ANISOTROPY OF AUTOMODULATION OF NONLINEAR FERROMAGNETIC RESONANCE

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We report here experimental observation of automodulation anisotropy in the region of the main ferromagnetic resonance.

The experiments were performed in the pulsed-pumping mode (pulse duration ∿ 10 μsec, pulse repetition frequency ∿ 100 Hz) at a frequency 9300 MHz. We used spherical samples of ∿ 1.4 mm diameter, made of single-crystal yttrium ferrites, and placed in a waveguide sections operating "in transmission." The samples were oriented in the (110) plane by a magnetic method.

We investigated experimentally the anisotropy of the excitation threshold[1)] and of the automodulation intensity.

[1)] The excitation threshold of the nonlinear ferromagnetic resonance was not measured.

The automodulation excitation threshold was determined in the following manner: A magnetizing field strength equal to the resonant value was first established at as low a power level as possible. The power level was then increased with the magnetizing field kept constant. At a certain power level, oscillations of frequency ~1 MHz (automodulation) appeared on the crest of the pulse envelope [1]. This power level was taken to be the threshold value.

The automodulation intensity was read at the instant when it reached the maximum value in the same magnetizing field (at a power approximately two times the threshold value). In this case the automodulation was observed on the screen of the S4-8 spectrum analyzer.

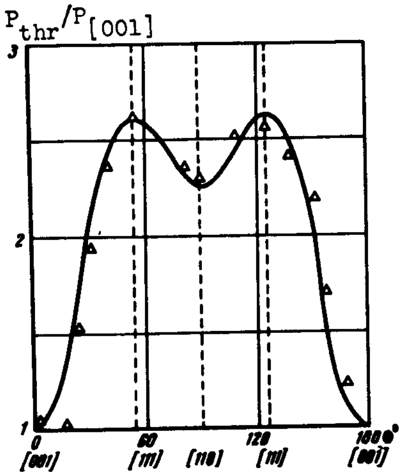

Fig. 1

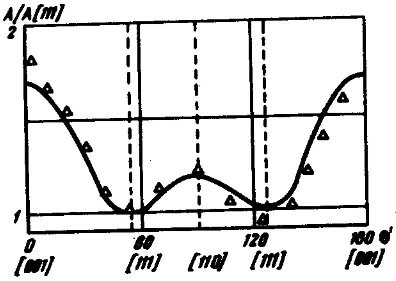

Fig. 2

Fig. 1. Anisotropy of threshold automodulation excitation power. Solid curve - calculated from formula (1), Δ - experimental data.

Fig. 2. Anisotropy of modulation intensity. Solid curve - calculated from formula (2), Δ - experimental data.

Figure 1 shows the dependence of the threshold power P_{thr} of automodulation excitation on the angle θ between the direction of the magnetizing field and the [001] axis. We see that the automodulation excitation threshold is strongly anisotropic. The ratio of the maximum (magnetization along the [111] axis) to the minimum (magnetization along [011]) threshold power amounts to about 2.6.

It was observed that the experimentally measured threshold can be approximated by an empirical relation in the form

$$P_{thr}/P_{[001]} = P_1 + P_2 \quad -\left(\frac{3}{16} + \frac{5}{4}\cos 2\theta + \frac{15}{16}\cos 4\theta\right), \tag{1}$$

where $P_{1,2}$ are experimentally determined coefficients and $P_{[001]}$ is the minimum value of the excitation threshold observed in the automodulation case of magnetization along [001].

Figure 2 shows the dependence of the automodulation intensity on the angle θ. Attention is called to the strong intensity anisotropy. The highest intensity, $A_{[001]}$, is observed in the case of magnetization along the [001] axis, and the lowest, $A_{[111]}$ for magnetization along [111]. The ratio of these values is about 1.8.

The experimentally measured intensity is satisfactorily approximated by an empirical relation in the form

$$\frac{A}{A_{[111]}} = A_1 - A_2\left(-\frac{3}{16} + \frac{5}{4}\cos 2\theta + \frac{15}{16}\cos 4\theta\right), \qquad (2)$$

where $A_{1,2}$ are experimentally determined coefficients.

Measurements were made also of the automodulation intensity when tuned to the maximum value by varying the magnetizing field and pump power level. The anisotropy of this intensity retains the same form as shown in Fig. 2, but the ratio of the maximum and minimum values is now about 10.

The anisotropy of the excitation threshold and of the automodulation intensity, observed in these experiments, is generally speaking unusual, because the crystallographic anisotropy of single-crystal yttrium ferrite is small.

It is interesting that the empirical relations (1) and (2) coincide with those describing the anisotropy of the frequency and of the width of the ferromagnetic-resonance curve [2].

[1] Yu. S. Lifanov, Ya. A. Monosov, and V. V. Surin, Fiz. tverd. tela 11, 764 (1969) [Sov. Phys.-Solid State 11, 612 (1969)].
[2] A. G. Gurevich, Ferrity na sverkhvysokikh chastotakh (Ferrites at Microwave Frequencies), Fizmatgiz, 1960.