the transverse modes (in the latter case five TEM_{00q} modes are generated).

Thus, the introduction of an absorbing film makes it easy to obtain discrimination of modes with different longitudinal and transverse indices and to realize a single-mode laser. This method differs from the Michelson interferometer method in that it is simpler, is insensitive to polarization, and has lower initial losses.

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ADDITIONAL RADIATION CONES OF ANTI-STOKES SRS COMPONENTS IN CALCITE

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The experimental investigation of the angular distribution of the anti-Stokes components of stimulated Raman scattering (SRS) in liquids has been reported in a number of papers (see [1,2]). It was established in these investigations that all the anti-Stokes components are emitted essentially in cones whose axes coincide with the axis of the scattered beam incident on the medium (pump). Concentric circles of various anti-Stokes components are obtained in this case on a photographic film placed behind the sample perpendicular to the pump beam. At the same time it was theoretically predicted in [3] that additional radiation of anti-Stokes components is possible in crystals, and should propagate at a different angle (which in general is variable) to the pump-beam direction. In the same paper, equations were obtained determining the direction of its propagation. These equations are solved in the present paper for the case of uniaxial crystals, and we have observed the additional radiation of the anti-Stokes components experimentally in a uniaxial $CaCO_3$ crystal. The comparison presented below shows good agreement between the obtained experimental data and the results of the theory.

In the case when the pump and the first Stokes component (in the wave zone) constitute an ordinary wave, the angle θ_m^{12} of the additional radiation of the anti-Stokes component of order m is determined by the following relations [3]:

$$2\sin\frac{\theta_m^{12}}{2} = \left\{\frac{[k_{m2}(\theta_m^{12}) + mk_{-11} - (m+1)k_{01}][mk_{-11} + (m+1)k_{01} - k_{m2}(\theta_m^{12})]}{(m+1)k_{01}k_{m2}(\theta_m^{12})}\right\}^{1/2}$$

$$k_{e\alpha}(\theta) = \frac{\omega_e}{c}n_\alpha(\omega_e,\Theta),\quad \Theta^2 = \nu^2 + \theta^2 + 2\nu\theta\cos\phi,\quad n_1(\omega,\Theta) \equiv \sqrt{\epsilon^{(y)}(\omega)} \qquad (1)$$

$$n_2(\omega,\Theta) = \left[\frac{\sin^2\Theta}{\epsilon^{(x)}(\omega)} + \frac{\cos^2\Theta}{\epsilon^{(z)}(\omega)}\right]^{-1/2},$$

where, for uniaxial crystals, $\sqrt{\epsilon(y)} = \sqrt{\epsilon(z)} = n_\perp$ is the refractive index of the ordinary wave, $\sqrt{\epsilon(x)} = n_\parallel$, ν is the angle between the optical axis of the crystal (the x axis) with the pump wave vector, and $(\pi - \varphi)$ is the angle (i) between the plane passing through the scattering point, the pump wave vector, and the optical axis and (ii) between the plane passing through the same vector and the wave vector of the additional radiation. At small values of the angles $\theta_m^{\alpha\beta}$ and ν, the solution of (1) is given by the formula

$$\theta_m^{12} = \frac{1}{1+p_m^2}\{-p_m^2 \nu \cos\phi + \sqrt{p_m^4 \nu^2 \cos^2\phi + (1+p_m^2)[(\theta_m^{11})^2 - p_m^2\nu^2]}\}, \tag{2}$$

where

$$\theta_m^{11} = \sqrt{\frac{2mk_{-11}[k_{m1} + mk_{-11} - (m+1)k_{01}]}{(m+1)k_{01}k_{m1}}}, \tag{3}$$

$$p_m = \sqrt{\frac{mk_{-11}}{(m+1)k_{01}} \frac{n_\perp^2(\omega_m) - n_\parallel^2(\omega_m)}{m^2_\parallel(\omega_m)}}. \tag{4}$$

θ_m^{11} is the angle of the main radiation of the anti-Stokes component of order m, which does not depend on ν (see [3-5]). It is easy to verify that the plot of (2) in the polar coordinates θ_m^{12} and φ is a circle whose center lies between the pump wave vector and the optical axis (in the plane passing through them); the distance between the center and the direction of the pump wave vector is

$$d_m^{12} = \frac{p_m^2 \nu}{1+p_m^2}. \tag{5}$$

The radius R_m^{12} of this circle is

$$R_m^{12} = \frac{1}{1+p_m^2}\sqrt{(1+p_m^2)(\theta_m^{11})^2 - p_m^2\nu^2}. \tag{6}$$

According to (5) and (6) we obtain for the additional-radiation circles an entirely different picture compared with the circles of the main radiation. In particular, it follows from (6) that for each anti-Stokes component the additional circle will be observed only in the angle interval $\nu < \nu_m^{12}$, where

$$\nu_m^{12} = \theta_m^{11}\frac{\sqrt{1+p_m^2}}{p_m}. \tag{7}$$

For a numerical calculation of the angles θ_m^{11} and the coefficients p_m, we used data on the refractive indices of calcite, taken from [6], and data on the wavelengths of the scattered radiation, taken from [1,7]. From (3), (4), and (7) we obtained the following values:

$$\theta_1^{11} = 1{,}54\cdot10^{-2}\ (0);\ p_1 = 0{,}334\,(4);\ \nu_1^{12} = 4{,}87\cdot10^{-2}\ (2°47')$$
$$\theta_2^{11} = 3{,}00\cdot10^{-2}\,(8);\ p_2 = 0{,}387\,(6);\ \nu_2^{12} = 8{,}32\cdot10^{-2}\ (4°46').$$

