JETP LETTERS VOLUME 6, NUMBER 11 1 DECEMBER 1967

STIMULATED MANDEL'SHTAM-BRILLOUIN SCATTERING IN FUSED AND CRYSTALLINE QUARTZ WITHOUT DAMAGE TO SAMPLES AT T = 300°K

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Submitted 20 July 1967
ZhETF Pis'ma 6, No. 11, 927-931 (1 December 1967)

Stimulated Mandel'shtam-Brillouin scattering (SMBS) was first observed in glass and fused quartz by Fabelinskii et al. [1] and in crystalline quartz by Chiao, Townes, and Stoicheff [2]. The present investigation is devoted to the measurement and comparison of the SMBS threshold powers and to damage produced in these substances at room temperature.

We used in the experiment a Q-switched ruby laser delivering 100 MW in a pulse of 15 nsec duration with beam divergence ~0.4°. The beam intensity was varied by means of calibrated neutral filters at a constant laser pump, thus ensuring an identical structure of the light field in the sample placed in the focus of a lens with f = 5 cm. The SMBS was observed in the backward direction (scattering angle 180°).

The SMBS threshold powers (P_{SMBS}) were determined from the sharp increase in the intensity of the light reflected by the investigated sample unto a vacuum photodiode (in the absence of SMBS, the light is reflected from the polished end faces of the sample). To compare the wave forms of the ruby-laser pulse and of the light pulse reflected by the sample, part of the laser light was delayed 32 nsec and was incident on the same photodiode. If SMBS was produced, then the reflected light revealed, besides a strong intensity increase, also additional pulsations (Fig. 1). The damage threshold powers (P_{dam}) were registered visually and revealed by the appearance in the sample of defects that scattered

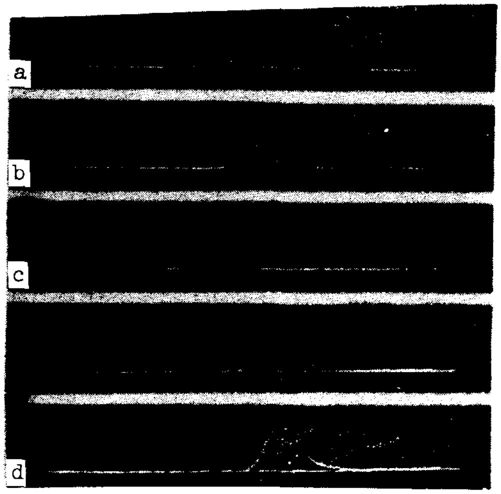

Fig. 1. Reflected-light oscillograms for fused quartz (a, b) and crystalline quartz (c, d, e): a) $P < P_{SMBS}$, b) $P \simeq P_{SMBS}$, c) $P < P_{SMBS}$, d) $P = 1.1P_{SMBS}$, e) $P = 1.75P_{SMBS}$ (c, d - light attenuated about ~2 times compared with a and b; e - attenuation 10 times). Entire sweep - 100 nsec.

the light of an auxiliary Ne-He laser. The results of the experiment are summarized in the table.

Table

Material	P_{SMBS}			P_{dam}			P_{dam}/P_{SMBS}
	MW	J/cm^2	MW/cm^2	MW	J/cm^2	MW/cm^2	
K-8 glass	6.0	164	10 900	4.9	133	8 900	0.8
Fused quartz	6.1	167	11 100	8.0	220	14 500	1.3
Crystalline quartz (laser light along z axis)	4.9	133	8 900	10.7* 16.8	290* 450	19 500* 31 000	2.2* 3.5

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* Pointlike damage to entrance face, all other numbers correspond to volume damage to samples

It is seen from the table that SMBS is produced in K-8 glass at a power higher than the damage power. This result agrees qualitatively with the data of [3], where $P_{dam}/P_{SMBS} = 0.5$ for silicate glass; the quantitative discrepancy is apparently due to the differences in the brand of glass.

The glass damage threshold found in [3] ($\approx 100\ J/cm^2$) is close to the value obtained in the present paper. The fact that damage is produced before the SMBS threshold is reached indicates that the SMBS is not responsible for the damage to the glass.

