Competition between nonlinear processes in gaseous SF_6 as a result of pumping by 2-nsec pulses

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The competition between SMBS, SRS and optical breakdown in compressed SF_6 due to pumping by an iodine laser with a 2-nsec pulse is investigated. It is shown that the onset of a given process is determined to a large extent by the power of the pump pulse and by the shape of its leading edge.

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The feasibility of using stimulated Mandelstam-Brillouin scattering (SMBS) in laser-mediated thermonuclear fusion (LTF) systems was examined and experimentally tested in Refs. 1-4 in order to increase the contrast, to sharpen the leading edge and to decrease the pulse duration.

Since the duration τ of pump pulses is $\tau \lesssim 1$ nsec in the existing devices,[5-7] the stimulated-scattering process is highly unsteady and the pump intensities needed to activate the SMBS can approach the threshold values for other nonlinear effects such as stimulated Raman scattering (SRS) (Refs. 9 and 11) and optical breakdown of gas (see Ref. 8 and the literature cited therein).

For example, the radiation intensity in a nonlinear medium (SF_6 at a pressure of about 20 atm) reaches 10 - 100 GW/cm^2 in experiments corresponding to the operating conditions of the first cascades of the device described in Ref. 7, and the threshold conditions can be satisfied for all three types of nonlinear interactions.

In this paper we investigate the conditions for the onset of SMBS and SRS and their relative competition arising from the pumping by short, iodine-laser pulses ($\tau_{0.5\,J} \sim 2$ nsec) according to the scheme described in Ref. 2.

The spectrum of scattered radiation was measured with use of a diffraction grating. The incident energy, the reflected energy and the energy transmitted through a cell were recorded by calorimeters.

The shape of the pump and Stokes radiation pulses was recorded by photodiodes (the time resolution of the instruments was 280 nsec). The Stokes radiation in one channel was recorded behind the x-ray filter and in the other channel it was recorded behind the interference filter with a transmission maximum $\lambda = 1.315$ μm and passband halfwidth $\Delta\lambda = 0.01$ μm. This enabled us to separate the time evolution pictures of SRS from those of SMBS.

The pump energy reached 2J at a radiation divergence $\theta_{0.1\,J} = 5 \times 10^{-4}$ rad.

Two spectral components, the SMBS component ($\lambda \sim 1.31$ μm) and the SRS component ($\lambda \sim 1.46$ μm) were observed in the spectrum of backward scattered radiation.

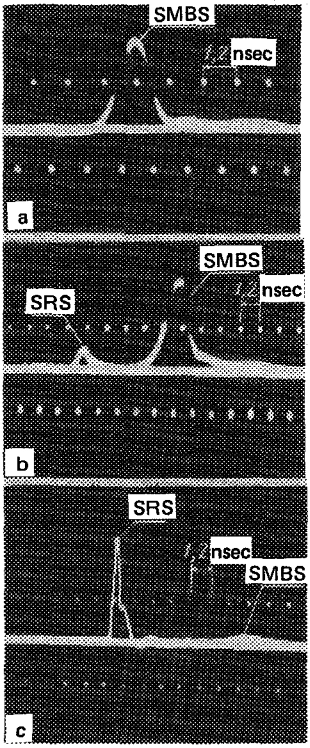

FIG. 1. Stokes radiation pulses for different pump energy densities. (a) $\mathscr{E}_{pump} = 16$ J/cm², (b) $\mathscr{E}_{pump} = 26$ J/cm², (c) $\mathscr{E}_{pump} = 73$ J/cm².

As the experiments have showed, the advantage of a given process is determined to a great extent by the energy of the pump pulse and by the shape of its leading edge.

Only SMBS is in effect when the density of the pump energy is $\mathscr{E}_{pump} \lesssim 20$ J/cm² (Fig. 1a). At $\mathscr{E}_{pump} \gtrsim 30$ J/cm² there is initially a relatively short SRS pulse, which is followed by an SMBS pulse (Fig. 1b). At $\mathscr{E}_{pump} \gtrsim 80$ J/cm² there is almost a total suppression of SMBS due to a gas breakdown in the cell and only on SRS can be observed (Fig. 1c). Note that SRS preceded the gas breakdown and possibly facilitated its development in all the conducted experiments, because the local energy density increases in the medium as a result of SRS. Figure 2 shows the development of SRS and SMBS as a function of the shape of the pump pulse.

The threshold energy of nonsteady-state SMBS is initially built up if the front is slightly sloped (see Fig. 2a) (Ref.10)

$$(E_{thresh})_{SMBS} = \frac{\tau_f \left(20 + \frac{\tau}{\tau_f}\right)^2}{4\, g_{SMBS} \int_l \frac{dx}{S}}, \tag{1}$$

where τ_f is the lifetime of the acoustic phonon, τ is the duration of the pump pulse, g_{SMBS} is the steady-state amplification factor of the Stokes component, l is the inter-

