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Abstract

Laser excitation ultrasound in light absorbing liquids imputing laser radiation through optical fiber with colloidal coating of distal tip by a single layer of transparent spheres

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Abstract:

Efficient converters of optical laser radiation into high frequency acoustic for medicine and technologies are an important applied problem. A possible solution is to inject radiation into a liquid through the fiber, the distal end of which is covered by a layer of transparent microspheres. Microspheres act as lens here creating highly concentrated areas of light radiation in the liquid. In the presence of light absorption in the liquid, there arises a system of local heated volumes which leads to an optoacoustic (OA) response due to the thermoelastic effect. From this point of view, the layer of transparent microspheres at the distal tip of the fiber in a light absorbing medium can be considered to be a fiber laser–acoustic converter (LAC). Two opposite schemes of LAC are investigated experimentally in this report.

At first (a) we investigate ultrasound [1] excited by laser radiation through a quartz optical fiber Ø 1 mm with LAC — a coating at the distal tip of the fiber with Ø 0.96 μm polysterene (PS) spheres. The laser is YAG: Nd laser with λ = 1.064 μm, and distilled water is used as medium (light absorbtion coefficient α ≈ 0.1 cm-1). The laser generated in the zero transverse mode regime (beam diameter ≈2 mm) a train of pulses with a total duration of ≈300 ns with a spike frequency of ≈ 2 × 105 Hz using an optical passive modulator. This configuration of the experiment allows studying the basic parameters of the system in "primeval" form, avoiding the influence of more complex effects, such as thermal self-defocusing and superheated liquid states.

The second (b), opposite case is a use the coating of Ø 200 μm glass spheres on a glass substrate as the LAC in the laser beam (approx. Ø 1 mm) of second harmonic (λ = 0.532 μm) with impulse time 15 ns. The media is water - ink solution (α ≈ 100 cm-1) in this case [2].

The coatings consisting of spheres 1 and 200 μm in diameter (see Fig) are applied onto the fiber tip face using a 2-stage technology. First, a single layer of spheres is formed on a flat glass plate. Then the obtained single layer is glued onto the fiber end with a pre-applied thin layer of cyanoacrylate optical adhesive. A single layer of small-sized spheres (up to 10 μm) is deposited onto the plate from a colloidal solution. Large-sized spheres are spread in one layer onto a flat plate (within a limited filling area). Microphotographs of the spheres at the tip of a 1-mm fiber on the adhesive are

(a) In pure water at λ = 1.064 μm (light absorption ~ 0.1 cm□1), a thermal microstructure is formed with a characteristic size of fractions of ≈ □, a maximum temperature up to 10□2 degree at an energy of a short laser pulse of ≈0.005 J. The developed equipment allows accurate recording of ultrasound generation with expected

microheating.

(b) In the water - ink solution case it is shown that both pressure level and the frequency range of the generated ultrasound can be substantially enhanced if the irradiation is performed through the layer of the glass spheres. The frequency range of the generated ultrasound is determined by the dimensions of the volume where the light is absorbed. In the absence of spheres, this dimension is the light penetration depth into the liquid. With the spheres, it is the size of those hot spots.

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Recent Publications:

- Vladimir I. Bredikhin and Viacheslav V. Kazakov. "The Excitation of Ultrasound by Laser Radiation in Water Using an Optical Fiber Laser Converter with a 2D Colloidal Crystalline Coating", Coatings 2019, 9, 857, 1-9.
- Vladislav Kamensky, Viacheslav Kazakov, Vladimir Bredikhin , Alexander Pikulin And Nikita Bityurin. "Use of Colloidal Monolayers of Glass Spheres for the Improvement of the Optoacoustic Ultrasound Generation". Mater. Res. Express 2019 6 045201.

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