[1] A. A. Malyutin and M. Ya. Shchelev, ZhETF Pis. Red. 9, 445 (1969) [JETP Lett. 9, 266 (1969)].
[2] T. I. Kuznetsova, Zh. Eksp. Teor. Fiz. 57, 1673 (1969) [Sov. Phys.-JETP 29, No. 5 (1970)].
[3] V. S. Letokhov, FIAN Preprint No. 106, 1968.
[4] J. A. Armstrong, Appl. Phys. Lett. 10, 16 (1967).
[5] J. A. Giordmaine, P. M. Rentzepis, S. L. Shapiro, and K. W. Wecht, Appl. Phys. Lett. 11, 216 (1967).

DETERMINATION OF THE PARAMETERS OF QUADRUPOLE INTERACTION IN YTTRIUM IRON GARNETS

G. N. Belozerskii, V. N. Gitsovich, A. N. Murin, Yu. P. Khimich, and Yu. M. Yakovlev
Leningrad State University
Submitted 29 December 1969
ZhETF Pis. Red. 11, No. 3, 173 - 177 (5 February 1970)

Yttrium iron garnets (YIG) have been thoroughly investigated by various methods, including NGR [1, 2]. In the present investigation we made sufficiently full use of the characteristic physical and methodological features of the NGR method.

The absorbers were oriented cuts of single-crystal YIG about 70 μ thick. The source was Co^{57} in chromium, which produced in our electrodynamic setup, with a sodium nitroprusside absorber, two perfectly symmetrical lines with $\Gamma = 0.25$ mm/sec. The spectra were recorded with a 400-channel analyzer operating in the time mode. From 1.5×10^5 to 10^6 pulses were accumulated in each channel. Such statistics, together with computer processing of the spectra, has made it possible to determine their parameters quite accurately.

It is known that the case $e^2qQ \sim \mu H$ is realized in YIG. Consequently, the expression

$$E_m = -g_{3/2}\mu_{nuc} mH + \frac{e^2qQ}{4I(2I-1)}[3m^2 - I(I+1)]\frac{3\cos^2\theta - 1}{2} \qquad (1)$$

for the determination of the hyperfine structure (hfs) levels of the nucleus is in general incorrect. Greatest interest attaches in this sense to the NGR spectrum of single-crystal YIG with orientation [100] in a longitudinal magnetic field $H_{\parallel}$. The value H was varied from 2 to 11 kG. The obtained NGR spectra constitute superpositions of three "quartets," since there are no lines corresponding to transitions with $\Delta m = 0$. One of the quartets corresponds to the atoms Fe^{57} in positions a and a', and the two others, designated by us d_1 and d_2, with an intensity ratio 1:2, correspond to Fe^{57} atoms in d-positions, for which $\theta = 0°$ and $\theta = 90°$ respectively (see the figure).

Indeed, it is impossible to interpret this spectrum under the assumption that formula (1) is valid (since this formula presupposes the equality of all the quantities $E_n(Q)$, where

$$E_n(Q) = \epsilon_n - E_n(H),$$

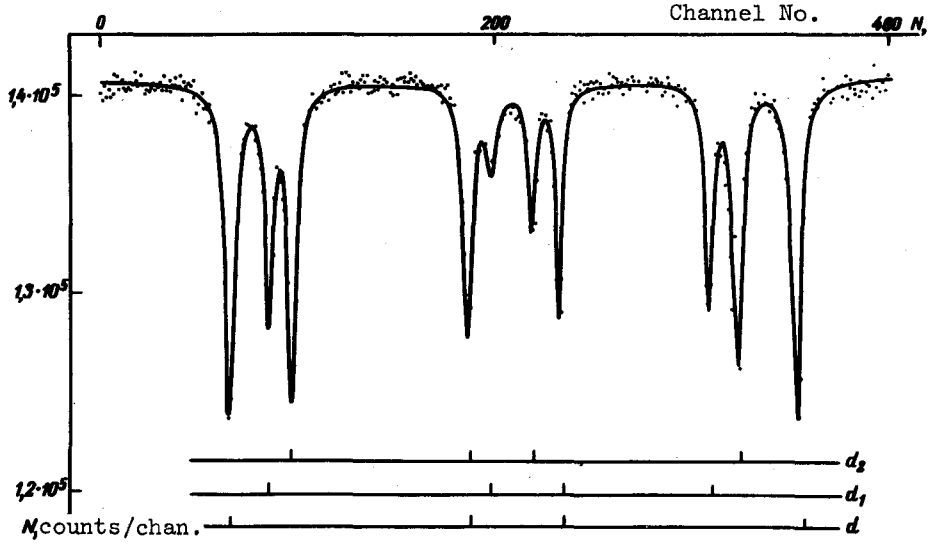
ϵ_n is the energy of the n-th level of hfs the nucleus in the excited state, n = 1, 2, 3, 4, and $E_n(H)$ is the energy of this level assuming the presence of magnetic interaction only). The parameters of the obtained spectrum are listed in the table.

