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INVESTIGATION OF THE DOMAIN STRUCTURE OF A KDP CRYSTAL BY OPTICAL METHODS

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The domain structure of ferroelectric crystals is an important characteristic of the pyroelectric phase of ferroelectrics. The usual optical method of domain study, used in [1, 2], consists of using the optical system of a polarization microscope, in which local observation of the domains is possible. In our experiments we employed two methods: 1) the method of Fraunhofer diffraction of light by domains, previously employed in [3], and 2) a shadow (Toepler) method of domain observation.

In the first case the domain structure of a transparent crystal is used as an optical phase diffraction grating. A KDP crystal measuring 10 x 10 x 10 mm, cut perpendicular to the z axis, was placed in an isothermal thermostatically controlled copper block of a vacuum cryostat. The block had only two small apertures for the passage of light. The primary light beam from an He-Ne laser was passed through the crystal along its z axis. The diffracted light emerged from the crystal through a cryostat window diametrically opposite to the entrance window. The crystal temperature was measured with a copper-constantan thermocouple connected in a potentiometer circuit.

Special attention was paid to the formation of the primary light beam. Namely, a narrow spectrographic slit was placed in the path of the laser beam and could be rotated around the beam axis relative to the orientation of the domains produced in the crystal. It is obvious that, in the case of a band-like domain structure, alignment of the slit edges parallel to the domain boundaries should produce the sharpest diffraction pattern. In order that the cross section of the beam have the required shape of a narrow plane on emerging from the spectrographic slit, a diaphragm was placed behind the slit and cut out the zero-order maximum from the diffraction pattern on the slit. This maximum was indeed the light beam that was subsequently idffracted by the domain structure of the KDP crystal. The diffraction pattern was either photographed or observed visually on a screen located 2 meters away from the exit window of the cryostat. When the diffraction pattern was photographed, the camera (without lens) was mounted in such a way that the plane of the photographic film was 150 mm away from the crystal.

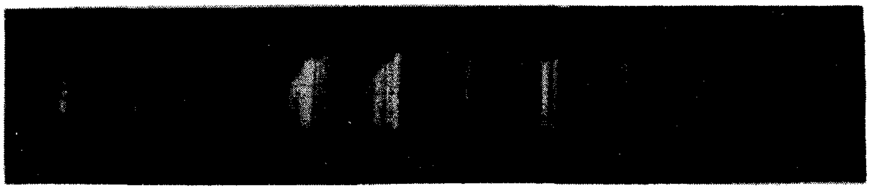

Fig. 1

At a temperature higher than the KDP phase-transition point, a sharp rectangular image of the laser light beam passing through the spectrographic slit, the diaphragm, and the KDP crystal in the cryostat is observed on the screen or on the photographic film. When the crystal reaches the phase-transition temperature, bright diffraction patterns are seen on the screen (film). The experiments were consistently reproducible and were performed dozens of times. The structure of the diffraction patterns depended both on the crystal temperature and on the kinetics of the time variation of this temperature.

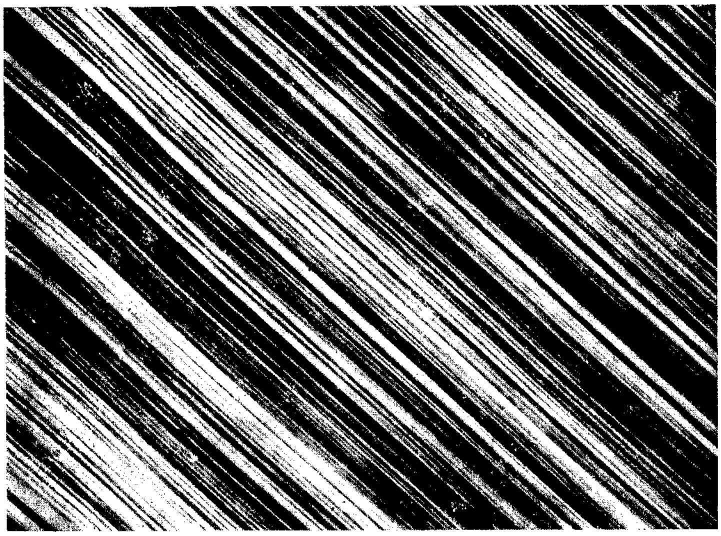

Fig. 2

Fig. 3

In some experiments, the diffraction patterns were located along the line of intersection of the xz plane of the crystal with the screen surface. Such a diffraction pattern may arise if the domains are rectangular plates whose walls are parallel to the yz plane. In other experiments, the diffraction pattern was perpendicular to the first picture, corresponding to formation of domains with walls parallel to the xz plane. In individual cases, both patterns could be observed simultaneously.

