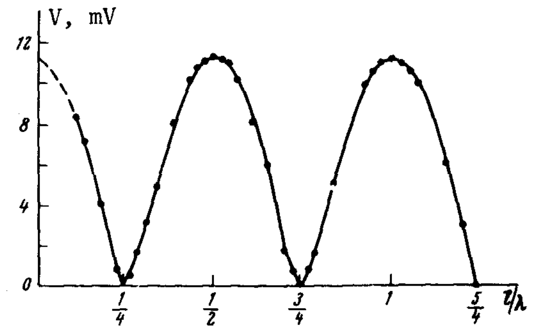

Fig. 3. Resonant value of dc emf vs the distance between the sample and the short-circuited waveguide wall.

magnetized disk was placed in the antinode of the magnetic field of the short-circuited waveguide. At a power less than 1 W, the emf was linear in the power.

As a check on the fact that the emf is caused by the microwave magnetic field, Fig. 3 shows the dependence of the resonant value of the dc emf on the distance between the transversely-magnetized disk and the short-circuited waveguide wall. The absence of a signal in the antinode of the microwave electric field indicates that the induced emf is of magnetic origin and there is no contribution from the possible small nonlinearity of the contacts.

Similar results were obtained with single crystals of other compounds, viz., Mg-Mn ferrospinels and $CdCr_2Se_4$ doped with silver.

The measured emf exceeds by three orders of magnitude the emf obtained from an estimate of the model of the anomalous microwave Hall effect [1 - 3]. The influence of the anomalous Hall effect can therefore be neglected.

Several causes of this emf can be suggested: (a) Scattering of the homogeneous precession by magnetic inhomogeneities (0-k process) excites spin waves. The emf is then the result of dragging of the carriers by the propagating spin waves. This dragging mechanism was considered theoretically in [5] for magnetic semiconductors. (b) The presence of a gradient of the amplitude of the alternating magnetization in the sample, due to the s-d exchange interaction, leads to inhomogeneous heating of the electrons, and the dc emf results from the redistribution of the electron density.

Magnetoelectric resonance can serve as a new method of investigating the properties of magnetic semiconductors, can possibly be used to detect microwave signals (filter-detector), for selective measurement of pulsed power or frequency, etc.

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STIMULATED LINE NARROWING AND THE MOSSBAUER EFFECT ON LONG-LIVED ISOMERS

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The possibility is considered of suppressing the inhomogeneous shift of the Mossbauer line of a long-lived nuclear isomer by placing the crystal in an external periodically-varying electromagnetic field with a specially chosen temporal waveform of the signal.

In real crystals there are a number of mechanisms that lead to broadening and inhomogeneous shift of the Mossbauer lines (ML) of long-lived nuclear isomers with lifetimes $\tau >> 10^{-6}$ sec [1 - 4]; these mechanism limit the accuracy of Mossbauer measurements. It is reported in [1], for example, that the inhomogeneous Mossbauer-line shift due to random electric and magnetic fields produced by defects and impurities is much larger than the natural line widths of long-lived isomers.

The purpose of the present paper is to show that it is possible in principle to suppress[1)] the inhomogeneous Mossbauer-level shift by placing the crystal in a periodically varying electromagnetic field with a signal of special waveform.

We consider the simplest model of a crystal with an inhomogeneous Mossbauer level shift. We assume that a nuclear isomer with spin S and magnetic moment μ goes over after emitting a γ quantum of energy E_0 into a state with zero spin. We assume furthermore that there exists in the crystal a random magnetic field that varies from site to site and leads to a splitting and inhomogeneous shift of the upper isomer level. We can introduce a quantity that characterizes this magnetic field, $\delta H_0 = [\overline{|\delta H(r_j)|^2}]^{1/2}$ (the superior bar denotes averaging over the lattice sites); the width of the Mossbauer line in the absence of an electromagnetic field can then be estimated at $\mu\delta H_0/\hbar$. The external electromagnetic field excites transitions between the sublevels of the oper isomer level; these sublevels have different spin projections on the z axis, so that the time-averaged magnetic moment of the nucleus, which characterizes the level shift, is decreased[2]. The ML is then split into a number of spikes, and the width of each spike may be much smaller than the initial width. Usually the spike width decreases with increasing distance between spikes. The Schrodinger equation describing transitions between the sublevels of the upper isomer level in the presence of an external periodic magnetic field has formal solutions in the form of Bloch functions:

$$\psi(t) = e^{-iE_j't/\hbar} \sum_k (C_k + \delta C_k(r_j))\, e^{2\pi ikt/T}, \tag{1}$$

where E_j' is, in accord with the terminology of [5], the quasi-energy of the isomer situated at the j-th site. The line-narrowing conditions can be written in the form

$$\beta = \left[\frac{\overline{(E_j' - \bar{E}_j')^2}}{\overline{(E_j - \bar{E}_j)^2}}\right]^{1/2} << 1. \tag{2}$$

