Observation of wave-front inversion in stimulated Raman scattering of light

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The inversion of the wave front in stimulated Raman scattering (SRS) of ruby-laser radiation was registered in experiment. A pump beam of diffraction property was distorted by a factor 300 with an inhomogeneous phase plate, after which is excited the first Stokes component of SRS in carbon disulfide. The backscattered radiation after the return passage through the phase plate also had a diffraction-type divergence.

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Inversion of the wave front in stimulated scattering of light was observed in[1]. Its gist is that when the exciting-radiation intensity $I_0(\mathbf{r}) = |E_0(\mathbf{r})|^2$ has a spatially inhomogeneous distribution, the backscattered field coincides with the complex-conjugate pump field, i.e.,

$$E_s(\mathbf{r}) = \text{const}\, E_0^*(\mathbf{r})\,. \tag{1}$$

The existence of this phenomenon was experimentally demonstrated in[1] (see also[2,3]) for scattering with a small frequency shift ($\Delta\nu/\nu \sim 10^{-5}$). The physical nature of the effect, however, is such that it should appear also at much larger shifts. Quantitative estimates of the admissible change of frequency, given in the theoretical paper,[4] demonstrate the possibility of observing the effect for SRS characterized by values $\Delta\nu/\nu \sim 10^{-1}$. There are many investiga-

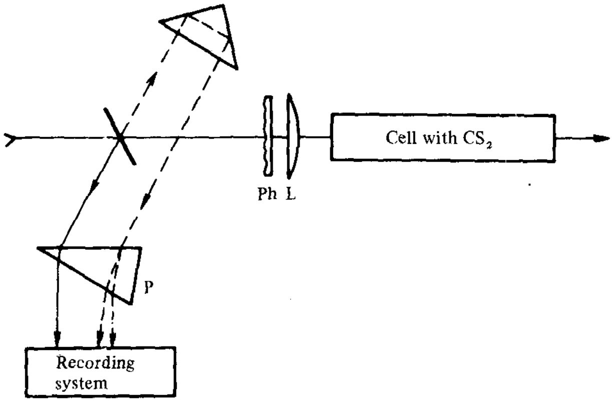

FIG. 1. Experimental setup: Ph—inhomogeneous phase plate (transverse dimension of the inhomogeneities $\sim 150\ \mu$, depth $\sim 1\ \mu$); L—lens of K-8 glass with focal length 7 cm; the cell with the CS_2 had a length 19 cm and an inside diameter 1 cm; P—prism of TF-1 glass.

tions of the backward SRS process (see, e.g., [5-7]), but there have been so far no reports of inversion of the wavefront in this process. This phenomenon was observed by us in the present study for SRS.

The experimental setup is illustrated in Fig. 1. A beam with almost flat wavefront was obtained from a ruby laser with the aid of a diaphragm. Its diameter was 4 mm and its peak power ~ 0.7 MW at a pulse duration 10 nsec. To prevent the scattered light from affecting the operation of the laser, the latter was placed 5 meters away from the remainder of the apparatus. After passing through the diaphragm, part of the beam was diverted to the recording system, and the bulk of the beam passed through an inhomogeneous phase plate Ph. As a result, the wave front was distorted and the solid angle occupied by the radiation increased by ~ 300 times (see Figs. 2a and 2b). This light was then focused by lens L into a cell with liquid carbon disulfide, where stimulated Raman scattering with a frequency shift $\Delta\nu = 656\ \text{cm}^{-1}$ was produced, as well as Mandel'shtam—Brillouin scattering (SMBS). The backscattered radiation passed through a lens and a phase plate and was directed into the registration system. To separate the SRS and SMBS beams, we used a dispersing element—a prism P. The material of the lens L was so chosen that the system comprising the lens and the cell with the CS_2 was achromatic. The depth of the inhomogeneities of the phase plate was $h \sim 1\ \mu$. Therefore the phase shifts introduced by this plate, equal to $2\pi(n-1)h/\lambda$, differed in the case of the exciting light and the SRS light by an amount $2\pi(n-1)h\Delta\lambda/\lambda^2 = 2\pi(n-1)h\Delta\nu \sim$ ~ 0.2 rad. This difference between the phase shifts should not lead to a noticeable change of the wave front of the SRS. Thus, the phase plate likewise introduced practically no chromatic aberrations. To preserve the achromatism, the angular distribution of the beams was registered with the aid of a mirror-objective by the procedure of[8].

A photograph of the far zone of the SRS radiation is shown in Fig. 2c. Comparison of Figs. 2a and 2c shows that the divergences of both beams—exciting and scattered—are practically equal; the angle widths at half-heights are re-

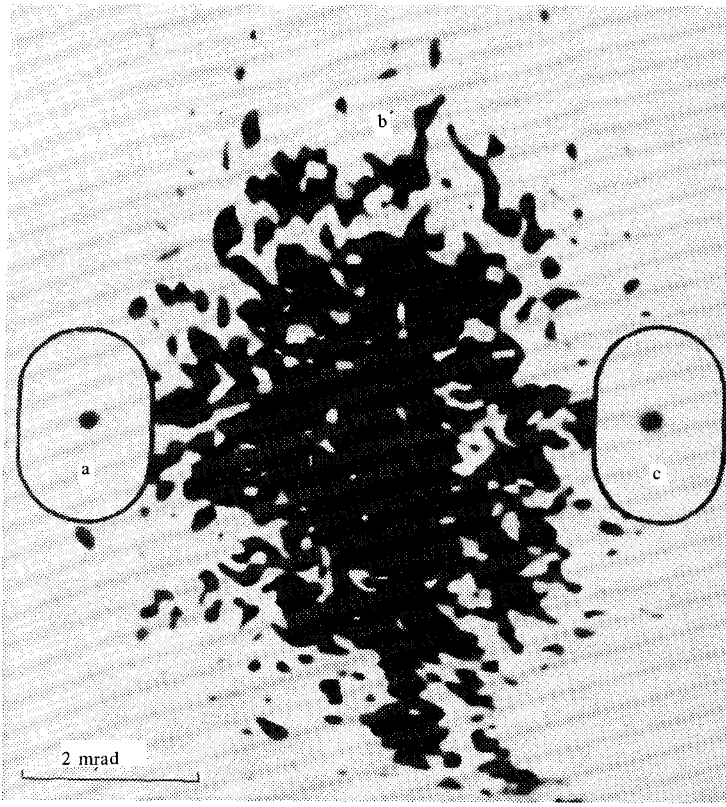

FIG. 2. Photographs of the distributions in the far zone: a) of the initial laser radiation; b) of the same beam after passing through the phase plate; c) of the reconstructed SRS beam. The same scale is used for all photographs.

spectively 0.14 and 0.17 mrad and are close to the diffraction limit. This result indicates that in our experiments relation (1) is satisfied for the SRS radiation.

Thus, the previously observed inversion of the wave front was registered in the present study for stimulated Raman scattering of light.

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