

Photoinduced change in NMR of ^{57}Fe in $\text{Y}_3\text{Fe}_5\text{O}_{12}$

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It has been observed that light changes the NMR spectrum of $\text{Y}_3\text{Fe}_5\text{O}_{12}$. The effect is attributed to a complete suppression of domain-wall signals and an improvement in the conditions for the detection of NMR absorption in the interior of domains.

In this letter we are reporting the first studies of the effect of light on NMR absorption in yttrium iron garnet. We used a continuous method to observe the NMR. The absorption signals were detected by recording the first derivative of the changes in the oscillation level of an autodyne pickup (detector) with frequency modulation and frequency sweep.

The photoinduced changes were studied in single-crystal $Y_3Fe_5O_{12}$ samples with the natural abundance of the isotope ^{57}Fe . The samples were grown under spontaneous-crystallization conditions from a $BaO-B_2O_3$ solvent without any deliberate doping. Measurements were taken at liquid-nitrogen temperature in a zero external field. The samples were illuminated with the light from an KGM9-70 lamp.

The data which we are reporting here were obtained from a single untreated crystal with maximum linear dimensions of $4 \times 6 \times 11$ mm. The rf magnetic field was oriented along one of the easy-magnetization axes.

In accordance with the ferrimagnetic structure of $Y_3Fe_5O_{12}$, we observe two groups of MNR signals, corresponding to absorption by the nuclei of ions of the d and a sublattices. Figure 1 shows the absorption spectra. Shown in the same figure, by the dashed lines, are the positions of the individual signals in the spectrum. The illumination causes a pronounced change in the amplitude of the signals, in a nonuniform way over the spectrum. In the d sublattice we observe a decrease in the amplitudes of signals A , B , and C . After illumination for 20 min, we are left with signal D , which is not observed in the original spectrum. In the a sublattice, signal F decreases, and signal E increases. The amplitude of a weak signal at 74.4 MHz (signal G), not shown in this figure, varies only negligibly. The resonant frequencies remain the same as the signal amplitudes change.

A distinctive feature of the spectra in the initial state and after a partial illumination is the pronounced difference between the shapes of the NMR signal lines. Along with the signals which are typical of NMR in magnetic materials, with a shape determined by a superposition of absorption and dispersion curves, we observe two signals

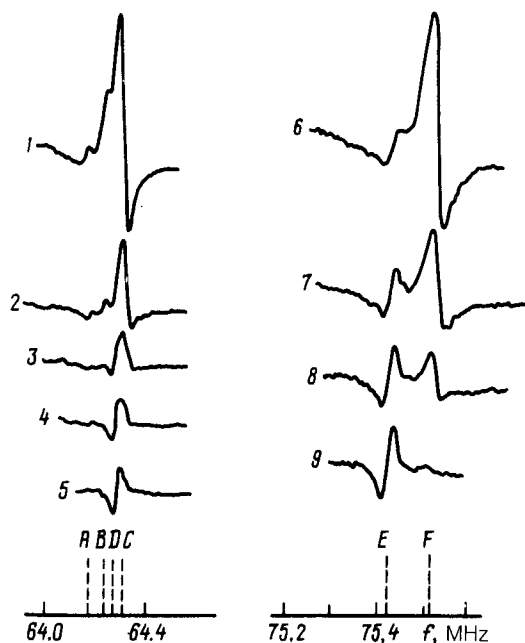


FIG. 1. First derivative of the primary NMR absorption signals for various durations of the illumination, τ (min): 1,6—0; 2—1.0; 3—3.0; 4—6.0; 5—16.0; 7—1.5; 8—4.5; 9—17.0.

which have the shape of inverted absorption signals (signals C and F).

To explain the results, we consider the influence of the anisotropy of the local magnetic field on the structure of the NMR spectrum of domain walls. The unit cell of yttrium iron garnet has three types of d ions, which differ in the direction of the anisotropy axis of the local magnetic field (the $\langle 100 \rangle$ direction), and four types of a ions, whose local anisotropy axes are directed along $\langle 111 \rangle$ directions. For the ions of each type, the NMR frequency can be written as a function of the magnetization direction as follows¹:

