DETERMINATION OF MATERIAL CONSTANTS OF MAGNETO-OPTICAL CRYSTALS USING THE FARADAY EFFECT UNDER MAGNETO-MECHANICAL RESONANCE CONDITIONS

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It is theoretically substantiated and experimentally proven by the example of yttrium garnet ferrite that, in ferro- and ferrimagnetic crystals subjected to a constant bias and an additional alternating magnetic fields, magnetostriction phenomena result in additional changes of the variable magnetization component in a vicinity of the alternating-field frequencies close to the resonance frequencies of natural magneto-mechanical oscillations of the crystal. It is shown that these changes can be revealed by measuring the variable component of a turn of the polarization plane of light that passes through the crystal. A technique for the determination of the material constants of a crystal is proposed.

1. Introduction

Among the known methods of investigating the magnetostriction (MS) [1–3], there is one that assumes the excitation of the magneto-mechanical resonance (MMR) in a ferromagnetic [3].

For this purpose, a ferromagnetic is simultaneously subjected to external constant (polarizing) and alternating magnetic fields. Moreover, the constant magnetic field must be lower than the saturation field of the ferromagnetic. Under such conditions, the magnetostriction induces oscillations of the ferromagnetic. These oscillations give rise to time-variable mechanical stresses and a further change of the variable magnetization component at their frequency. Such variations of the magnetization can be revealed, for example, by observing changes in the inductance of a coil with a polarized ferromagnetic ring core in a vicinity of the frequencies of its magneto-mechanical resonances [4].

On the other hand, the magnetization of magneto-optical crystals (MOC), particularly yttrium garnet ferrite (YGF) $Y_3Fe_5O_{12}$ representing a ferrimagnetic, is widely investigated using the Faraday effect (FE) [5, 6]. However, magnetostriction properties of MOC samples under study are usually not taken into account. Moreover, the authors of [5] have made assumption about the insignificant contribution of MS phenomena to photoelastic processes, whereas their possible effect on the variable MOC magnetization in the case of the magneto-mechanical resonance, as well as the possibility of their influence on a turn of the polarization plane of an electromagnetic wave (EMW) due to the Faraday effect, have not been mentioned at all.

It is evident that, under the MMR conditions, high-Q mechanical oscillations of a magneto-optical crystal can induce considerable alternating mechanical stresses in the latter. They will result in the appearance of an additional magnetization component of the MOC as well as an internal magnetic field (Villari effect) at the frequencies of the applied variable field, which can be fixed with the help of the Faraday effect. The use of the Faraday effect to study variations of the magnetization of ferro- and ferrimagnetic MOCs under the MMR conditions opens new possibilities to determine MOC material constants.

The aim of this work is to demonstrate by the example of IGF that taking the magnetostriction into account results in significant changes of the modulation amplitude of the MOC magnetization in a vicinity of the MMR frequencies and to show that these changes can be determined from the frequency dependence of the variable component of the Faraday effect. In addition, we propose a technique for finding some material constants of MOCs.

2. Mathematical Model

We consider the propagation of a linearly polarized electromagnetic wave (EMW) through MOC 1 (see Fig. 1) located in coil 2 representing a solenoid $2L$ in length. A direct current passing through the solenoid generates a longitudinal component $\hat{H}_0$ of the intensity vector of the constant (polarizing) magnetic field, whose direction coincides with that of propagation of the electromagnetic wave, while an alternating current of the required frequency ω additionally creates a variable component of the external magnetic field $\hat{H}^*$ so that $|\hat{H}^*| \ll |\hat{H}_0|$.

The direction of the EMW wave vector and the axis of easy magnetization of the MOC coincide with the axis X_2. The construction of the coil allows the sample to perform mechanical oscillations. The sample has a form of a bar $2l$ in length and a square cross section with the side b ($b \ll 2l$). The distance δ between the MOC side face and the coil windings is much smaller than b. The length l is chosen to be smaller than L, so that the magnetic field generated by the current inside the solenoid is uniform within the sample.

