Use of nonlinear processes to shape subnanosecond high-contrast laser pulses

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(Submitted 24 September 1982)
Zh. Eksp. Teor. Fiz. **82**, 1079–1091 (April 1982)

The features of stimulated Brillouin scattering (SBS) of short high-power laser pulses in compressed gases are investigated. The possibility is demonstrated of shaping high-contrast pulses with steep rising fronts in a nonstationary scattering regime. The conditions under which such pulses can be shortened in nonlinear interactions (amplification in the saturation regime, bleaching of phototropic media, optical breakdown of gases) are investigated. It is shown that the emission frequency of an iodine laser operating on the $^2P_{1/2} \rightarrow {}^2P_{3/2}$ transition can be converted in the SBS process into other transitions of the hyperfine structure of the iodine atom. The competition between SBS, stimulated Raman scattering, and optical breakdown in compressed gases is investigated experimentally. A driving laser with an SBS mirror is developed and is used in the ISKRA-IV iodine laser for research into laser-mediated thermonuclear fusion. An energy 1–2 kJ within $\tau \approx 0.3$ nsec is obtained in a single-channel laser.

PACS numbers: 42.60.He, 42.65.Cq, 51.70. + f

1. INTRODUCTION

Compression of fuel (DT gas) in a microtarget under the action of laser radiation calls for matching the waveform and the duration of the laser pulse to the target parameters. This calls in turn for methods of shaping a laser pulse of a particular waveform and duration. One more requirement is a sufficiently high radiation contrast, both in energy and in power.

To solve this problem one can use nonlinear processes, such as stimulated Brillouin scattering (SBS) and others. A test of the possibility of using nonlinear processes for the purposes indicated above was made with an iodine laser. As indicated, e.g., in Refs. 1–4, this laser is a useful tool for the study of troublesome problems of laser mediated thermonuclear fusion. Investigations of the possibility of using an SBS mirror to produce a driving oscillator and for nonlinear shortening of the pulse duration as it propagates in an iodine amplifier have demonstrated[5-12] that this trend of research is promising. Tests have shown the possibility of obtaining at the output of the "Iskra-IV" facility[2] (in one channel) a high-contrast short ($\tau \lesssim 0.3$ nsec) laser pulse with energy 1–2 kJ.[35]

2. OPTICAL DECOUPLING AND RADIATION CONTRAST

One of the problems in the development of apparatus for laser mediated thermonuclear fusion (LTF) is the attainment of a high radiation contrast, both in energy and in power[1)] ($K_E, K_P \lesssim 10^8$), which is necessary to prevent damage to the target as well as formation of plasma prior to the arrival of the main pulse. Special measures taken for this purpose in multistage amplification systems prevent self-excitation of the amplifiers. Included, in particular, are such optical decouplers as Kerr and Pockels cells, bleachable shutters, etc.

To obtain sufficiently high contrast at the output of the entire system as a whole it is necessary to recognize that the weak-signal gain in each amplifier of the "Iskra-IV" facility is ~10^2, and the strong-signal gain is ~10–15. This means that the radiation contrast in each amplifier stage decreases by approximately 10 times. The decouplers between the stages should compensate for the deterioration of the contrast in the amplifier and improve, under optimal conditions, the contrast of the initial signal. For the same purpose, a reasonable choice should be made of the parameters of the individual amplifiers.

2.1. One of the main properties of the interstage decoupling, which determines the possibility of its use in one system or another to prevent self-excitation of the amplifier and to increase the radiation contrast, is the ratio of the transmission of the main radiation pulse (T_{strong}) to the weak-signal transmission (T_{weak}), $\varkappa = T_{strong}/T_{weak}$. The highest values of $\varkappa$ can be obtained with nonlinear radiation conversion, e.g., in decouplers based on SBS.[2)] This possibility, due to the threshold of the onset of stimulated scattering and to the fact that the backward Stokes radiation propagates in approximately the same solid angle as the pump beam, was investigated by us in Refs. 5–9. The experimental results and an analysis of the conditions of duplicating the angular spectrum in SBS of the radiation of an iodine laser are given in Refs. 6, 7, and 10.[3)]

One of the possible means of increasing the contrast and the stage decoupling is shown in Fig. 1a. For iodine lasers with a narrow gain line $\delta\nu_L \approx 0.1$ cm^{-1} (Ref. 3) effective amplification of the Stokes signal is

