

NMR OF Fe^{57} IN YTTRIUM ORTHOFERRITE SINGLE CRYSTALS¹⁾

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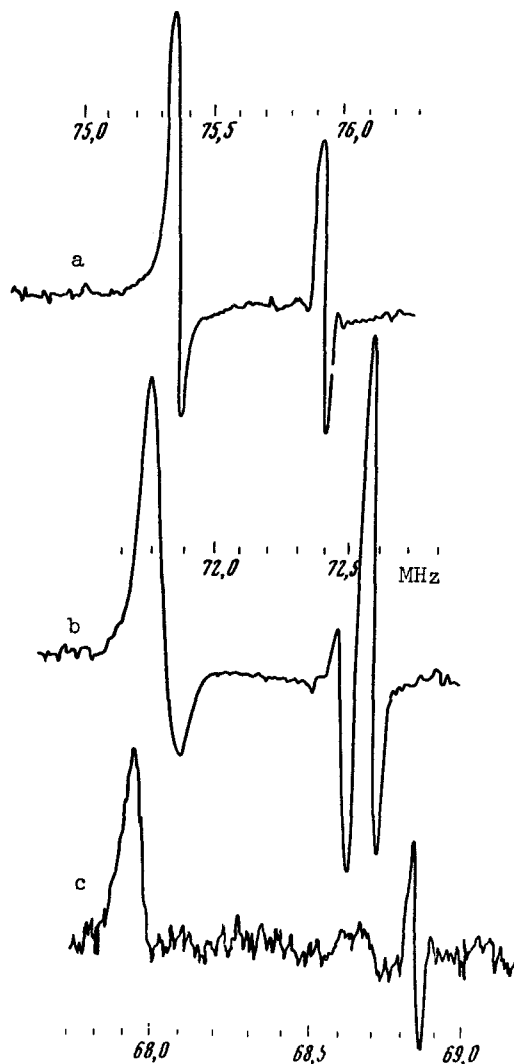


Fig. 1. NMR signals obtained with the aid of a superregenerator (first derivative, quenching frequency 20 kHz) from 10 g of randomly ordered YFeO_3 crystals with an average dimension 1 - 3 mm: a - 77°K, b - 221°K, c - 294°K. The recording-system sensitivities were different for each case.

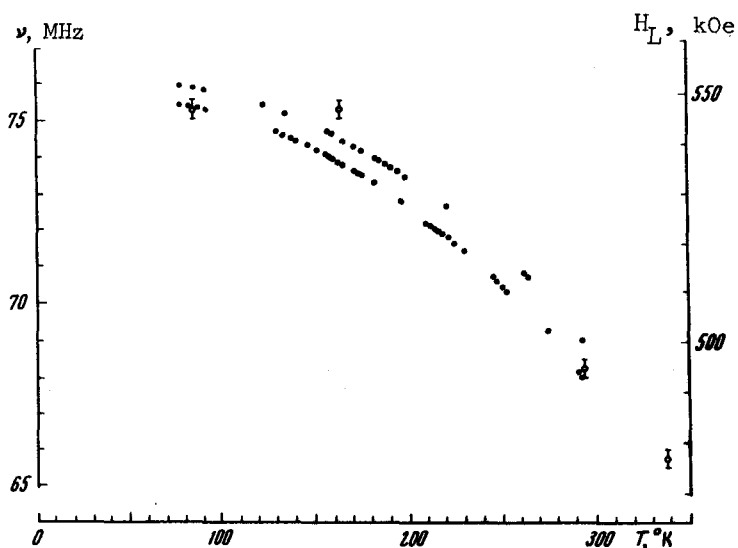
Compounds of the type RFeO_3 (called orthoferrites), where R is the rare-earth or yttrium ion, are among the ferromagnets in which, insofar as we know, no NMR has been observed in the hyperfine fields, although attempts of this kind were made (but unsuccessfully) in [1]. We report here brief information on the first successful attempt to observe NMR of Fe^{57} in YFeO_3 single crystals.

The search for an NMR signal at frequencies corresponding to the local fields obtained in [1] from Mossbauer spectra was carried out with the aid of a superregenerator. The samples were YFeO_3 crystals with a natural content of the Fe^{57} isotope, grown by different methods: from a solution in the melt and by the hydrothermal method with spontaneous crystallization. The NMR was observed only in the latter crystals, synthesized by O.K. Mel'nikov in the laboratory for hydrothermal synthesis of our institute.

It is known that the weak ferromagnetism of the orthoferrites is due to the noncollinearity of the two identically antiferromagnetically-ordered sublattices of the Fe^{3+} ions, which occupy crystallographically equivalent positions in the structure. Accordingly a single value of the local field at the Fe^{57} nuclei at a given temperature was obtained in [1] for each of the orthoferrites. But the search for NMR in YFeO_3 led to the observation of two closely-lying lines, 75.38 and 75.95 MHz, at 77°K (corresponding to local fields 547.2 and 551.4 kOe for the Fe^{57} nuclei), and 67.89 and 63.83 MHz (592.9 and 499.71 kOe) at 294°K. The errors in the frequencies (~ 0.01 MHz) and in the local fields (~ 0.07 kOe) are connected mainly with the difficulty of determining the exact center of the line from the superregenerator signal. Figure 1 shows the NMR signals observed at different temperatures, and Fig. 2 the temperature dependence of the resonant frequencies, and accordingly of the local field H_L . The segments show the Mossbauer values of H_L , taken from the data of [1] for YFeO_3 , with allowance for the measurement error cited by the authors.