YGF belongs to cubic crystals with the $m3m$ crystal system (O_h^{10} in the Schönflies notation), that is why the elasticity tensor has three non-zero linearly independent components. Therefore, the YGF elastic properties are almost isotropic [7].

The magnetic field $\hat{H}_0$ forms a matrix of piezomagnetic constants determined in the linear approximation as [8]

$$m_{kij} = m_{2kij}\hat{H}_0, \quad (1)$$

where m_{pkij}stands for the component of the tensor of MS constants. In this case,

$$m_{pkij} = m_2\delta_{pk}\delta_{ij} + \frac{m_1 - m_2}{2}(\delta_{pi}\delta_{kj} + \delta_{pj}\delta_{ki}), \quad (2)$$

where m_1 are m_2 are experimentally determined constants and δ_{ij} is the Kronecker symbol. Expressions (1) and (2) yield the following matrix of piezomagnetic constants:

$$\begin{vmatrix} 0 & 0 & 0 & 0 & 0 & m_{16} \\ m_{21} & m_{22} & m_{23} & 0 & 0 & 0 \\ 0 & 0 & 0 & m_{34} & 0 & 0 \end{vmatrix}, \quad \alpha \Leftrightarrow i,j,$$

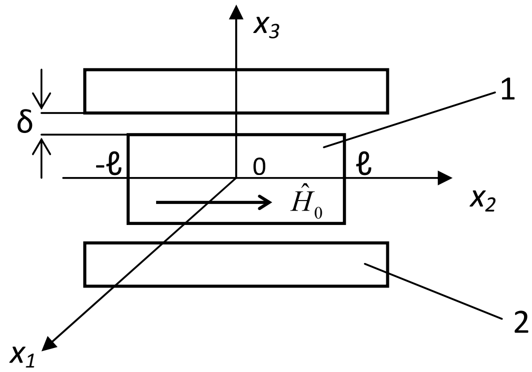

Fig. 1. Diagram of the investigated model

where $m_{21} = m_{23} = m_2\hat{H}_0$, $m_{\overline{\overline{22}}}m_1\hat{H}_0$, and $m_{16} = m_{34} = \frac{m_1-m_2}{2}\hat{H}_0$. The physical state of the bar material is determined by the system of equations [9]:

$$\sigma^*_{ij} = c_{ijkl}\varepsilon^*_{kl} - m_{kij}H^*_k,$$

$$B^*_n = m_{npq}\varepsilon^*_{pq} + \mu_{nm}\varepsilon H^*_m, \quad (3)$$

where $\sigma^*_{ij}, \varepsilon^*_{kl}, H^*_k, B^*_n$ are the amplitudes of harmonically changing components of the mechanical stresses, deformations, and vectors of the intensity and induction of the magnetic field, respectively, ; c_{ijkl} the component of the tensor of elastic moduli of the demagnetized MOC, and μ^ε_{nm} the component of the magnetic permeability tensor in the absence of deformations.

Let us suppose that the components of the displacement vector of material particles u(x_k, t) change in time according to the harmonic law, i.e. $u_j(x_k,t) = u^*_j(x_k)e^{i\omega t}$, where $u^*_j(x_k)$ is the amplitude of the j-th component of the displacement vector. The quantities σ^*_{ij} and u^*_j united by the first physical state equation (3) must satisfy the second Newton law. In the absence of external forces, they are described by the equation

$$\sigma^*_{ij,j} + \rho^2_\omega u^*_i = 0 \forall x_k \in V, \quad (4)$$

where ρ is the density, and V is the volume of the sample. If the bar has no contact with other elastic bodies (for example, the solenoid), the mechanical stress components σ^*_{ij} satisfy the boundary conditions:

