MIXED ELECTRON-NUCLEAR RESONANCE IN ANTIFERROMAGNETIC $MnCO_3$

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Recently it was shown in several experiments [1-4] and in theoretical papers [5,6] that polarization of nuclei in antiferromagnets gives rise to a strong coupling between the spin oscillations of the electronic and nuclear systems. The magnitude of the coupling is determined by the product of two effective fields: exchange H_E and nuclear $H_A = A\langle m\rangle$ (A - hyperfine interaction constant, $\langle m\rangle$ - average magnetization of nuclei in the sublattice). The presence of such a coupling leads to noticeable change in the natural resonant frequencies of both systems and in their dependence on the external field.

Of greatest interest is the case when the resonance spectra of the noninteracting electronic and nuclear systems have a point of intersection. From among the known antiferromagnets, such a picture can be expected for $MnCO_3$.

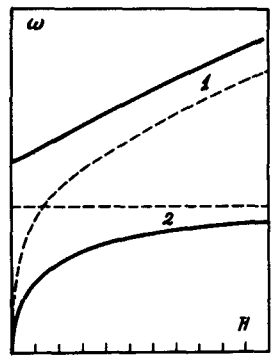

Fig. 1. Dependence of the resonant frequencies of the electronic (1) and nuclear components (2) of the spin systems on the magnetic field in the absence of coupling (dashed lines) and in the presence of strong coupling. The curves are not to scale.

The dashed lines in Fig. 1 show the dependence on the external field H_0 of the frequencies of the electronic (1) (low-frequency branch) and nuclear (2) resonances in the absence of the coupling on the basis of data of [2]. They are of the form

$$\omega_{e0}^2 = \gamma_e^2 H_0 (H_0 + H_D) \tag{1a}$$

$$\omega_{n0} = \gamma_n A M_0 \tag{2a}$$

where γ_e and γ_n are respectively the electron and nuclear gyromagnetic ratios, H_D is the Dzyaloshinskii field, and M_0 is the magnetization of the electrons in the sublattice. It is obvious that in the presence of coupling the resonance spectrum will have the form shown by the solid lines in Fig. 1.

A quantitative solution of the problem of the oscillations of the electronic and nuclear spin systems in an antiferromagnet with a structure of the type $MnCO_3$ shows that four natural frequencies should be observed [6]. The two resonant frequencies corresponding to the low-

frequency branch are obtained from the equation

$$\gamma_e^2 H_0(H_0 + H_D) = \frac{[\gamma_n^2(AM_0)^2 + \gamma_e^2 2H_E H_A]\omega^2 - \omega^4}{\gamma_n^2(AM_0)^2 - \omega^2} \tag{3}$$

The solid curves on Fig. 1 correspond to the approximate solutions of this equation

$$\omega_I^2 = \gamma_e^2[H_0(H_0 + H_D) + 2H_E H_A \tag{1b}$$

$$\omega_{II}^2 = \gamma_n^2(AM_0)^2 \frac{H_0(H_0 + H_D)}{H_0(H_0 + H_D) + 2H_E H_A} \tag{2b}$$

Curve (1b) was found experimentally in [2].

In this investigation we studied the dependence of the resonance frequency on the magnetic field in the region of the lowest frequencies. The experiment was carried out with a spectrometer with low-frequency modulation of the magnetic field, and we recorded the derivative of the absorption line with slow passage through the magnetic field. The $MnCO_3$ single crystal[1)] was placed in a coil, which was connected through an attenuator to a 150 - 700 Mcs generator. The coil was coupled inductively with a receiving loop connected to a crystal detector. The ac signal from the detector, at the magnetic-field modulation frequency, was amplified and automatically recorded. Such a simple scheme made possible measurements over a very wide frequency range. The constant magnetic field and the radio-frequency field were mutually perpendicular and located in the (111) plane of the sample; this excited the low-frequency branch of the resonant spectrum [6].

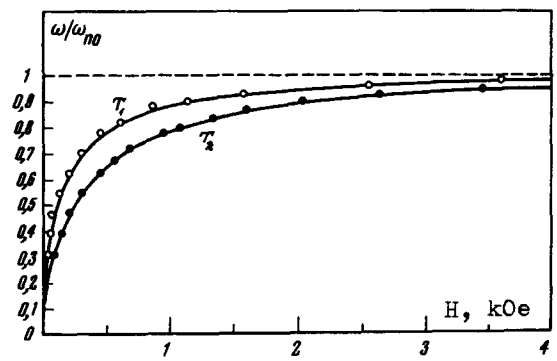

Fig. 2. Dependence of resonant frequency of electron-nuclear resonance on the magnetic field at temperatures T_1 and T_2 of 4.2 and 1.8°K. The solid curves correspond to Eq. (2b).

Figure 2 shows the experimental results for two values of temperatures $T_1 = 4.2$°K and $T_2 = 1.8$°K. The solid curves were calculated from equation (2b) with constants $H_D = 4.4$ kOe, $2H_A H_E = 1.6$ kOe^2 at $T_1 = 4.2$K and $2H_A H_E = 3.6$ kOe^2 at $T_2 = 1.8$°K [2]. The best agreement with the experimental data was obtained by choosing a value $f_{n0} = 640$ Mcs, which differed by only 8% from the value obtained from the data on the specific heat [7].

It is seen from Fig. 1 that the resonance which we observed in weak fields is a mixed electron-nuclear resonance. At sufficiently strong fields, when the frequencies of the nuclear and electronic resonances differ greatly, we have a weakly perturbed muclear magnetic resonance spectrum. With increasing magnetic field, the radio-frequency power is absorbed by the electrons and nuclei together.

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DEPENDENCE OF SPECTRAL COMPOSITION OF STIMULATED EMISSION ON THE VELOCITY OF MOTION OF THE CRYSTAL

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The stimulated emission from solid media (crystals, glasses, etc.) is known [1,2] to occur at many cavity modes. The width of the spectrum is determined here by the number of axial (longitudinal) modes engaged in the generation. This number can reach many dozens [3], greatly reducing the monochromaticity and the spectral density of the radiation.

We predicted [4] and by now observed experimentally 1) the effect of narrowing down the stimulated emission spectrum of a crystal moving relative to the resonator.

The inhomogeneity of the inverse population, resulting from the spatial inhomogeneity of the modes in the cavity (which in turn causes the multimode nature of the spectrum), becomes smoothed out when the crystal moves. Because of this, the number of generated modes decreases, the emission spectrum becomes narrower, but the total intensity remains unchanged, so that the