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Magnetoelectric response of bismuth-substituted ferrite-garnet films irradiated by a high-power laser pulse

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The electromagneto-optical (EMO) effect as magnetoelectric response for bismuth-substituted ferrite-garnet film exposed to an external electrical field have been investigated. It was shown that irradiation of the film by a high-power neodymium laser results in increase of the EMO characterics that may result from removal of pressure inhomogeneites or local mechanical strains in ferrite-garnet films.

Исследован электромагнито-оптический (ЭМО) эффект как магнитоэлектрический отклик висмут-замещенных пленок ферритовых гранатов во внешнем электрическом поле. Показано, что облучение пленки лучом мощного неодимового лазера приводит к возрастанию величины ЭМО характеристик, что может быть результатом снятия неоднородностей давления или локальных механических напряжений в пленках ферритового граната.

Nowadays, numerous materials where the magnetoelectric effect (the effect of magnetic state changing under external electric field E) is observed are being investigated [1–3]. Such materials include ferrite garnets well known as materials exhibiting a strong magnetooptical response, as well as bismuth-substituted ferrite garnets with high value of Faraday rotation. Among the experimental methods for research of the magnetoelectric (ME) phenomena, there is the electromagneto-optical effect (EMOE) consisting in the light polarization plane rotation in crystals induced by an electric field [4]. EMOE deals with the registration of the changes in the light polarization plane Faraday rotation under action of external electric field applied to the sample.

In our earlier investigations, it has been shown that EMOE is a high-sensitivity method for registration of structure changes in ME materials (yttrium iron garnet (YIG) films) under an external mechanical strain [5]. In this work, we report some studies of the high-power pulse laser irradiation effect on the character of EMO dependences in bismuth-substituted ferrite garnet films.

The experimental setup consists of a high-sensitive laser polarimeter [6, 7]. The essence of this method is the registration of the E-field-induced changes of the Faraday rotation, α_{EMO}, in the film being studied. As a probing beam, a He–Ne laser ($\lambda = 0.63$ μm) is used in our polarimeter. For the sample irradiation, a pulse neodymium laser ($\lambda = 1.06$ μm) was used, i.e. irradiation in the ferrite garnet transparency range. The laser pulse energy density was varied in the range 0–50 J/cm^2; $\tau = 2$ ms. A small area of the film ($d \approx 3$ mm) was irradiated.

We have studied a unilateral bismuth-substituted ferrite garnet film of about 14 μm thickness deposited on an about 500 μm thick $Gd_3Ga_5O_{12}$ substrate. An alternating voltage $U_{\sim}$ of 900 Hz frequency and up to 3 kV amplitude was applied to

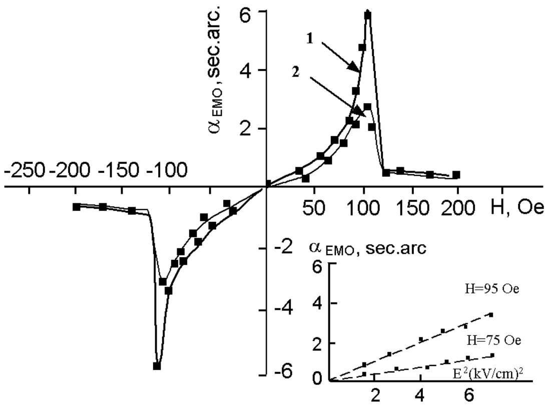

Fig. 1. The magnetic-field dependences of EMOE at optical probing of multidomain site of bismuth-substituted ferrite-garnet film in geometry **H** ∥ **E** ∥ **k**(*1* — E = 2.6 kV/cm, *2* — E = 2.1 kV/cm). On the insert — the electric-field dependences of EMOE (H_1 = 75 Oe, H_2 = 95 Oe).