$$n_j\sigma^*_{ij} = 0 \forall x_k \in S, \quad (5)$$

where n_j is the component of the outer normal to the surface S that restricts the volume V. It is also taken into account that the induction vector of the variable magnetic field $\mathbf{B}^*(x_k)$ satisfies the condition of the absence of magnetic charges:

$$\text{div}\mathbf{B}^*(x_k) = 0 \forall x_k \in V. \quad (6)$$

These assumptions about the distribution of the magnetic field and mechanical deformations in the MOC bulk yield the equations for the amplitudes of mechanical stresses σ^*_{ij}:

$$\sigma^*_{11} = c_{11}\varepsilon^*_1 + c_{12}\varepsilon^*_2 + c_{13}\varepsilon^*_3 - m_{21}H^*, \quad (7)$$

$$\sigma^*_{22} = c_{21}\varepsilon^*_1 + c_{22}\varepsilon^*_2 + c_{23}\varepsilon^*_3 - m_{22}H^*, \quad (8)$$

$$\sigma^*_{33} = c_{31}\varepsilon^*_1 + c_{32}\varepsilon^*_2 + c_{33}\varepsilon^*_3 - m^0_{23}H^*, \quad (9)$$

$$\sigma^*_{32} = \sigma^*_{23} = c_{44}\varepsilon^*_4, \quad \sigma^*_{31} = \sigma^*_{13} = c_{55}\varepsilon^*_5,$$

$$\sigma^*_{12} = \sigma^*_{21} = c_{66}\varepsilon^*_6. \quad (10)$$

The symbol H^* in Eqs. (7)–(10) denotes the intensity of the effective total internal magnetic field that is a sum of the applied alternating field $\hat{H}^*$ and the additional alternating magnetic field h^* with circular frequency ω that appears due to variable mechanical stresses arising in the polarized crystal h^* [10].

Let us assume that the length of the elastic wave is commensurable to that of the bar. In this case, the stresses and deformations in the cross section plane are practically uniform. At the side face of the bar, $\sigma^*_{11} = \sigma^*_{33} = 0$, so it can be considered that the mechanical stresses σ^*_{11} and σ^*_{33} are equal to zero in the whole bulk. In this case, we obtain

$$\varepsilon^*_1 = \varepsilon^*_3 = -\frac{c_{12}}{c^+_{11}c_{12}}\varepsilon^*_2 + \frac{m_{21}}{c_{11}+c_{12}}H^*, \quad (11)$$

$$\sigma^*_{22} = Y\varepsilon^*_2 - \tilde{m}_{22}H^*, \quad (12)$$

where $Y{=}c^-_{22}\frac{4c^2_{12}}{c_{11}+c_{12}}$ denotes the Young modulus of the demagnetized MOC in the form of a thin bar, $\tilde{m}_{22} = m^-_{22}2m_{21}^{\frac{c_{12}}{c_{11}+c_{12}}}$ is the piezomagnetic constant of the polarized MS material for a uniaxial stress-strain state. The quantities Y and $\tilde{m}_{22}$ were determined under the assumption that the shear deformations $\varepsilon^*_4 = \varepsilon^*_5 = \varepsilon^*_6 = 0$. Thus, only one component of the mechanical stress tensor (σ^*_{22}) is non-zero and the boundary-value problem (5), (6) is formulated as follows:

$$\frac{\partial\sigma^*_{22}}{\partial x_2} + \rho^2_\omega u^*_2 = 0\forall x_2 \in [-l,l]\,, \quad \sigma^*_{22}\,|_{x_2=\pm l} = 0\,. \quad (13)$$