$$f(\alpha) = f(\perp) - [f(\perp) - f(\parallel)] \cos^2 \alpha, \quad (a)$$

where α is the angle between the magnetization direction and the corresponding anisotropy axis, and $f(\perp)$ are the values at $\alpha = 0$ and $\pi/2$, respectively. The difference $f(\perp) - f(\parallel)$ is 130 kHz for the d sublattice and 1125 kHz for the a sublattice.¹ As the magnetization direction in a domain wall changes, there is a corresponding dependence of the NMR frequencies on the coordinate y , along the normal to the plane of the domain wall, $f(y)$, for the ions of each type. According to Ref. 2, the steady-state NMR spectra of a domain wall contain absorption peaks which may be interpreted as NMR signals from a domain wall with resonant frequencies which are determined by the condition for a maximum of the spectral density of nuclear spins, $(df(y)/dy)^{-1}$. For yttrium iron garnet, both the $f(y)$ dependence and the frequencies of the NMR signals of a domain wall depend on the orientation of the plane of the wall in the crystal. Figure 2 shows the frequencies of NMR signals of a domain wall for three types of Bloch domain walls, characteristic of bulk $Y_3Fe_5O_{12}$ samples.³ The arrows show the positions of the NMR signals in the domains. Comparison with the experimental data shows that we are observing only those signals ($A_1, B_3, C_1, C_2, C_3, F_1, F_2$, and F_3) for which there is little or no additional inhomogeneous broadening caused by the spread in the orientation angles of the planes of the domain walls. The subscripts 1, 2, and 3 specify 180° , 109° , and 71° domain walls, respectively. Signal A can thus arise only as a result of 180° domain walls; signal B can arise only as a result of 71° domain walls; while signals C and F can arise as a result of all three types of domain walls considered. Signals D_0, E_0 , and G_0 , which remain after the illumination, are a consequence of absorption in the interior of domains. The reason for the slight change in signal G is that two signals are observed at this frequency: a signal from 180° domain walls, G_1 , which decreases upon illumination, and a signal from domains, G_0 .

The shape of the NMR signals of domain walls and their amplitude are related to the particular features of the dynamics of domain walls at the NMR frequencies. When there is absorption in the electron system, the shape of the signal is determined by a superposition of absorption and dispersion curves, in proportions determined by the phase-shift angle between the exciting magnetic field and the transverse component of the local magnetic field.² In particular, an inversion of the NMR signals of a domain wall occurs when the NMR frequency is equal to the resonant frequency of the domain wall.⁴ The observed diversity of signal shapes for the different types of domain walls stems from differences in the dynamic characteristics of the walls. The inverted line shape of signals C and F is due to the resonant nature of the absorption in the electron system. As we know, the spectrum of elementary excitations of a domain

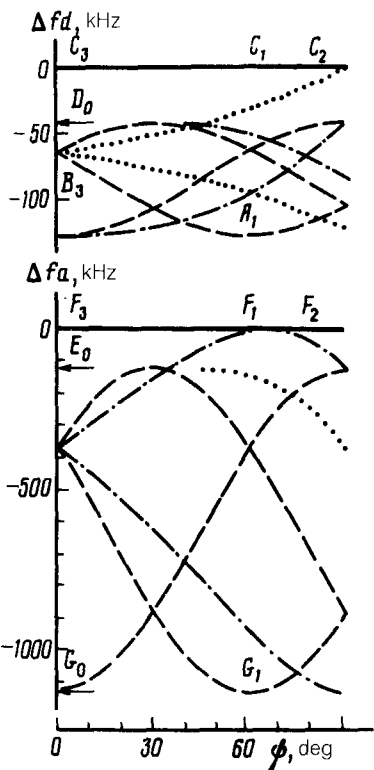


FIG. 2. Calculated behavior of the frequencies as functions of the angle (ψ) between the domain wall and the (110) plane. Dashed lines— 180° domain walls; dot-dashed lines— 109° domain walls; dotted lines— 71° domain walls; solid lines—all three types of walls considered. The frequencies are expressed with respect to the values of $f(\perp)$.

wall in $Y_3Fe_5O_{12}$ includes, in addition to a uniform resonant displacement, a large number of nonuniform resonant oscillation modes which are distributed over a wide frequency interval.⁵ The large spectral width of the resonant absorption of a domain wall may be responsible for the identical shape of signals C and F and also the insignificant change in this shape upon a photoinduced increase in the amplitudes of the signals. The photoinduced change in the domain-wall NMR signals is thus explained on the basis that the light reduces the amplitude of domain-wall oscillations, including resonant oscillations, to the point that they are completely suppressed. The primary reason for the increase in the amplitude of NMR signals in domains is an increase in the Q of the oscillator circuit upon a photoinduced decrease in the rf absorption by domain walls.

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³V. K. Vlasko-Vlasov *et al.*, *Zh. Eksp. Teor. Fiz.* **71**, 2291 (1976) [*Sov. Phys. JETP* **44**, 1208 (1976)].

⁴M. A. Shamsutdinov *et al.*, *Fiz. Tverd. Tela (Leningrad)* **29**, 1589 (1987) [*Sov. Phys. Solid State* **29**, 914 (1987)].

⁵L. M. Dedukh *et al.*, *Zh. Eksp. Teor. Fiz.* **94**, 312 (1988) [*Sov. Phys. JETP* **67**, 1265 (1988)].

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