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FERMI RESONANCE IN RAMAN SCATTERING OF LIGHT BY POLARITONS IN AN α-HIO$_3$ CRYSTAL

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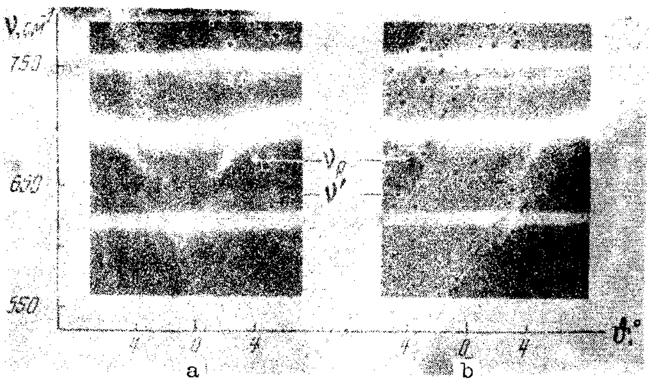
Polariton Fermi resonance occurs when the frequency ν' of the dipole-active vibration of the crystal lattice (in the general case, of any order) is close to the frequency $\nu_p(\theta)$ of a polariton of the same symmetry.

This communication is devoted to the first observation of polariton Fermi resonance in Raman scattering of light by polaritons in the biaxial crystal α-HIO$_3$, which belongs to the point symmetry 222. This phenomenon occurs when the polariton branch $\nu_p(\theta)$ connected with the dipole active phonon B_1 ($\nu_p(\theta=90°) = 736$ cm^{-1} [3]) crosses the branch of two bound photons of symmetry B_2 and B_3, which form upon binding a state with symmetry $B_2 \times B_3 \times A = B_1$ and with frequency $\nu' \simeq 650$ cm^{-1} (a weak vibration of symmetry B_1 at frequency ~ 650 cm^{-1} was observed in absorption [3]). The crossing of the branches of the bound state of two phonons and a polariton was attained by suitable choice of the directions of polarization and propagation of the exciting radiation in the crystal, with allowance for the polariton character of the optical-phonon dispersion. The scattering of light by polaritons was observed with the aid of a photographic technique wherein the spectrograph slit was placed in the focal plane of a lens located behind the investigated sample.

The figure shows the frequency vs. angle spectra of the Raman scattering of light in an α-HIO$_3$ crystal when the exciting radiation of an argon laser ($\lambda_0 = 5145$ Å) propagates in the principal plane YZ of the crystal at an angle $\theta = 32°$ (a) and 39° (b) to the crystallographic axis Z (the designation of the crystallographic axes corresponds to the condition $N_X \gtrsim N_Y > N_Z$, where N_i are the principal values of the refractive indices of the crystal), where θ is the angle between the directions of the wave vectors $\vec{k}_0$ and $\vec{k}_s$ of the exciting and scattered radiation, and ν is the frequency shift of the scattered Stokes radiation. The exciting radiation was polarized perpendicular and the spectrograph slit was parallel to the crystallographic X axis.

The three intense horizontal lines in the figure, with frequencies 633, 715, and 782 cm^{-1}, correspond to the Raman scattering of light by the nonpolar lattice vibrations of symmetry A [3], whose scattering frequency does not depend on the scattering angle θ.



Frequency vs. angle spectrum $\nu_p(\theta)$ of light scattering by polaritons in an α-HIO_3 crystal excited by a laser with λ = 5145 Å; ν is the frequency shift of the scattered Stokes radiation, θ is the angle between the directions of the wave vectors of the exciting and scattered radiation, and Θ is the angle between the wave vector of the exciting radiation and the crystallographic axis Z: a) $\Theta = 32°$, b) $\Theta = 39°$.

