Stable laser-plasma picosecond kHz X-ray source using melted metal target

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We have developed a new source of picoseconds hard x-ray pulses, which are generated under interaction of high intensity ultrashort laser radiation on a melted metal target. Using such target one could not renew the target surface after each laser shot, comparing to commonly used solid state targets. This permitted us to create a stable x-ray source with high repetition rate of pulses. Using a laser pulse with a prepulse and varying the energy of a prepulse it is possible to easily control the parameters of plasma. The size of the source is 4 μm, it has 1-10 ps duration of pulse at 1 kHz repetition rate, which allow to use this source in nanostructures investigation, x-ray spectroscopy with high temporal resolution, EXAFS spectroscopy, medical researches etc.

In our experiments plasma was created by laser pulse delivered by Ti:Sa laser system (pulse duration – 60 fs, wavelength – 800 nm, energy of pulse – 1 mJ, repetition rate – 10 Hz). As target we used melted gallium at temperature of 300 ^{o}C. In stability research experiment we have exploited the other similar Ti:Sa laser system (pulse duration – 100 fs, wavelength – 800 nm, energy of pulse – 2 mJ, repetition rate – 100-1000 Hz).

We have shown that usage of laser pulse with a prepulse, advancing the main pulse over few nanoseconds, can lead to appreciable increase in x-ray yield and hot electron energy. At prepulse energy ~50^{-1} of main pulse energy we achieved a 60 times increase in x-ray yield and almost fourfold growth of hot electron energy in plasma (from 20 keV to 75 keV), comparing to plasma, formed by a pulse without prepulse. Furthermore, excitation of linear radiation of plasma takes place, corresponding to K_α (9.3 keV) and K_β (10.3 keV) lines of gallium, which intensity also increases with prepulse energy growth. At the same time parameters of plasma do not depend on laser pulse polarization.

Optical shadowgraphy revealed that main pulse interacts with highly deformed target surface with 10 μm scale of convexity. That might lead to local electric field amplification and also independency of plasma parameters on polarization. Moreover, the main pulse propagates not in vacuum, but in a cloud of matter 130 μm in length, which can lead to additional self-focusing.

We also have demonstrated that liquid gallium can be used as a stable laser-plasma source of x-ray pulse with repetition rate up to 1 kHz. Without additional focusing such source remains stable about 30 seconds, whereas at additional focusing – up to few hours of continuous work with more than 10^9 x-ray quantum per second power.

This work was supported by RFBR, grant # 07-02-00724-a.