To screen the sample and the NMR circuit against the penetration of the high-frequency voltage exciting the force, the ends of the sample were metallized with allowance for the depth of the skin layer and placed in screens. When the quartz was replaced by a dielectric, the NMR of Al^{27} did not change when electromagnetic excitation was turned on.

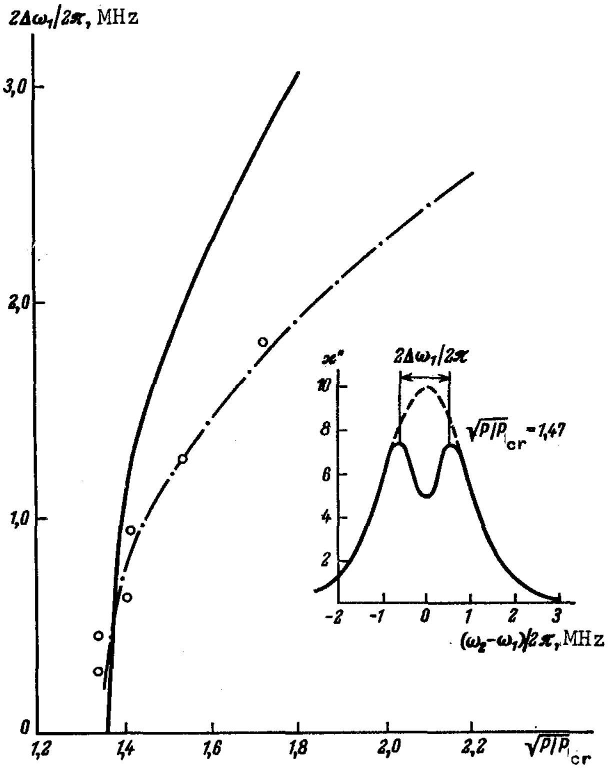
Additional proof that the observed effect is indeed caused by sound is the sharp difference between the widths of the lines of ANMR of Cr^{53} in the case of electromagnetic and acoustic excitation.

[1] U. Kh. Kopvillem, Dissertation, Kazan' University, 1958, pp. 22-23.
[2] J. Lambe, N. Laurance, E. C. McIrvine, and R. W. Terhune, Phys. Rev. 122, 1161 (1961).
[3] H. Joshioka, J. Phys. Soc. Japan 20, 623 (1965).
[4] K. A. Valiev, Uch. zap. (Science Notes), Kazan' Univ. 117, No. 9, 149 (1957).
[5] Sh. Sh. Bashkirov and U. Kh. Kopvillem, Fifth All-Union Conference on Semiconductor Theory, Baku, 1962; Abstracts of Papers, p. 9.

DOUBLE FERROMAGNETIC RESONANCE

I. A. Deryugin, V. V. Zaporozhets, and M. G. Lysenko
Kiev State University
Submitted 2 December 1968
ZhETF Pis. Red. 9, No. 2, 89-91 (20 January 1969)

Let a ferromagnetic sample be situated in a constant magnetic field H_0 and in the radiation field of two close microwave frequencies ω_1 and ω_2. A photon incident on the ferrite excites in it a spin wave with energy equal to the photon energy, and with a zero wave vector (homogeneous precession).



Owing to this process, saturation can be reached in any region of the FMR line at a sufficiently large amplitude of the microwave field. This saturation can be observed when plotting the absorption curve, by varying the frequency ω_2 of the so-called detecting microwave radiation, the amplitude of which is such that parametric excitation of the undamped spin waves by this field is impossible. The ferromagnetic-resonance line recorded in this manner is the usual curve with a dip in the vicinity of the saturation point (see the figure). The dip is due to the interaction between the parametrically-excited spin waves saturating the spin system and the homogeneous precession excited by the detecting field. We shall call this phenomenon double ferromagnetic resonance (DFMR). Using the expansion of the magnetization vector in plane waves [1] and a successive-approximation method, we can obtain from the

Landau-Lifshitz equations an expression for the imaginary part of the magnetic susceptibility χ''. For the particular case of saturation of the central region of the curve and a spherical sample, we have

$$\chi'' = \gamma M_0 \frac{(\omega_2 - \gamma H_0)^2 \eta_0 + \eta_0 \eta_k^2 \left(2\sqrt{\frac{P}{P_{cr}}} - 1\right)}{\left[(\omega_2 - \gamma H_0)^2 - \eta_0 \eta_k \left(2\sqrt{\frac{P}{P_{cr}}} - 1\right)\right]^2 + (\eta_0 + \eta_k)^2 (\omega_2 - \gamma H_0)^2}, \tag{1}$$

where γ - gyromagnetic ration, M_0 - saturation magnetization, η_k - attenuation constant of spin wave with wave vector $\vec{k}$, P - saturating radiation field, and P_{cr} - critical power of saturating radiation at which the undamped spin waves are excited.

We investigated the DFMR experimentally at a frequency 2000 MHz in a single-crystal of yttrium-gallium garnet sphere of 3 mm diameter ($4\pi M_0 = 1100$ G). The source of the saturating radiation was a G4-8 generator, and the detecting field was produced by a G3-22 generator. Linear tuning of the freguency of the detecting radiation was by means of a special device. The frequency deviation within the limits of the FMR line did not lead to appreciable changes in the level of the detecting radiation.