Definition (3) of the components of the magnetic induction vector implies that

$$B^*_1 = B^*_3 = 0, \quad B^*_2 = \tilde{m}_{22}\varepsilon^*_2 + \mu^\sigma_{22}H^*, \quad (14)$$

where μ^σ_{22} is the permeability along the bias field in the mode where the time-variable stresses are independent of the transverse coordinates. With regard for the relation $\varepsilon^*_2 = \partial u^*_2/\partial x_2$, Eqs. (13)–(14) take the form

$$Y^{\frac{\partial^2 u^*_2}{\partial x^2_2}} - \tilde{m}_{22}\left(\frac{\partial h^*}{\partial x_2} + \frac{\partial\hat{H}^*}{\partial x_2}\right) +$$

$$+\rho_0\omega^2 u^*_2 = 0\forall x_2 \in [-l,l]\,, \quad (15)$$

$$\tilde{m}_{22}\frac{\partial^2 u^*_2}{\partial x^2_2} + \mu^\sigma_2\left(\frac{\partial h^*}{\partial x_2} + \frac{\partial\hat{H}^*}{\partial x_2}\right) = 0\forall x_2 \in [-l,l]\,. \quad (16)$$

If the coil length considerably exceeds that of the bar, then $\hat{H}^*(x_2)$=const. Hence, Eq. (15) can be put down as

$$\frac{\partial^2 u^*_2}{\partial x^2_2} + \gamma^2 u^*_2 = 0\forall x_2 \in [-l,l]\,, \quad (17)$$

where $\gamma^2 = \omega^2\rho/Y^B = (\omega/v^B)^2$, v^B is the velocity of sound in the magnetized bar, and $Y^B = Y^+\Delta Y$ is its Young modulus,

$$\Delta Y = \tilde{m}^2_{22}/(\mu^\sigma_2). \quad (18)$$

Considering that the sample under study completely closes the flux of the magnetic induction vector in the coil cavity, $h^* \approx -\frac{\tilde{m}_{22}}{\mu^\sigma_{22}}\frac{\partial u^*_2}{\partial x_2}$. With regard for formula (12), the solution of Eq. (17) yields an expression for the amplitude of time-variable stresses in a dynamically deformed bar: $\sigma^*_{22}(x_2) = \tilde{m}_{22}\hat{H}^*(\frac{\cos\gamma x_2}{\cos\gamma l} - 1)$. The MOC deformations result in changes of the EMW polarization. There exist three possible mechanisms of such an influence: linear birefringence (photoelastic effect), magnetic birefringence, and Faraday effect.

Let us investigate the possibility of linear birefringence in the framework of the stated problem. YGF has three non-zero coefficients in the photoelasticity tensor p_{ij}: p_{11}, p_{12}, and p_{44}.

The variations of the polarization coefficients δA_{ij} (where $A_{ij} = 1/n^2_{ij}$ and n_{ij} are the refractive indices) at the relative deformations ε_{ij} have the form [11]

$$\delta A_{ij} = p_{ijkl}\varepsilon_{kl}. \quad (19)$$

With regard for Eq. (11) and in the absence of shear deformations, expression (18) yields the following relation for the variation of the optical indicatrix A_{ij}:

$$\Delta A_{11} = \Delta A_{33} = (p_{11} + p_{12})\,\varepsilon_1 + p_{12}\varepsilon_2. \quad (20)$$

Expressions (19) imply that the linear birefringence is absent. Due to the symmetry of the magneto-optical tensor ρ_{ij} that (similarly to the photoelasticity tensor) has three independent and non-zero components $(\rho_{11}, \rho_{12}, \rho_{44})$, the absence of the magnetic birefringence can be explained analogously. That is why other contributions to a change of the polarization of an EMW propagating in a MOC are to be sought in the Faraday effect due to the appearance of the additional time-varying component of the magnetization J^*_σ arising due to the mechanical stresses σ^*_{22}.

The magnetic field $\hat{H}^*$ creates the time-varying FE component with the amplitude $\hat{\varphi}^* = 2\hat{J}^*\alpha l$ at the MOC output, where $\hat{J}^*$ is the amplitude of the variable magnetization component determined by the alternating magnetic field $\hat{H}^*$, and α is the coefficient of proportionality between the rotation angle of the EMW polarization plane normalized to the MOC unit length and the MOC magnetization. The amplitude $\hat{\varphi}^*$ does not depend on the presence of mechanical stresses in the MOC under the MMR conditions; therefore, we consider that $\hat{\varphi}^*$ is independent of ω.

