

INFLUENCE OF LIGHT ON MAGNETIC ORDER MODULATION CRYSTAL FeBO₃:Mg

Fayziev Shakhobiddin*¹ and Saidov Kurbon²

*¹Department of Physics, Bukhara State University, Bukhara, Uzbekistan
fayziyev_83@mail.ru¹

²Department of Physics, Bukhara State University, Bukhara, Uzbekistan
qurbonsaid@mail.ru²

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 FeBO₃:Mg crystal.

Studies of photo-induced changes in the parameters of the modulated magnetic structure (MMS) FeBO₃: 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 FeBO₃, 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 FeBO₃:Ni proposed in [2], it follows that it is excited by the magnetoacoustic 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 FeBO₃ 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 FeBO₃: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 FeBO₃:Mg MMS, corresponding photomagnetic 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/ cm².

The process of technical magnetization in the FeBO₃: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 C₃ axis was an angle of $\sim 10^\circ$ 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 / cm² (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 unpolarized white light did not lead to observable change of DS or band system that exists on the image of the sample at $H \parallel C_2 \parallel Y$ (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).

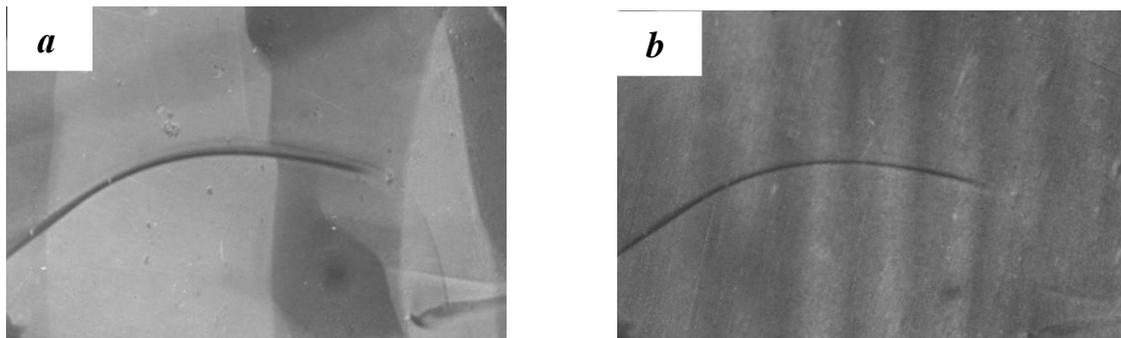


Figure. 1. FeBO₃:Mg images observed in polarized light at T = 80 K with different magnetic field strengths: a-H = 0; b-H = 7 Oe (N || X). (a), (C) -- the sample was first magnetized in the field H = 5 Oe to a monodomain state and then exposed to illumination for 10 minutes.

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_c 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 = H₁ ≈ 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 ≈ 17 Oe at T = 80 K. The noticeable asymmetry of the curve F (H) at H ⊥ C₂ 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 FeBO₃: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 H₁ ≈ 6.5 Oe and existed until H_c ≈ 21Oe, 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.

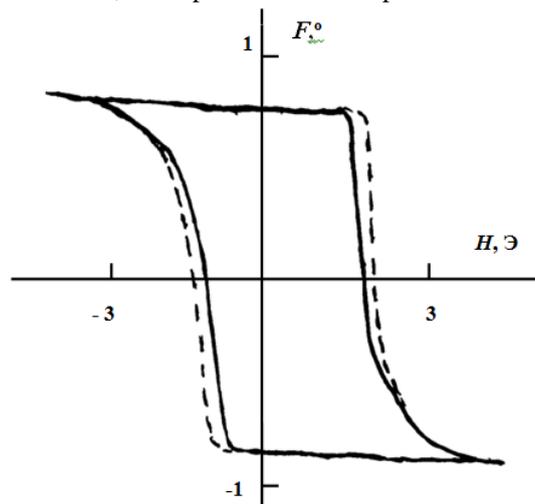


Figure. 2. Hysteresis loops of the Faraday effect obtained by remagnetization of FeBO₃: Mg (H || Y, T = 80 K). The time for scanning the magnetic field is ~ 30 seconds. the Solid curve is an "unlit" sample, the dotted curve is a sample that was previously illuminated with non-polarized white light at 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

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

(n_e n_o – 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

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

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 $\theta \leq 10^\circ$ (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°). 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.

