sults show that the presence of such bridges does not change qualitatively the picture of the Josephson effect.

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INTERFERENCE OF CONVERSION AND PHOTOEFFECT PROCESSES UPON ABSORPTION OF MOSSBAUER RADIATION

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1. An interesting phenomenon takes place when resonant γ radiation interacts with atoms. We have in mind the fact that two inelastic processes occurring on the same atom - conversion and photoeffect - can interfere with each other. For this to happen it is necessary that the final states be strictly identical in both cases, i.e., that they be physically indistinguishable. It is possible to distinguish between these processes only if the spin of the nucleus changes during the conversion process. Otherwise photoeffect and conversion are indistinguishable.

In principle, interference of these inelastic processes can be observed by measuring the differential cross section of the (γ, e) reaction, or even in ordinary measurements of γ-quantum absorption - in both cases as functions of the velocity of the source relative to the absorber in Mossbauer-type experiments. (The conversion amplitude changes and the amplitude of the photoeffect remains unchanged with changing velocity.)

2. The amplitude of conversion with absorption of a γ quantum having a wave vector $\vec{k}$ and with emission of an electron with momentum $\vec{p}$, accompanied by a transition of the atom from the ground state to the state α, and of the phonon spectrum from the state $\{n_0\}$ to the state $\{n\}$, can be written in the form

$$f_{c_{ii'}} = f^{0}_{c_{ii'}}(\mathbf{k};\ \mathbf{p},\ \alpha)(e^{i\mathbf{k}\mathbf{u}})_{\{n_0\}\{n\}}(e^{-i\mathbf{p}\mathbf{u}})_{\{n_0\}\{n\}}. \tag{1}$$

Here i, i' are the initial and final values of the projection of the ground state of the nucleus and $\vec{u}$ is the displacement of the atom. The index "0" denotes the amplitude corresponding to a rigidly secured nucleus.

For the photoeffect we have analogously

$$f_{ph} = f^{0}_{ph}(\mathbf{k};\ \mathbf{p},\ \alpha)(e^{i(\mathbf{k}-\mathbf{p})\mathbf{u}})_{\{n_0\}\{n\}}. \tag{2}$$

For the coherent part (i' = i) of the differential cross section of the process (γ, e) we get

$$d\sigma_{\gamma e}^{coh} = \frac{1}{2I_0+1}\sum_{\alpha,l}\sum_{\{n\}}|f_{c_{ll}} + f_{ph}|^2 d\Omega_p.$$

Summing over {n} in explicit form, we obtain directly

$$d\sigma_{\gamma e}^{coh} = \frac{1}{2I_0+1}\sum_{\alpha,l}\{|f_{ph}^{\circ}|^2 + e^{-Z(k)}|f_{c_{ll}}^{\circ}|^2 + + e^{-Z(k)}2\mathrm{Re}(f_{c_{ll}}^{\circ} f_{ph})\}d\Omega_p. \quad (3)$$

Here $e^{-Z(k)}$ is the ordinary probability of the Mossbauer effect. The interference term (the third term in the curly brackets) has the same temperature dependence as the conversion cross section.

Interference always takes place for each fixed final state α of the atom. On the other hand, the presence of a sum over α in (3) can lead to a strong decrease of the interference term. The degree of decrease depends significantly on the multipolarities of the nuclear transition and the photoeffect. The latter circumstance becomes particularly critical as we go over to the total cross section.

Recognizing that the photoeffect has predominantly a dipole character in the γ-quantum energy region of interest to us, it is easy to understand that the interference in the total cross section, and consequently also in the picture of γ-absorption in matter, can have a significant magnitude only for nuclear transitions of the E1 type (otherwise the states of the knocked-out electrons differ in angular momentum or in parity). In this case the amplitudes f_{ph}^0 and $f_{c_{ii}}^0$ (at any rate, neglecting relativistic effects) are strictly proportional to each other, the proportionality coefficient being independent of $\vec{p}$ or α. Because of this, a large interference term remains also in the integral cross section.

