arametric excitation of Stokes waves in timulated Raman scattering with spatially nhomogeneous pumping

F. A. Korolev, O. M. Vokhnik, and V. I. Odintsov

Moscow State University

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Following amplification of the initial Stokes waves in the field of two intersecting single-mode beams, parametric excitation of one or two new SRS, whose directions were different from those of the initial wave, was observed. Bending of an amplified Stokes ray was observed in a diverging multimode beam.

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To investigate the amplification in the field of two pump waves, a fraction of the adiation of a single-mode ruby laser (pulse duration 25 nsec, line width 10^{-2} cm^{-1}) vas split into two beams L1 and L2 of equal intensity, which intersected at a small ngle inside the liquid-nitrogen amplifier cell. The rest of the laser radiation was irected to a generator cell, likewise filled with liquid nitrogen, where the fundamental node of the first Stokes component of SRS ($\lambda = 828$ nm) was excited. The SRS beam 1 was directed to the amplifier cell in such a way that the axes of all three beams L1, 2, and S1 lied in one plane and intersected at the same point of the cell. The throats"of the beams were located near the point of their intersection. The diameters f the pump beams L1 and L2, measured at the half-intensity level, were 0.4 mm at the ntersection point, while the diameter of the Stokes beam S1 was 0.5 mm. The radition leaving the amplifier cell was recorded on a photographic plate located far nough from the cell.

The appearance of the parametrically excited Stokes wave S2 is shown in Fig. 1 or two values of the angle between the pump beams L1 and L2: $2\alpha = 2 \times 10^{-2}$ rad (a,b) nd $2\alpha = 5.5 \times 10^{-3}$ rad (c,d). Only the "spots of the Stokes beams S1 and S2 are

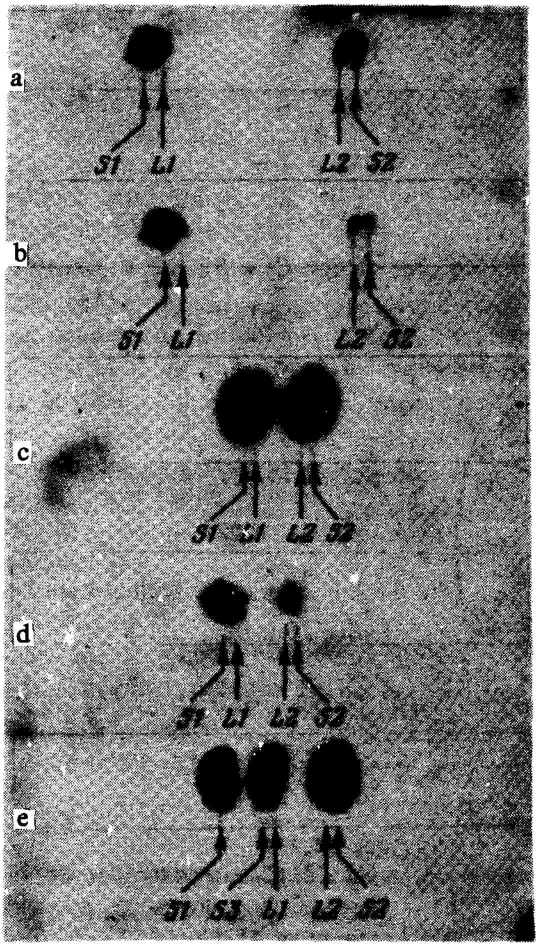

FIG. 1. Parametric excitation of Stokes waves S2 and S3: $2\alpha = 2\times10^{-2}$ rad (a,b), $2\alpha = 5.5\times10^{-3}$ rad (c–e).

shown (the exciting radiation was absorbed by a colored light filter). The positions of the pump components L1 and L2 indicated by the arrows were determined from other photographs, on which, using colored light filters, we recorded pairs of non-superimposed "spots," L1 and L2 or S2 and L1, as well as L1 and L2. When one of the beams L1, L2, or S1 was blocked, the component S2 did not appear even when the pump intensity was appreciably increased. At $\alpha = 10^{-2}$ rad, a dip was observed quite frequently at the center of the "spot" S2, in the form of a strip perpendicular to the plane of the beams [Figs. 1(a) and 1(b)]. Its depth reached 10–20% of the intensity at the maximimum.

The observed position of the component S2 agrees well with the theoretically predicted one.[1] From the condition that the projections of the wave vectors of the phonon waves be equal, $q_{1x} = q_{2x}$, it follows with allowance for the smallness of the angles [see Fig. 2(a), where $\beta_2 < 0$] that:

$$\beta_2 = \beta_1 - 2\frac{k_L}{k_S}\alpha. \tag{1}$$

Experiment confirms this relation well. Thus, the symmetrical position of the angular components S1 and S2 relative to L1 and L2 is observed, in accordance with (1), at $\beta_1 = \beta_{\text{symm}} = (k_L/k_S)\,\alpha$ [see Figs. 1(a) and 1(c)]. The change of the component S1 from the "symmetrical" position leads to a change of equal magnitude of S2 [Figs. 1(b) and 1(d)].

With the components S1 and S2 symmetrically arranged, we measured the ratio of the energy W_{S2} of the component S2 to the energy W_{S1} of the component S1 at the output of the amplifier as a function of the pump intensity (Fig. 3). To obtain an approximate theoretical estimate, we replace the real Gaussian beams L1, L2, and S1 by beams with cross section in the form of a square oriented along the axes x and y, with a side a equal to the diameter of the Gaussian beam. We assume the intensity to be constant over the cross section and equal to the axial intensity of the corresponding Gaussian beam. Then the interaction length over which the beams L1, L2, S1, and S2 overlap is $l' = a/2\alpha$. At $a = 0.4$ mm we have $l' = 2$ cm for the angle $2\alpha = 2 \times 10^{-2}$ rad. At $2\alpha = 5.5 \times 10^{-3}$ rad, l' was limited by the length 6.8 cm of the cell. Figure 3 shows, besides the experimental points, a theoretical plot of W_{S2}/W_{S1} against $G' = bI_L l'$ (b is the specific gain in the field of a homogeneous plane pump wave and I_L is the combined axial intensity of the beams L1 and L2), calculated from the results of[1].

Experiment has shown that deviation from the symmetrical position is accompanied by a rapid decrease of the ratio W_{S2}/W_{S1} if $|\Delta_{21}| > \frac{1}{2}g'$, where $g' = G'/l'$ and the detuning $\Delta_{21} = g_{2z} - g_{1z}$ is calculated from the formula

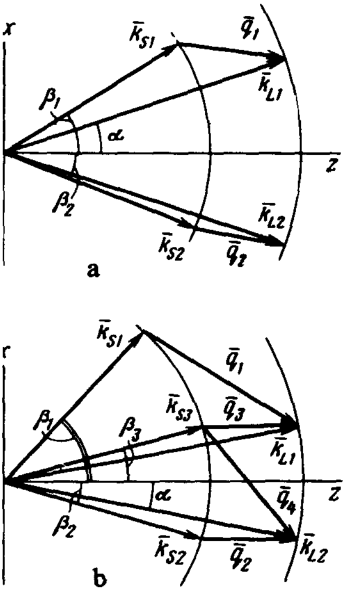

FIG. 2. Diagram of wave vectors: a—excitation of wave S2, b—excitation of waves S2 and S3.

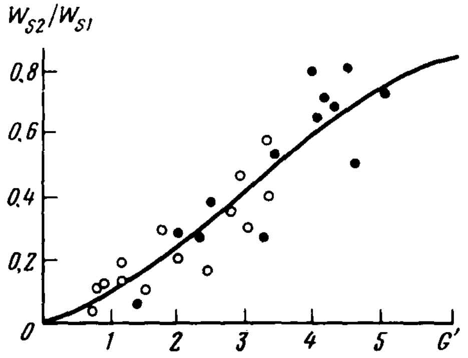

FIG. 3. Growth of the relative energy of the components S2 and S1 with increasing pump intensity: light and dark circles–experimental points at $2\alpha = 2\times10^{-2}$ rad and $2\alpha = 5.5\times10^{-3}$ rad, respectively, curve–theoretical plot.

$$\Delta_{21} = -2k_L\alpha(\beta_1 - \beta_{\rm symm}). \tag{2}$$

At large deviations of β_1 from $\beta_{\rm symm}$, the experimental values of W_{S2}/W_{S1} are in general in fair agreement with the theoretical estimate $W_{S2}/W_{S1} = (g'/2\Delta_{21})^2$, which is valid when $W_{S2} \ll W_{S1}$.

A qualitatively different scattering picture was observed in the case $2\alpha = 5.5\times10^{-3}$ rad at $\beta_1 \sim 3\beta_{\rm symm}$. In this case, at sufficiently high pump intensities, two new angular components of the Stokes radiation, S2 and S3, appeared immediately [Fig. 1(e)] and were nearly symmetrically arranged [$\beta_3 \approx \beta_{\rm symm}$, $\beta_2 \approx -\beta_{\rm symm}$. Fig. 2(b)]. Their energies were close to each other and reached $\sim 0.1\,W_{S1}$ It must be assumed that the first to occur is parametric excitation of S3 by the pump component L2 on the phonon wave q_1 produced by the components L1 and S3 (at $\beta_1 = 3\beta_{\rm symm}$ and $\beta_3 = \beta_{\rm symm}$, $\mathbf{q}_{4x} = \mathbf{q}_{1x}$). This is followed by parametric excitation of S2 by the component L2 on the phonon wave $\mathbf{q}_3$ produced by the components L1 and S3. At $\beta_1 \sim 3\beta_{\rm symm}$ the detuning $q_{4z} - q_{1z}$, in accordance with (2), is large even at a small angle $2\alpha = 5.5\times10^{-3}$ rad. The "bare" wave in the S3 direction is therefore weak. Since $q_{2z} - q_{3z} \sim 0$, however, a weak parametric coupling exists between the components S2 and S3 and leads, according to[1], to an increase in the gain by a factor of 1.5.

It was noted that even considerable deviations of β_1 from $3\beta_{\rm symm}$ does not lead to a substantial deviation of the components S2 and S3 from the symmetrical position. This becomes understandable if account is taken of the large role played by the parametric coupling of the components S2 and S3 at low intensity of the bare wave and if it is recognized that the condition $q_{1x} = q_{4x}$ is not rigorous, because of the limited transverse dimensions of the beams. In view of the relatively larger gain of the waves S2 and S3, the Stokes radiation at the output of the amplifier is concentrated, at sufficiently large G', mainly in these components, whereas the intensity of the S1 wave is small. A similar phenomenon was observed by us in the simplification of a single-mode Stokes wave propagating at a certain angle to the axis of a diverging multimode pump beam. At sufficiently high pump intensities, the bulk of the amplified radiation propagated along the pump beam. Thus, a deviation of the Stokes ray from its initial direction took place in the course of amplification.

[1] F.A. Korolev and V.I. Odintsov, Pis'ma Zh. Eksp. Teor. Fiz. **22**, 68 (1975) [JETP Lett. **22**, 30 (1975)].