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Researching of the influence of mechanical stresses on magneto-optical properties of iron borate crystal

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Annotation. Magneto-optical visualization methods are based on the phenomenon of rotation of the plane of polarization of light reflected from a magnetized material (Kerr effect) or passing through a magneto-optical medium (Faraday Effect). Among them, the most promising methods for the study of magnetic carriers are the methods of visualization of the magnetic fields of carriers using films of ferrite garnets. A film of ferrite garnets is grown on a gallium gadolinium garnet substrate, the upper face of which is clarified to increase the contrast of the observed pattern. From below, a mirror-protective layer is applied to the crystal to increase its wear resistance and reflection coefficient.

Key words: magneto-optics, magnetic hysteresis, diamagnetism, paramagnets, spectroscopy.

Introduction. In the absence of an external magnetic field, a spatial labyrinth domain structure exists in a magneto-optical crystal, with the magnetization directions in neighboring domains being opposite and perpendicular to the crystal surface. Local magnetization of a film of ferrite garnets in an external field occurs by rotating the magnetic moment vector. Therefore, when a crystal is placed in a magnetic field, it quickly rearranges itself in accordance with its spatial and amplitude characteristics, and after the field is removed, it returns to the unperturbed (initial) state [1].

When linear polarized light is reflected from a magnetized surface, the light polarization plane rotates through an angle, the value of which depends on the direction of sample magnetization. The rotation of the plane of polarization of light when it is reflected from the surface of a magnetized ferromagnetic is called the magneto optical Kerr effect. Depending on the relative position of the magnetization vector in the plane of the ferromagnetic sample and the plane of incidence of light, polar, meridional, and equatorial Kerr effects are distinguished.

The main element of the visualization device on ferrite-garnet films is a magneto-optical crystal, which converts the stray magnetic fields of the carrier into a light distribution corresponding to their magnitude and position in space [2]. Its structure has shown in Fig. 1.

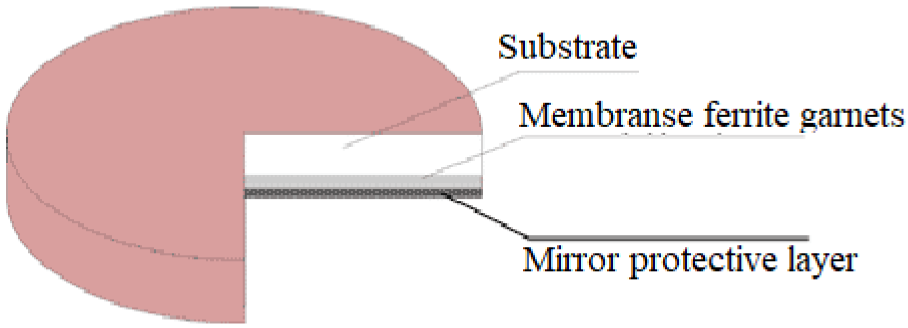

Figure 1. Structure of a magneto-optical crystal

Polar Kerr effect: the magnetization vector is perpendicular to the surface of the ferromagnetic mirror, but parallel to the plane of incidence of light (Figure 2 a). Meridional (longitudinal). Kerr effect: the magnetization vector is in the plane of the mirror and parallel to the plane of incidence of light (Figure 2 b). Equatorial (transverse) Kerr effect: the magnetization vector is located in the plane of the mirror, but perpendicular to the plane of incidence of light (Figure c) [8]

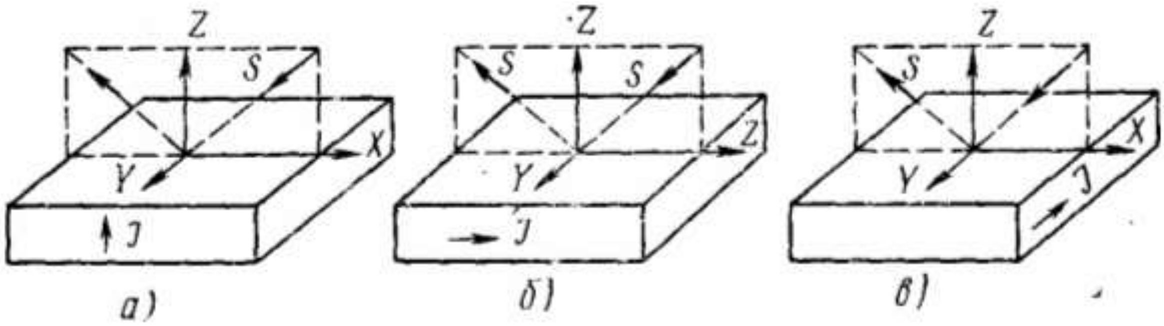

Figure 2. Kerr effect: a) - polar, b) - longitudinal, c) - transverse.