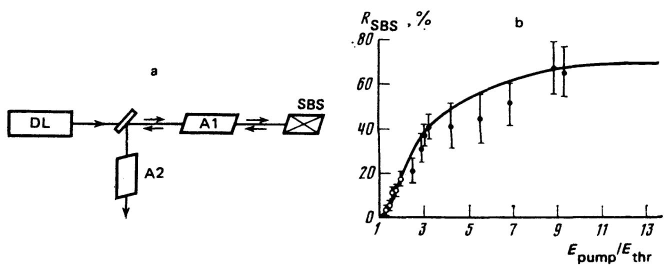

FIG. 1. a) Experimental setup, b) dependence of the reflection coefficient for SBS in SF_6 on the excess above threshold ($E_{thr} \approx 2.5$ kJ·cm^{-2}); ○, ●—experiment, solid curve—calculation.

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possible only when the frequency shift $\delta\nu_S$ is substantially smaller than $\delta\nu_L/2$ (Ref. 6), so that the best active media for SBS are gases with low second velocity (Xe, SF_6, and others). Thus, e.g., $\delta\nu_S \approx 7.5 \cdot 10^{-3}$ cm^{-1} for Xe at a pressure 39 atm and $\delta\nu_S \approx 5.7 \cdot 10^{-3}$ cm^{-1} for SF_6 ($P = 22$ atm).[14] Since the pulse duration in LTF facilities is $\tau \approx (0.1\text{–}1)$ nsec, and the damping time τ_p of the sound wave in the gases is long [$\tau_p = 50$ nsec for Xe at $P = 39$ atm and $\lambda \approx 1.315$ μm (Ref. 14), and $\tau_p = 26$ nsec for SF_6 at $P = 18$ atm (Ref. 15)], the scattering will be essentially nonstationary.

The possibility of obtaining high reflection coefficients from a SBS mirror under these conditions, when other nonlinear phenomena such as breakdown of the medium can also manifest themselves, seemed problematic and called for experimental investigations whose results[5,6] are shown in Fig. 1b in the form of a plot of the reflection coefficient of the SBS mirror against the excess above the pump energy (E_{pump}) over the threshold energy (E_{thr}) [for a definition of E_{thr} see Eq. (2) below]. The maximum reflection coefficient obtained in an experiment with SF_6 at $P = 20$ atm was $R_{\text{SBS}} = 70\%$. A numerical investigation of the energy characteristics of a Stokes pulse in SBS for the case of nonstationary interaction, carried out in Refs. 6 and 9 in the plane-wave approximation, gave good agreement with experiment (Fig. 1b). The calculated dependence of the reflection coefficient R_{SBS} on the excess of the energy density above threshold at $E_{\text{pump}}/E_{\text{thr}} \gtrsim 2$ can be approximated[9] by the expression

$$R_{\text{SBS}} = [1 - (E_{\text{thr}}/E_{\text{pump}})^{1/2}] \cdot 100\%. \qquad (1)$$

2.2. Experiments[2,5] [Fig. 2(a), (b) and calculation[6,8,12] [Fig. 2(c)] have shown that an SBS mirror eliminates the precursor and can increase the energy contrast substantially. From the experimental data it follows that the attained contrast is even now higher than 10^7 (the threshold of the resolution of our procedures at the present time), and it follows from the results of the calculations[9,12] that it can be raised to[4)] 10^8–10^9.

For example, at a contrast $(K_p) \approx 16$ of the SBS pump radiation calculation yields for the Stokes radiation a contrast $(K_p)_S = 2 \cdot 10^8$, and at $(K_p) \approx 64$ the value is $(K_p)_S) = 2 \cdot 10^9$.

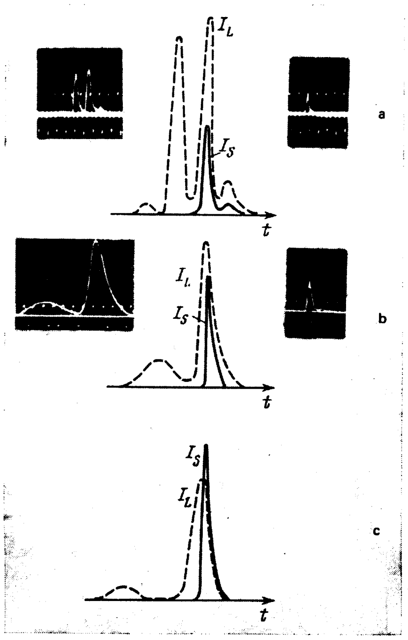

FIG. 2. Elimination of the precursor and sharpening of the radiation pulse of an iodine laser in SBS.