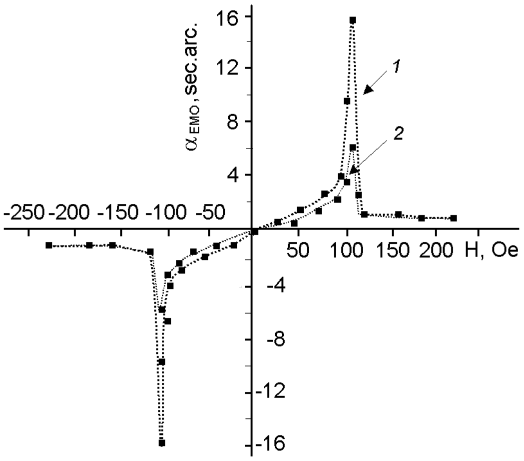

Fig. 2. The magnetic-field dependences of the EMOE measured in the irradiated by laser impulse bismuth-substituted ferrite-garnet film in geometry **H** ∥ **E** ∥ **k**(*1* — E = 2.6 kV/cm, *2* — E = 2.1 kV/cm). The film was irradiated by laser impulse with density of energy 40 J/cm^2.

the film. We had possibility to measure the rotation angle of the light polarization plane under magnetic field as well as its changes, α_{EMO}, caused by the electric field influence on the sample. The experiments were carried out at room temperature in longitudinal geometry (**E**∥**k**, **H**∥**k**, where **k** is a light wave vector). The film magnetisation was normal to its plane.

The magnetic field dependences of EMOE for unradiated film are shown in Fig. 1. These dependences are registered for two external electric field values E (kV/cm): 2.6 (curve *1*) and 2.1 (curve *2*). In the inset in Fig. 1, the electric field dependences of α_{EMO} are shown for two magnetic field values (H_1 = 75 Oe, H_2 = 95 Oe). It is seen from Fig. 1 that the registered signal value depends linearly on a squared **E** field. We made use of the high sensitivity of our experimental method to changes in structural characteristics of ferrite garnets, and high-power laser irradiation is considered as a means for purposeful effect on physical characteristics of the bismuth-substituted ferrite garnet film. We did not observe any essential changes in the electric and magnetic dependences of α_{EMO} when the film was irradiated by laser pulse at 20 J/cm^2 energy density. However, changes of EMOE value were registered when the pulse value was 40 J/cm^2 (Fig. 2). Thus, the α_{EMO} value in the registered effect maximum exceeded considerably the EMOE registered prior to irradiation. We also have measured the EMOE at different sites of the film in near to the irradiated area after the sample irradiation by 40 J/cm^2 laser pulse. In this case, α_{EMO} value in maximum is varied in different film sites but inconsiderable, however, it exceeds that registered prior to irradiation.

Such changes in magnetic-field dependences of EMOE in bismuth-substituted ferrite garnet film irradiated by laser pulse (see Fig. 2), in our opinion, has the following explanation. The center-symmetrical cubic crystal structure is typical of ferrite garnet single crystals and EMOE law squared in electric field is typical of ferrite-garnets (bismuth-substituted ferrite garnets) [8]. However, ferrite garnet (bismuth-substituted ferrite garnet) films grown on mismatched substrates may be strained, mainly due to lattice strain between the substrate and the film. At formation of epitaxial ferrite garnet films, micro- and macroscale strains arise. In the film volume, there may be present local areas or thin layers where the center-symmetric structure is broken due to an essential influence of film-substrate interlayers and of the film-surface ones (at the film-air interface) on the main parametres of ferrite garnet films. A thermal influence on a thin surface layer of a bismuth-substituted ferrite garnet film by means of irradiation with a neodymium laser pulse causes changes in the film real structure due to removal of local mechanical strains and, as a result, an integrated improvement in the film structure because of micropressure relaxation. The thermal influence acts mainly on the film-substrate interlayer. Thus, our experiments show that increase in the value in the areas of a bismuth-substituted ferrite garnet film irradiated by a high-power laser pulse testifies changes in the sample structure as a response to removal of local mechanical strains (or pressure inhomogeneities) in center-symmetrical crystal structure of ferrite garnet resulting in an essential increase of EMOE value.

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Магнітоелектричний відгук у вісмут-заміщених плівках ферит-гранатів, що опромінені потужним лазерним імпульсом

В.Є.Короновський

Досліджено електромагніто-оптичний (ЕМО) ефект як магнітоелектричний відгук вісмут-заміщених плівок феритових гранатів у зовнішньому електричному полі. Показано, що опромінення плівки променем потужного неодимового лазера призводить до зростання величини ЕМО характеристик, що може бути результатом зняття неоднорідностей тиску або локальних механічних напружень у плівках феритового гранату.