If the MOC placed in the constant polarizing magnetic field $\hat{H}_0$ is subjected to mechanical stresses σ^*_{22}, then there appears an additional variable magnetization component [12] with the amplitude J^*_σ that can be characterized by the function $\Lambda = \frac{\partial J^*_\sigma}{\partial \sigma^*_{22}}$. In the magnetization region of the MOC, where stresses change the magnetization due to a turn of domains (namely if the working point with respect to the induction of the polarizing magnetic field is chosen at the level $B^0_2 = 0.58\ B_s$, where B_s is the saturation induction), the function Λ has the maximum $\Lambda_m = 0.77\ \lambda_s J_s/K_1$ [13], where J_s and λ_s are the saturation magnetization and the magnetostriction, respectively, and K_1 is the MOC anisotropy constant. The component J^*_σ results in the appearance of the additional variable component in a turn of the EMW polarization plane at the distance dx_2 with the amplitude of the rotation angle $d\varphi^*_\sigma = \alpha\Lambda\sigma^*_{22}dx_2$. The amplitude of the total FE variable component at the MOC output φ^* under the MMR conditions is equal to

$$\varphi^* = \hat{\varphi}^* + \frac{2\alpha\Lambda\tilde{m}_{22}\hat{H}^*_2}{\gamma}(\mathrm{tg}(\gamma l) - \gamma l). \tag{21}$$

The second term in formula (21) characterizes the contribution made to the amplitude by the total variable FE component at the MOC output due to the appearance of the additional variable magnetization component J^*_σ in the case of time-varying mechanical stresses. This component becomes significant only at the frequencies in a vicinity of the MMR ones. It also follows from Eq. (21) that the resonance variations in the amplitude φ^* must take place in a vicinity of the frequencies f_0 satisfying the condition $\gamma_0 l = \pi/2 + n\pi$. In this case, the resonance frequencies themselves $(f = \omega/2\pi)$ amount to

$$f_0 = 1/2l\sqrt{\frac{Y^B}{\rho_0}}(1/2 + n). \tag{22}$$

The problem of importance for the proposed technique is the account of losses of the mechanical oscillation energy of the crystal. The Q-factor of the oscillating system depends on the parameters of the MOC itself (parallelism, polishing, and form of surfaces), a possible scattering of the magneto-acoustical mode that is converted to other ones characteristic of the sample of the specified form, and the treatment. It is also impossible to completely avoid the contact between the sample and the coil. The mentioned factors can be present in various degrees and make their contributions to the Q-factor of the sample. That is why one can consider only the integral account of energy losses. For this purpose, all the indicated losses will be treated as those equivalent to inherent losses of the MOC itself, whereas the Young modulus Y will be supposed to be a complex quantity $\dot{Y}$ [14] with a certain effective Q-factor Q, namely

$$\dot{Y} = Y(1 + i/Q), \tag{23}$$

where Y is determined according to the comment to formula (12). Figure 2 shows the calculated real part of the function $F = \mathrm{tg}(\gamma l) - \gamma l$ for several values of Q. Moreover, γ is taken in the form adduced after Eq. (17) with no regard for ΔY (18), while Y is given by Eq. (22). The calculation is performed with the following YGF parameters: Y=138.8 GPa and $\rho = 5.17 \times 10^3$ kg/m^3.

The plot reveals two characteristic frequencies in a vicinity of the resonance: $\gamma_p l$ and $\gamma_a l$. The difference between them and the value of the function F at these frequencies are determined by the Q-factor.