Microwave power of frequency ω_1 and ω_2 was introduced into the measuring waveguide section with the sample by means of a twin-T bridge. The connection between the constant magnetic field H_0 and the frequency of the saturating radiation ω_1 is

$$\omega_1 = \gamma H_0. \tag{2}$$

The absorption signal from the microwave detector, amplified by a dc amplifier, is registered on an automatic recorder chart. The absorption curve recorded by varying the frequency ω_2 has a dip in the central part (see the figure).

The theoretical relation (1) enables us to determine the most important parameters of the DFMR line. The figure shows also the dependence of the distance $2\Delta\omega_1$ between the extremal points of χ'' on the level of the power incident on the ferrite. The experiment has confirmed the theoretical calculations ($\eta_0 = 1.1$ MHz, $\eta_k = 210$ MHz) in the region where $\sqrt{P/P_{cr}}$ is smaller than 1.4. A further increase in the power of the signal of frequency ω_1 leads to excitation of other spin-wave types, thus changing the attenuation parameter η_k. Since expression (1) does not provide for this change, a quantitative discrepancy between the experimental and theoretical results is observed at $\sqrt{P/P_{cr}} > 1.4$.

It is convenient to employ the DFMR method in investigations of relaxation processes in the region beyond threshold, without determining the absolute values of the microwave fields, and also in exact measurements of the relaxation time of a spin wave excited in the given material.

Such a method of investigating nonlinear interactions in ferromagnets may find use also when the spin waves are excited by other methods, for example by longitudinal pumping, by sound, etc.

[1] H. Suhl, J. Phys. Chem. Sol. 1, 209 (1957).

CONCERNING THE ANISOTROPY OF THE PROBABILITY OF THE MOSSBAUER EFFECT ON Sn^{119} NUCLEI IN THE LATTICE OF WHITE TIN

N. E. Alekseevskii and A. P. Kir'yanov
Institute of Physics Problems, USSR Academy of Sciences
Submitted 25 November 1968
ZhETF Pis. Red. 9, No. 2, 92 - 95 (20 January 1969)

We have already reported [1] results of an investigation of the anisotropy of the Mossbauer effect as determined by the anisotropy of the resonant absorption of γ quanta by Sn^{119} nuclei in thin single-crystal absorbers made of white tin.

In the present paper we report the results of measurements of the amplitude of the absorption for so-called "black" resonant absorbers ($C_a \simeq 100$) combined with a thick single-crystal source ($C_s \geq 10$), using the previously described setup [1]. The absorption amplitude is proportional in this case to the probability of γ-quantum emission in the given direction of the crystal, and the proportionality coefficient itself is practically independent of either the thickness of the absorber and source, or of the hyperfine structure of the emission and absorption lines. This makes it possible to measure directly the anisotropy of the emission probability, and its temperature and angular dependences.

In the measurements we used as the "black" absorbers plates made of tin enriched to 88.1% of Sn^{119}. The effective thickness of resonant absorption C_a was in this case 53 at 290°K for an absorber 0.25 mm thick, and 330 at 4.2°K for an absorber 0.10 mm thick.

One of the single-crystal sources, in the form of a plate 70 μ thick, was grown from active tin with the aid of a single-crystal primer, using the method described by P. L. Kapitza for the growing of single crystals of bismuth [2]. The primer was a plate cut by the electric spark method from a single-crystal block in such a way that the normal to the plate made an angle of 45° with the crystal axes [001] and [100]. The surface layer deformed by the spark processing was removed electrolytically. The direction of the normal to the plane of the obtained single-crystal source relative to the crystal axis was monitored with an x-ray setup. The content of the Sn^{119} was 1.4% in the active tin material and 1.7% in the primer material. A second single-crystal source had the form of a cylinder of 1 mm diameter and 10 mm long. It was grown by the same method,

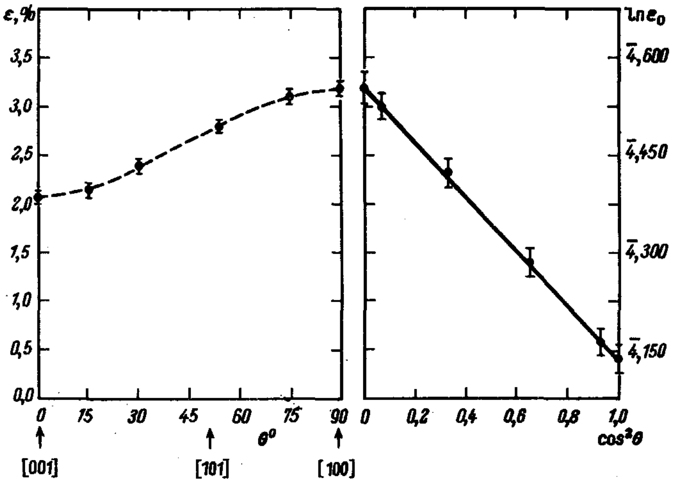


Fig. 1. Angular dependence of the emission probability of β-Sn(010), T = 290°K.