We shall write out below directly an expression for the total absorption cross section σ_t, which includes besides $\sigma_{\gamma e}^{coh}$ also the incoherent cross section of $\sigma_{\gamma e}^{incoh}$ conversion accompanied by a change in the spin of the nucleus, and also the cross section $\sigma_{\gamma\gamma}$ of elastic scattering by the atom. Taking into account the resonant character of the conversion amplitude $f_c^0 \sim 1/(E_\gamma - E_0 + i\Gamma/2)$, we have

$$\sigma_t = \sigma_{\gamma e}^{coh} + \sigma_{\gamma e}^{incoh} + \sigma_{\gamma\gamma} = \sigma_{ph} + e^{-Z(k)}\sigma_0 \frac{\Gamma^2/4}{(E_\gamma - E_0)^2 + \Gamma^2/4} + e^{-Z(k)}[\zeta\frac{\alpha}{1+\alpha}\sigma_0\sigma_{ph}]^{1/2}\frac{\Gamma(E_\gamma - E_0)}{(E_\gamma - E_0)^2 + \Gamma^2/4} \quad (4)$$

Here σ_{ph} - photoabsorption cross section, σ_0 - total nuclear cross section at resonance; Γ - width of resonant level E_0; α - conversion coefficient; $\zeta = (2I + 1)/3(2I_0 + 1)$ - ratio of the coherent part of the conversion cross section σ_c to the total part, and I, I_0 - spins of the nuclei in the excited and ground states. In writing out formula (4) we have retained in $\sigma_{\gamma\gamma}$ only the term corresponding to nuclear scattering. The cross section $\sigma^{e}_{\gamma\gamma}$ for scattering by electrons is as a rule much smaller than σ_{ph}. Actually, owing to interference between the nuclear and electron scattering $\sigma_{\gamma\gamma}$ contains interference terms having a dependence on E_γ similar to that in the last term of (4). This term is $\sim(\sigma^{0}_{\gamma\gamma}/\sigma_{ph})^{1/2}$ times the last term of (4) and can thus be neglected.

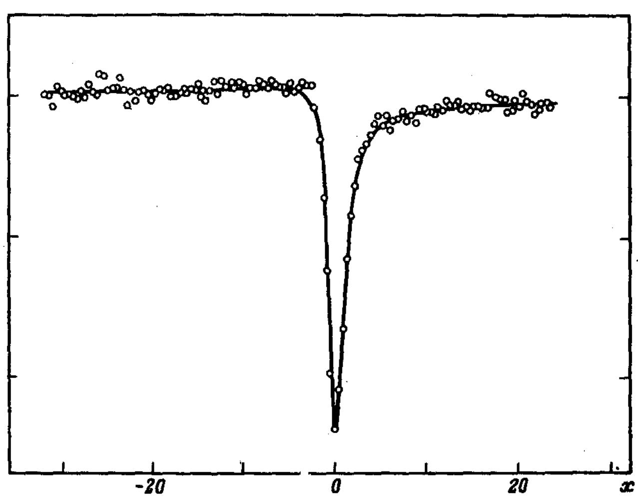
3. As is well known, most Mossbauer nuclei are characterized by transitions of the M1 and E2 type. This is precisely the reason why the interference between the photoeffect and conversion was not observed in experiments performed until most recently. However, in a recent investigation by Sauer et al. [1], the presence of a sharp asymmetry, the nature of which remained unclear, was observed in the absorption curve for the Mossbauer emission of Ta^{181} ($E_\gamma = 6.2$ keV). The considered transition in the tantalum was E1. This allows us to state that the observed picture is a direct consequence of the interference between the photoeffect and the conversion.

To compare the experimental data with the theoretical results it is necessary to take into account the line broadening in the source and in the absorber, a broadening particularly strong in the case of Ta^{181}. Assuming that the broadening is due to the random scatter of the center of the line in the source and in the absorber and has a Lorentz character, and carrying out the corresponding averaging of Eq. (4), we obtain

$$\sigma_t = \sigma_{ph} + e^{-Z(k)}\sigma_0 \frac{\Gamma\Gamma_0/4}{(E_\gamma - E_0)^2 + \Gamma_0^2/4} + e^{-Z(k)}\left[\zeta \frac{\alpha}{1+\alpha}\sigma_0\sigma_{ph}\right]^{1/2} \times \frac{\Gamma(E_\gamma - E_0)}{(E_\gamma - E_0)^2 + \Gamma_0^2/4}, \qquad (5)$$

where Γ_0 - experimentally observed width.

As follows from (5), the relative variation of the energy-dependent part of the absorption is a universal function of the parameter $x = 2(E_\gamma - E_0)\Gamma_0$.



The figure shows a plot of $e^{Z(k)}(\Gamma_0/\Gamma)(\sigma_t - \sigma_{ph})/\sigma_0$ against this parameter for the case of Ta^{181} ($\alpha = 44$, $\sigma_0 = 1.7 \times 10^{-18}$ cm^2 [2], $\sigma_{ph} = 8.8 \times 10^{-20}$ cm^2 [3]).

The points represent the experimental data of [1]. The theoretical curve was aligned with the experimental points at the maximum of absorption and Γ_0 was chosen to be $9 \times 2\Gamma$. It is seen from the figure that the theoretical and experimental results are in splendid agreement.

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