ISSN 2320 – 5822

Volume 7, No.1, January 2020

Journal of Global Research in Mathematical Archives

RESEARCH PAPER

Available online at http://www.jgrma.info

INFLUENCE OF LIGHT ON MAGNETIC ORDER MODULATION CRYSTAL $FeBO_3$:Mg

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***Abstract*:** The following article deals with the Investigation of the effect of optical illumination on the conditions of occurrence and parameters of the modulated magnetic structure of the $FeBO_3$:Mg crystal.

Studies of photo-induced changes in the parameters of the modulated magnetic structure (MMS) $FeBO_3$: Mg. Iron borate is one of the currently known magnetically ordered crystals. Under the influence of radiation, new magneto-optical properties appear in the crystal. So in $FeBO_3$, doped with Ni ions, when irradiated with non-polarized white light, a uniaxial magnetic anisotropy occurs, the axis of which does not coincide with the axes of crystallographic anisotropy [1], as well as spatially MMS [2]. From the theory of photo-induced MMC $FeBO_3$:Ni proposed in [2], it follows that it is excited by the magnetoacoustics interaction between complexes formed by Fe matrix ions and Ni impurity ions, which is insignificant in the absence of illumination, but increases when light is absorbed by the crystal. This theory, in principle, allows the occurrence of MMC in a Doped $FeBO_3$ impurity and without additional illumination, but the light effect should affect the parameters of the modulation of the magnetic order of the crystal. Detection of this effect on the parameters of the $FeBO_3$:Mg MMS would allow us to analyze the causes of a stable inhomogeneous magnetic state in this crystal on the basis of the microscopic theory developed in [2].

In order to detect the effect of additional illumination on the period and conditions of existence of the $FeBO_3$:Mg MMS, corresponding photo magnetic experiments were performed, the results of which are given below.

All studies were performed using the magneto-optical method in the optical transparency window of the crystal (in the region of wavelengths $\lambda \sim 0.5$ microns) in the temperature range $80 \leq T \leq 290$ K in the magnetic field $H \leq 50$Oe with the orientation of the vector H parallel to the plane (111) at small angles of light incident on the sample plane. The probing crystal light beam was "monochromatized" by a ZS – 1 band-pass glass filter and had an intensity of $\sim 10^{-5}$ W/ cm^2.

The process of technical magnetization in the $FeBO_3$:Mg light plane was studied on the basis of the Faraday effect hysteresis loops that were observed when the sample was remagnetized in the quasi-static magnetic field sweep mode. In these experiments, the sample was set so that the C_3 axis was an angle of $\sim 10^o$ with the direction of the light beam, and the h vector lay in the plane of the sample in the plane of incidence.

In photomagnetic experiments, the sample was cooled to T = 80 K and additionally irradiated with a stream of non-polarized white light focused on its surface with an intensity of $\sim 5 \times 10^{-2}$ W / cm^2 (the light source was a halogen incandescent lamp KGM12 -100); after holding the sample for some time under the light stream, additional illumination was turned off and visual observations of the domain structure (DS) and measurements of the Faraday effect were made.

As shown by experiments, additional illumination of the sample polarized white light did not lead to observable change of DS or band system that exists on the image of the sample at H $C_2 \parallel$ Y (orientation of the axes of the laboratory coordinate system is shown in Fig.1) . Remagnetization of the" illuminated" sample along the X-axis also did not reveal any effect of light on the shape of the hysteresis loop. However, when studying the field dependence of the Faraday effect at H $\parallel$ Y, it was found that prolonged illumination of a sample in the demagnetized state leads to an increase in the width of the magnetic hysteresis loop (an increase in the coercive force of the H_c) (Fig. 2).

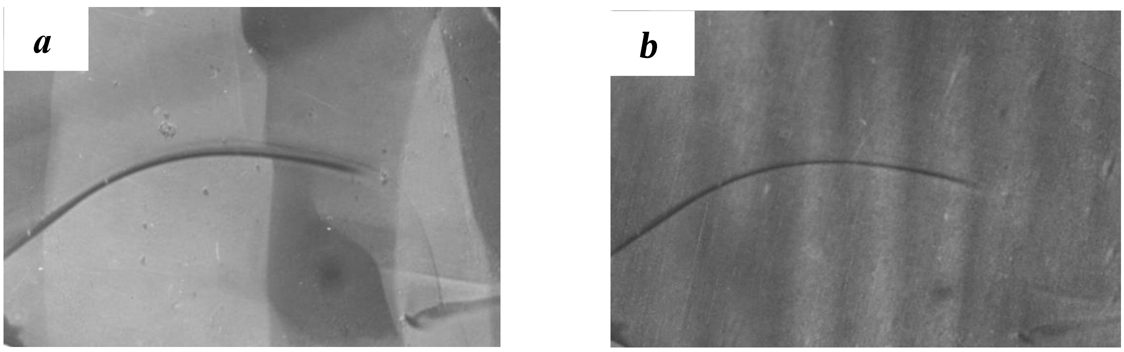

Figure. 1. $FeBO_3$:Mg images observed in polarized light at T = 80 K with different magnetic field strengths: a-H = 0; b-H = 7 Oe (N || X). (a), (C) -- the sample was first magnetized in the field H = 5 Oe to a monodomain state and then exposed to illumination for 10 minutes.

Moreover, a noticeable change (exceeding the experimental error ~ 0.02 Oe) in the width of the hysteresis loop of the Faraday effect was observed at the illumination duration $\tau > 2$ min, and the growth of the H_k value occurred up to $\tau \approx 10$ min, after which the increase in the pre-illumination time of the sample practically did not affect the appearance of the f(H) curve. If the "illuminated" sample was first magnetized to saturation at H || X, and then re-magnetized at H || Y, then the curve F (H) within the experimental error coincided with a similar curve obtained before the sample was illuminated.

