Effect of focal pumping conditions on the phase-conjugation characteristics of STS and SBS

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The phase-conjugation characteristics of stimulated thermal scattering (STS) in absorbing liquid and stimulated Brillouin scattering (SBS) separately excited in pure acetone were compared, and the effect of focal pumping conditions on them was studied. It is shown that high-quality phase conjugation can be obtained by STS in absorbing liquid under stronger pumping conditions.

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Stimulated thermal scattering (STS) in various media is a nonlinear process of interaction between an exciting wave and a wave scattered by thermal fluctuations, caused by absorption of radiation in the media. From the general nature of the wavefront reversal mechanism in stimulated backscattering, we can deduce that this effect should also be observed in STS under certain conditions. However, only several references[1,2] have reported its observation. This indicates the presence of certain fundamental difficulties. On the other hand, there are many reports[3−5] about stimulated Brillouin scattering (SBS) phase conjugation. Actually STS is usually observed only when a nonlinear liquid possesses appreciable absorption. In conjunction with the very high radiation density in the region of a beam caustic, the presence of appreciable absorption should lead to an appreciable specific heat release. Earlier papers just emphasized that the absorption coefficient must be greater than a critical value if one want to observe the STS, but they were lost to the increased loss of radiation energy along the path with increased absorption coefficient, and to the decreasing of gain and conjugation quality of STS caused by it. In this paper we report the high-quality phase conjugation by STS in absorbing liquid where the pumping beam waist is close to the front window of the cell.

Our experiments were carried out using master oscillator power amplifier (MOPA) system. The experimental setup is shown in Fig. 1. The parameters of the Nd:YAG oscillator radiation were as follows. The pulse duration was ~23 ns at midamplitude, the spectral width did not exceed 1.54 GHz, the beam divergence was 1.35 mrad, and the energy was ~3 mJ. The radiation was focused into a 200-mm liquid cell filled with acetone by a 64-mm focal length lens. We used acetone as pure liquid, whose absorption coefficient is about 0.012 cm^{-1}. As absorbing liquid we used acetone with $\mathrm{Cu(NO_3)_2}$ added to produce an absorption coefficient of 0.428 cm^{-1}, which is greater than the critical value[6] of 0.34 cm^{-1} at $\lambda = 1.06$ μm. A spectral analysis system ensured that SBS was excited in pure acetone and STS was excited in absorbing liquid. A Glan prism and a quarter-wave plate decoupled the laser from the cell. The SBS in pure acetone or the STS in the absorbing liquid passed back through the amplifier, after being amplified, it was output from the prism. The far-field spots were taken by a charge-coupled device (CCD) camera on the focal plane of a 2-m focal length lens, and the corresponding energy was collected by an

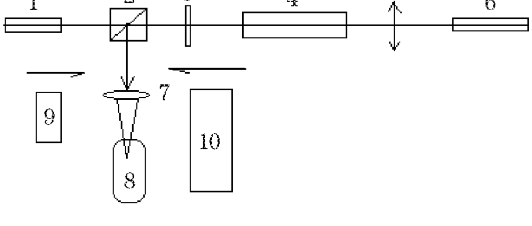

Fig. 1. Experimental setup. 1: Nd:YAG oscillator; 2: Glan prism; 3: $\lambda/4$ wave plate; 4: Nd:YAG amplifier; 5: $f = 64$ mm lens; 6: liquid cell; 7: $f = 2$ m lens; 8: CCD camera; 9: energy ratiometer; 10: spectral analysis system.

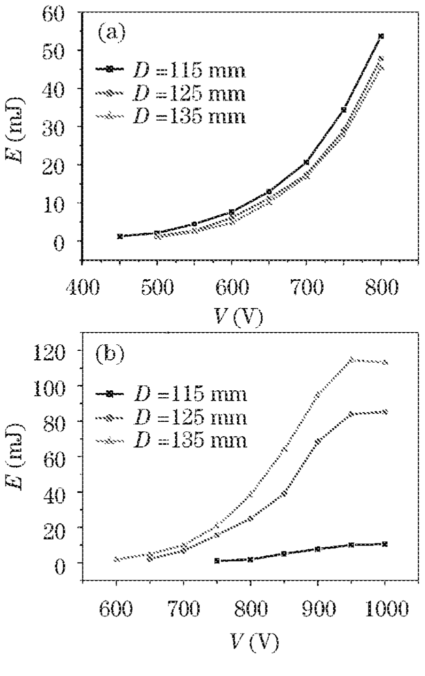

Fig. 2. The output energy from MOPA system (E) versus pump voltage of the Nd:YAG amplifier (V) with SBS ($\alpha = 0.012$ cm^{-1}) (a) and STS ($\alpha = 0.428$ cm^{-1}) (b) as phase-conjugation mirrors. The length of the liquid cell is 200 mm, the focal length of the focusing lens is 64 mm, D stands for the distance between the lens and the center of the liquid cell.