3. Experimental Set-up and Measurement Results

The experiments were carried out using a MOC with YGF in the form of a rectangular bar with the following dimensions: $2l$=15 mm and b=4 mm (Fig. 3).

A linearly polarized laser radiation passes through the MOC in parallel to its axis of easy magnetization. The coil is fabricated in the form of a solenoid that has N = 100 windings of a PEV-0.35 wire tightly winded round

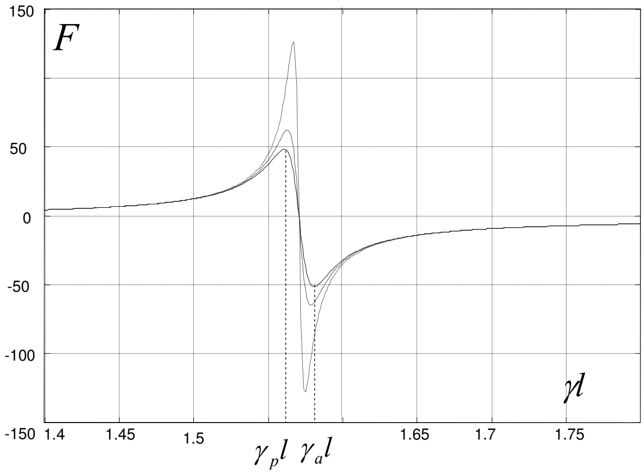

Fig. 2. Dependence of the real part of the function F on γl for Q=50 (—–), 100 (– –), and 200 (– · – ·)

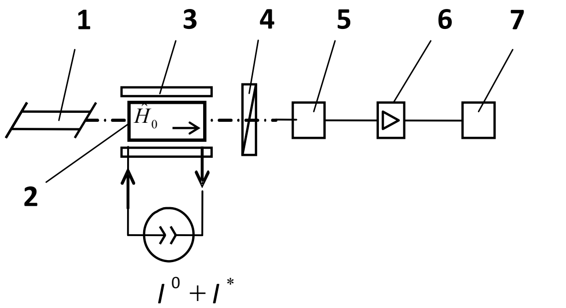

Fig. 3. Diagram of the experimental set-up: *1* – laser (λ = 1.15 μm), *2* – MOC, *3* – coil, *4* – analyzer, *5* – photoreceiver, *6* – selective amplifier (voltmeter), *7* – oscilloscope). I_0 and I^* are the direct and alternating currents

a thin-walled form with a square inner aperture 4.1×4.1 mm^2 in size. The coil length $2L = 35$ mm. If the MOC is placed in the middle of the coil, then the calculated nonuniformity of the magnetic fields $\hat{H}_0$ and $\hat{H}^*$ in the sample region amounts to 1.7%.

The EMW intensity at the analyzer output changes according to the Malus law. The azimuth of an analyzer is adjusted with respect to the maximum of the first harmonic of a signal at the photoreceiver output. The value of the magnetic field $\hat{H}_0$ is chosen so that the maximum changes in the amplitude φ^* are reached at the resonance. The described set-up was used to study the amplitude of the relative angle of the variable component of a turn of the EMW polarization plane $\tilde{\varphi} = \varphi^*/\hat{\varphi}^*$ as a function of the linear frequency f (Fig. 4). When normalizing the amplitude φ^* to the amplitude of its variable component $\hat{\varphi}^*$, the latter is measured at fre-