Instead of one particle with spin S we introduce 2S fictitious particles with spin 1/2 [6]. The condition (2) is satisfied if the following condition is satisfied for any fictitious particle a:

$$\beta_a = \left[\frac{\overline{(E_{a_j}' - \bar{E}_{a_j}')^2}}{\overline{(E_{a_j} - \bar{E}_{a_j})^2}}\right]^{1/2} << 1, \tag{3}$$

where E_{a_j}' is the quasi-energy of the a-th fictitious paritcle.

The Schrodinger equation for the fictitious particle with spin 1/2 is of the form

$$\frac{d}{dt}\begin{pmatrix}\psi_1(t)\\ \psi_2(t)\end{pmatrix} = \frac{i\mu}{2S\hbar}\left[\begin{pmatrix}H_z(t); & H_x(t) - iH_y(t)\\ H_x(t) + iH_y(t); & -H_z(t)\end{pmatrix} + |\delta \mathbf{H}(\mathbf{r}_j)| \times \begin{pmatrix}\cos\alpha_j; & \sin\alpha_j\, e^{-i\phi_j}\\ \sin\alpha_j\, e^{i\phi_j}; & -\cos\alpha_j\end{pmatrix}\right]\begin{pmatrix}\psi_1(t)\\ \psi_2(t)\end{pmatrix} \tag{4}$$

where $H_x(t)$, $H_y(t)$, and $H_z(t)$ are the external magnetic fields, and α_j and ϕ_j are angles defining the direction of the perturbing magnetic field at the i-th site. It can be shown that without loss of generality one can express the matrix made up of the fundamental solutions of (4) in the zeroth approximation in $[\delta\vec{H}(\vec{r}_j)]$ in the form

$$X_0 = \begin{pmatrix}\cos(\gamma(t))\, e^{-iq(t)+i\lambda t}; & \sin(\gamma(t))\, e^{i\theta(t)-i\lambda t}\\ \sin(\gamma(t))\, e^{-i\theta(t)+i\lambda t}; & -\cos(\gamma(t))\, e^{iq(t)-i\lambda t}\end{pmatrix}, \tag{5}$$

where $\cos(\gamma(t)$, $\exp[iq(t)]$, and $\exp[i\theta(t)]$ are periodic functions with period T, and the functions $\gamma(t)$, $q(t)$, and $\theta(t)$ themselves have no imaginary parts. It will be more convenient to assume that the matrix (5) is given and use it to reconstruct $\vec{H}(t)$ from Eq. (4):

$$H_z(t) = \frac{2S\hbar}{\mu}[q'\cos^2\gamma - \theta'\sin^2\gamma - \lambda\cos 2\gamma], \quad (6)$$

$$H_x(t) = \frac{2S\hbar}{\mu}[\gamma'\sin(\theta - q) + \frac{1}{2}(\theta' + q' - 2\lambda)\sin 2\gamma\cos(\theta - q)], \quad (7)$$

$$H_y(t) = \frac{2S\hbar}{\mu}[\gamma'\cos(\theta - q) - \frac{1}{2}(\theta' + q' - 2\lambda)\sin 2\gamma\sin(\theta - q)]. \quad (8)$$

We choose λ to satisfy the condition $\lambda \gg \mu\delta H_0/2S\hbar$; the quasi-energy can then be expanded in powers of the parameter $\varepsilon = \mu\delta H_0/2S\hbar\lambda$:

$$\begin{aligned} E'_{a_i} = -\hbar\{\lambda + \frac{\mu}{2S\hbar}|\delta H(r_i)|[(\cos a_i W_1 + \sin a_i e^{-i\phi_i} W_2 + \sin a_i e^{i\phi_i} W_3) + \\ + \epsilon P_i(\cos^2 a_i W_4 + \cos a_i \sin a_i e^{-i\phi_i} W_5 + \cos a_i \sin a_i e^{i\phi_i} W_6 + \\ + \sin^2 a_i e^{-2i\phi_i} W_7 + \sin^2 a_i e^{2i\phi_i} W_8 + \sin^2 a_i W_9) + P_i^2 \epsilon^2(\cos^3 a_i W_{10}^{+}\ldots) + \\ + \epsilon^3 P_i^3(\ldots) + \ldots]\} \end{aligned} \quad (9)$$

where W_1, W_2, and W_n are functionals of the functions γ, q, and θ; $P_j = |\delta\vec{H}(\vec{r}_j)|/\delta H_0$.

