COUPLING BETWEEN TWO SPIN SOCILLATION MODES IN ANTIFERROMAGNETIC RESONANCE

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In an antiferromagnet with two sublattices, there exist two different types of spin-system oscillations, corresponding to magnetization oscillations of each of the sublattices [1]; these oscillations are homogeneous over the entire crystal. The dependence of the frequencies of these oscillations on the applied field determines two branches of the antiferromagnetic-resonance spectrum. In the case of a uniaxial antiferromagnet with anisotropy of the "easy plane" type, these two branches cross in a strong field $H = \sqrt{H_A H_E}$ (H_A = anisotropy field, H_E = exchange field). We have observed a strong shift of the resonant frequencies near the intersection point, due to the mutual coupling between the two oscillation modes.

The tests were made on single-crystal $MnCO_3$ [1)], which is an antiferromagnet with weak ferromagnetism. Disregarding the hyperfine interaction, the expressions for the antiferromagentic resonance frequencies ν_1 and ν_2 are [3,4]

$$(\nu_1/\gamma)^2 = H(H + H_D), \tag{1}$$

$$(\nu_2/\gamma)^2 = H_A H_E + H_D(H + H_D), \tag{2}$$

where γ is the gyromagnetic ration, H_D the Dzyaloshinskii field, and H the external field applied to the basal plane. The form of this spectrum at T = 4.2°K is shown schematically in Fig. 1. The value of H_D was taken from a paper by one of the authors [3] and the value of $H_A H_E$ from Richards' paper [5].

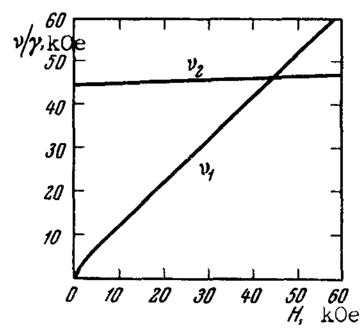

Fig. 1. Spectrum of antiferromagnetic resonance in $MnCO_3$.

The sample was mounted on a waveguide short-circuiting plunger. The antiferromagnetic resonance was determined from the change in the reflected microwave signal as a function of static field. The microwave power source was an OV-60022 tube [6]. The magnetic field was produced by a solenoid with superconducting wire type 65-BT [2)]. The end of the waveguide with the sample was thermally insulated and placed in a vacuum jacket immersed in liquid helium. This made it possible to vary the sample temperature from 2 to 4.2°K.

The results can be displayed most illustratively on plots of the resonant field against the temperature at a fixed frequency.

Dashed lines 1 and 2 on Fig. 2 represent the results obtained by us at 125 and 117 Gcs respectively in the case when the external field was strictly parallel to the basal plane of the crystal. These results agree well with formulas (1) and (2). Indeed, the first branch on the plot of H vs. T should be an almost-horizontal straight line, since $H \gg H_D$ at the

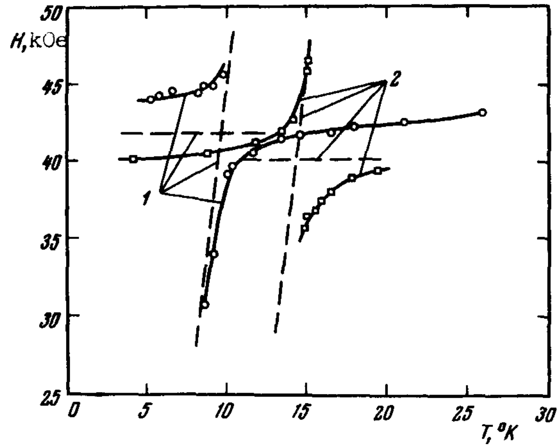

Fig. 2. Temperature dependence of the resonant field for $\alpha = 0°$ (dashed lines) and $\alpha \sim 2°$ (solid curves). 1 - ν = 125 Gcs, 2 - 117 Gcs.