3. POSSIBILITY OF USING NONLINEAR PROCESSES TO SHORTEN A LASER PULSE

3.1. Calculations and the accumulated experimental data (see, e.g., Ref. 23) show that at laser energies ≈1 kJ the largest neutron yield can be obtained in the "exploding shell" regime, when the intensity of the irradiating pulse can be large. It is necessary for this purpose that the pulse duration not exceed ≈0.3 nsec. We call attention in this connection to the fact that an SBS mirror can be used also in the nonstationary regime[5)] to shorten substantially the rise time of the pulse and its total duration.[5] Thus, in the experiment of Fig. 2(b) the rise time was decreased from ~1 to ~0.2 nsec (with allowance for the resolution of the apparatus), and the pulse duration was shortened from ~5 to ~1 nsec.

3.2. Calculations[6,9,12] under conditions close to the experimental ones have also shown that in the SBS process there takes place, besides the precursor cutoff, a shortening of the pulse duration ($\tau_S < \tau_L$) and a reduction of its rise time τ_f [see Fig. 2(c)]. The rise time depends significantly on the excess of the pump energy above the threshold ($\tau_f = 1$ nsec at $E_{\text{pump}}/E_{\text{thr}} = 1.4$ and $\tau_f = 0.2$ nsec at $E_{\text{pump}}/E_{\text{thr}} = 14$). The pump and Stokes-emission profiles shown in Fig. 2(c) correspond to $E_{\text{pump}}/E_{\text{thr}} = 4$. It is seen that the duration of the leading front is shortened by almost one order, and the remaining part of the profile practically duplicates the exciting-radiation pulse.

3.3. Further shortening of a laser pulse with a steep leading front can occur also when it propagates in amplifying stages that operate under conditions of sufficiently strong saturation (see, e.g., Ref. 24). The nonlinear narrowing of the pulse is due in this case to the predominant removal of the inversion in the amplifiers by the leading edge of the pulse. Calculations[12] using the specially developed "Kaskad" program have shown (see Fig. 3) that a laser pulse having at half maximum a duration $\tau_{\text{pump}} \approx 3$ nsec and shortened by SBS to

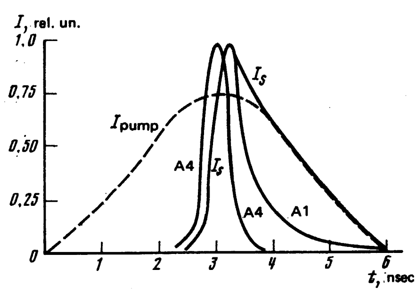

FIG. 3. Reduction of pulse duration upon amplification $\tau_{\text{pump}} = 3$, $\tau_S = 1.1$, $\tau_{A1} = 0.5$, $\tau_{A4} = 0.3$ nsec.

$\tau_S \approx 1$ nsec is additionally shortened by amplification in four stages of an iodine amplifier to $\tau_L \approx 0.3$ nsec. It should be noted that the calculations[6,9,12] were performed in the one-dimensional approximation, therefore this shortening should be expected in experiment, strictly speaking, when the driving laser operates in a regime with a single spatial mode. For multimode radiation with complicated spatial and temporal structures, the peaking and shortening of the pulse may not manifest itself so strongly.

3.4. Pulses with adjustable duration can be shaped by using the SBS-mirror setup described above a plasma shutter[27,8] that cuts off the trailing edge. The experimental setup and the results[8] are shown in Fig. 4. A radiation pulse shaped in this manner had a duration (with allowance for the resolution of the apparatus) ≈350–500 psec and an energy up to 0.1 J (see Fig. 4).

An interesting possibility of shaping a laser pulse of short duration is provided by a combination of an SBS mirror with iodine shutter[12] [Fig. 5(a)]. To this end, the steep-rise pulse reflected by the SBS mirror must be applied to a passive shutter with a narrow absorption line, which transmits the high-frequency leading front of the pulse and filters out its smooth rear part. This possibility was verified and confirmed by calculation [Fig. 5(b)]. In the calculation illustrated in Fig. 5(b), the time T_2 of the transverse relaxation in the shutter was assumed to be 0.5 nsec, and the weak-signal transmission of the shutter at the center of the line was 10^{-3}.

