Backscattering of a sound wave in a liquid with gas bubbles

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An intensification of the backscattering of sound has been detected in a liquid with gas bubbles, which is a dispersive medium. The intensification is seen as a peak in the scattering function.

Recent years have seen the widespread development of research on acoustic effects which have analogs among optical effects.[1] One is the intensification of backscattering of radiation in a randomly inhomogeneous medium.[2] In this effect, a peak appears in the scattering function at an angle of exactly 180°. The physical mechanism for the appearance of this peak is analogous to the optical mechanism. It involves coherence effects associated with the reversibility of the paths traced out by the exciting radiation and the scattered radiation in the medium.[3] The fact that the sound velocity is small in comparison with the velocity of electromagnetic waves imparts some distinctive features to the effect. In view of this circumstance, this effect has been observed experimentally in a limited volume.[4]

The use of a liquid with bubbles (a randomly inhomogeneous medium) as the scattering medium should apparently also lead to an intensification of the backscattering of sound as a result of multiple scattering.

In this letter we are reporting an experimental study of the angular distribution of the field of an acoustic wave scattered by gas bubbles in a liquid. A sound source (S) based on a ceramic piezoelectric transducer with a resonant frequency of 3 MHz and a working surface area of 22 mm; a hydrophone (H), made of the same ceramic, with a diameter of 5 mm; and a source of bubbles, at a distance $L=70$ cm from source S, were installed in a tank holding water (Fig. 1). The angle α was varied from 0 to 30°. The electronic system described in Ref. 5 was used to excite the sound and to detect the sound scattered by the bubbles. The sound pulses were 100 μs long with a repetition frequency of 150 Hz. The source of bubbles consisted of two metal electrodes: a wire grid and a plate, each with a diameter of 7 cm. The dimensions and density of the bubbles were controlled by adjusting the voltage U between the electrodes, from 2 to 50 V. The dimensions of the bubbles were measured at voltages of 2 and 5 V on the bubble source. These measurements revealed bubble diameters of 0.05 and 0.02 mm, respectively. For the particular sound used, with a wavelength $\lambda=$ 0.5 mm, the ratio of λ to the bubble diameter d is $\lambda/d=10$–25. At voltages of 10 V and up on the bubble source, it was difficult to determine the size of the bubbles. For this reason, we will report the results of this study of the angular distribution of the amplitude of the scattered sound as a function of the voltage on the bubble source (this voltage determines the size and density of the bubbles).

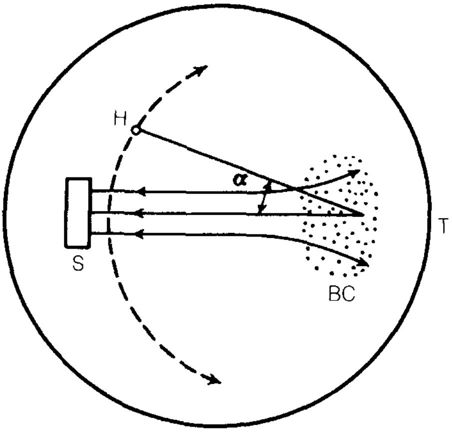

FIG. 1. Experimental layout. S—Source of sound; H—hydrophone; T—tank holding water; BC—column of bubbles.

Measurements of the angular distribution of the amplitude of the sound scattered by the gas bubbles in the water revealed a peak in the scattering function at an angle of 180° (Fig. 2) for all source voltages used. We are presenting the results in terms of a reduced amplitude here, defined as the ratio $I/I_{\max}$, where $I_{\max}$ is the amplitude of the sound scattered at an angle of 180°, and I is that of the sound at an angle of 180° $-\alpha$. Figure 2 shows data for only three values of U: 20, 30, and 50 V. We see from Fig. 2 that the shape of this distribution of the backscattering is the same in the entire range of bubble densities, and the intensification is ~ 5 (this is the ratio of the peak amplitude to the amplitude of the sound scattered for an angle of 150°). The amplitude of the scattered signal depends on the bubble density, increasing in a nonlinear fashion as this density is raised (Fig. 3). In Fig. 3, $I^{50}_{\max}$ is the amplitude of the sound signal scattered at an angle of 180° when the voltage on the bubble source is 50 V, while $I_{\max}$ corresponds to the other values of U studied. The amplitude of the scattered signal amounts to $\sim 1\%$ of the amplitude of the exciting sound.

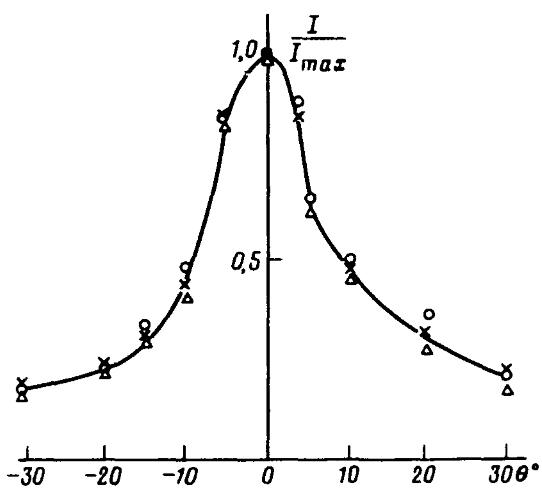

FIG. 2. Angular distribution of the amplitude of the backscattered sound. ×—20 V; △—30 V; ○—50 V.

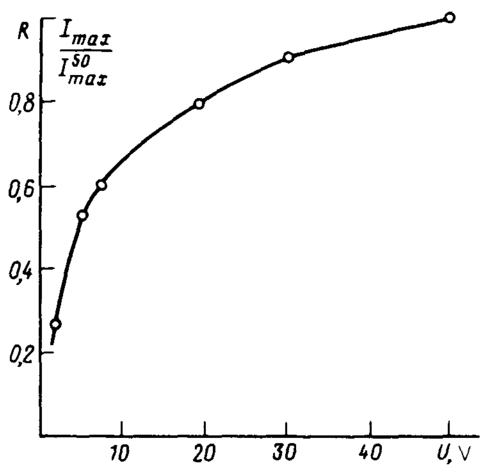

FIG. 3. Height of the peak versus the voltage on the bubble source.

In summary, the presence of a well-defined peak in the scattered radiation indicates that the intensification mechanism predicted in Ref. 2 also operates in the case in which the dispersive medium is a liquid with gas bubbles.

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