The laser plasma of TAC targets with Cu inclusions

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Abstract. The experimental results of laser-plasma interaction are discussed. Plasma was formed at the exposure of laser radiation on the low density targets with Cu inclusions. The scattering radiation emitted by the laser-produced plasma has investigated. In experiments diagnostics data on temporal characteristics of second harmonic plasma emission; integrated in time spectral characteristics plasma radiation; x-ray plasma emission were obtained.

1. Introduction
Low-density materials are a promising material from the point of view of studying the interaction with laser radiation. Interesting results were obtained with low-density targets in such research directions as: laser beam smoothing, equation of state studies, hydrodynamics of layered foam-payload targets and etc. [1, 2]

At present, various types of low-density targets are used: targets differing in original material, total target density, structure, multi-layer structures, with and without added particles of metals, etc. [3] Low-density targets with the addition of particles of metals with a high and average charge number value have shown their effectiveness in improving plasma parameters in laser fusion experiments and as diagnostic tools [4].

Targets with the addition of ultrafine and nanoparticles of metal have inhomogeneous structure and density fluctuations, but remain homogeneous in macro scale. The presented work is aimed at studying the features of the interaction of laser radiation with low-density targets with the addition of metal ultrafine particles of copper.

2. Experimental conditions
To form a laser plasma low-density three-dimensional polymeric grids from cellulose triacetate (TAC) with copper Cu addition were used as targets. Copper in the targets was added as ultrafine particles, which replaced 10% of the polymer mass in the sample. The target density was 7 mg/cm³, the thickness was 2000 μm.

The experiments were performed on the "Kanal-2" installation [5] with the following laser radiation parameters: pulse duration 2.5 ns at half-height, spectral width at half-height 20 Å. In the presented shots, the energy of the laser radiation incident on the target was ~ 40 and 50 J, respectively, the flux density of the radiation power on the target was ~ 7·10¹³ and 9·10¹³ W/cm².

For experimental investigation of the laser plasma interaction several diagnostic channels were used: to study the spectral composition of the scattered back radiation, the time evolution of the spectrum of the scattered radiation during the lifetime of the laser plasma, the image of the laser
plasma in its own x-ray range, the ion composition of the laser plasma. The scheme of the experiments is shown in Figure 1.

Figure 1. Experimental setup. 1 – Laser radiation, 2, 3 – plane-parallel plate, 4 – focusing lens 5 – target, 6 – x-ray pinhole camera, 7 – photographic camera, 8, 10 – spectrograph, 9 – streak camera, 11 – calorimeter. Registration channel: A – laser heating radiation, B – backscattering radiation. C – plasma ions registration, D – transmission and forward scattering radiation.

3. Experimental results
The spectrum of backscattering plasma radiation was registered in integrated regime for the whole time of the plasma emission for target, obtained in one shot of laser.

In time integrated spectrum backscattering radiation on laser wavelength was registered, but second harmonic is absent. In radiation registered on the backside of target with temporal sweep regime the second harmonic radiation of plasma was observed (Figure 2). It can be seen from the Figure 2 that the maximum of the second harmonic radiation intensity falls at a time of 3.2 ns. The total duration of the second-harmonic radiation exceeds the duration of the laser pulse. The wavelength of the second harmonic is changed in time evolution, and spectrum is broadened. This is most likely due to the movement of a region of electrons with a critical density.

In experiments plasma images was obtained by means of a pinhole camera. X-ray image of the plasma is showed in Figure 3. The spectral characteristics of the x-ray radiation detected by the pinhole camera were determined by external filters. Beryllium filter with thickness 100 μm was used, which corresponds to the wavelengths of hard x-rays λ≤9Å. The image of plasma demonstrates that there are nonuniformities of x-ray intensity in space. The emitting area size (650 μm) is exceeding the focal spot (180 μm).

The Faraday cylinder with a transimpedance amplifier and a mass spectrometer according to the Hughes-Rojansky scheme were used to measure the ion flux of plasma. For the experiment with the low-density target \( E/z = 5.6 \text{ keV} \), \( E \) - ion energy, and \( z \) - ion charge.

In the case of a TAC target with Cu (10%) inclusions at laser radiation energy of 50 J, at the beginning of the recorded signal a peak of hydrogen ions with energy of 3 keV is observed, and then there are peaks belonging to the ions of the materials making up the target. The obtained ion spectrum contains ions of hydrogen and carbon from the 1st to the 5th, as well as copper ions from the 1st to the 4th, despite the low (10%) concentration of copper in the target.
**Figure 2.** Temporal sweep of second harmonic generated in plasma at laser radiation energy of 50 J. A, B, C – spectrum profiles at different moments of the time heating radiation.

**Figure 3.** X-ray image of plasma emission at laser radiation energy of 50 J
4. Conclusion
Plasma of low-density TAC target with Cu inclusions experimentally was studied. The time evolution of second harmonic generation, x-ray image of plasma and ion composition were obtained. Analyses of second harmonic time sweep has shown that the second harmonic is generated in plasma in time exceeding the duration of the laser pulse. In X-ray image of plasma the intensity nonuniformities was observed. The ions of hydrogen, carbon, oxygen and Cu was identified for laser plasma of TAC target with Cu inclusions.

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