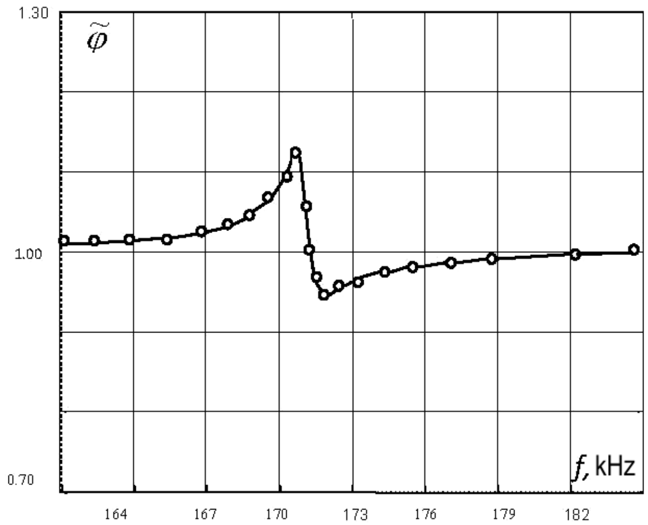

Fig. 4. Amplitude of the relative angle of the variable component of a turn of the polarization plane as a function of the linear frequency

quencies distant from the MMR ones (to provide the condition $J^*_\sigma \ll \hat{J}^*$).

The MMR frequency f_0 (the point where the function $\tilde{\varphi}$ takes the value $\tilde{\varphi} = 1.0$) allows one to determine the Young modulus $Y^B = 16\ f_0^2 l^2 \rho$. The piezomagnetic constant $\tilde{m}_{22}$ is found with regard for (21):

$$\tilde{m}_{22} = \left(\tilde{\varphi}\left(f_p\right) - 1\right) \frac{\hat{J}^* K_1 \gamma_p l}{0.77 J_s \lambda_s \hat{H}^* F\left(\gamma_p l\right)}. \quad (24)$$

The quantity $\tilde{m}_{22}$ is determined by formula (23) according to the following technique. The dependence $\tilde{\varphi}\left(f\right)$ yields the resonance frequencies, where the maximum (f_p) and minimum (f_a) amplitudes are observed. Based on these frequencies and using the comment to Eq. (17), the corresponding values of the parameters $\gamma_p l$ and $\gamma_a l$ are determined. After that, applying the preliminarily plotted graph of the dependence of $\gamma_a l - \gamma_p l$ on Q, we find the Q-factor and then calculate the value of the function $F\left(\gamma_p l\right)$. The ratio $\hat{J}^*/J_s = \hat{\varphi}^*/\varphi_s^0$ is derived with the help of the Faraday effect. The saturation magnetization J_s is reached, as the magnetic field $\hat{H}_0$ grows from zero to the saturation level. The saturation time moment is determined by the stopping of increasing the measured constant component of the Faraday effect that is equal to φ_s^0 at this time moment. The quantity $\hat{\varphi}^*$ is determined by the results of measuring the amplitude of the total variable FE component φ^*. To avoid the influence of the magnetization component J^*_σ, the linear frequency f for this measurement is chosen smaller than the resonance frequency f_0: f = (0.8–0.9)f_0 (at

$Q > 100$). The magnetic field $\hat{H}^*$ is found, by using the formula $\hat{H}^* = 2LI^*/N$. Under our measurement conditions, the ratio $\hat{J}_1^*/J_s$ amounted to $0.039 \pm 10\%$, $f_0 = 171.2$ kHz, $\hat{H}_2^* = 57$ A/m, $\gamma_p l = 1.565$, $\gamma_a l = 1.580$, $Q = 120$, and $F(\gamma_p l) = 75$. We also used the tabular data for YGF: $\lambda_s = -1.4 \times 10^{-6}$ and $K_1 = 6.2 \times 10^2$ J/m^3.

