INDUCED MANDEL'SHTAM-BRILLOUIN SCATTERING IN SOLID AMORPHOUS BODIES AND IN LIQUIDS

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We observed induced Mandel'shtam-Brillouin scattering (IMBS) [1-3] in three types of optical glass, fused quartz, and seven different liquids, by focusing light from a giant ruby-laser pulse (output power ~100 MW) inside these substances.

The installation used to observe the IMBS was the same as in [4].

IMBS was observed for the first time in the glasses and in the fused quartz. Thermal Mandel'shtam-Brillouin scattering was observed previously in fused quartz [5], but in optical glasses this phenomenon could not be observed, although attempts to do so were made many times [6-9].

Observation of IMBS in glasses refutes the opinion that the large static viscosity [8] prevents observation of the discrete components of the fine structure in these media.

The Table lists the results of some of our measurements of the frequency of the Mandel'shtam-Brillouin components (MBC) and of the velocity hypersound. The latter is compared with the velocity obtained from thermal scattering and from direct ultrasonic measurements.

Attention should be called to a systematic difference between the hypersound velocities obtained in induced and thermal scattering of light. This difference never goes beyond the limits of measurement accuracy, but in the case of carbon disulfide it exceeds the possible experimental errors.

The larger the number of MBC produced in the scattered light, the lower the velocity of hypersound in carbon disulfide. The number of MBC increases with in-

Values of hypersound velocity in some substances, obtained from induced and thermal scattering

Substance	Induced scattering		Thermal scattering	Ultrasound
	$\Delta\nu$, cm^{-1}	v, m/sec	v, m/sec	v, m/sec
Fused quartz	0.811±0.004	5804±30	5990 5840 [5]	5968
Crown (K-8)	0.856±0.005	5906±40	-	-
Benzene	0.206±0.002	1434±15	1471±8 [10]	1324
Nitrobenzene	0.232±0.002	1546±15	-	1473
CS_2 [1]	0.181±0.002 0.192±0.002	1162±15 1232±15	1265±22 [11]	1158
Acetic acid	0,145±0,002	1105±20	1140±35 [11]	1144
Salol 20°C	0.232±0.002	1544±15	-	-
Salol 180°C	0.106±0.002	740±20		

[1] Upper numbers - IMBS photographs showing ~10 MBC, lower - when two MBC are observed

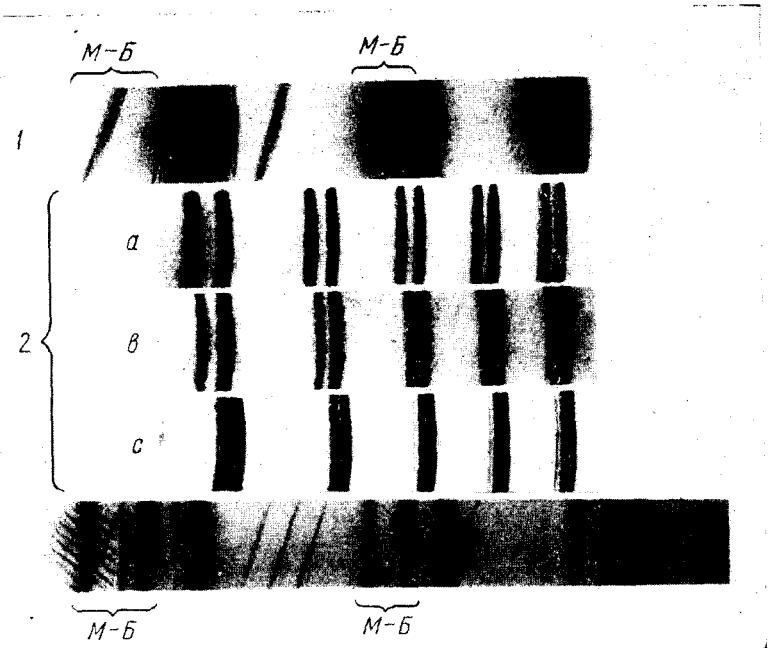

Fig. 1. Spectra of induced Mandel'shtam-Brillouin scattering, obtained with a Fabry-Perot etalon.

1 - Spectrum of light scattered in carbon disulfide. Seventeen components are observed. Etalon dispersion range 8.33 cm^{-1}. 2 - Spectrum of light scattered in nitrobenzene at different temperatures. Etalon dispersion 1 cm^{-1}; a - t = 20, b - t = 65, c - t = 180°C. 3 - Spectrum of light scattered in fused quartz. Two Stokes components are observed. Etalon dispersion 5 cm^{-1}.