It must be emphasized that in this method the radiation contrast turns out to be higher than in the method of "free decay of induction" (see, e.g., Ref. 28), in which a pulse with a steep trailing edge, obtained by passing a Gaussian pulse through a plasma shutter is applied to an iodine laser [Fig. 5(c)]. In the calculations, the pulse with the steep trailing edge was simulated by a time-inverted Stokes pulse [Fig. 5(b)]. As seen from a comparison of Figs. 5(b) and 5(d), a combination of an iodine shutter with an SMBS mirror ensures both shortening of the pulse and high contrast [Fig. 5(b)], while a combination of an iodine shutter with a plasma shutter is sufficient to suppress the low-frequency components that ensure shortening of the pulse, but is not sufficient to obtain a high contrast.

3.5. The use of SBS can make it possible to obtain radiation not only at the frequency of the main working transition of the iodine laser $F_{upper} = 3$ to $F_{lower} = 4$, but

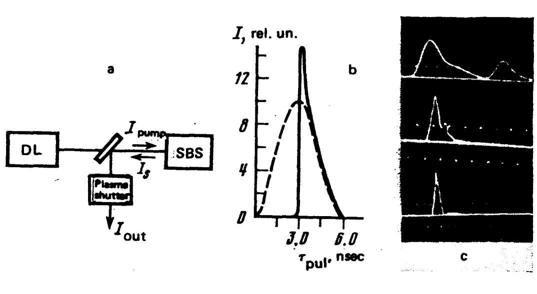

FIG. 4. Shortening of iodine-laser pulse duration with the aid of SBS in a plasma shutter: a—experimental setup, b—calculation, c—oscillograms of pulses.

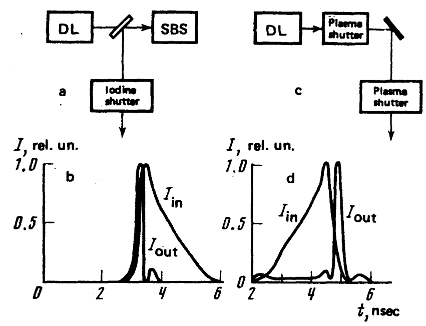

FIG. 5. Shortening of Stokes-pulse duration in an iodine shutter: a—experimental setup when the signal (I_{in}) enters the iodine shutter past the SBS mirror; b—calculation for the setup a; c—experimental setup when the signal (I_{in}) enters the iodine shutter past the plasma shutter; d—calculation for system c; $\tau_{in} = 1$ nsec, $\tau_{out} = 0.25$ nsec.

also transform the radiation of the SBS pump at the frequency of the 3–4 transition into multifrequency pulses whose discrete spectrum overlaps practically the entire gain band (see Fig. 6). Subsequent amplification of the multifrequency pulse may be useful for modifying the shape of the laser-pulse front and increasing the efficiency of the action on the target.

During the first stage of the investigation of the amplification regime of a multifrequency laser pulse, greatest interest attaches to simultaneous amplification of the radiation at the frequencies of the transitions[6)] 3–4 and 2–2. It is seen from Fig. 6 that it is useful to obtain for this purpose SBS radiation at the frequency of the 3–4 transition in Xe, SF_6, or their mixture, and in K-8 glass, when the Stokes radiation lands practically exactly at the center of the line of the 2–2 transition.

With this in mind, we initiated experiments aimed at obtaining short ($\tau \approx 2$ nsec) SBS pulses in K-8 glass. The SBS was observed by focusing the iodine-laser radiation with a lens of 30 cm focal length into a rod of K-8 glass 12 cm long, inclined at an angle 10–15°. The experimental layout corresponded to Fig. 1(a). The reflection coefficient reached 20–30%. The investigations are being continued.

4. COMPETITION OF NONLINEAR PROCESSES

In the cases considered above the stimulated scattering, as indicated, is essentially nonstationary. Under

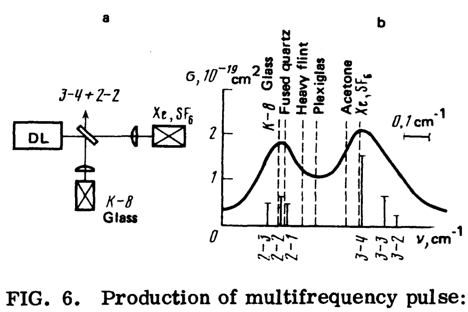

FIG. 6. Production of multifrequency pulse: a—experimental setup; b—distribution of Stokes lines in different nonlinear media over the gain contour of the iodine laser for SBS (the pumping is at the frequency of the 3–4 transition). Dashed—position of Stokes lines, solid line—gain contour of iodine laser ($\Delta\nu_L = 8.7$ Hz, Ref. 1).

