The results on fourth-harmonic generation in KDP and ADP crystals 40 and 12 mm long, respectively, are shown in Fig. 3. The maximum efficiency reached 30%.

An investigation of the spectral characteristics has shown that when the second harmonic is generated the spectrum broadens from 3 Å at the fundamental frequency to 7 Å at the harmonic frequency. Calculation has shown that when the second harmonic is excited in the field of a monochromatic wave (the spectral width of the synchronism is defined by the expression $\delta\theta = 5.56/K(d\theta/d\ell)\ell$, where $d\theta/d\ell$ is the dispersion of the synchronism direction, and K is a parameter proportional to the birefringence; $\delta\theta$ = 30 Å for KDP), then the generation of the fourth harmoni is essentially nonmonochromatic ($\delta\theta \sim 1$ Å). This explains the relatively low level of the efficiency of conversion into the fourth harmonic.

The optical strength of the KDP crystal was investigated in focused beams of the fundamental and the harmonic. The breakdown thresholds were 23 and 17 GW/cm , respectively.

[1] S. A. Akhmanov and R. V. Khokhlov, Problemy nelineinoi optiki (Problems of Nonlinear Optics Nauka, 1964.
[2] N. G. Basov, A. R. Zaritskii, S. D. Zakharov, et al., in: Kvantovaya elektronika No. 5, 63 (1972) [Sov. J. Quant. Electr. 2, 439 (1973)].
[3] N. G. Basov and O. N. Krokhin, Vestnik AN SSSR 6, 55 (1970).
[4] M. P. Vanyukov, V. I. Kryzhanovskii, V. A. Serebryakov, and A. D. Starikov, Kvantovaya electronika No. 5, 69 (1971) [Sov. J. Quant. Electr. 1, 489 (1972)].
[5] M. P. Vanyukov, V. I. Kryzhanovskii, et al., Opt. Mekh. Prom. No. 12, 31 (1972).
[6] V. I. Abdeeva, M. A. Al'perovich, M. P. Vanyukov, et al., Kvantovaya elektronika No. 2, 69 (1971) [Sov. J. Quant. Electr. 1, 166 (1971)].

NONLINEAR ABSORPTION OF ELECTROMAGNETIC ENERGY IN AN ISOTROPIC FERROMAGNET

V. M. Gryanik
L. D. Landau Institute of Theoretical Physics, USSR Academy of Sciences

Submitted 27 November 1973
ZhETF Pis. Red. 19, No. 1, 42 — 43 (5 January 1974)

It is shown that the electromagnetic dissipation at low frequencies in an isotropic ferromagnet near the phase transition curve is essentially nonlinear even in weak alternating fields.

It was shown in [1] that an isotropic ferromagnet is described in the hydrodynamic approximation, in a range of fields and temperatures such that $|M - M_S| \ll M_S$ ($HT^{-2} \ll 16\pi^2 c^3 M_S^5$) by the thermodynamic potential

$$\Phi = f(M_s^2) + \frac{A}{3}|M - M_s|^3 - \mathbf{MH},$$
$$A = 16\pi^2 c^3 M_s^3 T^{-2}, \qquad (1)$$

where $\vec{M}$ is the density of the magnetic moment, $\vec{M}_S$ is the density of the spontaneous magnetic moment, c is a constant proportional to the exchange integral, and $\vec{H}$ is the external magnetic field. The cubic term describes the contribution from the long-wave fluctuations that are strongly developed near the phase-transition curve. Its concrete form is closely connected with the principle of conservation of the magnetic moment, a principle that is asymptotically exact for homogeneous fluctuation, and is locally correct in volumes $T/M_S H \ll V \ll R_c^3$ ($R_c = \sqrt{cM_S/H}$ is the correlation radius).

