Inversion of wavefront in SMBS of a depolarized pump

N. G. Basov, V. F. Efimkov, I. G. Zubarev, A. V. Kotov, S. I. Mikhaĭlov, and M. G. Smirnov

P. N. Lebedev Physics Institute, USSR Academy of Sciences

It is established experimentally that the depolarization of the initiating radiation upsets the regime of wave-front inversion in SMBS in a light pipe. A scheme that makes it possible to obtain inversion of the wavefront of depolarized radiation is proposed and realized.

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1. The use of the effect of wave-front inversion (WFI)[1] in SMBS for the purpose of canceling out phase distortions of the signal in high-power optical-amplifier stages is presently attracting much attention.[2,3] Yet, when it comes to real systems, it becomes necessary to investigate the influence of new physical effects capable of upsetting the WFI regime. These effects arise when the operating regime and the active medium (particularly neodymium glass) in the high-power amplifiers, differ from those in the earlier WFI studies. Foremost among these effects is the depolarization of the radiation upon amplification[4] (in all the WFI experiments performed to date, the pump radiation was polarized) and the substantial nonlinearity of the scattering process used for the WFI, inasmuch as the duration of the laser pulse in high-power installations, $\tau \sim 1$ nsec, is less than or comparable with the characteristic SMBS establishment times.

An experimental fact long known and extensively used to realize polarization decoupling is that in SMBS of radiation with circular polarization, the direction of the Stokes-component polarization is reversed: if the pump is right-circular, then the

Stokes component is left-circular, and vice versa. This fact alone shows that the polarization state (with the exception of linear polarization) is not restored in SMBS. This is a result of the vector character of the fields, since complex-conjugate waves with circular polarizations are mutually orthogonal and do not interact.

The influence of the polarization state of the exciting radiation on the WFI regime was investigated theoretically in Ref. 5. It was shown there that spatially-inhomogeneous depolarization of the pump makes the WFI worse than in inhomogeneous polarization. In the present study we have investigated experimentally the influence of pump depolarization on WFI, and also propose and realize a scheme that makes it possible to observe the regime of WFI of radiation with arbitrary states of polarization.

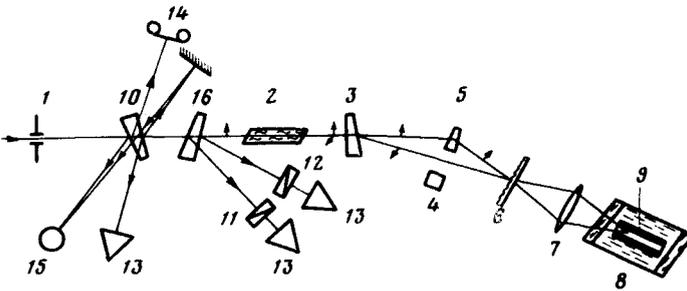2. A simplified block diagram of the experimental setup is shown in Fig. 1. Lin-

FIG. 1. Block diagram of the experimental setup: 1—exit diaphragm of pump radiation; 2—ruby rod of poor optical quality; 3—birefringent wedge; 4—plate that rotates the polarization vector of the radiation through 90°; 5—glass wedge; 6—phase plate; 7—lens; 8—cell with carbon disulfide; 9—glass light pipe; 10–16—elements of recording system.

early polarized pump radiation, shaped by means of the master laser and a system of neodymium-glass amplifiers (pulse duration $\tau = 25$ nsec, spectrum width $\Delta\nu \leqslant 0.005$ cm^{-1}, energy $E = 0.5$ J, and divergence $\theta = 2 \times 10^{-4}$ rad at a beam diameter 6 mm), after passing through diaphragm 1 and two glass wedges of the measurement assembly, was incident on the depolarizing element 2. The wedge 3, made of birefringent material (Iceland spar), split the pump beam into two beams with mutually perpendicular polarization vectors. The two beams were then directed to a phase plate 6, the image of the illuminated part of which was projected by a lens with $f = 25$ cm in a Brillouin cell 8 onto the entrance face of the light pipe 9 (glass tube 70 cm long with inside diameter 3 mm, filled with carbon disulfide). The measuring assembly made it possible to register simultaneously the directivity patterns of the exciting radiation and of the reflected signal, as well as the intensity distribution of the reflected signal at a point conjugate to the exit diaphragm 1. The energies of the pump and of the reflected signal were measured with a calorimeter, the reflected energy being determined for the two mutually perpendicular directions of the polarization vector. The depolarizing element was a ruby rod 25 cm long of poor optical quality. The phase plate was a glass substrate, etched in fluoric acid, 2 mm thick, which broadened the directivity pattern of the pump radiation to $\theta \approx 2 \times 10^{-2}$ rad.