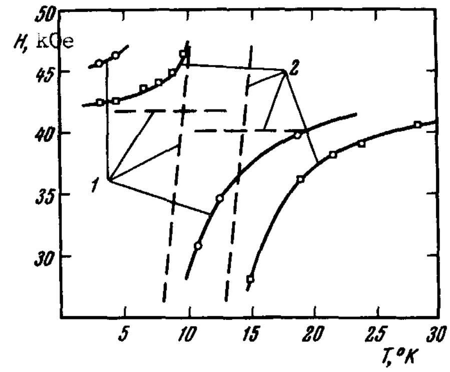

Fig. 3. Temperature dependence of the resonant field for $\alpha \sim 6°$ (solid curves). 1 - ν = 125 Gcs, 2 - 117 Gcs.

frequencies employed. On the other hand, the frequency of the second branch depends relatively little on the field. Therefore even a small decrease in the value of $H_A H_E$ with temperature corresponds to an extraordinarily steep increase of the resonant field.

It was observed that even when the direction of the external field deviates little from the basal plane the temperature dependence of the resonant field changes abruptly. The solid curves on Fig. 2 were obtained at an angle $\alpha \sim 2°$ between the field and the basal plane. The form of these curves indicates that a strong interaction takes place between both types of oscillation, causing a shift of the resonant fields by an amount ~1.5 kOe. An experiment was also carried out at an angle $\alpha \sim 6°$, and the corresponding shift of the resonant fields reached ~5 kOe (Fig. 3).

It can be shown that if one uses the Hamiltonian for the rhombohedral crystals of the D_{3d}^6 group [3,4], then in first approximation the equation for determining the antiferromagnetic resonance for an external field making a small angle α with the basal plane is

$$\nu^4 - \nu^2(\nu_1^2 + \nu_2^2 + \gamma^2 H_0^2 \sin^2\alpha) + \nu_1^2\nu_2^2 = 0.$$

Our results agree qualitatively with the solutions of this equation.

A more detailed comparison of the experiment with calculation will be made after measurements at other temperatures are completed.

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1) We used synthetic $MnCO_3$ crystals produced at the Crystallography Institute of the USSR Academy of Sciences by N. Yu. Ikornikova [2]. The authors are grateful to her for supplying the samples.

2) The authors are grateful to N. N. Mikhailov and L. N. Vasil'ev for constructing the solenoid and placing it at our disposal.

BEAM LASER FOR THE INFRARED BAND

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The problem of obtaining a source of electromagnetic oscillations with high frequency stability has always been related in quantum radiophysics to the construction of a quantum generator based on a beam of atoms or molecules, since there is practically no shift of the top of the spectral line as a result of interaction between molecules in a beam quantum generator.

The beam quantum generators realized to date have been confined to the radio band. We consider in this article the possibility of producing a laser for the infrared band, with thermal excitation. Thermal pumping is based on choosing molecular energy levels E_β and E_α such that the time of their radiative decay satisfies the relation $\tau_\beta > \tau_\alpha$ ($E_\beta > E_\alpha$). The idea of the laser under consideration is simple: a highly heated beam of molecules is allowed to escape to a vacuum in which the equilibrium radiation is much smaller than $(E_\beta - E_\alpha)/k$. Spontaneous emission soon depletes the α level and a state with population inversion can be produced for the $\beta \to \alpha$ transition. The necessary condition for the occurrence of population inversion between the levels β and α is

$$\tau_\beta > \left(1 + \frac{\tau_{\beta\alpha}}{\tau_\beta}\right)\tau_\alpha.$$

The most convenient range of wavelengths, from the point of view of the proposed method, is 3 - 20 μ. For shorter wavelengths, the lifetimes in the excited states are too small. For long-wave transitions, the lifetime in the excited state becomes too large, calling for excessively large apparatus dimensions.

The figure shows the CO_2 molecule vibrational levels suitable for obtaining population inversion in a molecular beam [1]. The thick arrow denotes very intense transitions, and the