these conditions the pump intensities are close to those needed for other nonlinear processes, such as stimulated Raman scattering (SRS) in polyatomic gases and optical breakdown (see Ref. 11, as well as Refs. 31–33). For example, in the experiments under the operating conditions of the first amplification stages of the "Iskra-IV"[2] ($E_{in} \approx 0.3$ J), the intensity of the radiation fed to the nonlinear medium (SF_6 at a pressure ~20 atm) reaches 10–100 GW/cm² at $\tau \approx 1$ nsec, and the threshold conditions can be satisfied for all three nonlinear interactions discussed above.

An investigation of the conditions for the onset of SBS and SRS and for the competition between them has shown[11] that the appearance either process is determined by the pump-pulse energy and by the shape of its leading front. In these experiments, the scattered-radiation spectrum was diagnosed with a diffraction grating. The energies incident on, reflected from, and passing through the cell were registered with calorimeters. The pump and Stokes-radiation pulse shapes were registered with photodiodes (time resolution of the apparatus ~380 psec). The Stokes radiation was registered in one channel behind an IKS filter, and in the other behind an interference filter with maximum transmission at $\lambda = 1.315\ \mu$m and with half width of the transmission band $\Delta\lambda \approx 0.01\ \mu$m. This made it possible to separate the temporal evolutions of the SRS and the SBS.

Under the experimental conditions of Ref. 11, illustrated in Fig. 1(a), at pump energy density $\mathscr{E}_{pump} \leq 20$ J/cm², only SBS is observed [Fig. 7(a)]. At $\mathscr{E}_{pump} \geq 20$ J/cm², a relatively low-power SRS pulse is first produced, followed by the SBS pulse [Fig. 7(b)]. At $\mathscr{E}_{pump} \gtrsim 70$ J/cm² a powerful SRS pulse is observed, as well as practically complete suppression of the SBS [Figs. 7(c)] on account of breakdown of the gas (SF_6 at a pressure 20 atm in the cell). We note that in all the experiments the SRS took place ahead of the gas-breakdown development, and possibly contributed also to its development, if for no other reason than the increase of the optical energy density in the medium.

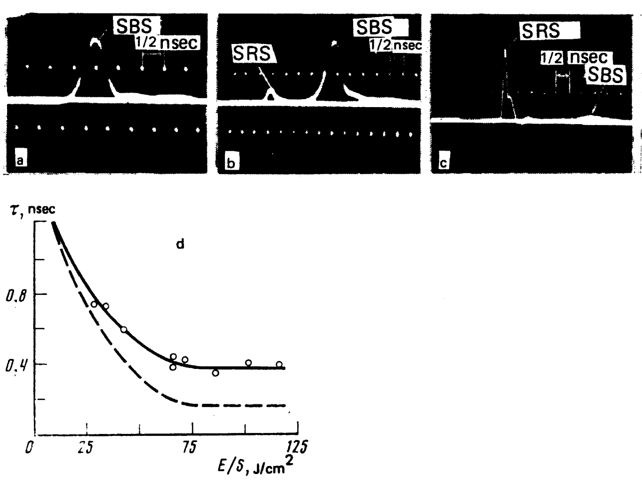

FIG. 7. Stokes-radiation pulses (a—$\mathscr{E}_{pump} = 16$, b—$\mathscr{E}_{pump} = 26$; c—$\mathscr{E}_{pump} = 73$ J·cm⁻²) and d—dependence of the SRS pulse duration on the pump radiation energy density. o—Values registered by the apparatus, dashed—plot of $\tau = f(E/S)$ with allowance for the instrumental function.

The duration of the SRS pulse was found to depend on the pump energy density [see Fig. 7(d)] and decreased from 0.7 to 0.38 nsec (the apparatus resolution limit was 0.38 nsec). Estimates of the duration of the SRS pulse with allowance for the apparatus resolution yield a value $\tau \sim 100$ psec at $\mathscr{E}_{pump} \gtrsim 75$ J/cm².