It is seen from the figure that the polariton branch $\nu_p(\theta)$ experience doublet splitting with $\delta\nu \simeq 10$ cm^{-1} in the vicinity of the weaker vibration $\nu' \simeq 650$ cm^{-1}, and a redistribution of the intensity of the scattered light in the ν' branch and in the polariton branch $\nu_p(\theta)$ take place. As the angle increases from $\theta = 0°$ and the frequency $\nu_p(\theta)$ approaches ν', the scattering intensity becomes much weaker and eventually goes over into the corresponding (weak) line of the pure Raman scattering by the lattice vibrations with frequency ν'.1) Further, near $\nu_p(\theta) \approx \nu' + \delta\nu$, a short wave component of the polariton branch arises and its intensity increases with increasing distance between $\nu_p(\theta)$ and $\nu' + \delta\nu$, and rapidly becomes predominant. In the resonance region, the contributions of both branches to the scattering intensity becomes of the same order of magnitude. It should be noted that the observed behavior of the polariton branch $\nu_p(\theta)$ agrees well qualitatively with the theoretical deductions of [1, 2], but quantitative comparisons are made difficult by the lack of published values of the α-HIO_3 crystal parameters needed for the calculations.

We note that the observed phenomenon can be apparently regarded as experimental proof of the existence of a bound state of two phonons in the α-HIO_3 crystal, for in the absence of a bound state at frequency ν' there should be no splitting (gap) observed in the polariton spectrum, according to [2]. We note that the crossing of the polariton branch and a phonon line of second order was observed earlier in the $K_3Cu(CN)_4$ crystal [4], but only exchange in the intensities of the scattered radiation by the polariton and in the phonon replica was observed there, and the question of the existence of a gap in the polariton spectrum remained unanswered.

In conclusion, the authors are grateful to A.M. Prokhorov and N.N. Sobolev for support and to G.F. Dobrzhanskii for supplying the α-HIO_3 crystals.

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CONSERVATION OF WAVE FRONT IN STRONGLY DEFORMED SOLID MEDIA

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It is known that optical pumping of laser media cause thermo-optical strains that disturb the homogeneity of the medium. These strains give rise to many phenomena (thermal lens, birefringence, rotation of the plane of polarization) that distort the field inside an optical resonator and disturb the coherence of the laser emission.

We consider here optical resonators in which oscillations that conserve the shape of the wave front can exist in active media that are strongly and uniformly deformed over their entire length.

The simplest variants of such resonators, which we shall call "waveguide resonators," are shown in Fig. 1. The active element, in the form of a flat plate, has polished side faces. The light enters the active element through the end face at a certain angle, experiences total reflection from the side faces, and emerges through the other end face. These oscillation modes can be classified in accordance with the number of reflections from the side faces and in accordance with the sign of the angle at which the beam is incident on the end face. For example, mode "0" corresponds to the lowest mode of the ordinary Fabry-Perot resonator.

The individual modes are separated by rough-grinding definite sections of the side faces, which do not take part in the reflection (the dull ground sections are shown in Fig. 1 by the wavy lines).

The light beam can pass not only parallel to the side faces, but also at an arbitrary angle. In this case all four side faces must be polished, since the beam can experience multiple reflection from all faces before emerging from the second end face. Such modes must be designated by two indices (±1/±1, ±1/±2, ±2/±2, etc.).

It is possible to consider in similar fashion more complicated resonators of the waveguide type, with the sample made in the form of a polyhedron that is developable into a surface.

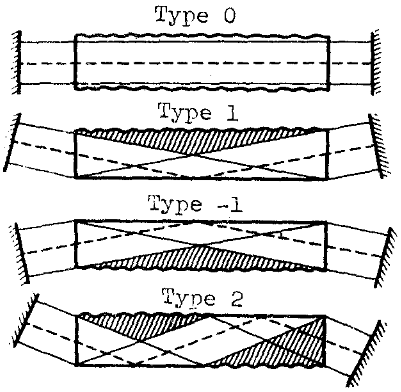

Fig. 1 Simplest types of "waveguide" resonators.

To confirm the properties of the indicated oscillation modes, we investigated the front of a wave passing through a neodymium-glass or garnet plate of rectangular cross section located in the arm of a Mach-Zender interferrometer. The sample was flushed alternately on both sides with cold and hot water, using the method described in [1]; the temperature difference was 30°C. A comparison of the interference pattern for an ordinary resonator and a resonator of waveguide type (Fig. 2) shows that in the latter case the thermal-lens effect does not appear at all. The reason is that in the case of the ordinary resonator the refractive index n(x) in the sample cross section depends on the thermo-optical constants P and Q [2, 3]