$T_N = 1.96$°K. A similar phenomenon was observed, for example, in FeF_3 [6]. Investigation of polycrystalline $CoSO_4$ indicate that the transition to weak ferromagnetism causes depolarization of neutrons passing through such a sample.

All the foregoing favors the assumption of a possible existence in $FeCl_2$ of a transition to weak ferromagnetism near H_c^0. Regions with such a magnetic moment can serve as nuclei of the saturated phase in the metamagnetic transition.

We are grateful to G.M. Drabkin for constant interest in the work and discussion, and to G.N. Popova for help with the work.

[1] J.S. Jacobs and P.E. Lawrence, Phys. Rev. 164, 866 (1967).

[2] G.M. Drabkin, A.I. Egorov, V.A. Trunov, R.P. Dmitriev, V.A. Ul'yanov, and A.Z. Yagud, Abstract of Papers of 16th All-union Conference on Low-temperature Physics, Leningrad, 1970, p. 172.

[3] P. Carrara, J. de Grunzbourg, and Y. Allain, J. Appl. Phys. 40, 1035 (1969).

[4] G.M. Drabkin, V.A. Trunov, and A.F. Shchebetov, ZhETF Pis. Red. 10, 572 (1969) [JETP Lett. 10, 336 (1969)].

[5] V.G. Bar'yakhtar, A.E. Borovik, V.A. Popov, and E.P. Stefanovskii, Zh. Eksp. Teor. Fiz. 59, 1299 (1970) [Sov. Phys.-JETP 32, 709 (1971)].

[6] V.Ya. Gamlitskii, S.S. Yakimov, V.I. Nikolaev, and N.F. Simonov, ZhETF Pis. Red. 13, 129 (1971) [JETP Lett. 13, 88 (1971)].

EXCITATION OF MAGNETOSONIC RESONANCE IN THE TOKAMAK PLASMA

V.L. Vdovin, O.A. Zinov'ev, A.A. Ivanov, L.L. Kozorovitskii, V.V. Parail,
Ya.R. Rakhimbabaev, and V.D. Rusanov
Submitted 7 July 1971
ZhETF Pis. Red. 14, No. 4, 228 - 231 (20 August 1971)

Considerable progress has been attained by now in the heating and containment of plasma by current in Tokamak installations [1]. It is known at the same time that the efficiency of Joule heating of the plasma decreases with increasing electron temperature. It therefore becomes vital to solve the problem of plasma heating with the aid of alternating electromagnetic fields, especially via excitation of magnetosonic resonance, which ensures penetration of the field into the plasma and even enhancement of the field [2].

We investigated the excitation of magnetosonic resonance (MSR) in a toroidal plasma with current in the TM1-VCh installation, which comprises a Tokamak [3] with major torus radius $R = 40$ cm, diaphragm radius $a = 8$ cm, stabilizing field $H_m = 20$ kOe, and discharge current $I_m = 10$ kA. The hydrogen pressure in the chamber was $P = (4 - 8) \times 10^{-4}$ Torr. The electron temperature, estimated from the conductivity, was $T_e = 70$ eV, and the charged-particle density (determined with a microwave interferometer) was $\bar{n} \gtrsim 2 \times 10^{13}$ cm^{-3}. The magnetosonic oscillations at 21 MHz were excited with a narrow coupling loop surrounding the plasma column. The signal was registered with the aid of magnetic probes lying inside the liner in the shadow of the diaphragm. One pickup was placed at a distance 22 cm away from the central plane of the excitation loop, outside the section bounded by the diaphragm, and could measure the local intensity $\tilde{H}_z$ of the HF magnetic field, and another pickup surrounded the column and the distance between it and the region of the exciter was equal to half the perimeter of the torus. The main measurements were made under conditions when the absorbed HF power ($P_{act} \lesssim 20$ kW) was of the same order as

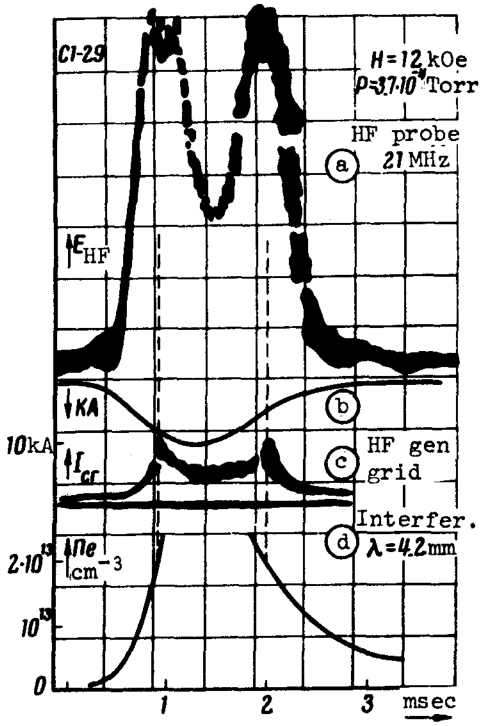

Fig. 1. a) Time variation of the H_z component of the HF magnetic field. b) Discharge current. c) Grid current of exciting-generator tube (21 MHz). d) Time behavior of electron density (as given by the microwave interferometer).

the power of the Joule heating by the longitudinal current.

