FERMI RESONANCE IN THE PHONON SPECTRUM OF THE CRYSTAL α-HIO_3

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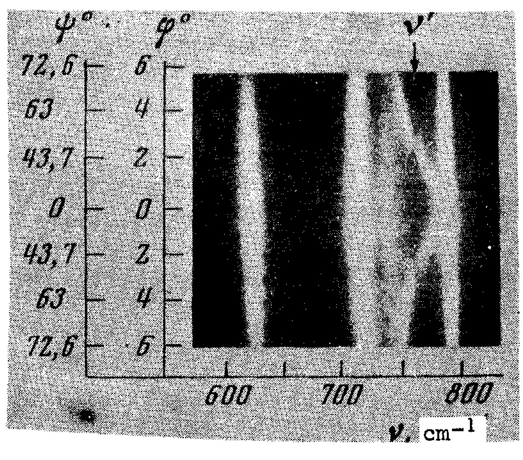
Submitted 3 October 1972
ZhETF Pis. Red. 16, No. 10, 541 - 543 (20 November 1972)

We have previously reported observation of Fermi resonance in Raman scattering of light by polaritons in the crystal α-HIO_3 [1]. This occurs when the branch of the bound state of two optical phonons (biphonon) crosses the polariton branch. This phenomenon is accompanied by exchange in the intensities of the light scattered by the polariton and the biphonon, and by the occurrence of an energy gap near the resonant crossing of the biphonon and polariton branches.

Let us imagine a situation in which a phonon branch with a large oscillator strength exists in the investigated crystal. We then have an appreciable distance between the frequencies ν_{LO} and ν_{TO} of the longitudinal and transverse optical phonons. We assume further that the frequency ν' of any optical phonon in the general case of any order, with a small oscillator strength, falls in the region between the frequencies ν_{LO} and ν_{TO} ($\nu_{LO} > \nu' > \nu_{TO}$). If we now change the direction of the phonon wave vector relative to its polarization, then we can vary the frequency of the phonon in the interval from ν_{LO} to ν_{TO}, and consequently realize the condition under which the frequency of the "strong" optical phonon crosses the frequency of the "weak" optical phonon ν'. A resonant interaction should then be observed between these two phonons, which we shall call Fermi resonance in the phonon spectrum of the crystal.

We have observed for the first time the Fermi resonance in the phonon spectrum of an α-HIO_3 crystal using Raman scattering of light by optical phonons at small angles. The Raman scattering of light at small angles was observed by a photographic procedure, in which the spectrograph slit is placed in the focal plane of a lens located behind the investigated sample. The photograph then shows the dependence of the frequency of the scattered light on the scattering angle. Since the wave vectors of the exciting scattering radiations are much larger than the wave vector of the optical phonon, it follows that a small change in the small angle of the Raman scattering will result in a large change of the direction of the optical-phonon wave vector. This can be used to cause the branches of the "strong" and "weak" optical phonons to cross.



Frequency-angle spectrum of Raman scattering in α-HIO_3: ν- frequency of Stokes shift, ϕ - scattering angle, ψ - angle between the direction of the wave vector of the optical phonon and the crystallographic axis Y.

The figure shows the frequency-angle spectrum of small-angle Raman scattering of light in an α-HIO_3 crystal, following excitation by an argon laser of wavelength 5145 Å. The exciting radiation propagated and was polarized along the crystallographic axes Y and Z, respectively (the axes are designated such that $N_X > N_Y > N_Z$, where N_i are the principal values of the refractive indices). Three intense lines whose frequencies are 628, 714, and 781 cm^{-1} and are independent of the scattering angle, correspond to scattering of light by nonpolar vibration of the lattice of symmetry A [2]. The line whose frequency depends on the scattering angle corresponds to scattering of light by a polar lattice vibration for which $\nu_{LO} = 778.5$ cm^{-1} and $\nu_{TO} = 736.5$ cm^{-1} [2], and the Raman-scattering tensor is of the form $B(Y) = \begin{pmatrix} 0 & 0 & a \\ 0 & 0 & 0 \\ a & 0 & 0 \end{pmatrix}$. Thus, in the case of forward scattering ($\phi = 0°$) one observes light scattering by longitudinal optical phonons. It is seen from the figure that when the scattering angle ϕ varies from 0 to 6° in the YX plane, the angle ψ between the optical-phonon wave vector and the crystallographic axis Y varies from 0 to 72.6°, and the frequency of the optical photon from which the scattering takes place changes from $\nu_{LO} \approx 776$ to $\nu_{LO,TO} \approx 745$ cm^{-1}. These results are in good agreement with the results obtained by observing Raman scattering of light at 90° [2]. We note that owing to the large birefringence, the wave vector of the phonon at the given scattering geometry amounts to $\sim 10^4$ cm^{-1}. At such values of the phonon wave vector, the polariton effect makes a negligible contribution to the change of the frequency of scattered light.

It is also seen from the figure that the scattered-radiation line, whose frequency depends on the scattering angle, experiences a "break" near the frequency $\nu' \approx 756$ cm^{-1} (at $\phi \approx 3°$). We attribute this "break" to the existence of an optical phonon, of frequency ν', which is very weak in Raman scattering and in infrared absorption, and which interacts strongly with the phonon observed by us in the scattering, in the region of the crossing of their branches. This results in an energy gap (lifting of the degeneracy owing to resonant interaction) and an interchange of the intensities of the light scattered by the strong and weak phonons.

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

[1] V.F. Kitaeva, L.A. Kulevskii, Yu.N. Polivanov, and S.N. Poluektov, ZhETF Pis. Red. 16, 23 (1972) [JETP Lett. 16, 15 (1972)].
[2] L. Couture, M. Krauzman, and J.P. Mathieu, C.R. Acad. Sci. 269, B1278 (1969); C.R. Acad. Sci. 270, B1246 (1970).

PRODUCTION OF C AND Al NUCLEI IN A LASER SOURCE OF MULTIPLY-CHARGED IONS

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Submitted 12 October 1972
ZhETF Pis. Red. 16, No. 10, 543 - 548 (20 November 1972)

1. The ionization of atoms in a high-temperature laser plasma is a promising method from the point of view of obtaining multiply-charged ions and their use in accelerator injectors[1)] [1]. Ions with $z > 20$ have already been obtained in a laser plasma [2]. In connection with the realized acceleration of deuterium nuclei in a proton synchrotron [3], the need for obtaining fully ionized atoms with a ratio $A/z = 2$ has already been mentioned in the literature. Acceleration of nuclei of the elements from D to Ca in a proton synchrotron makes it

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1) Author's certificate (patent) No. 324938, disclosure No. 1337085/26-25 of 8 July 1969, by Yu.A. Bykovskii, Yu.P. Kozyrev, S.V. Ryzhikh, S.M. Sil'nov, V.F. Elesin, and V.I. Dymovich.