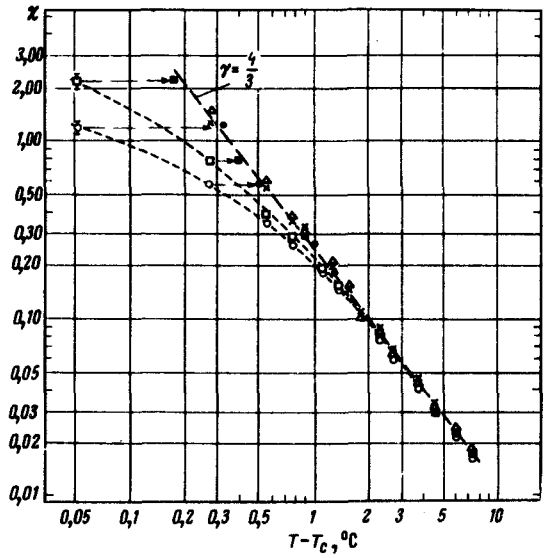

Fig. 2. Temperature dependence of the susceptibility χ of nickel. $T_C = T_C(0)$: Δ - H = 15 Oe, × - 60 Oe, □ - 100 Oe, o - 150 Oe; $T_C = T_C(H)$: ■ - H = 100 Oe, o - 150 Oe.

$T_C(0)$, but against $T - T_C(H)$, which is determined by the shifted position of the maximum of dP/dT in the field H (Fig. 1), then the power-law dependence with exponent $\gamma = 4/3$ is restored. The absence of a shift of the maximum in fields 15 - 60 Oe is apparently due to the fact that in this case the effective internal magnetic field, which is equal to the external field minus the demagnetization field, is close to zero, and the external field becomes more noticeable only in fields exceeding 60 Oe. The foregoing data on the temperature dependence of the susceptibility confirm our previous conclusions concerning the influence of the magnetic field on the positions of the singularities in phase transitions [7], and also explain the susceptibility variation previously observed by the method of rotating the polarization vector.

We are grateful to D. M. Kaminker for constant interest in the work, and to V. N. Sumarokov and A. F. Shebetov for help in constructing the apparatus.

[1] K. P. Belov, Magnitnye prevrahscheniya (Magnetic Transformations) Fizmatgiz, 1959.
[2] G. M. Drabkin, E. I. Zabidarov, Ya. A. Kasman, and A. I. Okorokov, Zh. Eksp. Teor. Fiz. 56, 478 (1969) [Sov. Phys.-JETP 29, 261 (1969)].
[3] Reports on Progress in Physics 30, part 3, p. 796. A. S. Stickland, ed., London, 1967.
[4] G. M. Drabkin, E. I. Zabidarov, Ya. A. Kasman, A. I. Okorokov, and V. A. Trunov, Preprint, Physico-tech. Inst. Leningrad, FTI-183, 1969.
[5] S. Arajs and R. V. Colvin, J. Appl. Phys. 35, 2424 (1964).
[6] S. Arajs, J. Appl. Phys. 36, 1136 (1965).
[7] G. M. Drabkin, A. I. Okoorkov, E. I. Zabidarov, and Ya. A. Kasman, ZhETF Pis. Red. 8, 549 (1968) [JETP Lett. 8, 335 (1968)].

PARAMETRIC LUMINESCENCE AND LIGHT SCATTERING BY POLARITONS

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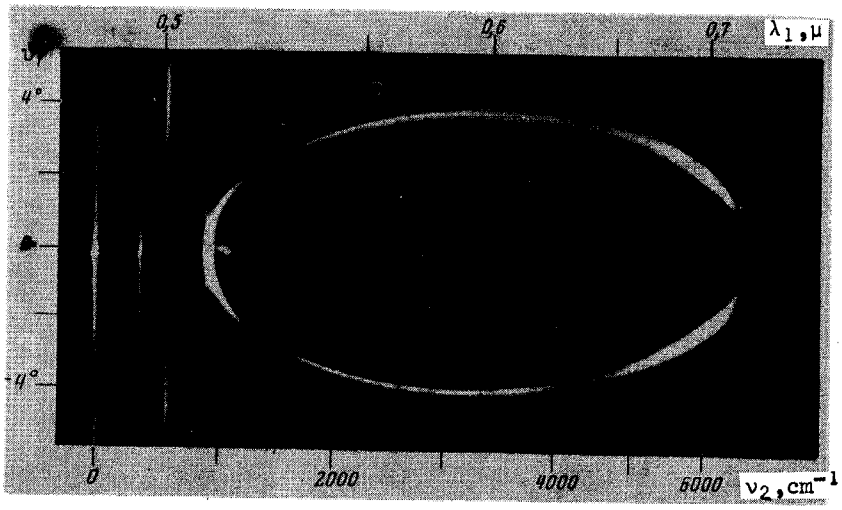
Submitted 11 November 1969
ZhETF Pis. Red. 11, No. 1, 11 - 14 (5 January 1970)