The dependence of the SRS and SBS evolution time on the pump-pulse shape is shown in Fig. 8. At a relatively slow rise time [Fig. 8(a)], the threshold energy of the nonstationary SBS is acquired earlier.[11,34]

$$(E_{thr})_{SBS} = \tau_p\left(G + \frac{\tau}{\tau_p}\right)^2 \Big/ 4g_{SBS} \int\limits_l \frac{dx}{S} \approx (50\text{–}70)\ \text{mJ}. \qquad (2)$$

Here τ_p is the lifetime of the acoustic phonon, τ is the duration of the pump pulse, g_{SBS} is the stationary gain of the Stokes component, l is the interaction length, S is the area of the cross section along the interaction, G is the gain growth rate ($G = 20$–30). The threshold SRS power has not yet been reached, and only SBS is observed in experiment.

In the case of a relatively short pump rise time [Fig. 8(b)] the threshold power of the stationary SRS is reached earlier,[11] at[34]

$$(P_{thr})_{SRS} = G/g_{SRS} \int\limits_l \frac{dx}{S} \approx 60\ \text{MW}, \qquad (3)$$

and therefore the SRS is first to develop. After the SBS threshold energy is reached, the SRS is suppressed, and the Stokes radiation contains subsequently practically only the SBS component.

Under conditions of competition between stationary SRS and nonstationary SBS, as follows from relations (2) and (3), there exists a certain limiting pump-pulse front duration when SBS can be obtained without SRS. Indeed, for the onset of SBS it is necessary to have

$$\int\limits_{-\infty}^{t_{max}} P(t)\,dt \geqslant (E_{thr})_{SBS}, \qquad (4)$$

where $P(t)$ is the pump power.

On the other hand, the SRS is suppressed if

$$P(t_{max}) = P_{max} \leqslant (P_{thr})_{SRS}. \qquad (5)$$

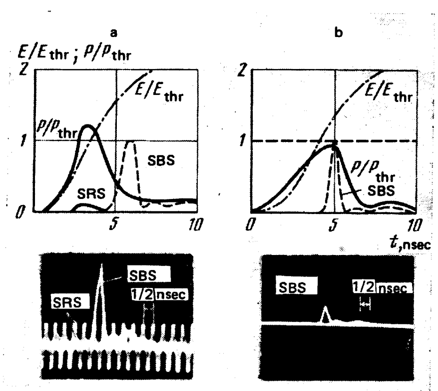

FIG. 8. Dependence of the shape of the scattered radiation pulse on the shape of the pump pulse: a—steep pump front, b—gently sloping pump front.

Estimating the integral in the left-hand side of (4)

$$\int_{-\infty}^{t_{max}} P(t)\,dt \approx P_{max} t_{fr} K, \tag{6}$$

where t_{fr} is the characteristic pulse growth time and K is a numerical factor that depends on the pulse waveform ($K=2$ for a triangular pulse), we arrive at the condition of obtaining SBS without SRS

$$\tau_{fr} \gg K \frac{(E_{thr})_{SBS}}{(P_{thr})_{SRS}} \sim G\tau_{p\,SBS} \frac{g_{SRS}}{g_{SBS}}. \tag{7}$$

For a Gaussian pulse it is more convenient to rewrite (7) in the form

$$\tau_{pul} \gg 2(E_{thr})_{SBS}/(P_{thr})_{SRS}, \tag{8}$$

where τ_{pul} is the pulse duration.

If the parameters of the pump pulse and of the active medium do not satisfy relations (7) and (8), then the SRS appears earlier and the considered method of obtaining short SBS pulses cannot be used.

It is possible to get rid of the SRS by using as the active medium for the SBS not SF_6, but a monatomic gas, where there should be not SRS. Such a medium may be xenon gas at pressures of several dozen atmospheres. However, experiments have shown[7] that in the conditions of interest to us (focused beams with $I_{pump} \gtrsim 10$ GW/cm^2) breakdown of the Xe gas occurs and limits the possibility of obtaining Stokes SBS signals having the required parameters.

Breakdown in an SBS-active medium and the onset of SRS can be avoided by using an active medium which is a mixture of two gases, monatomic Xe and polyatomic SF_6. The addition of SF_6 raises by several times the mixture breakdown threshold compared with pure xenon. Thus, e.g., under the conditions considered the breakdown thresholds of various gases are $I_{Xe} \approx 4$, $I_{SF_6} \approx 16$, $I_{Xe(40\,atm)+SF_6(6\,atm)} \approx 12$ GW/cm^2 (Ref. 36).