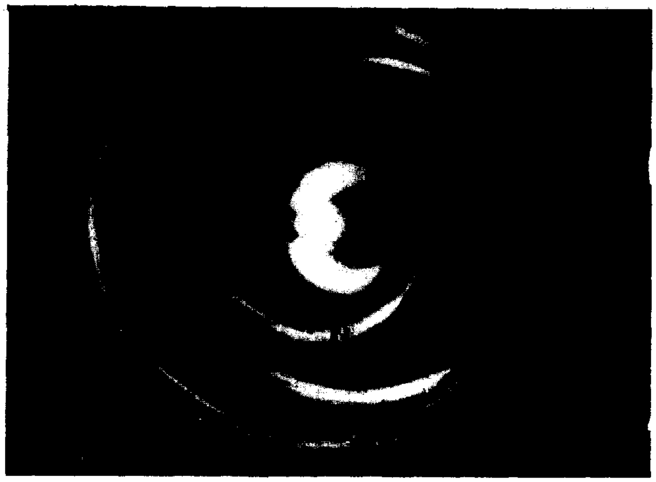

Fig. 1. Pattern of anti-Stokes SRS components in calcite, observed at $\nu = 4.02 \times 10^{-2}$. The main circles of the first and second anti-Stokes components are seen concentric with the laser spot, and additional circles of the same components are displaced to the right.

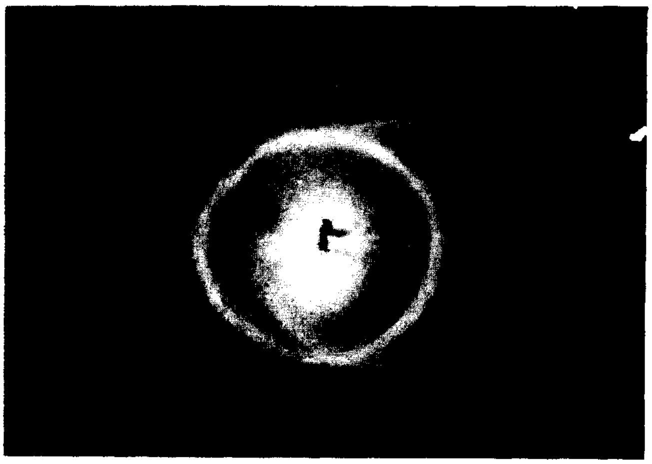

Fig. 2. Pattern of anti-Stokes SRS components in calcite, observed at $\nu = 6.63 \times 10^{-2}$. The main circle of the first anti-Stokes component is seen concentric with the laser spot, and the additional circle of the second anti-Stokes component is displaced to the right.

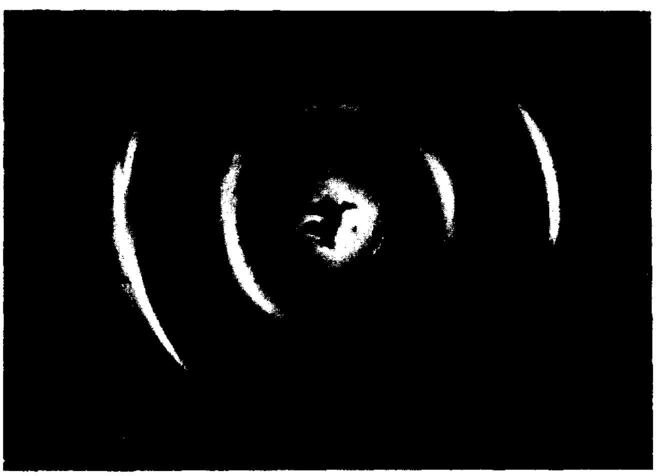

Fig. 3. Pattern of anti-Stokes SRS components in calcite, observed at $\nu = 7.68 \times 10^{-2}$. The main circles of the first and second anti-Stokes components are seen concentric with the laser spot, and the additional circle of the first anti-Stokes component is displaced to the right.

In our experiments, the pump was a linearly polarized ruby-laser beam passing through the calcite as the ordinary wave. The scattered radiation was passed through a filter that attenuated the Stokes components and the pump beam passing through the sample. It was then incident on a photographic film mounted perpendicular to the laser beam. We observed the additional circles of the anti-Stokes components. They were shifted relative to the main circles towards the optical axis of the crystal. Typical experimental scattering patterns are shown in Figs. 1 - 3. In most cases one could see clearly the first main anti-Stokes component and the first and second additional anti-Stokes scattering components. Accordingly the table lists the experimental and theoretical values of the ratios of the diameters R_1^{12}/θ_1^{11} and R_2^{12}/θ_1^{11} for different values of ν. This table shows good agreement between the experimenatal and calculated values. It must be noted here that the calculations presented above are based on the SRS theory developed in [3-5]. It can also be verified that with respect to the additional radiation of the second anti-Stokes component, the SRS model used in [8,9,etc.] does not explain (even qualitatively) the photographs shown in Figs. 1 - 3.

T a b l e

$\nu \times 10^2$ rad	Theory		Experiment	
	R_1^{12}/θ_1^{11}	R_2^{12}/θ_1^{11}	R_1^{12}/θ_1^{11}	R_2^{12}/θ_1^{11}
2.40	0.82	1.74	0.80	1.75
3.46	0.67	1.66	0.68	1.65
4.02	0.53	1.59	0.50	1.58
4.51	0.35	1.53	0.35	1.50
5.04	-	1.45	-	1.44
5.83	-	1.30	-	1.31
6.63	-	1.10	-	1.10
7.68	-	0.70	-	0.71

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