OBSERVATION OF THE SUPPRESSION OF THE INELASTIC CHANNEL OF A NUCLEAR REACTION IN RESONANT NUCLEAR SCATTERING OF GAMMA RAYS IN A PERFECT SINGLE CRYSTAL

V. K. Voitovetskii, I. L. Korsunskii, A. I. Novikov, and Yu. F. Pazhin
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We have previously observed and investigated a particular case of effective suppression of the inelastic channel of a nuclear reaction for γ-rays [1], which was predicted theoretically by Kagan and Afanas'ev on the basis of concepts they developed concerning the interaction of resonant radiation with nuclei in an ideal crystal [2].

The gist of this effect is that when resonant radiation is scattered in an ideal crystal, where the Bragg conditions are satisfied, the amplitude of compound-nucleus production should vanish and, as a result the nuclear-reaction channel (electron conversion in the case of γ rays) should be suppressed. This process is realized rigorously for one polarization of the γ quanta and is realized approximately under definite conditions for another polarization. The experimental geometry in [1] was specially chosen (small scattering angle) to cause the suppression effect to appear also for the other polarization.

In [1] we observed an appreciable attenuation of the resonant absorption of Mossbauer radiation passing at the Bragg angle through a tin single crystal of natural isotopic composition[1)]. In such a crystal, the coherent part of the amplitude for the scattering of the γ quanta by the nuclei at resonance, $|f^r_{nuc}|$, is smaller than the coherent part of the amplitude f_e of electron scattering, and the formation of the wave fields is connected to a considerable degree with scattering by electrons.

The greatest interest attaches, naturally, to observation of the suppression of the elastic channel under conditions when the nuclear resonant scattering is decisive ($|f^r_{nuc}| > f_e$). This effect is possible only if the excitation of the nuclei in the crystal has a collective character and the excitation is "smeared out" over the crystal [3].

To observe the effect of the nuclear-reaction channel suppression for this case, and also to investigate all the possible mechanisms of wave-field formation leading to the suppression of the inelastic channels in the crystal, we have performed an experiment with a perfect tin single crystal containing 88% Sn^{119} ($|f^r_{nuc}| > f_e$ in a crystal with this Sn^{119} content).

The experimental setup is shown in Fig. 1. The intensity of the reflected beam was investigated as a function of the relative velocity of the γ-ray source and of the Sn^{119} crystal in a Laue geometry. The experimental setup is identical with that reported in [1], but the monochromator-crystal was replaced by a multiple-slit collimator with a divergence angle 5', making it possible to separate in the reflected beam, without loss of intensity, the

[1)] Under the experimental conditions $\mu_{nuc} t = 64$ for resonant radiation (μ_{nuc} - coefficient of resonant nuclear absorption, t - crystal thickness.

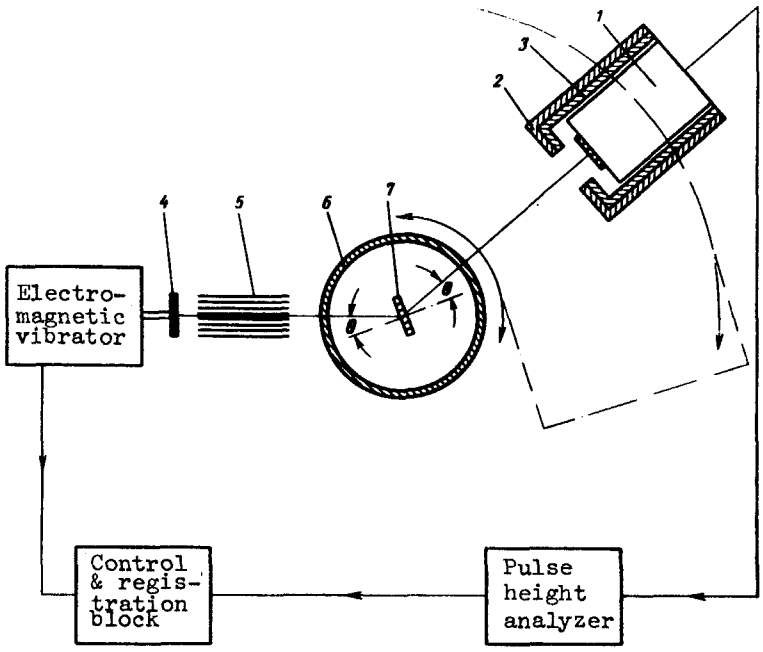

Fig. 1. Experimental setup: 1 - scintillation counter, 2 - lead screen, 3 - steel screen, 4 - $Sn^{119m}O_2$ source, 5 - multislit collimator, 6 - cryostat vacuum chamber, 7 - Sn^{119} crystal.