Figure 1 shows the following: an oscillogram of the emf from the magnetic field, showing the time behavior of the $\tilde{H}_z$ component of the HF magnetic field (Fig. 1a) and the current in the plasma (Fig. 1b). The generator pulse duration was 10 msec and exceeded the current pulse duration. One can see intensive excitation of oscillations in a definite interval of the concentration on the rising and falling parts of the current curve. The concentration averaged over the cross section is shown in Fig. 1d (lower curve). At the instant of maximum buildup of the HF oscillations, there is an intense absorption of power, as is evidenced by the reaction of the grid current of the generator tube (Fig. 1c). Analogous oscillograms were obtained from the pickup surrounding the plasma column.

The amplitude of the oscillations of the alternating magnetic field $\tilde{H}_z$ decreases by approximately a factor of e at a distance 22 cm from the exciting loop, making it possible to estimate the efficiency with which a wave is excited by a narrow loop.

We present an estimate of the magnetosonic resonance frequency, based on a very simple formula, assuming the contribution of the longitudinal wave number to be small, assuming the plasma to be limited only by the magnetic field, and neglecting the corrections due to the longitudinal current and the toroidal inhomogeneity [2]:

$$\omega_{res} = (2.4/a)(H_0/\sqrt{4\pi nM}).$$

At H_0 = 12 kOe, a = 7 cm, and an average concentration n = 2.3 × 10^{13} we obtained for hydrogen f_{res} = 30 MHz. The agreement with the generator frequency 21 MHz can be regarded as good, when account is taken of the character of the approximations in the formula.

The plasma Q estimated from the half-width of the resonance dependence of the alternating field in the plasma turns out to be Q = 5. We note that absorption at very low excitation amplitudes (we used a GSS-6 standard signal generator) was smaller by a factor 3 - 4, and at the same time large enough in comparison with the value determined by the classical dissipative mechanisms. The most important from our point of view is the fact of effective excitation and absorption of HF power on the descending part of the current curve, when the electrons are already heated and the intensity of the Joule heating decreases.

Control experiments performed at a relatively high generator power P ≈ 200 kW and at a pulse duration τ ≈ 500 μsec have shown that the absorption efficiency remains equally high in this case.

The experimentally obtained Q does not contradict the theory, which predicts the existence of nonlinear dissipative mechanisms with very low thresholds, but cannot be obtained on the basis of the mechanism of classical dissipation, including the mechanisms of linear transformation.

It is easy to show that a magnetosonic wave with frequency $\Omega \sim \omega_{hi}$ can decay into a sum of two waves, an ion cyclotron wave and a drift wave with frequency $\omega_* \ll \omega_{hi}$ and $k\rho_{\ell i} > 1$, if the following condition is satisfied:

$$u^2 > v_{Ti}^2 \frac{\omega_*}{k^2 \rho_{\ell i}^2 \omega_{hi}} .$$

Here

$$\rho_{\ell i} = \frac{v_{Ti}}{\omega_{hi}} ; \quad \omega_* = \frac{k_\perp \kappa c T_e}{eH} ;$$

$R = 1/\kappa$ is the dimension of the plasma inhomogeneity, and $u = \Omega R(\tilde{H}/H_0)$ is the electron velocity in the field of the magnetosonic wave. Since $\omega_* \ll \omega_{hi}$ and $k\rho_{\ell i} > 1$, the threshold buildup velocity is much smaller than the thermal velocity of the ions; under the conditions of the experiment described above, the buildup takes place at $H \geq 10$ Oe.

From the decay equations it follows that

$$\frac{\partial W_{ms}}{\partial t} = - \sum_{\alpha} (\gamma_{\ell\alpha} - \gamma_{n\ell}) W_{\alpha} ,$$

where W_{ms} is the energy density of the magnetosonic waves, $\gamma_{\ell\alpha}$ is the linear damping decrement of the wave with index α, and $\gamma_{n\ell}$ is the growth increment of the ion-acoustic and drift waves. Since the damping decrement of the cyclotron wave, which characterizes the degree of its absorption by the plasma, is much larger than the growth increment of the waves as a result of the decay, the absorption of the energy of the magnetosonic wave is determined precisely by the linear decrement. Since $W_{ms} \sim W_c$ during the final stage of the decay, the Q of the system is given by the expression $Q \simeq \Omega/2\gamma_{\ell c}$ and for the experiments described above we have $Q \lesssim 10$.