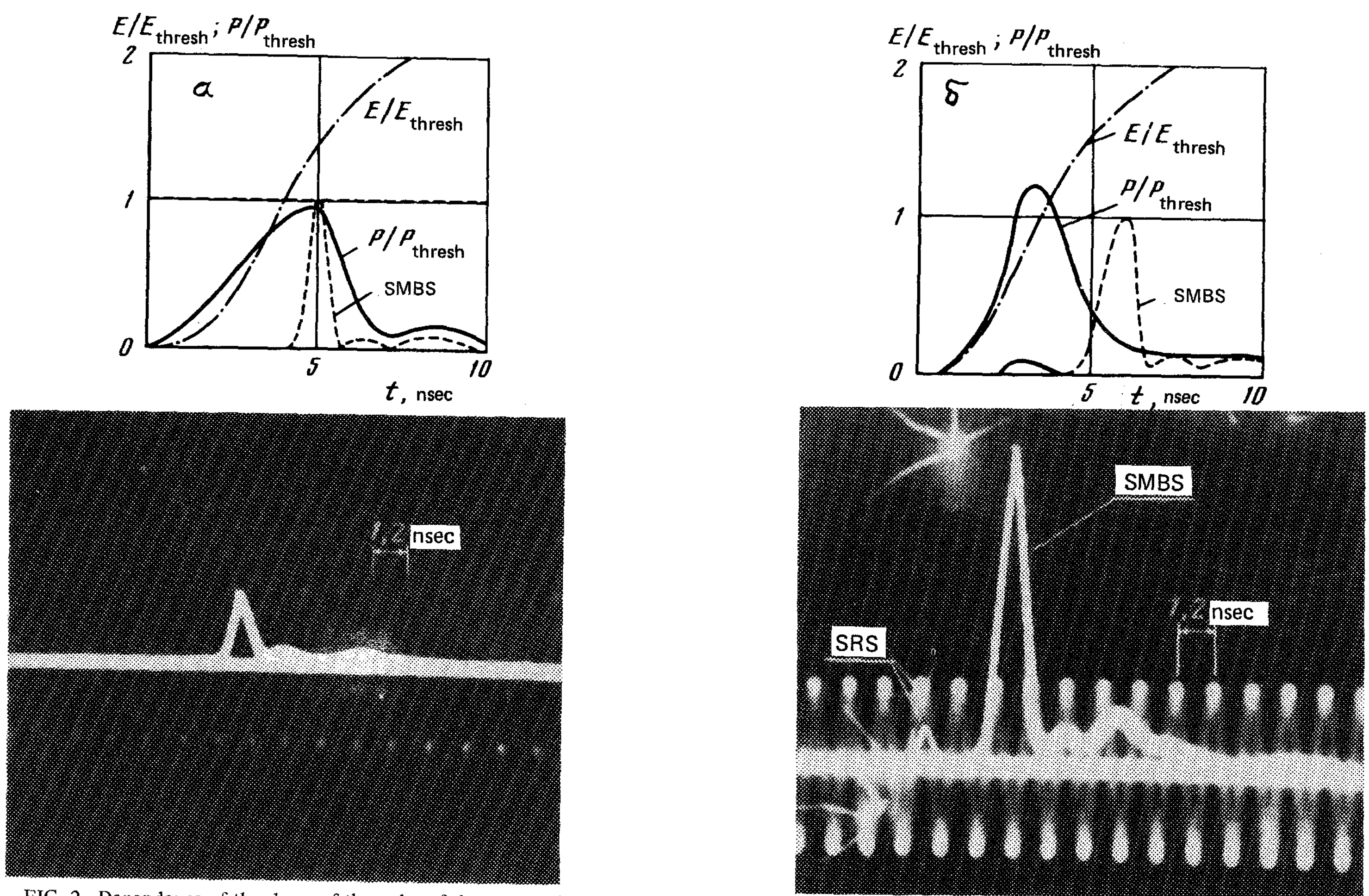

FIG. 2. Dependence of the shape of the pulse of the scattered radiation on the shape of the pump pulse. (a) Flat pulse front and (b) steep pulse front.

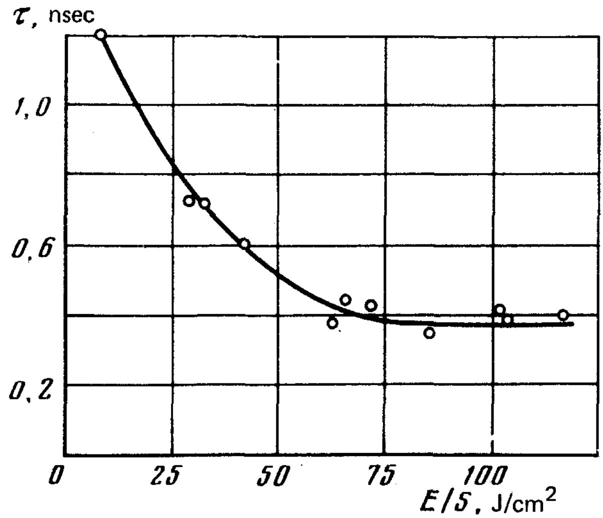

FIG. 3. Dependence of the recorded pulse duration of SRS on the pump radiation energy density.

action length, and S is the cross-sectional area of the interaction length. The threshold power of SRS has not been reached yet and only SMBS has been observed in the experiments.

Since the threshold power of the steady-state SRS is initially reached when the leading edge of the pulse is relatively steep (Fig. 2b) (Ref. 9)

$$(P_{thresh})_{SRS} = \frac{20}{g_{SRS} \int_{l} \frac{dx}{S}} \tag{2}$$

the SRS is developed first. The SRS is suppressed after the SMBS threshold energy is reached and the Stokes radiation will subsequently contain essentially only the SMBS component. The duration of the SRS pulse, which also turned out to be dependent on the density of the pump energy (see Fig. 3), decreased from 0.7 to 0.38 nsec (the limit of the resolution of the apparatus is 0.38 nsec). An estimate of the duration of the SRS pulse with allowance for the instrumental resolution gives the value $\tau \sim 100$ psec for $\mathscr{E} \geqslant 75$ J/cm^2.

In conclusion, we note that, as follows from the relations (1) and (2), when the steady-state SRS competes with the nonsteady-state SMBS the pulse front is of a certain limiting duration during which SMBS can occur in it without SRS

$$\tau_f \gtrsim K \frac{(E_{thresh})_{SMBS}}{(P_{thresh})_{SRS}}$$

where K is a numerical factor ($K = 2$ for a triangular pulse).

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