Effect of a static electric field on stimulated Brillouin scattering in compressed hydrogen

N. V. Kravtsov and N. I. Naumkin

Scientific-Research Institute of Nuclear Physics, M. V. Lomonosov Moscow State University, 119899 Moscow, Russia

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The application of a static electric field to a stimulated-Brillouin-active medium increases the efficiency of the stimulated scattering. © *1995 American Institute of Physics.*

1. Stimulated Brillouin scattering (SBS) (or "stimulated Mandel'shtam–Brillouin scattering") arises because electrostrictive forces give rise to a space–time modulation of the density (and thus the dielectric constant) of the stimulated-Brillouin-active medium at hypersonic frequencies. Stimulated Brillouin scattering is characterized by a large gain for the Stokes wave [$E_s = E_{s0}\exp G|E_L(r)|^2 z$] and by a pronounced spatial nonuniformity of the local gain [$g = G|E_L(r|)^2$] . This nonuniformity, caused by the spatial nonuniformity of the pump $E_L(r)$, sets the stage for phase conjugation in the course of SBS.

Even a small change in gain $\Delta g/g$ can evidently lead to radical changes in the excitation of SBS.[1] One might thus expect that the imposition of an electric field would affect SBS characteristics.

2. In this letter we are reporting a study of how a static external electric field affects SBS in compressed hydrogen. Although the gain is high, it is difficult to excite SBS in compressed gases because of their low density and because of the need to use intense pump sources.[2-5] We accordingly took the approach of studying the SBS by placing the SBS-active medium directly in the cavity of the pump laser. This layout has the added advantage that one can simultaneously monitor the SBS process by monitoring the onset of a phase-conjugation mirror in the cell holding the compressed hydrogen. The experimental apparatus (Fig. 1) consists of a linear ruby laser with a telescope system (the focal lengths of the lenses are 150 mm) in the cavity. A chamber filled with compressed hydrogen is inside the telescope system. The laser operates under Q-switched conditions, achieved with the help of a nonlinear filter (a solution of cryptocyanine in ethyl alcohol with an initial transmission ~37%). A system of electrodes in the chamber sets up a spatially periodic static electric field with a strength up to 50 kV/cm. This system of electrodes contains ten metal rings with an outside diameter of 15 mm, an inside diameter of 5 mm, and a thickness of 0.5 mm. Between these rings are insulating Teflon spacers 5 mm thick.

In the course of an experiment we measure the intensity, temporal characteristics, and spectral characteristics of the laser output in both directions, at wavelengths near both $\lambda = 0.69$ and 0.53 μm (the first anti-Stokes component of stimulated Raman scattering in hydrogen). The laser is designed in such way that one can move the waist of the caustic of the telescope system, i.e., the region in which stimulated processes arise, with respect

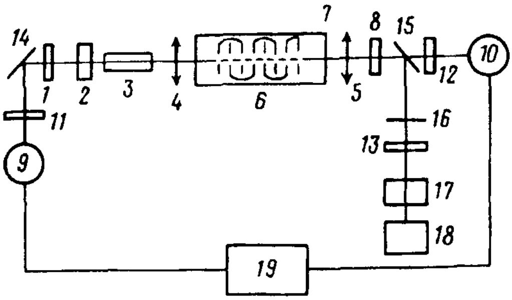

FIG. 1. Schematic diagram of the experimental apparatus. 1—Total-reflection mirror of the cavity; 2—saturable filter; 3—ruby crystal; 4, 5—lenses of telescope system; 6—chamber filled with compressed hydrogen; 7—electrodes; 8—output mirror of cavity; 9,10—photodetectors; 11–13—optical filters; 14,15—beam splitters; 16—lens; 17—Fabry-Perot interferometer; 18—camera; 19—oscilloscope.

to the electrode system. The generation occurs on the fundamental mode. The length of the light pulse in the case of an empty chamber is ~ 30 ns, and its energy about 0.1 J.

3. We studied the behavior of the temporal and spectral characteristics of the light as a function of the pressure, the strength of the longitudinal electric field, and the position of this field with respect to the region in which the stimulated emission is generated (the position of the waist of the caustic of the telescope system). These measurements were carried out at a fixed pump level of 900 J.

The study revealed that SBS does not occur in the laser at low hydrogen pressures ($P<60$ atm). All that occurs is an intense stimulated Raman emission. At pressures above 60 atm, the stimulated Raman scattering is joined by one or two components of SBS. The SBS components arise both near the pump frequency ($\lambda = 0.6943$ μm) and near the Stokes and anti-Stokes components of the stimulated Raman scattering, i.e., at wavelengths near 0.97 μm (this is the first Stokes component of stimulated Raman scattering) and 0.53 μm (the first anti-Stokes component).

The imposition of a static electric field on the Raman-active medium results in a significant increase in the SBS efficiency, as can be seen from the increase in the number

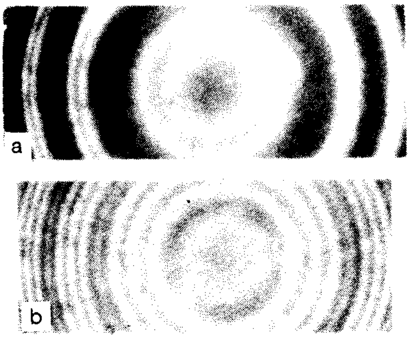

FIG. 2. Spectrograms of the laser output in the absence of an electric field (a) and in the presence of a field (b).

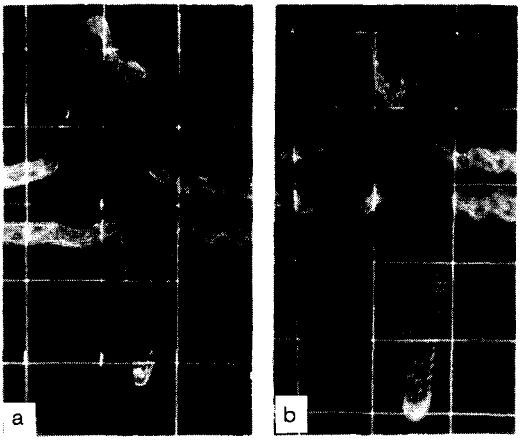

FIG. 3. Oscilloscope traces of the emission pulses in the absence of an electric field (a) and in the presence of a field (b). The upper traces are the emission in the "forward" direction; the lower traces are those in the "backward" direction.

of SBS components. The number of components increases with increasing field strength. At 50 kV/cm, the integrated spectral width of the emission in the specified wavelength regions can reach 1.5 cm^{-1}. Figure 2 shows some typical spectrograms of the laser output at a hydrogen pressure of 70 atm in the region of the pump frequency in the absence of an electric field (Fig. 2a) and with a field (Fig. 2b).

The chamber with the compressed hydrogen acts as a phase-conjugating mirror during excitation of SBS in this laser.[1] An increase in the efficiency of SBS upon the imposition of an electric field thus raises the reflection coefficient of the phase-conjugating mirror and, consequently, increases the intensity of the emission in the opposite direction (i.e., toward the ruby; Fig. 1). At a field level of 50 kV/cm, this increase amounts to about 30%. The situation is illustrated by the oscilloscope traces in Fig. 3, which were found with the electric field turned off (Fig. 3a) and turned on (Fig. 3b).

Shifting the electrode system 3–4 cm with respect to the center of the waist of the caustic in the chamber holding the compressed hydrogen causes the output characteristics of the emission to become independent of the electric field.

In summary, this study has revealed that a static electric field influences stimulated Brillouin scattering and the efficiency of the phase-conjugating mirror which arises in the process.

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