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Features of optical breakdown of liquid under the action of ultrasound

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Abstract

The experimental results show the sharply strengthened effects of acoustic emission from a breakdown zone by the joint influence of laser and ultrasonic irradiation. Various breakdown thresholds and character of acoustic emission in fresh and sea water are observed. The experimental result established that acoustic emission from optical breakdown of sea water in the presence and absence of ultrasound exceeds acoustic emission for the same experimental conditions in fresh water.

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Keywords: laser induced breakdown spectroscopy; ultrasound

1. Introduction

Numerous experiments have been carried out for optical breakdown in gases, for which a detailed description of mechanisms was given previously in the literature by Vogel, Fisher, Bukin et al. (1999). Optical breakdown in condensed media remains poorly studied. An excellent review of recent achievements in the physics of bubble oscillations in liquids, and particularly in the dynamics of bubbles that form under the effect of laser radiation in liquids, was presented by Lauterborn. Vogel et al. revealed the high efficiency of optical energy transformation into

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acoustic energy, which was in the range of 10–49% and depended largely on the energy and duration of the laser pulse. Most experiments were conducted in fresh water. It is interesting to study optical breakdown in salt water containing different chemical elements in a saline solution. Special attention is attracted by possibilities of a significant influence of an additional source of sound that could facilitate optical breakdown.

2. Experiment

Our experimental cell is shown in Fig. 1. To excite optical breakdown in each experiment, we used a Brilliant B Nd:YAG laser (Quantel, France) with an emission wave length of 532 nm, a pulse duration of 10 ns, and pulse energies of up to 180 mJ, with the last varied in a modulated Q-mode. The power density of the laser radiation grew in addition, due to sharp focusing of the radiation wherever needed (in the liquid's depth, near its surface, or on its surface) using lenses with different focal lengths F = 40, 75, and 125 mm . The distribution of the radiation in the breakdown region varied, depending on whether a short or long focus lens was used. Optical breakdown was detected using a Flame Vision PRO System optical multichannel spectral analyzer (Acton Research Corporation (USA), PCO CCD IMAGING (Germany)) with a temporal resolution of 3 ns. As a whole the optical scheme of the experiment is similar to the schemes presented in other papers Bulanov (2012-2014). Acoustic radiation was controlled using a GSPF_053 (Rudnev and Shilyev, Russia) digital generator of arbitrarily shaped signals and broad band amplifier with maximum amplitude at a resonance of 10^5 Pa.

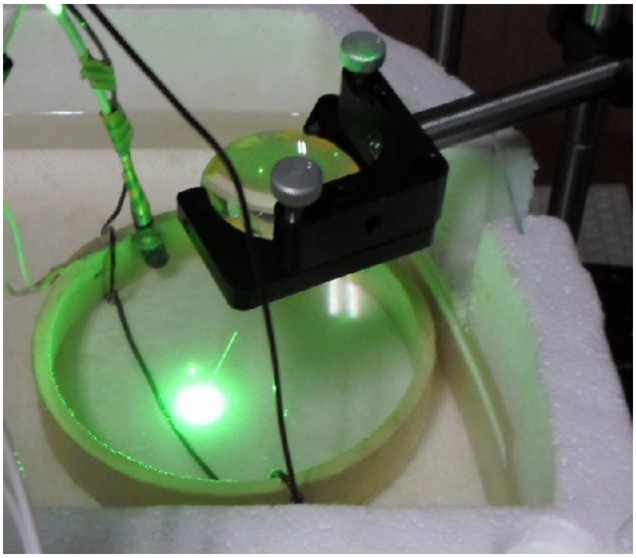

Fig. 1. Experimental cell irradiated with laser radiation. The yellow cylinder is a piezoelectric radiator with resonant frequency 29 kHz, the black cylinder near to an internal surface of a radiator is a hydrophone of type 8103 Brüel & Kjær.

3. Features of acoustical emission for different types of optical breakdown

Different types of breakdown in water were achieved by focusing the laser radiation with a variety of lenses. Breakdown thus occurred either in the water's depth, or in near-surface layers, or in a combination of the two types. In Fig. 2 the main differences for the spectral density of acoustic emission are presented for different types of breakdown in the water: near the surface and within the water. In Fig. 3 the spectral density of acoustic emission is presented for two different types of breakdown in the water that takes place near the surface and within the water