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The magnification of atomic lines intensity originated by laser breakdown in ultrasound field

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Abstract

Atomic lines of some chemical elements like sodium and magnesium were investigated for laser breakdown of water with the ultrasound field. The effect of magnification of these atomic lines resolution for salt water in ultrasound field was obtained. It is shown that the method of registration of acoustic emission from a breakdown zone allows to investigate thresholds and dynamics of laser breakdown which will be in accord with high-speed optical methods. The study revealed important practical applications of acoustic emission for breakdown and diagnostics of cavitation in opaque environments.

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Keywords: laser induced breakdown spectroscopy; ultrasound

1. Introduction

The development of chemical sensors in situ is very important for modern oceanography. Different authors have carried out laboratory researches to study the use of LIBS (Laser induced breakdown spectroscopy) spectroscopy for detection of chemical elements in large volumes of water at oceanic pressure. The method of LIBS was used to investigate intensive lines of sodium, manganese, calcium, potassium, lithium in the dissolved solutions at pressure 27.6 MPa. Influence on an optical spectrum of effects of pressure, energy of laser pulse, delay of an impulse,

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temperatures and concentration NaCl has been investigated. Authors have found an optimum range of laser pulse energy for detection of chemical elements in water solutions at low and a high pressure. An improvement of intensity of spectral lines of calcium and sodium at pressure increase was not revealed. However, such an effect was present for manganese.

The presence of NaCl has increased intensity of issue for Ca, but had no effect on peak intensity Mn or K. From results of research by several authors (Michel Anna P. M. et al. (2007)) the conclusion was drawn that LIBS is a viable chemical method of detection of chemical elements at in situ measurements in the environment with high static pressure, as, for example, in the very deep depths of the World's ocean.

It is obviously important to try to replace static influence of pressure by the influence of acoustical pressure. In this case it would be possible to realize LIBS in the focused acoustic fields for the purpose of revealing the efficiency of such an improved method for operative detection of chemical elements in different liquids.

2. Experiments and results

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 A.V. et al. (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.

The experiment scheme is shown in Fig. 1. The laser system consisted of Nd:YAG lasers (1). Radiation of the laser (1) through lens (9) was focused in a liquid. Radiation of plasma optical breakdown was projected by lens (10) on the entrance slit monochromator, interfaced with CCD - camera (6). Control was carried out by the computer (7). The studying of parameters of the acoustic wave initiated by optical breakdown was made with the aid of the broadband hydrophone of type Brüel&Kjær 8103 (8).

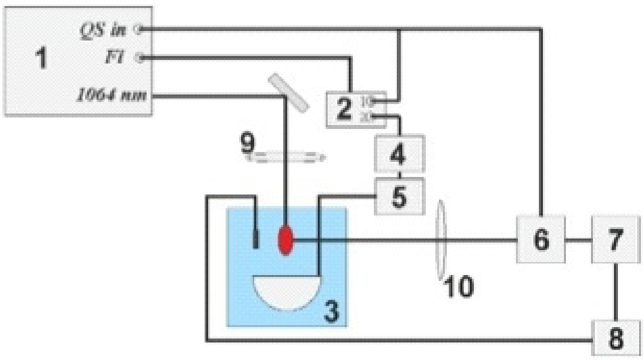

Fig. 1. The experiment scheme.

In Figure 2 the dependence of the intensity of the Na line with the energy of the laser is presented. One can see that the intensity of the Na line is reduced with increase of laser energy.