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Fig. 2. Temperature dependence of the resonant frequencies and of the local field H_L for $YFeO_3$. The circles with the bars represent the values of H_L from the data of [1].



The features of NMR in $YFeO_3$ reduce to the following: (a) the frequency difference $\Delta\nu$ increases slowly and linearly on going from 77°K to room temperature, $\Delta\nu = (0.44 \pm 0.02) + (1.70 \pm 0.15) \times 10^{-3}T$ MHz; (b) a noticeable broadening of the low-frequency signal is observed at increased temperatures (see Figs. 1b and 1c); (c) the two signals disappear when the crystals are ground to a powder; (d) no NMR signals were observed in crystals showing no sign of resonant oscillations of the domain boundaries; (e) preliminary measurements of individual crystals at room temperature show that both signals have maximum intensity when the radio-frequency field h is directed along the c axis of the rhombic $YFeO_3$ crystal (i.e., parallel to the domain boundaries and to the ferromagnetic moment σ_s in the domains), and vanish when $h \perp c$.

Since there are no grounds for the splitting of the NMR frequency to be due to the magnetic and crystallographic nonequivalence of the sublattices, this splitting must be attributed to the distinctive features of the NMR in the domain boundaries.

The properties (a) and (b), in analogy with the situation for the compounds CrX_3 ($X = Cl, Br, I$) [2], can be explained by ascribing the low-frequency signal that decreases more rapidly with the temperature to nuclei in the domain boundaries, and the high-frequency signal to nuclei inside the domains. An interpretation of such properties similar to Winter's [3], on the basis of the analysis of the spin waves in the domains and on the boundaries, can be found, for example, in [4] and also in the later theoretical papers [5]. The splitting remaining when $T \rightarrow 0$, just as in the case of the chromites [2], might be attributed to the anisotropy of the hyperfine interaction and of the dipole field. Both effects are possible in this case, since the Fe^{57} nuclei have a noncubic surrounding in the $YFeO_3$ structure. Somewhat discouraging is the fact that the Mossbauer data on H_L , which pertain naturally to the nuclei of the sample, are in good agreement with the temperature dependence of the low-frequency signal, with the exception of a distinct deviation (or a misprint in [1] for H_L at 164°K).

On the other hand, the features (c) - (e) offer evidence that both signals are due to oscillations of the domain boundaries. If it is assumed that one of the signals is connected with the usual mechanism of amplification due to the rotation of σ_s in the domains, then it is difficult to understand the comparable intensity of both signals (and the practically identical shape at 77°K), and also the absence of a high-frequency signal when $h \perp c$. In order

to cause rotation of σ_s in YFeO_3 ; it is necessary to overcome an effective anisotropy field H_A on the order of 10^5 Oe. Such a value of H_A indicates a negligible amplification in the domains (since it is proportional to H_L/H_A).

When the features of the NMR in YFeO_3 are considered in their entirety, it can be assumed that the results constitute the first experimental confirmation of the possible appearance of nuclear resonance, predicted theoretically in [5], at a frequency corresponding to NMR in the domains, but observed on the nuclei in the domain boundaries together with the "interboundary" resonant signal. In this case the contradictions between the results are eliminated.

Further information on the nature of the NMR of Fe^{57} in YFeO_3 can be obtained from investigations now being carried out on crystals with different orientations relative to h and to the external static field.

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MOSSBAUER EFFECT IN THE COMPOUNDS Pt_3Cr AND Au_4Mn

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It is well known [1, 2] that experimental searches for nonconservation of time parity in electromagnetic nuclear transitions can be carried out with the aid of the Mossbauer procedure, which makes it possible to obtain elliptically-polarized γ radiation in transitions between the magnetic sublevels of the excited and ground states of the nucleus (m_i, m_f). The parity-nonconservation effect should become manifest in a change of the orientation of the axes of the polarization ellipse, both when tuning to the component with opposite signs of m_i and m_f and when the sign of the magnetic field at the radiation-source nuclei is reversed.

Since not all elements have compounds with magnetic structures, such experiments are performed by introducing the investigated nuclei (source and absorber) as impurities in an iron lattice. This leads, however, to a large loss of intensity of the low-energy γ radiation, owing to photoelectric absorption. This is an undesirable consequence of the fact that in order to attain the required level of sensitivity to the effect it is necessary to obtain a statistical accuracy much better than 10^{-3} .

The investigated substance was Au^{197} , in which there is a 77.3-keV Mossbauer transition of mixed multipolarity. To reduce the photoabsorption to a minimum, we used a ferromagnetic gold compound for the absorber and a Pt^{196} compound, obtained by neutron bombardment, as the source.

At present there is only one known ferromagnetic gold compound with a Curie point higher than 78°K , namely Au_4Mn ($T_c \sim 90^\circ$ [3]). In addition, we attempted to choose a platinum compound such that the hyperfine splitting and the isomer level shift of the gold nuclei produced in this compound following the β decay would permit an analysis of the polarized γ radiation at zero source velocity relative to the absorber. The change of the orientation