Parametric and polariton scattering of light have been heretefore studied separately, both in theoretical and experimental investigations (cf., e.g., [1 - 6]), although it was clear [2, 3] that these are limiting cases of a single phenomenon. Parametric luminescence is a scat-

tering process in which an incident-radiation photon decays into a pair of photons ($\omega_3 \rightarrow \omega_1 + \omega_2$) as a result of interaction with the electrons of the medium. It is customary to describe this interaction macroscopically by means of the nonlinear polarizability χ, which differs from zero in piezoelectric crystals. On the other hand Raman scattering in a crystal is a decay into a photon and a phonon, and the effectiveness of the process is usually described by the Placzek polarizability. In piezoelectric crystals, this phonon can be active also in infrared absorption, i.e., it can have a mixed mechanical and electromagnetic nature, and should then be called a polariton. It is obvious that with increasing polariton frequency ω_2 and with increasing difference between it and the mechanical lattice resonance frequency ω_n the polariton is transformed into a "pure" photon and scattering by polaritons goes over into parametric scattering.

The present communication is devoted to the first observation of scattering in the transition region, where it is due to both the electronic and the lattice (Placzek) nonlinearities. Experiments aimed at observing scattering in a wide frequency interval make it possible to determine the dispersion of the nonlinear (as well as the linear) polarizability of a medium and serve as a particularly convenient method of nonlinear spectroscopy. In particular, we have observed the effect of mutual compensation of the electronic and lattice nonlinearities in a lithium-niobate crystal, which leads to a "dip" in the brightness of the scattered light at a definite frequency (the long-wave slope of this dip was observed earlier [3,5] and in our opinion was erroneously attributed in [5] to the influence of absorption).

A characteristic feature of coherent inelastic scattering is the dependence of the frequency of the scattered light on the observation direction. The figure shows a spectrogram that illustrates this dependence directly: the ordinates are the scattering angles, and the abscissas the differences between the frequencies of the observed and incident light, i.e., the idling frequency $\omega_2 = \omega_3 - \omega_1$. Such a frequency-angle spectrum was obtained when the spectrograph slit (which was parallel to the crystal axis) was located at the focus of the lens; the exciting beam of the argon laser was perpendicular to the crystal axis and had



Frequency-angle spectrum of light scattered upon excitation by an Ar laser (λ_3 = 4880 Å). Abscissas - wavelength λ_3 of scattered light and idling frequency $\nu_2 \equiv \lambda_3^{-1} - \lambda_1^{-1}$. Ordinate - angle between the laser beam and the observation direction (recalculated to the interior of the crystal). The line with λ_1 = 4965 Å and the points with $\theta \approx 0°$ are due to the laser parasitic radiation.

extraordinary polarization, while the scattered light and the polariton had ordinary polarization. In earlier investigations of parametric luminescence [3 - 5], only the right side of the "ellipse" was observed (see the figure). The idling frequencies here are much higher than the optical lattice frequencies ω_n and the scattering is due to the electronic nonlinear susceptibility χ_∞. The left side of the ellipse corresponds to the intermediate type of scattering, due simultaneously to χ_∞ and to the lattice nonlinearity, which is proportional to the deformation potential or to the Placzek polarizability. The vertical or slightly bent lines to the left of the ellipse are the result of scattering by longitudinal lattice vibrations and polaritons due to the lattice nonlinearity. For example, the 880 cm^{-1} line adjacent to the ellipse on the left was observed by a number of investigators in a 90-degree spectrum [7, 8].

The most important feature of the spectrogram is the "dip" in the brightness of the scattered light at $\omega_2 \sim 1500$ cm^{-1}. This phenomenon is due to the fact that the electronic and lattice nonlinearity cancel each other at this frequency [3]. The frequency dependence of the components of the nonlinear-susceptibility tensor have in this frequency region the following form [8 - 10]:

$$\chi(\omega_2) = \chi_\infty + \sum \frac{C_n}{1 - \omega_2^2/\omega_n^2} \approx \chi_\infty \left(1 - \frac{\omega_0^2}{\omega_2^2}\right), \qquad (1)$$

where $\omega_0^2 \equiv \sum C_n \omega_n^2/\chi_\infty$. Estimates of ω_0 from the data of [8] with allowance for the contribution of seven oscillations of type E, under the condition that all $C_n > 0$ (cf. [10]) yielded the value 1760 cm^{-1}. Giallorenzi and Tang [5] observed only the right slope of this dip and attributed it to the influence of absorption at the idling frequency. It is clear from the figure, however, that with further decrease of ω_2 the scattering brightness again increases[1)], although the absorption coefficient increases almost monotonically at the same time [7] (and reaches 1000 cm^{-1} on the left edge of the ellipse).