3. The initial experiments were performed on WFI of polarized pumping, with the aid of suitable orientation of the optical axis of the depolarizing element relative to the polarization vector of the exciting wave. A comparison of the directivity patterns of the incident and reflected radiations has shown them to be perfectly identical, and the dimensions of the back scattered light beam at the point conjugate to the exit diaphragm coincided with the dimensions of the pump radiation emerging from the diaphragm (see Figs. 2a and 2b). The ruby rod was then rotated 45° around the longi-
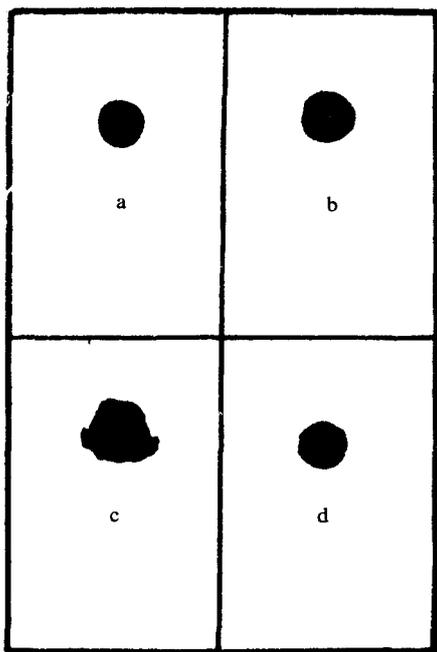

FIG. 2. Photographs showing the distribution of the intensity of the radiation in the pump beam at the exit from diaphragm 1 and of the reflected signal at the point conjugate to the exit diaphragm 1: a—distribution of intensity in the pump beam; b—distribution of intensity in the reflected beam in the absence of depolarization; c—the same in the presence of depolarization of the pump radiation; d—the same in the presence of depolarization of the pump radiation, but with plate 4 introduced into the system to rotate the radiation polarization vector through 90°.

tudinal axis. In this case, at the exit from the rod, the state of the radiation polarization was inhomogeneous over the cross section of the beam. The share of the integrated pump energy in each of the two mutually perpendicular directions of the polarization vector was 50%. Figure 2c shows a typical photograph of the distribution of the intensity of the reflected signal in the case of depolarized pumping, while Fig. 3 shows the corresponding directivity pattern. It is clearly seen that the dimensions of the reflected beam do not coincide with the dimensions of the beam of the excited radiation, and the directivity pattern of the reflected signal is broadened compared with the directivity pattern of the pump. The calorimetric-measurement data show that at the reflected signal returning through the ruby rod remains depolarized (50% of the reflected energy had a polarization-vector directed perpendicular to the pump-polarization vector). The obtained experimental data indicate that the reflected wave in the case of depolarized pumping is not inverted relative to the wave incident on the cell, i.e., the relation $E^{ref} = \text{const} \cdot E^{*inc}$ is not satisfied.

4. If a plate 4 that rotates the polarization vector by 90° is introduced into one of the pump beams polarized in mutually perpendicular direction (see Fig. 1) (in these

experiments we used a plate of left-rotating quartz 14 mm thick), then this optical system makes it possible to obtain the effect of WFI of depolarized radiation. It is easily seen that now, regardless of the state of the polarization of the initial radiation, the pump beam entering the Brillouin cell is linearly polarized and the conditions for WFI are satisfied. Since the amplitude of the backscattered Stokes component satisfies in the case of WFI the condition $E^{\text{ref}} = \text{const} \cdot E^{*\text{inc}}$, all the phase and polarization distortions are cancelled out in the radiation leaving the cell after passing back through the inhomogeneous plate and through the depolarizing element, i.e., the wave proceeding in the opposite direction has not only a plane front, but also the same state of polarization as the exciting radiation.

The experimental results have fully confirmed these conclusions. According to the data of calorimetric measurements, up to 90–100% of the entire energy of the SMBS Stokes component at the exit of the depolarizing element was contained in the polarization that coincided with that of the pump. The directivity pattern of this radiation coincided in practice with the corresponding characteristic of the exciting wave, Fig. 3. The reflected beam had at the point conjugate to the exit diaphragm (Fig.
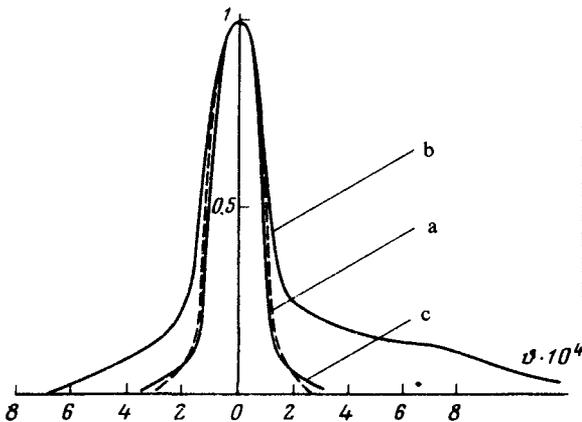

FIG. 3. Directivity patterns of pump and reflected-signal radiation: a—directivity pattern of pump radiation; b—directivity pattern of reflected signal in the case of depolarized pumping; c—the same but with plate 4 introduced to rotate the radiation polarization vector through 90°.

2d) the same diameter as the pump. Similar results were obtained with a quartz-wave plate in place of the depolarizing ruby element.

5. The experiments allow us to draw the following conclusion: depolarization of exciting radiation greatly deteriorates the WFI regime compared with the case of polarized pumping; however, the use of special schemes makes it possible to obtain a WFI regime of depolarized radiation.

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