Diagnostic of soft X-ray pulses from laser-produced plasmas of ns duration

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Conventional pulsed X-rays sources are easily realizable in vacuum chambers by high voltage breakdown using fast capacitors as energy storage. Instead, the production of soft X-rays, having energy in the range of few hundreds of eV, is very difficult to obtain by conventional methods. Such X-rays are suitable for ultra-short exposure and to improve the contrast and the spatial resolution of the images [1]. Beside, an important biological application of soft X-rays consists to improve the potentiality on studying of the sequencing of DNA [2,3].

Laser-produced plasmas induced by pulsed laser ablation (PLA) of solid targets offers the possibility to generate easily soft X-rays [4]. The efficiency on the production of X-rays bunches and their emission spectrum depends on many factors such as laser incident energy, characteristic of focused beam, laser wavelength, laser pulse duration and atomic number of the target.

In particular, the short wavelength of excimer lasers is useful on the production of plasmas characterized by high density and high temperature values which makes this plasma an innovative media for the production of X-rays bunches [5].

We studied the results concerning the emission of soft X-rays induced by laser plasmas from three metal targets of different atomic weight. The diagnostic device was a very sensitivity Faraday cup which, working as X-rays diode, was able to catch on X-ray signals and to estimate the energy in the range from near extreme ultra-violet (EUV) to soft X-rays.

All the measurements were performed in a vacuum stainless-steel chamber pumped up to 10^{-7} mbar pressure. The interaction chamber was equipped by a drift tube. We used an excimer KrF of 248 nm laser wavelength, operating with laser pulses of 23 ns FWHM and energies of 40, 80 and 120 mJ. The laser beam was focused on the target by a 15 cm focal length forming a spot dimension of about 0.01 cm^2, with a resulting irradiance of 1.7, 3.5 and 5.2 x $10^8 W/cm^2$. The incident angle of the laser beam respect to the normal of the target surface was 70° in order to limit the interaction of laser beam with the produced plasma. A beam splitter, located outside the apparatus, sent about the 5% of the laser beam energy to a fast photodiode connected to a digitizing oscilloscope. In this way it was possible to record the laser waveform which was also used as trigger to measure the signals of the diagnostic device.

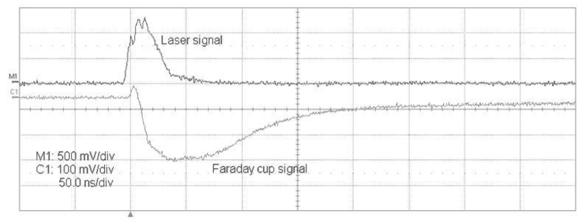

Figure 1. Typical waveforms of the laser pulse and FC signal obtained from laser induced Ta plasma with 40 mJ laser energy. The FC signal was obtained by a bias voltage of +25 V.

Three different targets were utilised, Si, Cu and Ta having a purity of 99.99%. The characterization of the X-rays radiation emitted by laser-produced plasma was performed utilising a home made Faraday cup (FC) which worked as X-rays diode. The advantage to use this device consists to the possibility to diagnostic the X-rays energy and the ion temperature when the signal was detected at long time.

The X-rays, emitted from the laser plasma, strikes the FC collector inducing photoelectron production. Without any bias, the FC signal results to be positive in amplitude. This behaviour points out that, in this case, the photo-peak, ascribed to the photoelectron emission from the FC, was predominant with respect to the signal of the electron arriving from the chamber walls. When we applied a positive bias, the FC signal was modified. In this case the photo-peak diminished, while the chamber wall electrons were attracted inducing a negative signal just after a few

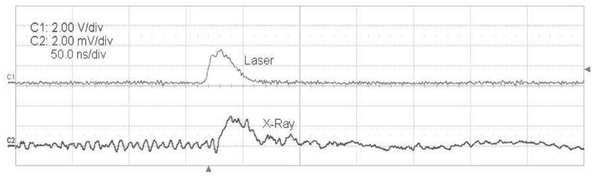

Figure 2. X-ray waveform with the application of the filter for the laser energy of 40 mJ and Cu plasma.

nanoseconds. Fig. 1 shows the typical waveforms of the laser pulse and the FC signal.

To characterize and compare the photo-peak signal induced by X-rays of the three different plasmas, we utilised the collimator of 10 mm in diameter in order to reduce the electrons fron the wall but to not reduce too much the fraction of X-ray radiation which arrived to the collector. We placed an aluminium filter of 0.2 μm thickness, deposited on 1 μm of C_3H_6, in front of the hole of collimator. The resulting filter is sensitive to the transmission of X-ray radiation of energy up to about 1.2 keV. Fig. 2 shows an example of X-rays signal with the use of the filter obtained with a laser beam of 40 mJ of energy with the Cu target. By recording the photo-peak signal with and without the filter and along to the characteristic of the filter transmission, we determined the upper average energy of the X-rays bunch. The results was compared with the ones concerning to the ion temperature of the plasmas. This last was determined by the shifted Maxwell−Boltzmann distribution (MBD) which characterizes the velocity distribution of ions far from the target, where the ion charge-states are frozen and ions freely drift into the vacuum [6].

The laser-induced Ta plasma was characterized by an ion temperature higher than the other two plasmas [7].

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