Performs amplitude modulation, rotates the polarization plane (polarization modulation) by a certain angle. Magneto-optical effects can be divided into two main groups: effects observed when light passes through a magneto-optical material and effects when light is reflected from the surface of a magneto-optical material. In this work, the effect of the first group is applied. Bi^{3+} ions make the largest contribution to the specific Faraday rotation. It is several times higher than the contribution of the most magneto-optically active rare-earth ions $Rg3^{+}$ и Nd^{3+}. All other rare-earth ions give the same order of magnitude contribution with θ_F (table 1), and of a different sign than Bi^{3+}, R^{3+} or Nd^{3+}. In connection with this, the specific Faraday rotation in Bi-containing MPGF weakly depends on the type of rare-earth ion.

Table 1. Faraday rotation and MO coefficients

Compound	λ, Mkm	θ_F ,grad/sm	A, grad/μw	D, grad/μw	C, grad/μw
$Y_3Fe_5O_{12}$	1,152	245	50±3	29 ± 2	0
$Eu_3Fe_5O_{12}$	1,152	202	55±3	33 ±2	0

$Gd_3Fe_5O_{12}$	1,152	70	42,4 ±1,8	27,1 ±1,3	1 ±0,2
$Tm_3Fe_5O_{12}$	1,152	110	23 ±7	12 ± 6	20±4
$Tb_3Fe_5O_{12}$	1,152	440	9 ± 15	10± 11	84,4 ±2,5
$Y_3Fe_5O_{12}$	0,633	835	493,9	321,3	0
$Y_3Fe_{3,07}Ga_{1,93}O_{12}$	0,633	0	300,1	203,1	0
$Y_{2,35}Bi_{0,65}Fe_5O_{12}$	0,633	12 600	419,5	799,5	0
$Y_{1,97}Bi_{1,03}Fe_5O_{12}$	0,633	19 300	876,3	1394,1	0

The effects of the first group are associated with double circular refraction, i.e. with a difference in the complex refractive indices of right- and left-hand circularly polarized waves. The real part of birefringence describes the rotation of the plane of polarization, and its imaginary part describes the transformation of linearly polarized radiation into elliptically polarized. If light propagates through a magneto-optical material parallel to its magnetization vector, then a magnetic circular birefringence is observed, which is called the Faraday effect. The Faraday effect is proportional to the path of a light beam in a magnetically ordered medium

$$F_M = \theta_F h \cos\alpha ,$$

where θ_F - specific faraday rotation; h - path length in a magnetic film of ferrite garnet, α – the angle between the direction of radiation propagation and the magnetization vector M.

Thus, the plane of polarization is rotated by an angle: $F_M = 1[gr/mkm] \cdot 8[mkm] \cdot \cos 90^\circ = 8^\circ$;

A ferrite garnet magnetic film can be represented as a phase plate described by the Muller matrix:

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\delta & -\sin\delta & 0 \\ 0 & \sin\delta & \cos\delta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix};$$

Analyzer - a device designed to analyze the nature of the polarization of light. In this work, a linear analyzer is used - an employee to detect linearly polarized light and determine the angle of inclination of its polarization plane

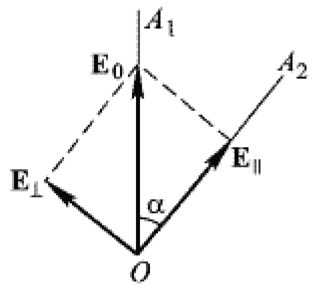

Figure 3.Two Polaroid's are placed one behind the other, so that their axes OA1 and OA2 form a certain angle α between themselves

The first Polaroid will transmit light whose electric vector E_0 is parallel to its axis OA1. Denote by I_0 the intensity of this light. Let us decompose E_0 into the vector E||, parallel to the OA2 axis of the second Polaroid, and the length of which is E= E0cos α, will pass through both Polaroid.

Conclusion. As a result of the analysis of existing magneto-optical materials, it was found that bismuth-containing films of ferrite garnets are the most suitable material for solving the problem due to a number of advantages: high Faraday rotation, which makes it possible to obtain high image contrast, low optical absorption and, as a result, high magneto-optical quality factor. The mathematical description of the optical-electronic device for registration of magnetic stray fields by the device of polarization optics is carried out. Expressions are obtained that determine the optimal parameters of a magneto-optical crystal (film thickness, magneto-optical quality factor).

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