as do waves diffracted without polarization reversal. The splitting of the diffraction lines is indistinguishable.

Figure 1c shows the SB pattern for the second crystal with oriented (110), (110),

(001) planes. The polarization of the incident light is vertical in the plane of the figure. The crystal was rotated about the [110] axis, which was also vertical in the plane of the figure. The angle of rotation is 11.7°. Accordingly, both cases shown in Fig. 1a and 1b are realized. This circumstance gives rise to double diffraction curves due to new components of the wave vector of light.

The diffraction patterns disappear as the crystal is rotated further in all three cases. This behavior is attributable to the fact that for diffraction with a polarization flip, the magnitude of the acoustic wave vector at the frequency used by us is no longer sufficient.

[1] D. F. Nelson and M. Lax, Phys. Rev. B **3**, 2778 (1971).

[2] V. V. Savchenko *et al.*, *Authors' Abstracts of Reports of the First All Union Conference on Optical Information Processing*. Leningrad, 1988, 30 May – 1 June, Pt. 1, p. 138.

[3] V. V. Savchenko, Appl. VINITI No. 6576-V87, Dnepropetrovsk, 1987.

Translated by A. Peiperl