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ON THE NECESSITY OF ACCOUNTING THE PONDEROMOTOR MOMENT OF FORCES WHEN STUDYING NONLINEAR FERROMAGNETIC RESONANCE IN ANISOTROPIC SAMPLES

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Taking into account the ponderomotive effect of the electromagnetic field makes it possible to quite simply explain some of the features of the behavior of nonlinear ferromagnetic resonance (NFMR). The appearance of some (low-frequency pulsations of the reflected wave amplitude and the excitation spectrum of magnetoacoustic resonance) is due to the action of ponderomotive forces under FMR conditions [1-3]. The reasons for the appearance of others (significant hysteresis of the excitation of magnetoacoustic resonance and the absorption line in the field for unfixed samples) have not yet been fully clarified [1-5]. For fixed samples, the magnitude of the absorption line hysteresis over the field decreases sharply and is explained within the framework of the models proposed earlier [6,7].

In this paper, we estimate the moment of forces acting on an anisotropic sample during NFMR, and note the need to take it into account when interpreting hysteresis phenomena on unattached samples.

To estimate the magnitude of the moment of forces arising under FMR conditions, we use its definition from the expression for energy [8].

$$K_i = \partial U / \partial \Phi_i, \qquad (1)$$

where F_i in our case are the angles that determine the orientation of the crystallographic axes relative to the external magnetic field.

Consider an anisotropic nonconducting spherical sample magnetized to saturation with magnetization **M**, placed in a uniform external magnetic field $\mathbf{H} = (H_1 \cos \omega t,\ H_1 \sin \omega t,\ H_0)$.

Then, in the magnetostatic approximation, the effective field inside the sample (without taking into account the exchange interaction) is determined by the formula [9]

$$\mathbf{H}_{eff} = \mathbf{H} + \mathbf{H}_a + \mathbf{H}_p, \qquad (2)$$

where N_a is the anisotropy field, $N_p = -4\pi/3 \bullet M$ - is the demagnetizing field. The expression for the energy will be written in the form [9]

$$U = -\mu \cdot \mathbf{H} - \frac{1}{2} \mu \cdot \mathbf{H}_a - \frac{1}{2} \mu \cdot \mathbf{H}_p, \qquad (3)$$

where $\mu = \mathbf{M}V$ is the magnetic moment, V is the sample volume. Its minimum is the condition of equilibrium of the ferromagnet at a given field [9].

In the general case, the problem of finding the dependence $U(\Phi_i)$ with allowance for p $\mu [H_{рез}(\Phi_i) - \omega/\gamma]$ is a complex (here $-\gamma-$ is the gyromagnetic ratio, $H_{рез}$ is the resonance value of the field). Therefore, to estimate K_i it is advisable to simplify it by assuming $H_0 \gg H_a|,\ M_0$ (M_0 is the saturation magnetization). Then we get

$$K_i \approx -\frac{1}{2}\mu_k \frac{\partial H_{ak}}{\partial \Phi_i} - H_k \frac{\partial \mu_k}{\partial \Phi_i} = K_i^{(1)} + K_i^{(2)}. \qquad (4)$$

Second term (4)

$$K_i^{(2)} = -H_k \frac{\partial \mu_k}{\partial \Phi_i} \approx -H_0 \frac{\partial \mu_z}{\partial (H_{рез} - \omega/\gamma)} \frac{\partial (H_{рез} - \omega/\gamma)}{\partial \Phi_i} \qquad (5)$$

depends resonantly on the field and at moderate saturation (the pump field is equal to the width of the FMR $H_1 = 2\Delta H$) in the framework of this model is in order of magnitude

$$K_i^{(2)} \simeq \mu_0 H_0 / \Phi_{ai}, \qquad (6)$$

Where $\Phi_{ai} \approx \frac{\Delta H}{\partial\left(H_{рез} - \frac{\omega}{\gamma}\right)/\partial \Phi_i}$ – characteristic angle of rotation of the sample as a whole, at where the value $H_{рез}$ changes by the value ΔH и $\left|\partial \mu_z / \partial\left(H_{рез} - \frac{\omega}{\gamma}\right)\right|_{max} \approx \mu_0/\Delta H$ (см. [2]).

Substitution of numerical values for YIG into (6) (see [9, p 95] and [3]:

$0.2\Delta H/|H_a|$ рад $\approx 10^{-3}$ рад, $\Delta H \simeq 0.2$ Э, $|H_a| \approx 40$ Э, $H_0 \approx 3300$ Э, $4\pi M_0 \simeq 1750$ Гс, $\rho = 5.2$ г/см^3, $2r = 0.1$ см) leads to the following estimate of the magnitude of the moment of forces: $K \simeq K^{(2)} \approx 10^5 K_т$, where $K_т = F_т r$, $F_т = \rho V g$ - gravity, r - sample radius, $K^{(2)} \gg K^{(1)}$, while $K^{(1)} \approx \mu_0 |H_a|$ and

$$K^{(2)}/K^{(1)} \approx H_0/\Delta H. \qquad (7)$$

Outside of resonance, only the moment of forces $K^{(1)}$ acts on a loose sample, orienting it with the axis of easy magnetization along the field. Under resonance conditions, an additional moment of forces $K^{(2)}$ (6) appears, which changes the orientation of the sample, which leads to a violation of the resonance conditions (due to the dependence of the resonance field value on the orientation of the crystallographic axes of the YIG relative to the external magnetic field). As a result, the effect of "runaway" of the FMR absorption line is observed when sweeping over the field or frequency due to sample rotations (similar to the effect of "runaway" of the line due to sample rotations caused by the appearance of a force at FMR, described earlier [1,3]; see details [3]).

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