In most cases, the observed diffraction pattern had no clearly pronounced periodicity. In some experiments, a periodic diffraction pattern was obtained (Fig. 1), and made it possible to determine the domain dimensions. The periodicity of the picture in various experiments was different, corresponding to domain-plate thicknesses 10^{-3} - 10^{-2} mm.

Simultaneously with observing the diffraction of the light by the domains, a direct observation was made of the domains by the shadow method. To this end, a lens of focal length 8.5 cm was placed behind the crystal. At the focus of the lens was a small screen blocking the central light spot. A magnified image of the domains was obtained at a distance on the order of 2 meters from the crystal, where it was possible either to observe the domains visually through an eyepiece of 15× magnification, or photograph the domains of film (Fig. 2).

The experimentally obtained distribution of the number of domains by dimensions was a symmetrical curve with a maximum. The domain width ranged from 6×10^{-4} to 11×10^{-4} cm. In the experiments that yielded the sharpest diffraction pattern, the domain dimension distribution had a rather sharply pronounced maximum. The position of the diffraction maxima corresponded to diffraction by a grating having a period $d = 9 \times 10^{-4}$ cm (Fig. 1). The same domain dimension corresponds to the maximum of the domain dimension distribution.

In the case when two mutually perpendicular diffraction patterns were observed simultaneously, a direct examination of the domains has shown that the illuminated part of the crystal contains domains with walls parallel to the xz plane, domains parallel to the yz plane, and a region intermediate between the two (Fig. 3).

The obtained average domain dimensions make it possible to determine the energy σ of production of a unit surface of the domain wall of the KDP crystal, using the formula: $\sigma = 3.4d^2P_0^2[(1 + \sqrt{\epsilon_x\epsilon_y})t]^{-1}$, where t is the crystal thickness, P_0 the spontaneous polarization, and ϵ_x and ϵ_y the dielectric constants [4]. Substituting in the foregoing formula the values $d = 10^{-3}$ cm, $t = 1$ cm, $P_0 = 4 \times 10^{-6}$ C/cm^2 and recognizing that $2[1 + \sqrt{\epsilon_x\epsilon_y}]^{-1} = 1/5$, we obtain $\sigma = 50$ erg/cm^2.

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[1] B. Zwicker and P. Scherer, Helv. Phys. Acta 17, 346 (1944).
[2] T. Mitsui and I. Furuichi, Phys. Rev. 90, 193 (1952).
[3] R. M. Hill and S. K. Ishiki, ibid. 135, 1622 (1964).
[4] W. Kanzig, Ferroelectrics and Antiferroelectrics, in Solid State Physics, v. 4, Academic Press, 1957.

ATTENUATION OF A MAGNETOSONIC WAVE IN A TURBULENT PLASMA

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As indicated in a number of theoretical papers, the turbulence of a plasma can greatly alter its dispersive and dissipative properties [1,2]. Measurement of the size of the anomalous skin layer in a turbulent plasma has confirmed the existence of such changes [3]. In the present paper we demonstrate the influence of turbulence excited in a plasma by a straight discharge current on the damping of magnetosonic waves. The described experiments [4] were performed under the same conditions as the investigations of turbulent plasma heating by a strong current along the force lines of a magnetic field [5-7]. The excitation of the current instability leads to a sharp increase of the effective electron and ion collision frequency and to the appearance of an anomalous resistance. As a result, the magnetosonic wave propagating in the region where the plasma has an anomalous resistance should be absorbed more strongly. Thus, it becomes possible to compare the collision frequencies calculated from the values of the anomalous resistance and from the wave damping coefficient.

A diagram of the experimental setup is shown in Fig. 1. A surge circuit was located