It is relatively easy to choose γ, q, and θ such that W_1, W_2, and W_3 vanish. To this end it is necessary to satisfy the conditions

$$\overline{\cos(2\gamma(t))} = 0, \quad (10)$$

$$\overline{\sin(2\gamma(t))e^{iq(t) - i\theta(t)}} = 0 \quad (11)$$

the superior bar denotes here averaging with respect to time. Putting

$$\gamma(t) \equiv \pi/4; \quad q(t) = 2\pi t/T; \quad \theta(t) = -2\pi t/T \quad (12)$$

we can obtain one of the solutions satisfying the conditions (10) and (11). For solutions of the type (14) we have $\beta_a \sim \varepsilon \ll 1$.

We can choose γ, q, and θ such that not only the coefficients W_1, W_2, and W_3 vanish, but also all the coefficients of the terms of order ε and ε^2. An example of such a solution is

$$\begin{cases} \gamma(t) = \frac{\pi}{4} \\ q(t) = \frac{2\pi t}{T} + c_1 \sin\frac{48\pi t}{T}, \\ \theta(T) = -\frac{2\pi t}{T} + c_2 \sin\frac{48\pi t}{T} \end{cases} \quad (13)$$

where c_1, c_2, and $\alpha = \lambda T/2\pi$ satisfy the system of transcendental equations

$$\begin{cases} \dfrac{\mathcal{J}_0^2(2c_1)}{2(\alpha - 1)} + \sum\limits_{k=1}^{\infty} \mathcal{J}_k^2(2c_1) \dfrac{\alpha - 1}{(\alpha - 1)^2 - 144k^2} = 0 \\ \dfrac{\mathcal{J}_0^2(2c_2)}{2(\alpha + 1)} + \sum\limits_{k=1}^{\infty} \mathcal{J}_k^2(2c_2) \dfrac{\alpha + 1}{(\alpha + 1)^2 - 144k^2} = 0, \\ \dfrac{\mathcal{J}_0^2(c_1 + c_2)}{2\alpha} + \sum\limits_{k=1}^{\infty} \mathcal{J}_k^2(c_1 + c_2) \dfrac{\alpha}{\alpha^2 - 144k^2} = 0 \end{cases} \qquad (14)$$

One of the solutions of the system (14) is $2c_1 \approx 2.3$, $2c_2 \approx 2.5$, $\alpha \approx 0.02$.

For solutions of the type (13) we have $\beta_a \sim \varepsilon^3$. For example, if we grow a crystal in which the inhomogeneous ML shift due to a random perturbing magnetic field does not exceed $\Delta\omega = 10^3$ sec, then by placing the crystal in an alternating magnetic field corresponding to the solution (13) with $T = 10^{-6}$ sec we could decrease the line width by 5 - 6 orders of magnitude.

The case considered here can, of course, not be regarded as proof that the ML width can be decreased in more realistic crystal models in which other broadening and inhomogeneous-shift mechanisms besides the magnetic-dipole one are taken into account. It should be noted, however, that formulas of the type (1) and (9) remain in force for all broadening mechanisms, so that the problem of choosing an external electromagnetic field that minimizes the quasienergy dispersion is meaningful for any crystal model.

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1) With the exception of the so-called "monopole" inhomogeneous shift.

2) The idea of "time averaging" the dipole-dipole interaction for a laser based on Mossbauer isomers was advanced in [2]; see [7] concerning EPR line narrowing.

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STATIONARY "POTENTIAL WELL" FOR PLASMA IONS

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It is shown experimentally that a stationary "potential well" can be produced for the ions of a plasma produced in crossed axially-symmetric electric and magnetic fields of "mirror" geometry with a stabilizing magnetic field of opposite sign. The well "depth" reaches -700 V, or as much as 60 - 65% of the applied voltage.

It was shown theoretically in [1] that in a plasma placed in an exter-nal field the magnetic induction lines become exponential if the electron Larmor radius is much smaller than the