As a result of changing from pure Xe to its mixture with SF_6 ($P_{Xe} \approx 40$ atm, $P_{SF_6} \approx 6$ atm) the two undesirable phenomena do not occur in the region $\mathscr{E}_{pump} \lesssim 100$ J/cm^2. No SRS components were observed in the experiments in the spectrum of the Stokes radiation measured by the method described above. The absence of any noticeable manifestations of SRS and of gas breakdown under these conditions is demonstrated, in particular, also by the fact that the sum of the energy reflected in the SBS process and the energy passing through the SBS cell is close (within the limits of measurement error) to the pump energy (see Fig. 9).

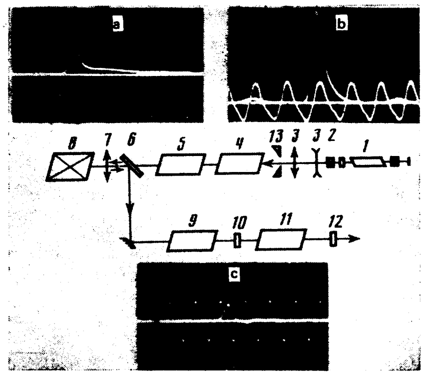

FIG. 10. Driving laser with SBS mirror of the "Iskra-IV" facility: 1—laser with active Q switching; 2—chopping Kerr cell; 3—broadening telescope; 4, 5, 9, 11—amplification stages PA1, PA2, PA3, and PA4; 6—beam-splitting mirror; 7—input system; 8—SBS cell; 10, 12—interstage decoupling of amplifier stages; 13—soft diaphragm. a—Oscillogram of driver-laser cell ahead of the chopping Kerr shutter ($T_{calib}=10$ nsec); b—oscillogram of pulse of SBS pump radiation ($T_{calib}=2.5$ nsec); c—oscillogram of emission pulse at the exit from the amplifier PA4 ($T_{calib}=1.2$ nsec).

Thus, the computational-theoretical and experimental investigations have demonstrated the feasibility of peaking and shortening the duration of short laser pulses, and considerably increasing the contrast, in nonstationary SBS. Amplification of a Stokes SBS pulse in the saturation regime should be accompanied, under specially chosen conditions, by a shortening of its duration to $\tau \approx 0.3$ nsec.

5. DRIVING LASER WITH SBS MIRROR FOR THE "Iskra-IV" INSTALLATION

On the basis of the results, a driving laser with SBS mirror was developed; its optical system is shown in Fig. 10. The initial pulse, shaped in an actively Q-switched laser, has a characteristic "three-hump" profile (Fig. 10) and an energy 15 mJ. After chopping with a Kerr shutter 2 and amplification in the preamplifiers

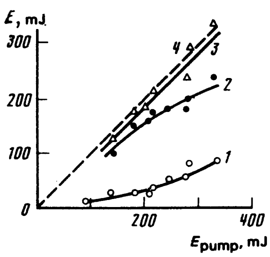

FIG. 9. Redistribution of the radiation energy in the SBS cell as a function of the pump energy: 1—E_{SBS}, 2—E_{trans}, 3—$E=E_{SBS}+E_{trans}$, 4—$E=E_{pump}$.

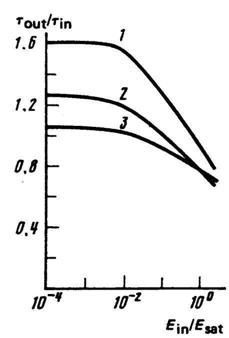

FIG. 11. Dependence τ_{out}/τ_{in} on the relative energy density at the input to the amplifier ($K_0=50$): 1—$\tau_{in}=1.7\ T_2$; 2—$\tau_{in}=3.3\ T_2$; 3—$\tau_{in}=8.3\ T_2$.

PA1(4) and PA2(5), it is converted into a single pulse with duration at half-maximum $\tau_{0,5I} \approx 2.5$ nsec (Fig. 10) and with energy 1–2 J. The duration at the base is 19 nsec. The radiation leaving the amplifier PA2 is focused by a lens 7 with $f = 1.2$ m into the SBS cell of length 2 m, filled with a mixture of SF_6 at $P = 6$ atm and Xe at $P = 39$ atm. The SBS radiation with energy 30–50 mJ is reflected by beam-splitting mirror 6 and is amplified (with its duration shortened) in the preamplifiers PA3(9), and PA4(11), and is fed to the decouplers 10 and 12. The parameters of the radiation pulse at the exit from the system is: energy 0.5 J, duration $\tau_{0.5I} \approx 0.6$ nsec, rise time $\tau_{(0.1\text{-}0.9)I} \approx 0.17$–$0.2$, divergence $\theta_{0.5} \approx 1 \cdot 10^{-3}$ rad, light diameter ~40 mm.