According to the experimental results, the values of the material constants of the sample are equal to: $Y^B = 136.4$ GPa and $\tilde{m}_{22} = 1060$ T at $\hat{H}_0 = 0.5$ kA/m. For comparison, the theoretical value of the Young modulus $Y = 138.8$ GPa, which is obtained according to the comment to Eq.(12) and using the data from Y [9]: $c_{11} = 268$ GPa, $c_{12} = 110.6$ GPa, and $c_{44} = 76.6$ GPa. The disagreement between the theoretical (Y) and experimental (Y^B) Young moduli can be explained by two factors. First, the component ΔY must result in an increase of the Young modulus. Not knowing the value of μ_2^σ, the quantity ΔY will be estimated considering μ_2^σ equal to the initial YGF permeability: $\mu_2^\sigma \approx 4\pi \times 10^{-5}$ H/m [16]. Then, according to Eq. (18), ΔY will amount to 8.9 GPa, which is equal to 6.4% of Y. The second factor is a deviation from the model of a thin bar that appears in the experiment due to the fact that we use $2l = 3.75b$ instead of the required $2l \gg b$. The effect of this factor on the velocity of an elastic wave cannot be determined in the framework of the model of a thin bar. The both factors simultaneously influence the frequency $2lbf_0$. Therefore, it can be considered that the obtained experimental value Y^B only approaches the real value of the Young modulus of a thin magnetized bar.

If using the proposed technique, the requirements to the MOC mechanical Q-factor are not too critical. This is due to the fact that the MOC must be characterized by a high optical homogeneity and a quality of the treatment of working surfaces. That is why the requirements to the acoustic quality of the sample are fulfilled almost automatically. Possible deviations in the Q-factors of various MOC samples during the experiment will result in variations of the maximum of the function $F(\gamma_p l)$, which will result in the corresponding change of the field amplitude $\hat{H}^*$. Thus, formula (23) indirectly allows for possible deviations of the Q-factor of the sample.

One can see from Fig. 4 that, in a vicinity of the MMR frequencies, a change of the variable magnetization component results in a change of the amplitude of the variable FE component in MOCs (up to 15%). It is worth noting that, when fabricating mechanical stress sensors based on the Villari effect, one of the basic requirements to the material of a sensitive element is its ability to change the magnetization under mechanical stresses arising in a sample. In the experiments [10, 15] devoted to the study of new materials, the relative changes of the magnetic field induction due to deformations reached 7–26%. That is why the registered 15-percent change of the variable magnetization component taking place in MOCs due to elastic deformations under the MMR conditions, as well as the possibility to reveal these changes with the help of the Faraday effect, can be considered as a satisfactory result.

4. Conclusions

The results of theoretical studies have demonstrated that the magnetostriction effects taking place in ferro- and ferrimagnetic MOCs subjected to constant bias and additional alternating magnetic fields result in additional contributions to the variable magnetization component of MOCs in a vicinity of the MMR frequencies. These contributions can be revealed with the help of the Faraday effect. The results of experimental investigations with the use of MOCs with YGF have confirmed the validity of the proposed mathematical model. The registered additional variations of the amplitude of the variable FE component due to the magnetostriction under the MMR conditions reach 15%. The numerical values of the Young modulus and the piezomagnetic constant of YGF are determined. The obtained results can be used to find material constants of ferro- and ferrimagnetic MOCs when fabricating FE-based modulators and sensors of mechanical stresses.

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ВИЗНАЧЕННЯ МАТЕРІАЛЬНИХ КОНСТАНТ МАГНІТООПТИЧНИХ КРИСТАЛІВ ЗА ДОПОМОГОЮ ЕФЕКТУ ФАРАДЕЯ В УМОВАХ МАГНІТОМЕХАНІЧНОГО РЕЗОНАНСУ

І.В. Лінчевський, О.М. Петріщев

Р е з ю м е

Теоретично обґрунтовано та на прикладі ітрієвого ферит-гранату експериментально доведено, що у феро- й ферімагнітних кристалах, які вміщені у стале підмагнічуюче і додаткове змінне магнітні поля, за рахунок магнітострикційних явищ виникають додаткові зміни змінної складової намагніченості в околі частот змінного поля, близьких до резонансних частот власних магнітомеханічних коливань кристала. Показано, що ці зміни можуть бути виявлені шляхом вимірювання змінної складової повороту площини поляризації світла, яке проходить крізь кристал. Запропоновано методику визначення матеріальних констант кристала.