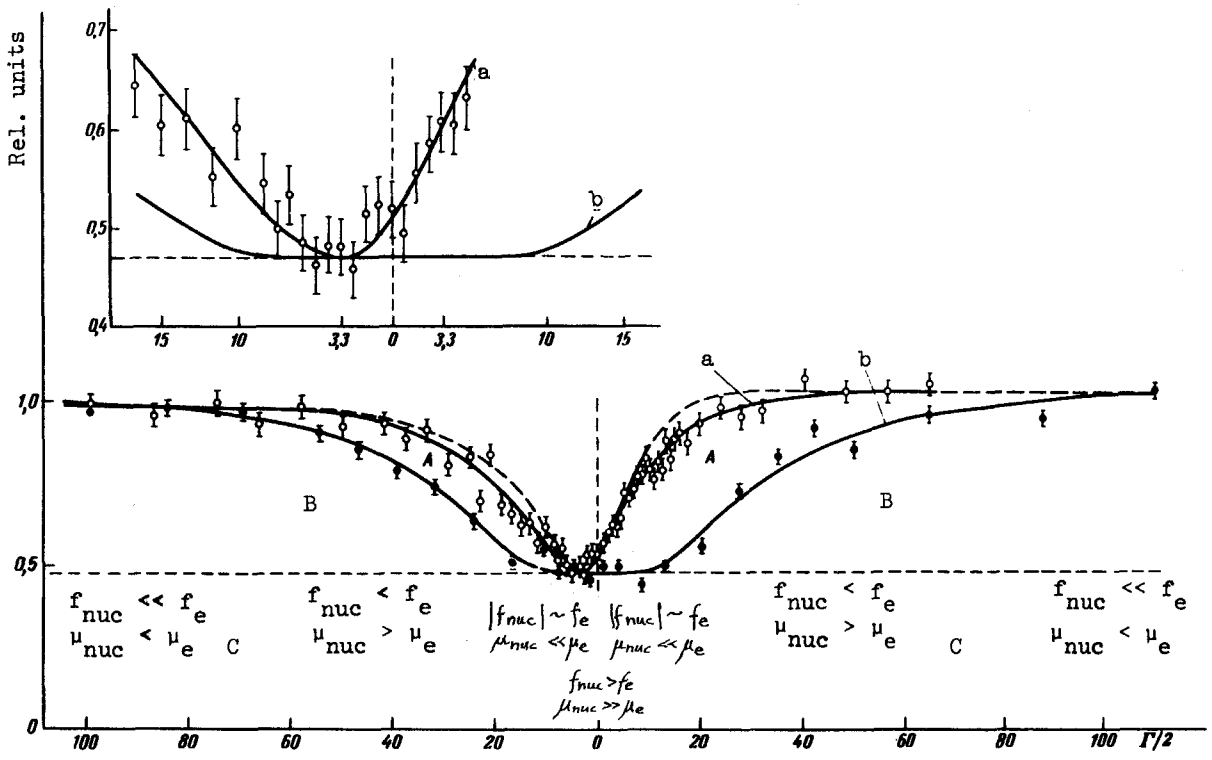

Fig. 2. Intensity of Sn^{119m} γ-radiation reflected upon Laue diffraction in single-crystal Sn^{119} (a) and transmitted through the crystal at an angle different from the Bragg angle (b) vs. the relative velocity of the source and crystal. Dashed line - calculation [2]; the solid curves a and b are drawn through the experimental points.

23.8 keV γ radiation. The crystal was 420 μ thick and was grown from specially purified material. The reflection was from the (200) planes. The crystal temperature was 90°K.

Figure 2 shows the experimental Mossbauer spectrum of the reflected radiation (a). (The dashed line corresponds to a computer calculation performed by A. M. Afanas'ev and V. G. Kon on the basis of the dynamic theory [2]). It differs greatly from the Mossbauer absorption spectrum (b) obtained for the same crystal, but with the γ rays incident on the crystal at an angle different from the Bragg angle. The difference between these two spectra shows clearly the effect of suppression of the inelastic channel of the nuclear reaction. It is obviously this effect which causes the excess intensity of the radiation transmitted through the crystal in the spectrum a (region A in Fig. 2).