This laser was used as the driver to shape the pulse in the "Iskra-IV",[2] operating in the pulse-shortening[7)] regime.[35] A pulse with $\tau \sim 10^{-9}$ sec amplified in iodine photodissociation amplifiers with transverse relaxation time $T_2 \approx 10^{-10}$ sec can be shortened only if the ratio of the density of the input energy to the density of the saturation energy E_{in}/E_{sat} is high enough (see Fig. 11, and Refs. 12 and 35).

Depending on the duration of the input pulse and on the gain of the stage, shortening requires various densities of the input energy. It can be shown, however, that the characteristic value E_{in}/E_{sat}, needed to shorten the pulse, amounts under our conditions to $\gtrsim 0.1$–0.3. This regime was obtained by introducing in the optical channel two additional amplification stages, A1.2 and A2.2 (see Fig. 12), and by suitably choosing the compositions of the working mixtures in all the stages. The time of transverse relaxation in the amplification stages was decreased here to $T_2 \lesssim 10^{-10}$ sec, and the weak-signal gain was $K_0 \approx 10$–20 in the intermediate stages and $K_0 \approx 40$–60 in the power stages. As a result, while the overall weak-signal gain of the entire system as a whole[8)] was substantially decreased, when account is taken of the initial transmission of the decouplers and the attenuation $K_0^{new} \approx 50$ in the system (in place of $K_0^{old} \approx 2 \cdot 10^3$), it was possible to realize for a number of amplification stages the conditions needed to shorten the pulses.

The results of one of the experiments[35] is demonstrated in Fig. 12, which shows the evolution of the pulse as it is amplified through the "Iskra-IV" facility. As seen from Fig. 12, the initial pulse of duration $\tau_{0.5I} \approx 0.6$ nsec was shortened at the output of the last stage to $\tau_{0.5I} \approx 0.3$ nsec, the output energy being $E_{out} \simeq 1100$ J from a 42 cm aperture.

1)By energy contrast of the radiation (K_E) is meant the ratio of the radiation energy in the single pulse to the energy incident on the target prior to its arrival, and by power contrast (K_P) is meant the ratio of the maximum pulse power to the precursor pulse power.

2)In Ref. 2 was considered the use, for LTF, of iodine passive shutters proposed by the authors of Refs. 16 and 17, and of thin bismuth films sputtered on glass.[18] We note that thin metallic coatings were used earlier[19] to reduce the pulse duration to ~5–7 nsec.

3)Much attention is being paid at present to the possibility of using wave-front inversion[20] to compensate for the optical inhomogeneities[21] and to aim on the target[7,12] in laser thermonuclear fusion installations.

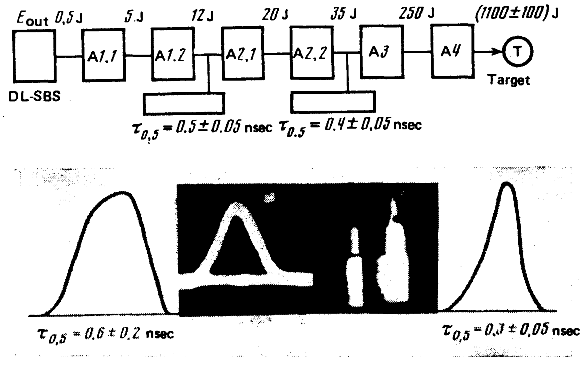

FIG. 12. Shaping of pulse in the "Iskra-IV" facility.

4)The attainment of extremely high values of K_P in interstage decoupling systems based on SBS is hindered by the backscattering of the pump radiation from the optical elements that admit the radiation in the SBS cell, and by the competition of other types of scattering in the SBS medium itself (some of these questions will be considered below).

5)The possibility of decreasing the rise time of a laser pulse with the aid of SBS in the stationary regime was demonstrated in Refs. 25 and 26.

6)The shaping of a two-frequency pulse at the frequency of the transitions 3–4 and 2–2 by other methods was considered in Refs. 29 and 30.

7)We note that the initial version of the setup[2] the radiation pulse duration remained practically unchanged in the course of amplification and amounted to $\tau_{0.5I} \approx 0.8 \pm 0.2$ nsec.

8)This improves considerably the radiation contrasts K_E and K_P.

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Translated by J. G. Adashko