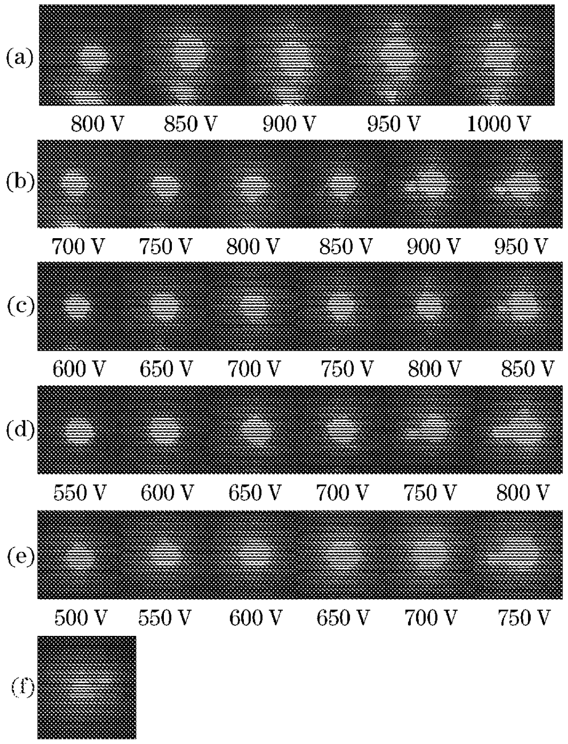

Fig. 3. Far-field spots from MOPA with STS [(a)−(d)], SBS (e) as phase-conjugation mirrors, and oscillator (f). (a): D=110 mm; (b): D = 115 mm; (c): D = 125 mm; (d): D = 135 mm. The corresponding pump voltages are also given.

R-938 dual channel intelligent laser energy ratiometer for three cases: the center of the cell was placed at 115, 125, and 135 mm from the lens, respectively. This means that the beam waist was located at 70.4, 56.8, and 43.2 mm from the front window of the cell correspondingly in our experimental condition.

Figure 2 shows the output energy from MOPA system with SBS and STS serving as phase-conjugation mirror. It can be seen in Fig. 2(a) that gain and threshold of the SBS have little change with changing the distance between the lens and the center of the cell, the SBS gain decreases and threshold increases with increasing this distance. In contradiction to this, Fig. 2(b) shows that gain and threshold of the STS have great change with changing the distance, the STS gain increases and threshold decreases obviously with increasing the distance. It is obviously caused by high radiation density in the region of a beam caustic, since moving the beam waist forward decreases the loss of beam energy along the path. From Figs. 3(a)−(d), we can see that with the distance changed from 110 to 135 mm and the pump voltage of the amplifier risen (that is, pump energy of the STS was increased), the far-field distributions of the STS are more and more similar to those of the oscillator (Fig. 3(f)) and the SBS (Fig. 3(e)). That is, the fidelity of phase conjugation by STS can be obtained as high as that by SBS when the beam waist is close to the front windows of the cell. It is really a good news for high-power laser systems and the systems with narrow-band amplifiers, because the accompanying frequency shift in STS is many times less than in SBS, and it is not easy to avoid the competition between SBS and STS in high-power laser systems with SBS phase-conjugation mirror.

In conclusion, high-quality phase conjugation can be obtained by STS in absorbing liquid as long as there are sufficiently high radiation density in the region of a beam caustic.

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References

1. V. B. Karpov, V. V. Korobkin, and D. A. Dolgolenko, Sov. J. Quantum Electron. **21,** 1235 (1991).
2. Yu. A. Ananev, A. V. Gorlanov, I. M. Kozlovskaya, and N. A. N. A. Sventsitskaya, Opt. Spectrosc. (USSR) **60,** 240 (1986).
3. Y. Ju, Q. Wang, D. Chen, X. Yu, and Y. Wang, Chin. Opt. Lett. **1,** 683 (2003).
4. C. Ge, W. Zhang, and J. Qu, Chin. Opt. Lett. **2,** 165 (2004).
5. C. Ge and W. Zhang, Chin. Opt. Lett. **1,** 350 (2003).
6. R. H. Herman and M. A. Gray, Phys. Rev. Lett. **11,** 824 (1967).