Of particular interest is a comparison of the curves in the resonance region ($|f_{nuc}| \geq f_e$, $\mu_{nuc} >> \mu_e$, μ_e - photoabsorption coefficient). We note first the fact that in this part of spectrum a, where the independent absorption by individual nuclei is maximal (for the resonant energy) $\mu_{nuc} t = 640$ and the formation of the wave fields occurs principally as a result of nuclear scattering, the absorption is strongly attenuated. This can be only the results of suppression of the inelastic channel, due in this case, as already noted, to the collective character of the excitation of the nuclei.

The sharp asymmetry of absorption near resonance in spectrum a is due to the change of the total scattering amplitude as a result of interference between the electron and nuclear scattering. On the left of the resonance, at an energy shift $\Delta E = 3.3\Gamma/2$ (Γ - natural width), the real part of the total scattering amplitude should vanish, thereby greatly reducing the absorption effect. Indeed, as seen from the figure, at this value of the energy shift the resonant absorption in spectrum a is maximal and coincides, within the limits of measurement accuracy, with the absorption by individual nuclei (curve b). On the right of the resonance, to the contrary, the intensity of the transmitted radiation in spectrum a increases, owing to the increase of the summary amplitude. We emphasize that the independent absorption by individual nuclei, in spite of the fact that the electron and nuclear scattering interfere in this case, is symmetrical relative to the resonance position (curve b).

That region of the spectrum, in which $|f_{nuc}| < f_e$ but $\mu_{nuc} > \mu_e$, corresponds to the mechanism of the effect observed in [1], where the resonant absorption is suppressed, but the wave fields are produced in the crystal mainly as a result of scattering by the electrons. With increasing distance from the resonance, an ever increasing role is played by the atomic analog of the effect of suppression of the inelastic channel of the nuclear reaction - the Borrmann effect (region B in Fig. 2). In the Borrmann effect, the wave fields are formed upon scattering the electron shells, and the photoeffect is suppressed (the photoeffect is suppressed also in the case of the purely nuclear or mixed mechanism of wave-field formation). For the non-Mossbauer part of the γ radiation, the Borrmann effect occurs naturally at any value of the energy shift (region C in Fig. 2).

The theoretical curve duplicates all the features of the experimentally observed Mossbauer spectrum of the reflected radiation. The slight disparity between the calculated and experimental relations may be due to the fact that the crystal was not perfectly ideal.

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SELF-FOCUSING FILAMENTS AS A RESULT OF THE MOTION OF FOCAL POINTS

V. V. Korobkin, A. M. Prokhorov, R. V. Serov, and M. Ya. Shchelev
P. N. Lebedev Physics Institute, USSR Academy of Sciences
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The question whether the filaments produced in self-focusing [1, 2] are the results of motion of individual focal points, as proposed in [3, 4], or whether these filaments exist as stationary formations, as proposed in [5 - 7], has been the subject of lively discussion in the recent literature.

An experimental verification of the correctness of either of these two points of view is far from a simple matter. It was first shown in [8 - 9] that the self-focusing filaments exist in liquids a very short time, $\sim 10^{-9} - 10^{-10}$ sec. In [10 - 12], self-focusing filaments were observed as a result of the motion of individual points. However, the results of [10 - 12] cannot be interpreted unequivocally in favor of the theory of focal points. The difficulty lies here in the fact that even in the case when the stationary theory is valid, the large radiation density inside the self-focusing filament can lead to a strong heating [9] and even to destruction [11] of the medium, owing to various nonlinear effects, plasma formation [13], etc. These phenomena alter radically the properties of the medium and lead to a rapid disintegration of the filament, as a result of which its length at some particular instant of time may be very small. When the laser power is varied, the starting point of such a short self-focusing filament will shift in the medium, thus creating the illusion of a moving focus. Moreover, the entering laser beam may break up into individual transverse regions with subsequent self-focusing of each of these regions [8, 13, 14]. In this case, even in the framework of the theory of stationary filaments, it is possible to explain the simultaneous existence of several moving foci. These foci will move in the medium, however, along different trajectories, separated by distances on the order of the dimension of the transverse-breakdown region ($\sim 50 - 100$ μ [13]).

To check on the validity of the two self-focusing theories, the authors used an electron-optical converter (EOC) to investigate to kinetics of self-focusing in liquids. The experimental setup is shown in Fig. 1.

The radiation from a single-mode (one angular and one axial mode) laser passed through a cell of length $\ell = 10$ cm, filled with nitrobenzene or carbon disulfide. The radiation entering the cell had a plane phase front with an approximately Gaussian transverse distribu-