Our experiments have thus shown that absorption at the idling frequency does not affect directly the strength of the scattered light $dP/d\Omega$. This confirms the conclusions of the phenomenological analysis [2], according to which the absorption (as well as the divergence of the exciting radiation - cf. [5]) affects only the line width $\Delta\omega$ and the spectral strength of the light $dP/d\Omega d\omega$, namely quantities that are observed only at high spectral ($\Delta\omega_n$) and angular resolution of the indicator. In our experiments $\Delta\omega_n \gg \Delta\omega$, so that the density of the spectrogram is proportional to $dP/d\Omega$, the latter being equal to [1 - 3][2)]

$$\frac{dP}{d\Omega} = \frac{2\pi\hbar\,\omega_1^4 n_1 \omega_2 P_3 \ell}{c^5 a_1^2 a_3^2 n_3 |1 - u_2 \cos\psi/u_1 a_1|} \frac{u_2 \chi^2}{n_2 a_2}. \qquad (2)$$

Here n are the refractive indices, $\chi \equiv \chi_{ijk} e_{1j} e_{2j} e_{3k}$ ($\vec{e}$ - polarization unit vectors, P_3 - power of exciting radiation, ℓ - thickness of crystal, α - cosines of angles between the ray and the wave vectors ($\vec{k}$), u - group velocities, and ψ - angle between $\vec{u}_2$ and $\vec{k}_1$. We emphasize that

1) This increase was first noted by D. P. Krindach (private communication).

2) See also the recent paper [11], where a slightly different expression is given.

the dispersion $\omega_2(\vec{k})$ must be determined from the dielectric constant ε without allowance for the damping [6, 9].

The frequency and angular dependences of $dP/d\Omega$ in the polariton region[1)], where $u_2 \ll u_1$, is determined mainly by the last factor in (2) (if ω_2 coincides with the longitudinal-oscillation frequencies, this factor must be replaced by $2c\chi^2(\omega_2 \partial\varepsilon/\partial\omega)^{-1}$). Owing to the characteristic dependence of χ on the direction of $\vec{k}_1$, the effect of the Raman scattering at small angles makes it easy to determine the type of polarization of the longitudinal or transverse lattice vibrations.

The authors are grateful to S. A. Akhmanov, R. V. Khokhlov, and D. P. Krindach for fruitful discussions.

[1] D. A. Kleinman, Phys. Rev. 174, 1027 (1968).
[2] D. N. Klyshko, Zh. Eksp. Teor. Fiz. 55, 1006 (1968) [Sov. Phys.-JETP 28,522 (1969)].
[3] D. N. Klyshko and D. P. Krindach, ibid. 54, 697 (1968) [27, 371 (1968)]; Opt. Spektrosk. 26, 981 (1969).
[4] J. P. Budin, B. Godard, and J. Ducuing, Proc. IEEE, QE-4, 831 (1968).
[5] T. G. Giallorenzi and C. L. Tang, Phys. Rev. 184, 353 (1969).
[6] H. E. Puthoff, R. H. Pantell, B. G. Huth, and M. A. Chacon, J. Appl. Phys. 39, 2144(1968)
[7] A. S. Barker and R. Loudon, Phys. Rev. 158, 433 (1967).
[8] L. P. Kaminov and W. D. Johnston, Phys. Rev. 160, 519 (1967).
[9] C. H. Henry, G. G. B. Garrett, Phys. Rev. 171, 1058 (1968).
[10] W. L. Faust, C. H. Henry, and R. H. Eick, Phys. Rev. 173, 781 (1968).
[11] V. V. Obukhovskii and V. L. Strizhevskii, Zh. Eksp. Teor. Fiz. 57, 520 (1969) [Sov. Phys.-JETP 30, No. 2 (1970)].

INFLUENCE OF EXTERNAL ELECTRIC FIELD ON QUADRUPOLE SPIN ECHO

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Submitted 13 November 1969
ZhETF Pis. Red. 11, No. 1, 15 - 18 (5 January 1970)

Superposition of a constant electric field E on a quadrupole spin system leads to a shift of the resonant frequency of the nuclear quadrupole resonance (NQR). In the case when the nuclear spin is I = 3/2, first-order perturbation theory leads to the following simple expression for single crystals [1]:

$$\frac{\Delta\nu_E}{\nu_0} = \frac{R_{zzz}E}{eq_0}\cos\theta = \frac{\Delta\nu_E^{max}}{\nu_0}\cos\theta \qquad (1)$$

where ν_0 is the NQR frequency without the field E and θ is the angle between the field E and the z axis, q_0 is the unperturbed component of the gradient of the electric field of the crystal along this axis, and R_{zzz} is the component of the (third-rank) tensor of the influence of the electric field.

In polycrystalline samples, a broadening takes place in the NQR lines, the shape of which depends on the mutual orientation of the constant electric and radio-frequency magnetic fields. The values of the parameter R_{zzz}, estimated from the measured width or from the second moment of the NQR lines [2] in the stationary method, are quite inaccurate, especially

[1)] These dependences are considered in detail in [11].