In addition, it was found that the pre-illumination of the sample (at T = 80 K, H = 0) changed the period and conditions of existence of MMS, which is realized in the crystal when it is magnetized along difficult axes oriented at an angle of 30° to the y axis.

In a pre-irradiated sample in this magnetization geometry, the band system occurs at $H = H_1 \approx 5.5$ Oe, exists in a certain T-dependent interval of the magnetizing field ΔH, and disappears when the field reaches a critical value of $H_c \approx 17$ Oe at T = 80 K. The noticeable asymmetry of the curve F (H) at $H \perp C_2$ is due to the even magnetization contribution to the rotation of the polarization plane of the light that passed through the sample from the magnetic linear dichroism that occurs in this measurement geometry due to the rotation of the magnetization vector M to the direction H, leading to the appearance of a projection of the vector M on the plane of polarization of light. It is obvious that when the vector H is oriented along the direction of the domain boundaries, this rotation does not occur and, therefore, in this case, the magnitude of the magnetic linear dichroism (provided that the polarization plane of the light incident on the sample is collinear with H) is zero.

In addition to visual observation of the DS and its evolution under the influence of an external magnetic field and temperature changes, research was conducted on the magnetization process and the associated magnetic characteristics of the $FeBO_3$:Mg crystal to solve the problems in the dissertation. The main information about the magnetic characteristics of the crystal was extracted from the results of studies of the magnetic – optical effect-the Faraday effect, which is odd in relation to the inversion of the direction of the magnetization vector. The experiments investigated the hysteresis loops of the magneto-optical signal F(H), observed in the quasi-static mode of magnetization or when the sample is magnetized at a frequency of 25 ÷ 95 Hz, as well as the temperature dependence of the magneto-optical susceptibility $\partial F/\partial H(T)$, measured in an alternating magnetic field.

It is known that the Faraday rotation angle (the angle of rotation of the polarization plane of the probing light beam relative to its original orientation) is defined as [2]:

$$F_o = h\,M\,d\ ,$$

where h is the Kund constant, M is the magnetization, and d is the length of the path of light in the crystal along the direction of magnetization.

In the pre - "illuminated" (at $\tau = 10$ min) sample, under the same experimental conditions, the band system appeared in the field $H_1 \approx 6.5$ Oe and existed until $H_c \approx 21$Oe, and its period increased in comparison with the value d observed on the "non-illuminated" sample, while the discontinuous nature of the dependence d(H) was preserved. The change of system parameters of the bands that arise when H || X, occurred only when the long exposure exposed sample, a pre-magnetized (in the field H = 5 Oe, H || X) to single-domain States: in this case also, an increase (about 10 %) of the period d and the interval days field of the existence of MMS. It turned out that in both cases, the exposure of the sample under white light did not change.

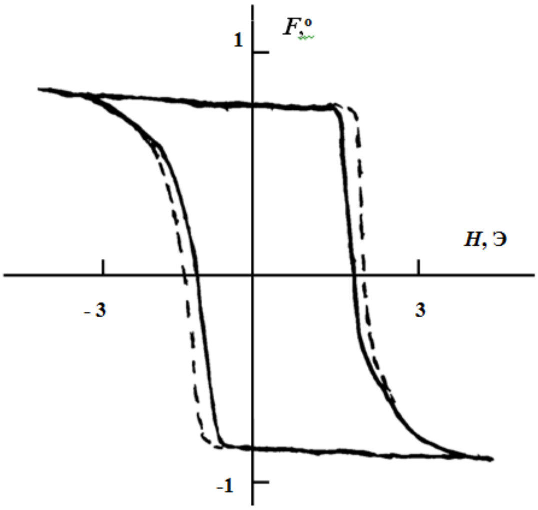

Figure. 2. Hysteresis loops of the Faraday effect obtained by remagnetization of $FeBO_3$: Mg (H || Y, T = 80 K). The time for scanning the magnetic field is ~ 30 seconds. the Solid curve is an "unlit" sample, the dotted curve is a sample that was previously illuminated with non-polarized white light at H = 0 for 10 minutes.

It is known from crystal optics [3] that when the light beam deviates from the optical axis of the crystal, birefringence occurs

$$B(\theta) = \frac{2\pi d}{\lambda}(n_e - n_o)\sin^2\theta$$

(ne no – the main refractive indices, λ- the length of the light wave, θ - the angle between the optical axis and the direction of the light beam), which will have a noticeable effect on the Faraday effect. In this case, the angle of rotation of the polarization plane of the probing magnetically ordered light crystal is determined by the expression [4]:

$$F(\theta) = \frac{F_o \sin\theta}{B(\theta)}\sin\left(\frac{B(\theta)}{\cos\theta}\right)$$

which for sufficiently thin samples can be converted to the form

$$F(\theta) \propto F_o \operatorname{tg}\theta \approx F_o\theta = hM\theta\ d.$$

As already noted, the studies of the $F(\theta)$ dependence performed in [5] showed that for $FeBO_3$ crystals with a thickness of ~50 microns when light propagates near the C_3 axis, the ratio is well fulfilled for the angles of incidence of $\theta \le 10^o$ (while the maximum angle of rotation of the visible range light polarization plane in the sample at t = 77 K Does not exceed 1.5^o). Therefore, in this measurement geometry, the value of the angle F can be considered to be proportional to the magnetization of the crystal with a sufficiently high accuracy.

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