To calculate the positions of the hfs levels of the nucleus, we must solve the secular equation with the Hamiltonian

$$\hat{\mathcal{H}} = -g_{3/2}\mu_{nuc} H\{\hat{I}_z\cos\theta - \frac{1}{2i}(I_+ - I_-)\sin\theta\} + \frac{e^2qQ}{4I(2I-1)}[3\hat{I}_z^2 - I(I+1)], \qquad (2)$$

	δ, mm/sec	$E_1(Q)$, mm/sec	$E_2(Q)$, mm/sec	$E_3(Q)$, mm/sec	$E_4(Q)$, mm/sec
$\theta = 0°$ d_1	0.16 ±0.02	−0.515 ±0.025	+0.515 ±1.025	+0.515 ±0.025	−0.515 ±0.025
$\theta = 90°$ d_2	0.16 ±0.02	+0.30 ±0.02	−0.17 ±0.02	−0.28 ±0.02	+0.16 ±0.02
Calculated data for d_2		+0.28 ±0.02	−0.20 ±0.02	−0.28 ±0.02	+0.20 ±0.02
$\theta = \arccos 1/\sqrt{3}$ a and a'	0.33 ±0.02	0.015 ±0.020	0.015 ±0.020	0.015 ±0.020	0.015 ±0.020

δ – chemical shift relative to Armco iron.



NGR spectra of single-crystal YIG cut perpendicular to [100]. The absorber is at room temperature in a longitudinal magnetic field of 11 kG.

where $I_\pm = I_x \pm iI_y$, and I_x, I_y, and I_z are the nuclear spin projection operators. The Hamiltonian was obtained assuming axial symmetry of the electric field gradient (EFG) tensor and expressed in a coordinate system coinciding with the system of principal axes of the EFG tensor. In the cases of interest to us, $\theta = 0°$ and $\theta = 90°$, the secular equations take respectively the form

$$(E_Q - 3E_H - \epsilon)(E_H + E_Q + \epsilon)(E_H - E_Q - \epsilon)(3E_H + E_Q - \epsilon) = 0,$$

$$\epsilon^4 - (10E_H^2 + 2E_Q^2)\epsilon^2 + 8E_H^2 E_Q \epsilon + (E_Q^4 + 2E_H^2 E_Q^2 + 9E_H^4) = 0,$$

where

$$E_H = \frac{1}{2} g_{3/2} \mu_{nuc} H, \quad E_Q = \frac{1}{4} e^2 qQ.$$

To calculate the coefficients of the secular equation, we used the values $e^2qQ/4 = 0.515$

mm/sec and H = 389 kG, obtained from the spectrum d_1, for which $\theta = 0°$ and, as follows from (3), expression (1) is valid. By solving Eq. (4) we obtained the following values of ε_n: $\varepsilon_1 = 4.382$ mm/sec, $\varepsilon_2 = 1.154$ mm/sec, $\varepsilon_3 = -1.648$ mm/sec, and $\varepsilon_4 = -3.888$ mm/sec. From this we readily find that $|E_1(Q)| = |E_3(Q)|$ and $|E_2(Q)| = |E_4(Q)|$, and, as seen from the table, all the calculated values of $E_n(Q)$ agree fully with experiment.

Thus, starting with the Hamiltonian (2) chosen by us, we calculated the levels of the hyperfine structure of the Fe^{57} nuclei in the d-sublattice of the garnet, and the agreement between the calculations and the experiment confirms the validity of our model, in which the energies of the quadrupole interaction are different for all the hfs levels. We have shown by the same token that to calculate the internal magnetic fields H when $E_n(Q) \neq 0$ it is necessary to use only the positions 2 and 4 or 3 and 5 of the spectral lines.

We have measured accurately, for the first time, the parameters of the quadrupole interaction in the d-sublattice at room temperature, something usually impossible to do because $\theta = \cos^{-1}(1/\sqrt{3})$ for these positions in the absence of an external field. The gradient of the electric field intensity in the d-sublattice at room temperature is $q = -2.1 \times 10^{24}$ cm^{-3}, for $Q = +0.33$ barn [3].

A determination of the degree of level "mixing" yielded a value on the order of several per cent, and therefore no additional lines were observed in the spectrum.

[1] C. Alff and G. K. Wertheim, Phys. Rev. 122, 1414 (1961).
[2] I. I. Van Loef, J. Appl. Phys. 39, 1258 (1968).
[3] A. Muir, Mossbauer data Index, 1965.

THERMAL SELF-FOCUSING OF LASER RADIATION IN MEDIA WITH NEGATIVE dn/dT

G. M. Zverev, E. A. Levchuk, E. K. Maldutis, and V. A. Pashkov

Submitted 5 January 1970
ZhETF Pis. Red. 11, No. 3, 177 - 181 (5 February 1970)

The propagation of laser radiation in weakly-absorbing media causes the latter to be heated and to experience a change in the refractive index. In media in which n increases with the temperature T, i.e., where $dn/dT > 0$, self-focusing is possible [1], while in media with $dn/dT < 0$ the laser radiation can become defocused [2].

Thermal self-focusing of the radiation of a pulsed laser was observed experimentally in ruby and sapphire crystals [3] and in colored glasses [4]. Self-focusing of radiation of CW lasers was also observed in glasses and lithium niobate crystals [5, 6]. In all these materials, $dn/dT > 0$[1)].

In substances for which $dn/dT < 0$, the thermal self-focusing is possible in principle for laser pulses of duration $\tau < \tau_0$ ($\tau_0 = a/v$, where a is the radius of the light beam and v the speed of sound), when the density of the medium in the light channel cannot change during the time of the pulse. Such a possibility was discussed in [7]. We note also the special case of self-focusing in beams having an intensity that increases towards the periphery [8].

We have previously observed [9] filament-like damage due to thermal self-focusing of

[1)] We refer to the experimentally measured dn/dT at constant pressure.