The authors are grateful to E.K. Zavoiskii for constant interest in the work, to L.A. Artsimovich for support in organizing the experiments and for stimulating discussions. The authors are also sincerely grateful to D.P. Ivanov, S.V. Mirnov, G.F. Zhalud', M.K. Romanovskii, K.I. Tarkanov, A.V. Titov, and D.A. Shcheglov for help with the work.

[1] L.A. Artsimovich, E.P. Gorbunov, S.V. Mirnov, V.S. Strelkov, et al., Paper at 4th Internat. Conf. in Plasma Research and Controlled Thermonuclear Reactions, Madison, Wisc., 1971.
[2] V.D. Vdovin, A.A. Ivanov, L.L. Kozorovitskii, V.D. Rusanov, D.A. Frank-Kamenetskii, et al., Paper at Internat. Symp. on Toroidal Systems, Dubna, 1969.

[3] L.A. Artsimovich, Zamknutye plazmennye konfiguratsii (Closed Plasma Configurations), Nauka, 1969. D.P. Ivanov and D.S. Perfenov, Paper C-21/144 at 2nd Internat. Conf. in Plasma Physics and Controlled Nuclear Fusion, Culham, 1965.

DOMAIN-WALL-CONNECTED NATURAL RESONANCE AT SUBMILLIMETER WAVELENGTH IN ORTHOFERRITES

G.A. Kraftmakher, V.V. Meriakri, and A.Ya. Chervonenkis
Institute of Radio Engineering and Electronics, USSR Academy of Sciences
Submitted 26 May 1971; resubmitted 8 July 1971
ZhETF Pis. Red. 14, No. 4, 231 - 233 (20 August 1971)

The use of a quasioptical spectrometer [1] revealed resonant absorption in $TmFeO_3$ at a wavelength $\lambda = 0.77$ mm in the absence of a magnetic field. The observations were made at room temperature.

The results reported below were obtained with a thulium orthoferrite sample in the form of a plate 5 × 5 × 1.2 mm cut perpendicular to the C axis. The dimension along the C axis was 1.2 mm.[1) The $TmFeO_3$ single crystal was grown by crucible-less zone melting with radiative heating [2].

To avoid diffraction losses in the quasioptical line, resulting from the fact that the crystal dimensions were smaller than the dimensions of the quasioptical beam, the $TmFeO_3$ sample was placed in a waveguide system matched to the quasioptical line with the aid of two horns.

Figure 1 shows the dependence of the coefficient T of transmission through the $TmFeO_3$ sample on the wavelength. The parameter of curves 1 - 4 is the longitudinal (parallel to the C axis) constant magnetic field H_0. We see from Fig. 1 that the wavelength at which resonant absorption takes place is practically independent of the value of H_0. The influence of H_0, unlike in [3], reduces only to a weakening of the resonant absorption.

We plotted in greater detail the dependence of the attenuation of the resonant absorption T_H/T on the magnitude and sign of H_0 for the resonant

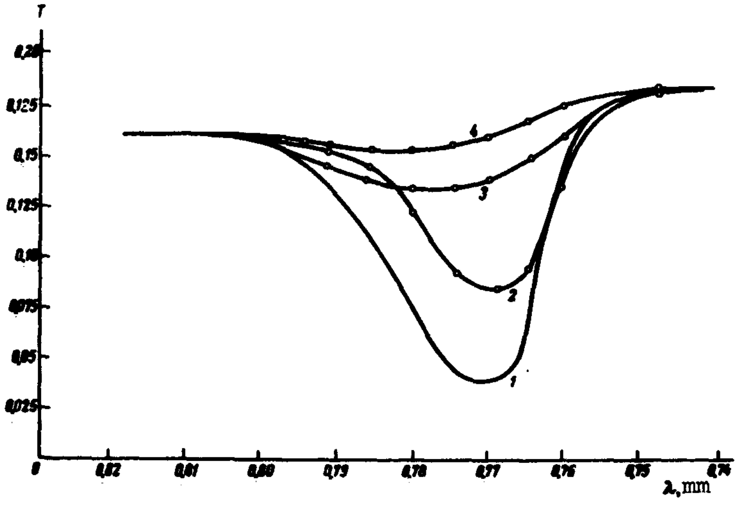

Fig. 1. Transmission coefficient T of $TmFeO_3$ vs. the wavelength λ: 1 - H_0 = 0, 2 - H_0 = -1400 Oe, 3 - H_0 = 100 Oe, 4 - H_0 = 1400 Oe.

[1)] Analogous results were obtained with other $TmFeO_3$ samples, and also with dysprosium orthoferrite $DyFeO_3$.