In fused and crystalline quartz we observed in the present investigation, for the first time, SMBS unaccompanied by damage to the samples, at a considerable excess over threshold and at room temperature. SMBS without damage to the samples was hitherto observed

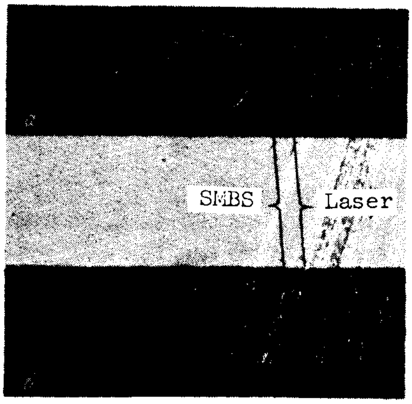

Fig. 2. SMBS interference patterns. a) In fused quartz at $P = 1.2P_{SMBS}$, b) in crystalline quartz at $P = 1.25P_{SMBS}$. Fabry-Perot interferometer dispersion region 2.5 cm^{-1}.

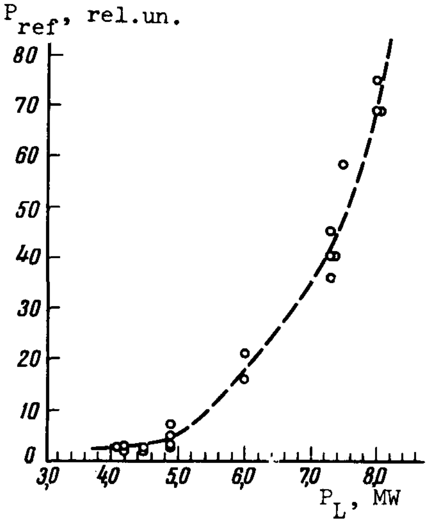

Fig. 3. Reflected-light intensity vs. incident light power for crystalline quartz.

only in crystalline quartz at $T = 80°\text{K}$ [4] and in Rochelle salt at $T \approx 300°\text{K}$ [5]. We were also able to record SMBS without damage to the samples photographically, with the aid of a Fabry-Perot interferometer (Fig. 2). The scattered-light frequency shifts $\Delta\nu = (0.825 \pm 0.025)\ \text{cm}^{-1}$ in fused quartz and $\Delta\nu = (0.975 \pm 0.025)\ \text{cm}^{-1}$ in crystalline quartz agree with those measured in [1,2]. The plot of the intensity of the reflected light against the power of the incident light, obtained for crystalline quartz, shows a rapid exponential growth near the SMBS threshold (Fig. 3).

The damage thresholds in fused and crystalline quartz differ greatly from sample to sample and even from point to point in the same sample, the damage and the SMBS thresholds being close to each other in a crystalline-quartz sample with large internal stresses. The SMBS thresholds hardly varied from sample to sample. The damage powers listed in the table for crystalline quartz correspond to points with maximum damage threshold in a sample without internal stresses.

In order to ascertain whether the damage to the fused or crystalline quartz is due to the action of the laser emission with SMBS, we estimated, using Kroll's theory [6], the hypersound power P_s generated during this scattering process. The estimates have shown that at laser-emission powers equal to the threshold for the volume damage of fused and crystalline quartz (see the table) P_s is equal to ~100 and $\sim 1.5 \times 10^4$ W/cm^2 respectively.

For crystalline quartz, the value of P_s is close to the sound-power flux $\sim 10^4$ W/cm^2 at which the wave amplitude exceeds the ultimate strength of this material [6]. This shows that the SMBS can be responsible for the damage to crystalline quartz, although another damage mechanism is possible, particularly ionization.

As to fused quartz, we can conclude here quite definitely that its damage is not due to SMBS, since the quoted hypersound power $P_s = 100$ W/cm^2 is much lower than the value required to produce damage (the elastic-stress amplitude $\sigma \simeq 60$ kg/cm^2 corresponding to this power is much lower than the rupture stress $\sigma_{\text{rup}} \simeq 3 \times 10^4$ kg/cm^2 for fused quartz [7]).

In conclusion, the authors are grateful to N. N. Denisov for help with the work.

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INVESTIGATION OF STIMULATED MANDEL'SHTAM-BRILLOUIN SCATTERING THRESHOLDS FOR DIFFERENT MEDIA AT WAVELENGTHS 0.35, 0.69, and 1.06 μ

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Submitted 7 September 1967
ZhETF Pis'ma 6, No. 11, 931-934 (1 December 1967)

We measured the stimulated Mandel'shtam-Brillouin scattering (SMBS) thresholds at an angle $\theta = 180°$ (backward scattering) in chlorobenzene, water, K-8 silicate glass, and crys-