REASULTS IN SHOCK IGNITION EXPERIMENTS AT PALS: Kα GENERATION AND HOT ELECTRONS STUDY

L. Antonelli[1 3], D. Batani[3], M. Richetta[1], P. Koester[2], L. Labate[2], T. Levato [1 2], L. Gizzi[2], E. Krousky[4], J, Skala[4], R. Dubzak[4], J. Ullshimied[4], O. Renner[5], M, Smid[5], M. Rosinski[6], J. Badziak[6], T. Pisarczyk[6], Z. Kalinowska[6], T. Chodukowski[6]

[1] *University of Rome "Tor Vergata", Roma, Italy*
[2] *INO-CNR, Pisa, Italy*
[3] *CELIA University of Bordeaux 1, Talence, France*
[4] *PALS, Prague, Czech Republic*
[5] *Czech Technical University, Prague, Czech Republic*
[6] *IPPLM, Warsaw, Poland*

In recent years several experiments to explore the Shock ignition regime were performed in different facilities.

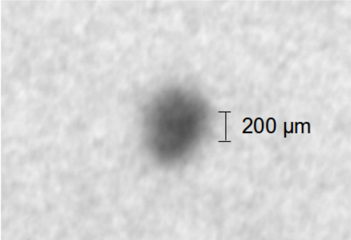

Figure 1: Experimental image of the Kα source

This approach to ICF is based on direct drive illumination at intensities in the order of $10^{13} - 10^{14}$ $Watt/cm^2$ for the compression phase and up to 10^{16} $Watt/cm^2$ for the ignition phase which creates a strong convergent shock wave. However at intensities of $> 10^{15}$ $Watt/cm^2$ parametric instabilities (Stimulated Raman Scattering, Stimulated Brillouin Scattering and Two Plasmon Decay) can be excited causing a reflection of a large amount of energy irradiated by the laser. Also parametric instabilities like SRS and TPD imply the conversion of part of the energy of the incident laser beam to plasma waves. They can therefore trap and accelerate some electrons. The presence of the hot electrons has to be characterized in order to understand if their effect can be beneficial (carrying the energy deep into the target and thus improving the laser/target coupling in presence of an extended corona) or if can cause the preheating of the target with a bad effect on target compression.

A first characterization of the hot electron production was done in an experiment related to the Shock Ignition intensity regime using Prague Asterix Laser System. This is a KJ Iodine gas laser system with a wavelength of 1.3 μm for 1ω and 0,438 μm for 3ω with a pulse duration of $\sim$ 300 ps. Two beams were used, one for the simulation of the compression phase with an intensity of $\sim 10^{13}\ Watt/cm^2$ at 1ω and the second (3ω) to simulate the phase of shock generation. The delay between these two beams was changed from 0 to 1200 ps to study the effect of the presence of the extension of plasma corona on the shock generation and laser-plasma interaction. To study the hot electron generation a layer of Cu was placed inside the target. In particular the used targets were:

- 30 μm of Cu
- 25 μm of plastic + 5 μm of Cu + 20 μm of Al
- 25 μm of plastic + thick Cu (several mm)
- 40 μm of plastic + thick Cu (several mm)

The plastic (Parylene C doped with Cl) layer simulate the low Z material of a external shell of the real ICF target while Al is used since it is a well known reference material for shock studies. In our experiment it was used to measure shock velocity and retrive shock pressure. In order to record the Kα signal a Quartz spherical bent crystal was used. It was aligned to obtain an image of the Cu Kα source and placed 33 cm far from the interaction point with an angle of 55 degrees with respect to the laser axis which had a normal incidence on the target. The magnification factor of the optical imaging system was 1.4. We measured the diameter of the source for all images finding an average width of 200 μm ± 50 μm. We did not observe a widening of the Kα spot increasing the plastic thickness.

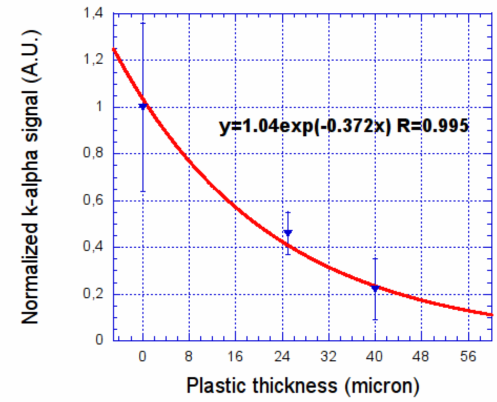

Figure 2: Plot of the crystal Kα signal versus plastic thickness

The image was recorded on a x-ray film. An example of the obtained image is shown in Fig. (1). Such image allows to obtain the size of the target region emitting the

Kα photons. Also by integrating over the whole image, we can get the total number of collected Kα photons.

