High-energy bremsstrahlung radiation from laser-plasma accelerators from solid high-Z targets to explore internal hot electron beam dynamics.

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As a high-intensity laser interacts with a solid target, a plasma is formed on the front surface, and electrons are accelerated into the target with a broad Maxwellian (or Maxwell-Jutner) distribution of energies. These 'hot' electrons interact with the atomic fields within the target and generate high-energy bremsstrahlung emission throughout the target as well as establishing charge-separation sheath fields on the target surfaces, which then accelerate ion beams. A full understanding of this aspect of extreme light-matter interaction physics is crucial to the development and optimisation of these laser-driven sources for use in clinical and industrial applications [1], such as radiography and neutron probing. Presented here is results and discussion of characterization of the escaping bremsstrahlung temperature, >150keV spatial profile and its relevance to the study of hot electron transport for radiation generation.

Unlike charged particle emission, the x-ray radiation can escape the target unperturbed by the sheath generated at the rear surface and therefore sampling this emission gives us a direct probe from which we gain information of the internal dynamics of the hot electron current and transport. The x-ray spectrum is dependent on the internal electron temperature and the radiation transport through the target material. By characterizing the x-ray emission we can then deconvolve the shot-by-shot internal electron temperature using radiation transport simulation codes [2] and avoid inferring temperatures from scaling laws. While the spectral information can tell us about the energy contained within the internal current, we can use the spatial profile of the x-ray emission to discern information about the global electron beam divergence [3]. For ultra-relativistic electrons (>*8MeV*) the emission angle of x- ray radiation collapses to fractions of a degree and so sampling this energy region allows us to profile the angular distribution of the high-energy tail of the electron beam.

We discuss a combination of results from experiments on the Vulcan Petawatt Laser system at the STFC Central Laser Facility, and simulation work using the Monte-Carlo code GEANT4. The results are discussed in line with imaging large scale industrial objects, exploring the trade-offs between changes in the emission to optimize the imaging capability. With that in mind, we discuss results from conventional x-ray converters, such as thick tantalum, and thin foil targets typically excluded due to low yield.

References

[1] C M Brenner et al 2016 Laser-driven x-ray and neutron source development for industrial applications of plasma accelerators Plasma Phys. Control. Fusion 58 014039; doi:10.1088/0741-3335/58/1/014039

[2] D.R. Rusby et al Pulsed x-ray imaging of high-density objects using a ten picosecond high-intensity laser driver Proc. SPIE 9992 (October 25, 2016); doi:10.1117/12.2241776.
[3] Green, J. S., et al. "Effect of laser intensity on fast-electron-beam divergence in solid-density plasmas." Physical review letters 100.1(2008): 015003.