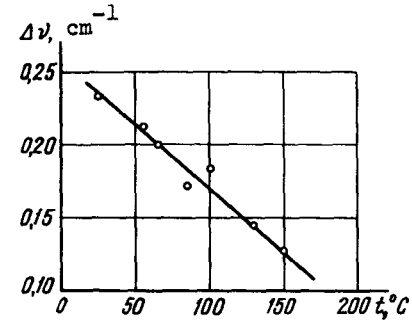

Fig. 2. Temperature dependence of the shift $\Delta\nu$ of the Mandel'shtam-Brillouin components in salol.

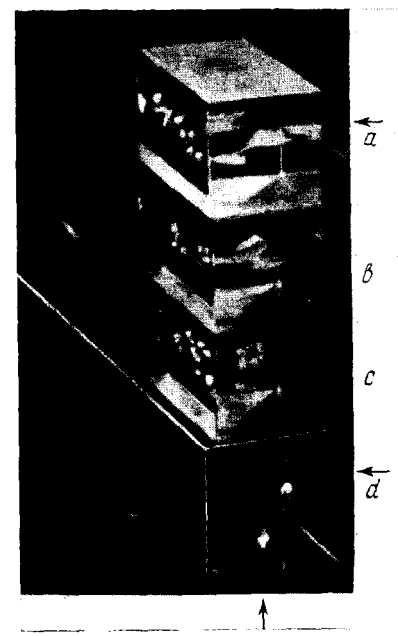

Fig. 3. Picture showing damage in different grades of glass. The arrows indicate the direction of propagation of the giant-pulse light.

a - Heavy flint, b - light flint, c - crown, d - fused quartz.

creasing power of the light pulse.

The observed dependence of the velocity (or of $\Delta\nu$) on the number of the components can be apparently attributed to the heating of the scattering medium by absorption of the hypersound. To explain the observed velocity difference in the case of carbon disulfide, it is sufficient to assume that the volume in which IMBS takes place is heated by ~30°C. If we assume that ~10^{-5} of the energy of the giant pulse (1 - 1.5 J) is transformed into hypersound (for each MBC), then a heat rise of 30°C calls for a scattering volume of 10^{-5} - 10^{-6} cm^3, which is perfectly realistic.

It is possible that in some other cases the decrease of the hypersound velocity obtained in IMBS is due to heating of the scattering volume. If this is so, then hope for determination

of the hypersound velocity by means of IMBS with much higher accuracy is not very likely to be realized soon.

In spite of the reduced values of the hypersound velocity obtained with IMBS, it is still possible to observe in nitrobenzene a velocity dispersion of ~5% (t = 20°C), which makes it possible to estimate the principal relaxation parameters [1].

Figure 1 shows a reproduction of the IMBS spectrum in nitrobenzene at three different temperatures, while Fig. 2 shows the result of the measurement of $\Delta\nu$ of IMBS in salol at different temperatures. The first point on the plot of Fig. 2 corresponds to liquid salol supercooled by 22°C.

The method of investigating the acoustic properties of supercooled liquids and glasses, based on the study of the spectrum of stimulated and thermal scattering, is apparently the most effective one, and in some cases the only one.

In investigations of IMBS in solid amorphous media, the intensity of the exciting light at the focus of the lens is such that the solid is damaged in this region. Damage of different crystals and glasses in the region of the focus was observed earlier [1,12-14].

We wish to call attention to the different character of the damage in the three types of glass and in fused quartz.

Figure 3 shows a photograph of such damage. In fused quartz and in K-8 optical glass, the shape of the internal damaged region is reminescent of nearly spherical ellipsoids of revolution. In 4F-5 glass these ellipsoids are already quite strongly elongated, and in TF-3 glass they stretch even further and reach sometimes the surface of the sample. The hardest medium is fused quartz, and the softest is TF-3. The character of the damage to the glass differs appreciably from the "character" of the damage recently observed in ruby [14].

There are several points of view concerning the causes of the damage [12-14], and this problem can not yet be regarded as solved.

No matter what the damage mechanism is, it can be assumed that the IMBS phenomenon has time to develop before the scattering medium becomes damaged. From this point of view, particular interest is attached to an investigation of the time sequence of the occurrence of the MBC and of the damage to the material. We plan to tackle this problem later.

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