Particular interest attaches to the low-frequency dynamics of these fluctuations. Its characteristic features can be explained by considering an isotropic ferromagnet placed in a homogeneous constant field and in an alternating field $|\vec{h}| = h \sin \omega t$ parallel to it. Owing to the strong exchange interaction, a local equilibrium is rapidly established in selected volumes, at least when $\omega \ll \gamma H$. The time variation of the magnetic moment is then determined by the Landau-Lifshitz equation of motion

$$\dot{\mathbf{M}} = -\gamma[\mathbf{M} \times \mathbf{H}_{eff}] + \mathbf{R}, \qquad (2)$$

where $\vec{H}_{eff} + -\delta\Phi/\delta\vec{M}$ is the effective magnetic field, γ is the gyromagnetic ratio, and $\vec{R}$ is the relaxation term. We take the relaxation into account by assuming $\vec{R}$ to be a linear function of $\vec{H}_{eff}$, namely $\vec{R} = (1/\tau_{\parallel})H_{eff} + (1/\tau_{\perp}M^2)M\times[M\times H_{eff}]$ [3]. The quantities $\tau_{\parallel}$ and $\tau_{\perp}$ characterize the relaxation and have the dimension of time.

Being interested in frequencies and fields lower than the threshold values for parametric excitation of spin waves [4], we can confine ourselves to an examination of Eq. (2) only for the moment component that is directed along the field

$$\dot{M}_z = -\frac{1}{\tau_{\parallel}}A(M_z - M_s)^2 + \frac{1}{\tau_{\parallel}}H + \frac{1}{\tau_{\parallel}}b\sin\omega t, \tag{3}$$

where it is assumed that τ does not depend on the external field. In the region of weak alternation fields and high frequencies, we solve (3) by perturbation theory, and in the region of low frequencies we use the adiabatic approximation. For the energy absorbed by a ferromagnet per unit time, $W = \overline{\dot{M}_z h}$ (the bar denotes averaging with respect to time), we obtain

$$W = \frac{\chi_{\parallel}b^2}{2}\,\frac{\chi_{\parallel}\tau_{\parallel}\omega^2}{1 + (\chi_{\parallel}\tau_{\parallel}\omega)^2}, \qquad \frac{b}{H} << 1 + \chi_{\parallel}\tau_{\parallel}\omega, \tag{4}$$

$$W = \chi_{\parallel}H^2\left(1 - \sqrt{1 - \frac{b^2}{H^2}}\right)\chi_{\parallel}\tau_{\parallel}\omega^2, \qquad \chi_{\parallel}\tau_{\parallel}\omega << \frac{(H - b)}{(H + b)b^{1/2}}, \tag{5}$$

where $\chi_{\parallel} = T/8\pi(cM_S)^{3/2}H^{1/2}$ is the longitudinal magnetic susceptibility.

We call attention to the fact that the true relaxation times are $\chi_{\parallel}\tau_{\parallel}$ and $\chi_{\perp}\tau_{\perp}$. As $H \to 0$, the longitudinal relaxation time becomes infinite as well as the transverse time. The nonlinear loss is appreciable at low frequencies even in weak alternating fields. Traces of nonlinearity remain also in the linear region, in the form of a dependence of the absorbed energy on the magnetizing field (4).

Such an absorption could be observed independently only in the region below threshold (this was indeed the case investigated). By virtue of the universality of the absorption along the entire phase-transition curve, such measurements would yield also useful information on the dynamic of the critical fluctuations in a wide range of fields and temperatures, and could explain the character of the relaxation in this region.

The author is indebted to V. L. Pokrovskii for suggesting the problem and directing the work, and to V. S. Lutovinov for a discussion.

[1] A. Z. Patashinskii and V. L. Pokrovskii, Zh. Eksp. Teor. Fiz. 64, 1445 (1973) [Sov. Phys.-JETP 37, No. 4 (1973)].
[2] L. D. Landau and E. M. Lifshitz, Phys. Z. Sowjet. 8, 153 (1953), or L. D. Landau, collected works (in Russian), Vol. 1, p. 128.
[3] A. I. Akhiezer, V. G. Bar'yakhtar, and S. V. Peletminskii, Spinovye volny (Spin Waves), Nauka, 1967, Sec. 52.
[4] H. Suhl, Phys. Chem. Sol. 1, 209 (1957); Ya. A. Monosov, Nelineinyi ferromagnitnyi rezonans (Nonlinear Ferromagnetic Resonance), Nauka, 1971, Sec.6.7.