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Studies of hard X-ray emission from ultrashort laser interactions with thin films

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The interaction of intense, ultrashort laser pulses with matter can accelerate electrons to very high energies. The interaction of these electrons with the target substrate or with the structures surrounding the target gives rise, via bremsstrahlung emission, to hard X-ray emission. This emission has been investigated in recent experiments [1] in which intense, 30fs laser pulses were focused on thin (0.1 or 1 µm thick) plastic targets at an intensity as high as 5×10^{18} W/cm^2. A set of 6 NaI(Tl) scintillator detectors were used as shown in Fig.1

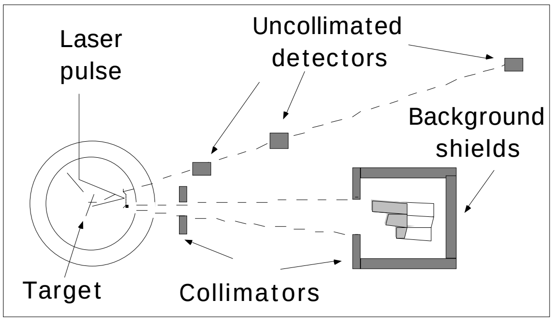

Fig.1. Experimental set up for the detection of hard X-ray emission from intense, ultrashort laser interaction with thin films.

When dealing with large fluxes of pulsed X-ray radiation, the standard hard X-ray spectroscopic techniques typically used in high energy physics and astrophysics cannot be applied directly. In some circumstances, when high repetition rates are available, the average number of photons on the detector can be reduced to <<1 and single photon spectra can be obtained integrating over many (thousands) laser shots. Alternatively, some information on the hard X-ray spectrum can be obtained by using several detectors whose sensitivities are optimised for different photon energies.

In our experiment we used scintillators of different thicknesses as described in Fig.2. One 12.5 mm, one 25.4 mm and one 50.8 mm thick, 25.4 mm diameter NaI(Tl) crystal detectors were placed at a distance of 425cm from the target. In addition, three 50.8 mm thick, 50.8 mm diameter NaI(Tl) crystals were used for cross-calibration purposes and distance/angle dependent measurements. The response of our detectors consists of a pulse with a rise time, of the order of a few ns, set by the photomultiplier tube that collects the light generated in the crystal and a fall time of 230ns which is the decay time of the scintillator. The height of the pulse is a measure of the energy released by the one or more photons in the crystal. The detectors were calibrated using photon emission lines from radioactive sources including the 1173.0 and the1332.0 keV lines from a Co60 source. The pulse height was found to be linearly dependent on the photon energy. Fig.2 shows the distribution of the X-ray energy detected by the collimated (left) and uncollimated (right) detectors per laser pulse. The histograms on the left were obtained simultaneously for the 12.5 mm (top), the 25.4 mm (middle) and the 50.8 mm (bottom) thick collimated crystals placed at a distance of 425cm from the target.

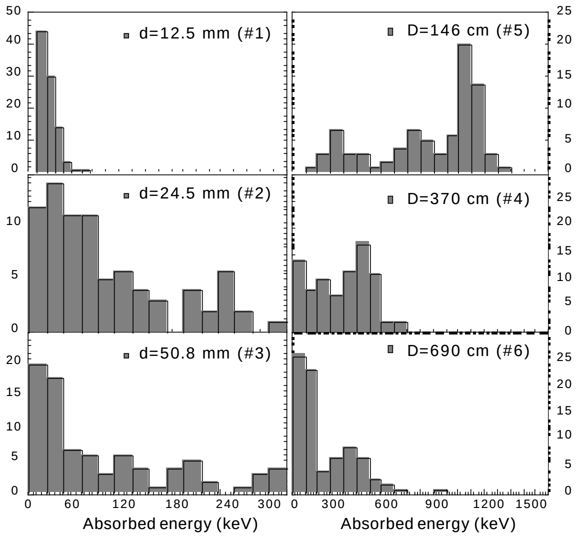

Fig.1. (left) Distribution of the X-ray energy detected per laser pulse by the 12.5mm (top), 24.5mm (middle) and 50.8mm (bottom) thick crystals. (right) Distribution obtained for the three 50.8mm thick uncollimated detectors placed at 146cm, 370cm and 690cm from the target.

According to Fig.2 the maximum energy detected by the 25.4mm crystal is substantially higher than the maximum energy detected by the 12.5mm crystal indicating that there is a large number of energetic photons that are not absorbed by the thinner crystal. Therefore, we must conclude that the bulk of the photons has an energy greater than 100keV. The results of the uncollimated detectors show that there is a large photon background. As the distance from the target increases, the maximum energy settles around 350-400 keV. This photons are probably generated by the interaction of very fast electrons generated by the laser-foil interaction with the matter surrounding the target and, in particular, by the target chamber.

[1] A.Giulietti et al, this report.