To record the spectrum of the source, a X-ray CCD in single photon counting was also used.

This diagnostic permits to record a wide energy spectrum. The total Kα emitted energy can be estimated either from the signal of the single photon counting CCD or from that of the Kα imaging system. The signal was recorded in different configurations using the targets described before. The CCD used in single photon regime we allowed to record the spectrum of the X-ray source as shown in Fig. (3). Here, the Cu Kα and Kβ lines are well identified together a continuous bremsstrahlung radiation.

In particular, by measuring the Kα signal from targets with plastic overlayers of different thickness, we can estimate the propagation range of hot electrons in plastic (hot electrons are partially stopped in the plastic layer before reaching the Cu layer and inducing Kα emission). Assuming the electrons refluxing negligible, and a monochromatic electron beam, considering the Kα signal of the crystal and assuming the behaviour of the Kα emission be exponential, the signal will follow the law:

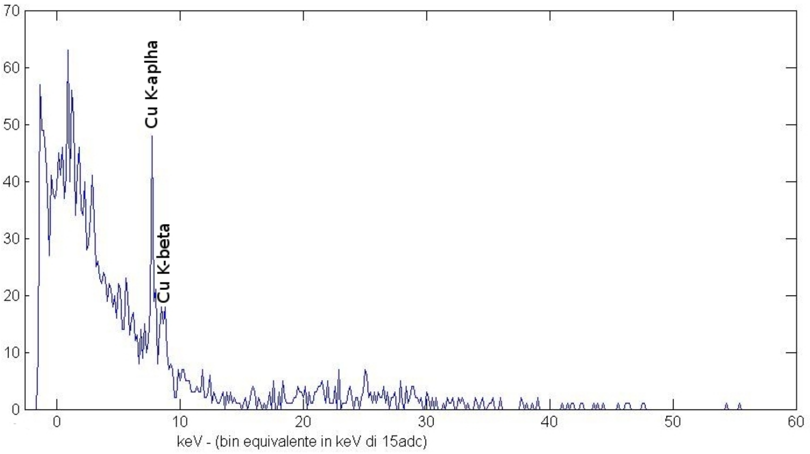

Figure 3: Experimental X-ray spectrum

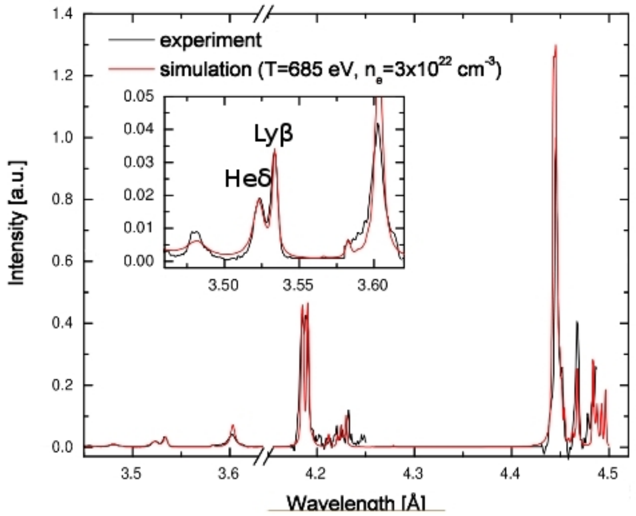

Figure 4: Experimental X-ray spectrum of the Chlorine emission

$$I(x) = I_0 e^{-\frac{x}{\lambda}} \tag{1}$$

where I_0 is the photon flux in the case of pure Cu (x=0), λ is the electron range penetration, x is the path inside plastic. We recorded the signal at 0, 25 and 40 μm of plastic and we plotted the results as show in figure (2) which also show the exponential fit which provides a preliminary result of $\lambda \sim 27\mu m$. The online database ESTAR of NIST was than used to compare the electron range using the table of Mylar which as a similar density of the plastic used in our experiment. The result is compatible with hot electrons with an average energy of $\sim$ 50 KeV. From the experimental measurements there was no clear correlation between the intensity of the signal with the delay between the two laser beams.

Finally a high resolution x-ray spectrometer using a spherical bent MICA crystal was used in the experiment to measure the electron plasma temperature. This diagnostic was aligned to obtain the X-ray spectrum of Chlorine emission coming from the plastic. The spectrum shown in Fig. (4) is well reproduced by the simulation performed using the code PrismSpec. The emission Ly_β and He_δ were used to estimate the electron temperature. The value found is an electron temperature of 685 eV ± 20 eV.

In conclusion, in this experiment a characterization of the hot electrons was done. We were able to measure an average energy of the hot electrons produced in our experiment regime relevant for SI. Fluctuations of the amount of the hot electrons are present but they seem not be affected by the delay between the laser beams (i.e. the extension of the plasma corona).

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