Photoinduced linear birefringence in iron borate

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The effect of illumination on the optical anisotropy in the basal plane of the magnetically ordered crystal $FeBO_3$ was investigated. An optically induced linear birefringence that depends on the magnitude and the direction of the external magnitude field was observed.

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In the investigation of linear birefringence in easy-plane antiferromagnets, it was)bserved that the magnetic ordering exerts an influence on the optical anisotropy of he crystals.[1] On the other hand, the change of the magnetic properties under the nfluence of light is a reliably established fact in a number of materials.[2–5] Therefore in :rystals having a combination of these properties one can expect changes in the optical)roperties, upon illumination, particularly magnetic birefringence. To ascertain the lependence of the magnetic birefringence on the illumination we have attempted to)bserve this effect in the transparent magnetically ordered crystal $FeBO_3$, in which the nfluence of illumination on the magnetic susceptibility and anisotropy has been ioted.[4,5]

Measurements of the magnetic birefringence were carried out by the Senarmont ompensation method with modulation of the plane of polarization in azimuth, which ıade it possible to register Δn accurate to 10^{-7}. To investigate the influence of the lumination on the optical anisotropy, we used a two-beam procedure: the first (con-:ol) beam was monochromatic with intensity $\sim 10^{-4}$ W/cm^2, and the second (illumi-ating) beam was "white" at ~ 1 W/cm^2. When the second beam was turned on, the :cording system was covered up to prevent overloading of the photoreceiver photomultiplier).

In the investigation of the dependence of the magnetic birefringence on the exter-al magnetic field it was noted that Δn in the basal plane is closed to zero in the bsence of a field and increases with increasing field, reaching saturation $n = 1.5 \times 10^{-4}$ ($\lambda = 510$ nm) in fields $H \geqslant 100$ Oe. The crystal in weak fields is broken p into non-degree domains,[4] the increase of Δn with increasing field points to an)preciable role of the anisotropic term in the dielectric tensor.[1]

The variation of the linear birefringence under the influence of the light in $FeBO_3$ as observed in the following manner.[1)] The sample was cooled to 78 K and was .turated with a magnetic field ($H_1 = 120$ Oe) applied to the basal plane. The linear refringence in this state was taken to be the zero reference point. All the subsequent easurements of Δn were carried out in a field H_1 as to maintain the same magnetic ate of the sample at the instant of measurement). After illuminating the crystal in e initial magnetic state, a change was noted in the birefringence ($\delta n \sim 10^{-6}$), and was eserved without relaxation. The action of the light in a field $H_\perp$ applied in the basal

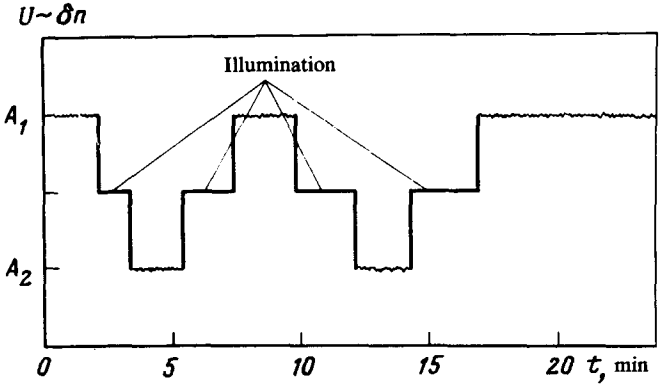

FIG. 1. Time schedule of the electric signal proportional to the linear birefringence. A_1, A_2-values of the signal when the crystal is illuminated in mutually perpendicular fields in the basal plane.

plane normal to the initial H_1 led to a change in the birefringence with opposite sign. The subsequent illumination in the initial field H_1 restored the value of the birefringence obtained after the first illumination. Thus, we observed a linear birefringence induced by the illumination and connected with the magnetic state of the crystal. ("Processing" the sample with magnetic fields only without applying light does not change the initial value of Δn). Figure 1 shows the time schedule of the variation of the electric signal proportional to the linear birefringence, under the influence of illumination in the fields H_1 and $H_\perp$. The initial state was chosen to be the value of the signal A_1 which was proportional to the birefringence of the crystal illuminated in the field H_1. The level of the signal H_2 corresponds to the birefringence after illuminating the sample in the presence of the field $H_\perp$. It is seen from the diagram that crystal "memorizes" its magnetic state at the instant of illumination, and the value of the birefringence is reproduced in the subsequent cycles of the optical and magnetic actions. The magnitude of the effect depends on the magnetic field intensity in which the sample was subjected to the light. With increasing field, Δn increases, reaching saturation in fields $H \geqslant 100$ Oe. The induced birefringence accumulates additively at short exposure times and has a maximum value at light-pulse durations $\tau \sim 1.5$ min. The observed change in the birefringence is due directly to the action of the light, since, first, no temperature relaxation of δn with time was observed and, second, raising the temperature to 90 K and subsequent cooling of the sample with analogous application of the magnetic fields did not lead to a change of Δn.

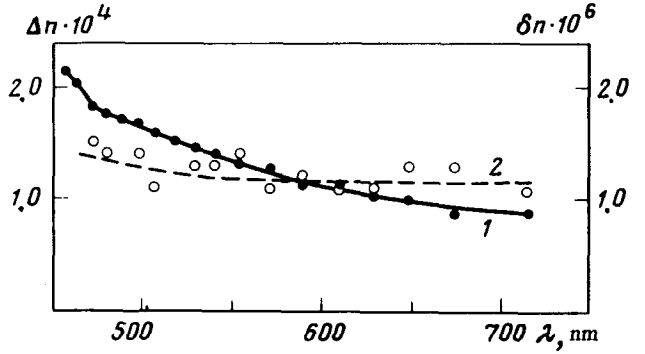

FIG. 2. Spectral dependences of the linear magnetic birefringence Δn (1) and induced birefringence δn (2).

Figure 2 shows the dispersion dependences of the magnetic (1) and induced (2) birefringence. It is seen from the curves that whereas the induced birefringence (δn) is practically independent of the wavelength of the light in the visible band, the magnetic birefringence Δn increases with increasing energy of the incident light. The different character of the spectral curves can be due to the fact that the electronic transitions responsible for both types of birefringence come from levels of either ions with different valence (Fe^{2+}, Fe^{3+}), or from identical ions but in different environments. Since the positions of the iron ion in the ion-borate lattice are equivalent, the change of the valence of the magnetoactive ion cannot produce an integral change in the optical anisotropy because of the conservation of the total charge. That is to say, the induced birefringence is apparently connected with a change in the ligand structure. The active element of such a structure can be an oxygen vacancy, which can have six equivalent positions relative to the magnetic ion. The presence of the vacancies leads to local lattice distortions that interact via magneto-elastic coupling with the magnetic subsystem of the crystal. The vacancy position is activated at high temperatures and "frozen" at low temperatures. With changing direction of the antiferromagnetism vector, the rearrangement of the local deformations to match the magnetostriction deformations is initiated by the illumination.

Thus, we have observed the appearance of optically induced linear birefringence, and investigated its field and frequency dependences. We have demonstrated a "memory" of the magnetic state of the crystal during the time of illumination and the possibility of controlling its magnitude by an external magnetic field.

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[1)]No change of the linear dichroism by illumination was observed.

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