QUADRUPOLE DIFFRACTION MAXIMA IN MOSSBAUER SCATTERING

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We show in this paper that in the case of Mossbauer scattering of gamma quanta there exist purely nuclear (quadrupole) diffraction maxima resulting from the dependence of the amplitude of the resonant scattering on the electric field gradient (EFG) at the scattering nucleus [1]. Their existence is possible if the Mossbauer nuclei located in the scatterer at crystallographically equivalent positions are acted upon by EFG having different orientations of the principal axes. In this case the Mossbauer-isotope atoms situated in crystallographically equivalent positions, which are identical in Rayleigh scattering, act effectively as different scatterers in the case of resonant scattering. The structural scattering amplitude F of such crystals can be represented in the form

$$F = F_r(\mathbf{k}-\mathbf{k}') + \sum_{m,q} f_r^q(\mathbf{k}-\mathbf{k}')\exp[i(\mathbf{k}-\mathbf{k}')\mathbf{r}_{mq}, \tag{1}$$

where F_r is the Rayleigh x-ray structure amplitude, f_r^q is the amplitude of the coherent Mossbauer scattering, m numbers the nuclei in positions with the q-th orientation of the EFG axes within the limits of the unit cell, and $\vec{k}$ and $\vec{k}'$ are the wave vectors of the initial and scattered gamma quanta. From (1) we get that the condition for the existence of a Bragg maximum corresponding to the reciprocal-lattice vector $\vec{\tau}$ is the satisfaction of at least one of the inequalities

$$F_r(\vec{\tau}) \neq 0, \qquad \sum_m \exp(2\pi i \mathbf{r}_{qm}\vec{\tau}) \neq 0. \tag{2}$$

It follows from (2) that the vectors $\vec{\tau}$, for which the second inequality of (2) is fulfilled, and for which $F_r(\vec{\tau}) = 0$, correspond to purely nuclear quadrupole maxima, which are missing from Rayleigh scattering. In view of the translational symmetry properties of the crystals, the quadrupole maxima can correspond only to reflections of the particular type $hh\ell$ or $ok\ell$, and cannot correspond to reflections $hk\ell$. We note that there is no known analog of quadrupole maxima in the scattering of other types of radiation. In this connection, the quadrupole maxima may turn out to be a useful source of information concerning the structure of the crystals. It is to be expected that the experimental difficulties of detecting quadrupole maxima are of the same order as in the case of nuclear magnetic maxima [2]. As an object for the observation of quadrupole maxima we suggest, for example, the crystal $ZnFe_2O_4$. The iron atoms in this compound occupy the position 16d, in which the EFG principal axes have four different orientations [2]. From (2) we get that the pure nuclear, quadrupole reflections for $ZnFe_2O_4$ are $ok\ell$ with $k = 4n + 2$ and $\ell = 4m$, where n and m are arbitrary integers. For the 14.4-keV transition in Fe^{57}, the Bragg angle of the first quadrupole reflection 002 equals 5°50'.

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NONLINEAR EFFECTS IN A SUPERCONDUCTOR IN AN ALTERNATING FIELD

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When the temperature of a superconductor approaches the critical value, nonlinear effects assume a role even in weak alternating external field, since the critical field of the superconductor tends to zero. Using the calculation method developed in [1], we investigated several such nonlinear effects, viz., generation at the frequency $3\omega_0$ and generation of combination frequencies, and we calculated the surface impedance of a superconductor in a strong alternating electromagnetic field.

It was assumed that the superconductor is pure with respect to its equilibrium properties, $\ell >> \xi_0$, but contains a small amount of impurities, so that the skin effect is normal, $\delta_s >> \vec{\ell}$ (ℓ is the mean free path, δ_s the depth of penetration of the field, and ξ_0 the correlation parameter). In the temperature region $1 - T/Tc << \kappa^2$ this makes it possible to write down for the current the expression (τ is the free path time):

$$j(q\omega) = -\frac{c}{4\pi}K(\omega)A(q\omega) = -\frac{Ne^2}{mc}\left[\frac{7\xi(3)}{4}\left(\frac{\Delta}{\pi T}\right)^2 - i\omega\tau\right]A(q\omega). \tag{1}$$

In order for the question to be of experimental interest, the region $1 - T/T_c << \kappa^2$ is assumed to be sufficiently large ($\kappa \sim 1$). It is known [2] that the behavior of a superconductor in an alternating field depends on the ratio of the frequency of the external field ω_0 to the frequencies Ω_1 and Ω_0 characterizing the dynamic behavior of the electromagnetic field and of the parameter $\Delta(r, t)$. In our case, using (1) and the formulas of [3], it can be shown that

$$\Omega_1 \sim \frac{1}{\tau T_c}\frac{\Delta^2}{T_c}, \quad \Omega_0 \sim \frac{\Delta^2}{T_c}, \quad \Omega_1 << \Omega_0. \tag{2}$$

Using the results of [1], we can also show that at external-field frequencies $\omega_0 << \Omega_0$ the gap responds to the instantaneous value of the field, and satisfies at temperatures $1 - T/T_c << \kappa^2$ the Ginzburg-Landau equation, in which, however, the field depends on the time as a parameter. At frequencies $\omega_0 >> \Omega_0$ we can use for the alternating part of $\Delta(r, t)$ the equation obtained in [4]. These equations form, in conjunction with Maxwell's equation, a closed nonlinear system whose solution was obtained by perturbation theory using the small parameter H_0/H_c, where H_0 is the amplitude of the external field and $H_c(T)$ is the critical field.

1. Third-harmonic generation. If an electromagnetic wave of frequency ω_0 is incident on the superconductor, then the presence of the harmonic $2\omega_0$ in the oscillations of the gap gives rise to a current of frequency $3\omega_0$, leading to radiation of the corresponding field harmonic. We calculated the power conversion coefficient $\eta(3\omega_0) = |\alpha(3\omega)|^2 = |E_{ref}(3\omega_0)/E_{inc}(\omega_0)|^2$ for the case of a half-space. The expression obtained for $\alpha(3\omega_0)$ is: