modes (according to our estimates $n \simeq 10$) for two values of the second-generator pump. We see that these plots agree qualitatively with (1), with the exception of the end sections. "The saturation" at small values of ΔW is due to the fact that ΔW becomes comparable with the energy of spontaneous emission in the cavity after the shutter is opened. A certain tendency to "saturation" in the region of large values of ΔW is apparently attributable to the fact that those modes of the first generator which do not coincide with those of the second and therefore do not take part in the lasing, begin to lift an appreciable part of the inversion. The spectra of both generators remain identical in the entire range of ΔW up to values 10^{-10} J.

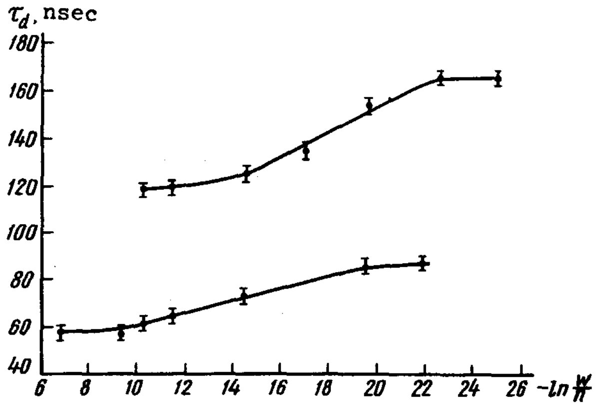


Fig. 3

We are continuing the present investigations in order to obtain synchronous lasing of several lasers using a driving laser operating in a single-frequency regime.

[1] A. A. Vuylsteke, J. Appl. Phys. 34, 1615 (1963).
[2] V. S. Letokhov and A. F. Suchkov, Zh. Eksp. Teor. Fiz. 50, 1148 (1966) [Sov. Phys.-JETP 23, 763 (1966)].
[3] V. S. Letokhov and A. F. Suchkov, Zh. Eksp. Teor. Fiz. 52, 282 (1966) [Sov. Phys.-JETP 25, 182 (1967).

OBSERVATION OF FOUR-PHOTON INTERACTION IN THE SPECTRUM OF STIMULATED SCATTERING OF THE LIGHT OF THE RAYLEIGH LINE WING

G. I. Zaitsev, Yu. I. Kyzylasov, V. S. Starunov, and I. L. Fabelinskii
P. N. Lebedev Physics Institute, USSR Academy of Sciences

Submitted 6 July 1967
ZhETF Pis'ma 6, No. 6, 695-697 (15 September 1967)

We have previously reported observation [1] and experimental [2] and theoretical [1,3] investigations of stimulated scattering of light in the wing of the Rayleigh line (RLW) when there is no interaction between the exciting, Stokes, and anti-Stokes waves with the nonlinear medium (four-photon interaction).

We report here that we have observed four-photon interaction in stimulated scattering of light in the RLW at small angles, which is the same as scattering of light by light in an optically nonlinear medium. In other words, the four-photon interaction effect observed by us is a particular case of parametric interaction between light waves in a nonlinear medium consisting of anisotropic molecules, when the angle between the propagation directions of these waves is small [2]. This question was considered theoretically by one of us [3] and also by Chiao et al. [4].

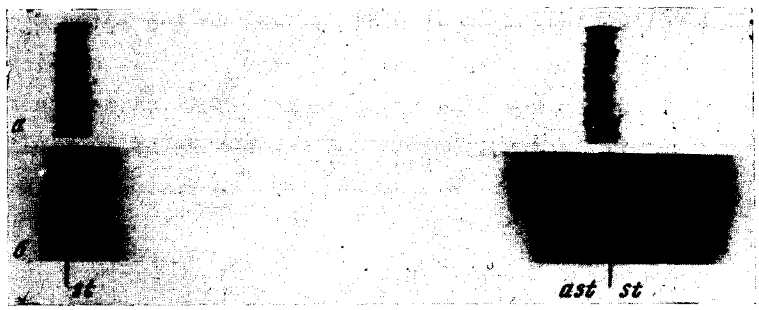
It follows from the theory [3] that for the case of four-photon interaction in RLW at the optimal angle $\theta_{opt} = |E_0|A^{1/2}$ the maximum gain is

$$g_2(\Omega) = -2K_\omega + A|\mathbf{K}_1||E_0|^2(1+\Omega^2\tau^2)^{-1/2}, \quad (1)$$

where $A = \epsilon_2/2\epsilon$, K_ω, $\vec{K}_1$, Ω, and τ are the amplitude coefficient of light absorption, the wave vector of the scattered light, the frequency reckoned from the frequency of the exciting light, and the anisotropy relaxation time, respectively. We see from (1) that the maximum gain occurs in this case when $\Omega = 0$.

The presence of four-photon interaction in RLW becomes manifest by the fact that at the optimal angle θ_{opt} it is possible to observe in the spectrum a wing which is the same on the Stokes and anti-Stokes sides and has a maximum at $\Omega = 0$. When there is no interaction between the Stokes and anti-Stokes waves, it is possible to observe only the Stokes wing with a maximum gain at $\Omega \sim 1/\tau$ [1,3]. In our experiments the interference patterns have revealed simultaneously both the wing corresponding to four-photon interaction and the ordinary Stokes RLW.

The work was performed with the setup described in [1,2]. The laser power was 90 MW. The light was focused inside a liquid-filled cell by a lens with f = 2.5 cm. In certain orders of the interference patterns corresponding to the optimal angles, the anti-Stokes wing was observed in RLW in o-xylol and nitrobenzene (see the figure).



Part of interference pattern of RLW spectrum in nitrobenzene. Fabry-Perot interferometer dispersion region 8.33 cm^{-1}. a - ruby laser emission spectrum; b - RLW spectrum, in the right side order of which are seen the Stokes and anti-Stokes (~1.5 cm^{-1}) parts of the wing. This order lies inside of the cone of the optimal angle for four-photon interaction. The left-side order lies outside this cone, and does not contain the anti-Stokes part of the RLW.

For the case of nitrobenzene, we observed simultaneously the RLW at angles $\theta \sim 0°$ and $\theta = 90°$. As expected, the Stokes and anti-Stokes wings of the RLW were observed only at small angles ($\theta \lesssim 2°$), and only the Stokes wing was observed at $\theta = 90°$.

Four-photon interaction was observed earlier by Maker and Terhune [5] in the Raman spectrum of light. Carman et al. [6] also observed four-photon interaction by mixing two beams obtained from a single light flash of a ruby laser and crossing at an optimal angle in a cell with nitrobenzene. The mechanism of nonlinear interaction of the light beams with the medium was the same in [6] as in our case, but in [6] $\Omega = 0$. In our case, on the other hand, the four-photon interaction was observed in a wide spectral region of the RLW and the gain was larger by two orders of magnitude than in [6].

We have already mentioned [2] that the occurrence of the RLW suppresses the stimulated Mandel'shtam-Brillouin scattering. It is interesting to note, that this suppression is even more strongly pronounced when the anti-Stokes wing is produced.

The authors are grateful to I. Dikhter for help with the experiment.

[1] D. I. Mash, V. V. Morozov, V. S. Starunov, and I. L. Fabelinskii, ZhETF Pis. Red. 2,

41 (1965) [JETP Lett. 2, 25 (1965)].
[2] G. I. Zaitsev, Yu. I. Kyzylasov, V. S. Starunov, and I. L. Fabelinskii, ZhETF Pis. Red. 6, 505 (1967) [JETP Lett. 6, 35 (1967)].
[3] V. S. Starunov, Investigation of the Spectrum of Thermal and Stimulated Molecular Scattering of Light. Dissertation, Physics Institute of the Academy of Sciences (FIAN), 1965; Trudy, FIAN, 39, 1967.
[4] R. Chiao, P. Kelly, and E. Garmire, Phys. Rev. Lett. 17, 1158 (1966).
[5] P. D. Maker and R. W. Terhune, Phys. Rev. 137, A801 (1965).
[6] B. L. Carman, R. Y. Chiao, and P. L. Kelly, Phys. Rev. Lett. 17, 1281 (1966).

CONNECTION BETWEEN THE ANTISYMMETRICAL EXCHANGE INTERACTION AND THE CHANGE OF MULTIPLICITY

S. V. Vonsovskii and M. S. Svirskii
Institute of Metal Physics, USSR Academy of Sciences
Submitted 13 March 1967; resubmitted 20 April 1967
ZhETF Pis'ma 6, No. 6, 697-700 (15 September 1967)

In the theory of weak ferromagnetism [1,2], an important role is played by exchange interaction of the type

$$H_1 = D[S_1 \times S_2], \tag{1}$$

which is antisymmetrical with respect to the spins $\vec{S}_1$ and $\vec{S}_2$. On the other hand, in the theory of exchange interaction connected with the change of multiplicity [3], antisymmetrical spin operators are also significant. This raises the natural question of the connection between the interaction (1) and the change of multiplicity.

To establish this connection, we introduce symmetrical and antisymmetrical spin operators

$$S = S_1 + S_2, \quad A = S_1 - S_2, \tag{2}$$

where $\vec{S}_1$ and $\vec{S}_2$ satisfy the commutation relations:

$$[S_1 \times S_1] = iS_1, \quad [S_2 \times S_2] = iS_2. \tag{3}$$

From (2) and (3) we get the following commutation relations for $\vec{S}$ and $\vec{A}$:

$$[S \times S] = [A \times A] = i S \tag{4}$$

$$S_i A_k - A_k S_i = i e_{ikl} A_l, \tag{5}$$

where e_{ikl} is an antisymmetrical unit tensor of third rank. Relation (5) leads [4] to the equality

$$S^4 A_x - 2S^2 A_x S^2 + A_x S^4 = 2(S^2 A_x + A_x S^2) - 4S_x(S \cdot A), \tag{6}$$

from which it follows that the operator $\vec{A}$ can transform the state of a system with spin S only into a state with spin S' satisfying the condition

$$S' - S = 0, \pm 1 . \tag{7}$$

The equality S' - S = 0 (conservation of multiplicity) can occur only if the last term of (6) does not vanish. In our case it follows from (2) that

$$(S \cdot A) = S_1^2 - S_2^2 = S_1(S_1 + 1) - S_2(S_2 + 1). \tag{8}$$

Consequently, if we confine ourselves to the case of two identical spins ($S_1 = S_2$), then