REFERENCES

1. Fedorov Yu. M., Leksikov A.A., Aksenov A.E. Photo-induced optical anisotropy in iron borate.// JETF. 1985. – No .89. P. 2099 – 2112.
2. Boidedaev S. R., Dzhuraev D. R., Sokolov B. Yu., Faiziev Sh. Sh. Effect of the Transformation of the magnetic structure of a $\text{FeBO}_3:\text{Mg}$ crystal on its magneto-optical anisotropy. Optics and Spectroscopy, 2009, Vol. 107 No. 4 -P. 651-654.
3. Sh.Sh.Fayziev. Effect of light on the modulation of the magnetic order of the $\text{FeBO}_3:\text{Mg}$ crystal. «Young Science». 2017, No.28, P.8-11
4. Sharipov M.Z., Sokolov B.Yu. Fayziev Sh.Sh., Mirjanova N.N. Influence of the magnetic structure rearrangement of a $\text{FeBO}_3:\text{Mg}$ crystal on its magneto-optical anisotropy. Science, technology and education. 2015. No.4 (10), -P. 15-18
5. D. R. Dzhuraev, B. Yu. Sokolov, and Sh. Sh. Faiziev. Photoinduced changes in the space-modulated magnetic order of a $\text{FeBO}_3:\text{Mg}$ single crystal. Russian Physics Journal, 2011, Vol. 54, №3, -P 382-385
6. D.R. Dzhuraev, Sh.Sh. Fayziev, B.Yu. Sokolov. ETDEWEB/Search Results/'Magnetic ripple'in rhombohedral FeBO_3 : Mg crystal;'Magnitnaya ryaba'v romboehdricheskom kristalle FeBO_3 : Mg. Mezhdunarodnaya konferentsiya, posvyashchennaya 80-letiyu akademika MS Saidova'Fundamental'nye i prikladnye voprosy fiziki'. 2010.
7. D.R. Dzhuraev, Sh. Fayziev, B.Yu. Sokolov. 'Magnetic ripple' in rhombohedral $\text{FeBO}_3:\text{Mg}$ crystal. Proceedings of fourth international conference dedicated to the eightieth anniversary of academician M.S. Saidov 'Fundamental and applied problems of physics'. 2010. -P. 342-344
8. D.R. Djuraev, Sh.Sh. Fayziev, B.Yu. Sokolov. The modulated magnetic state in weak ferromagnetic FeBO_3 : Mg; Modulirovanoe magnitnoe sostoyanie v slabom ferromagnetike FeBO_3 : Mg. Republic scientific conference on actual problems of modern physics and astronomy, II respublikanskaya nauchnaya konferentsiya'Aktual'nye problemy sovremennoj fiziki i astronomii', Karshi (Uzbekistan). 2010.
9. Valiyev U.V., Saidov K.S., Lukina M.M. On the nature of the Faraday effect in rare earth orthoaluminate TbAlO_3 . Solid state physics. 1999. No.11, P.2047-2052.
10. D.R. Dzhuraev, L.N. Niyazov, B.Y. Sokolov. Modulated magnetic phase of structurally heterogeneous easy-plane weak ferromagnets. Technical Physics 61 (6), 883-886
11. S.R. Boidedaev, D.Y. Sokolov, D.R. Dzhuraev, Sh. Fayziev. The 'magnetic ripple' state in weak ferromagnetic $\text{FeBO}_3:\text{Mg}$. Uzbekiston Fizika Zhurnali. 2009. No.5, P. 376-383
12. U.V. Valiev, D.R. Dzhuraev, E.E. Malyshev, K.S. Saidov. Electronic structure of the ground multiplet of the Dy^{3+} ion in the DyAlO_3 orthoaluminate. Optics and Spectroscopy. 1999. No.86, P. 703-706
13. U.V. Valiev, M.M. Lukina, K.S. Saidov. On the nature of the Faraday effect in the rare-earth ortho-aluminate TbAlO_3 . Physics of the Solid State. 1999. No.41, P. 1880-1884
14. D.R. Djuraev, L.N. Niyazov, K.S. Saidov, B.Yu. Sokolov. Investigation of the spontaneous spin-flip phase transition in terbium-yttrium iron-garnet by the magneto-optic method. Ukrainian journal of physics. 2012. No.5, P. 531-537
15. D.R. Dzhuraev, N. Mirzhanova, L.N. Niyazov, K.S. Saidov. The superconductivity and nanotechnology. Modern problems of semiconductor physics. 2011, P. 125-127
16. D.R. Dzhuraev, L.N. Niyazov, K.S. Saidov, B.Yu. Sokolov, L. Khaydarova. The spontaneous orientation phase transition in terbium-yttrium ferrite-garnet. Modern problems of semiconductor physics. 2011, P. 76-78
17. D.R. Djuraev, L.N. Niyazov, K.S. Saidov, B.Yu. Sokolov. Changing the cubic ferrimagnetic domain structure in temperature region of spin flip transition. Uzbekiston Fizika Zhurnali. 2011. No.5, P. 359-366
18. U.V. Valiev, J.B. Gruber, U.R. Rustamov, K.S. Saidov, V.Yu. Sokolov. A magneto-optical study of the odd crystal field component in a terbium-yttrium aluminum garnet. Technical Physics Letters. 2003. No.11, P. 882-885
19. U.V. Valiev, D.R. Dzhuraev, V. Nekvasil, K.S. Saidov. MAGNETOOPTICAL STUDIES OF EXCITED STATES OF RARE-EARTH IONS IN $\text{Y}_3\text{Al}_5\text{O}_{12}:\text{Tb}^{3+}$. Magnetic and Superconducting Materials: Volume 2. P. 1059-1064
20. Sh.Fayziev. Investigation of the magnetic structure of $\text{FeBO}_3:\text{Mg}$. III international scientific conference of young researchers. 2019. No.1, P. 105-107

SHORT BIODATA OF THE AUTHORS

Shakhobiddin Fayziev

Graduated from Bukhara State University. Scientific research interests are connected with magnetoptic analysis of crystals. Currently, Dr. Sh.Fayziev is a Head of Department of Physics, Bukhara State University.



Saidov Kurbon

Graduated from Bukhara State University. Scientific research interests are connected with magnetoptic analysis of crystals. K. Saidov is currently an associate professor of the Department of physics at Bukhara State University.

