I. S. Zheludev. *Optical Activity of Crystals Under the Action of an Electric Field (Electrogyration).* 1. It was shown comparatively recently that not only *frequency* dispersion, but also *spatial* dispersion, i.e., the dependence of the dielectric constant ε not only on the frequency ω, but also on the wave vector $\mathbf{k}$, must be taken into account to describe a number of phenomena in crystal optics. Thus, the long-familiar phenonema of natural *optical activity* (*gyrotropy*) of crystals is described from the standpoint of spatial dispersion not as an isolated phenomenon, but as the simplest particular case in which it is taken into account.[1-3] In fact, under certain constraints, we have for media with weak spatial dispersion,

$$\varepsilon_{ij}(\omega, k) = \varepsilon_{ij}(\omega) + i\eta_{ijk}(\omega) k_k, \qquad e_{lij}\eta_{ijk}(\omega) = g_{lj}(\omega), \tag{1}$$

where e_{lij} is the unit fully antisymmetric tensor and g_{lj} is an axial tensor (pseudotensor) of second rank, the *gyration* tensor. Thus, the gyrotropy is an effect of the order of a/λ (where a is the lattice constant and λ is the wavelength). The gyration tensor g_{lj} has nonzero coefficients only for noncentrally-symmetric crystals, in which activity can be observed. The *specific rotation ρ of the polarization plane* of the light is a measure of optical activity; in the simplest case, i.e., when the light propagates along the optical axis, it is determined by the relation

$$\rho = \frac{\pi}{\lambda n} g_{ij} l_i l_j, \tag{2}$$

where $l_i l_j$ are the direction cosines of the wave normal (optical axis) and n is the index of refraction. For uniaxial crystals, $g_{ij} l_i l_j = g_{33}$.

2. The *electrogyration* phenomenon that we have introduced consists of the influence of the electric field on the gyrotropy of the crystals.[4] It is written analytically in the form of the expansion of the *imaginary* part of the tensor ε_{ij} in powers of the electric field E:

$$g_{ij} = g^0_{ij} + \gamma_{ijk} E_k + \beta_{ijkl} E_k E_l, \tag{3}$$

where g^0_{ij} is the axial gyration tensor in the absence of the field and γ_{ijk} and β_{ijkl} are the axial tensors of third and fourth rank, respectively, which describe the linear and quadratic electrogyration effects. The linear electrogyration effect occurs in all classes of crystals except $m3m$, $\bar{4}3m$ and 432; the tensors γ_{ijk} coincide with the tensors describing piezomagnetism.

3. Phase transitions in ferroelectrics with the appearance (disappearance) of the spontaneous polarization P_s offer a natural opportunity for observation and study of *spontaneous* electrogyration. The cases in which optical activity *appears* in a centrally symmetric, optically inactive crystal are simplest and most reliable. This effect has been studied in several crystals. For example, investigation of the phase transitions in glycine sulfate (GS) crystals near 49 °C indicates that the specific rotation ρ of the polarization plane of light is indeed proportional to P_s below T_k.[5] However, this proportionality is not always observed. In Rochelle salt crystals, for example, ρ changes jumpwise near the upper Curie point, but does not depend on P_s, an indication that the optical activity of this crystal is of molecular rather than crystalline nature.[6]

4. For certain ferroelectrices, the appearance of a P_s of the opposite orientation results in the formation of domains that have enantiomorphism—and, consequently, optical activity—of opposite signs.[7] Among other things, this makes it possible to observe optical-activity sign changes and gyration hysteresis in ferroelectrics on domain polarization reversal (for example, in crystals of $5PbO \cdot 3GeO_2$[8]).

5. Observations of induced electrogyration required a careful search for suitable crystals and subtle experimental techniques. At this time, linear electrogyration has been observed, measured, and studied in α-HIO_3, $LiLO_3$, and $PbMoO_4$ crystals and certain others. Study of electrogyration in the optically biaxial α-HIO_3 crystal (class 222) is made difficult by the attendant electro-optical and piezoelectric phenomena. Even for this crystal, the experimentally determined electrogyration coefficient $\gamma_{52} = (4.33 \pm 0.70) \cdot 10^{-13}$ m/V for $\lambda = 632.8$ nm.[9]

6. In uniaxial crystals of classes 4, 6, 3, etc., electrogyration is not greatly complicated by electrical phenomena or the piezoeffect in an electric field with the wave normal coinciding with the optical axis (the crystal remains uniaxial). To arrive at any confident statement as to the possibility of experimental observation of induced electrogyration, it was therefore important to have experiments in which this phenomenon was stud-

ied on $LiIO_3$ crystals, which belong to class 6.[10] The effect was measured at $-140°C$, since these crystals possess ionic conductivity at room temperature. The electrogyration coefficient γ_{33} was found to equal $(1.57 \pm 0.30) \cdot 10^{-13}$ m/V with a piezoelectric deformation contribution amounting to 17% of the experimentally observed value.

7. Experiments to study induced electrogyration in $PbMoO_4$ crystals merit the greatest attention, since, unlike the crystals considered above, in which the *change* of optical activity under the action of the electric field was studied, the optical activity of $PbMoO_4$ *appears* on application of an external field (the crystal is centrally symmetric, of symmetry group $4/m$). Electrogyration can be studied without the usual accompanying electro-optical phenomena and piezoeffect. The specific rotation in this crystal at fields that are easily attainable in practice (~ 10 kV/cm) is quite large, amounting to several degrees. The phenomenon has dispersion: $\rho \approx 1.5°$ cm^{-1} at $E = 10$ kV/cm and $\lambda \cong 700$ nm, and $\rho \cong 5°$ cm^{-1} at the same field and $\lambda \cong 400$ nm. The value of the coefficient γ_{33} (field and wave normal along the optical axis) is $(1.23 \pm 0.12) \cdot 10^{-12}$ m/V even at $\gamma = 517$ nm.[11]

8. The *quadratic* electrogyration is described by an axial tensor of fourth rank and is possible only in acentric crystals.[12] This phenomenon has been observed experimentally in quartz crystals under the action of an electric field along the crystallographic axes and a plane-parallel wave propagating along the optical axis. The measured quadratic electrogyration coefficient is $\beta_{31} = (4.51 \pm 0.34) \cdot 10^{-20}$ m^2/V^2.[13]

9. Electrogyration broadens possibilities for study of structural and energy changes in the crystals on phase transitions in ferroelectrices and pyroelectrics. Evidently, elements that use the electrogyration phenomenon may have practical applications in control systems for optical radiation, e.g., laser control systems. These elements include amplitude and phase modulators, controlled optical filters, devices for spectrum scanning, deviators, and deflectors. Nor is it impossible that the use of electrogyration elements in optoelectronics might result in the creation of new (nonvacuum) types of color televisions, optical radars and rangefinders, and elements for optical computers. The use of electrogyration in spectroscopy appears possible.

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