Tailoring intense laser-plasma interactions to generate bright, coherent X-ray beams

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Project Background:

Numerical simulations are a key tool in practically all areas of Physics research and are particularly useful for determining important parameters of physical systems that are difficult or impossible to observe directly in experiments. In the Centre for Plasma Physics, we use them to study the evolution of highly ionised plasmas under extreme conditions. This project concerns the interaction of ultra-intense lasers with high density plasma surfaces. At sufficiently high intensities, the non-linear interaction leads to a modulation of the incident laser pulse which corresponds to the generation of broadband high frequency radiation which can extend into the extreme-ultraviolet (XUV) regime (<100nm and soft X-ray wavelengths (<10nm). This process can be highly efficient and the radiation retains the high coherence of the incident laser pulse yielding a laser-like beam of short wavelength radiation in an ultrashort pulse. This can be applied to ultrafast imaging of bound electron states, nanoscale probing of biological matter and non-linear X-ray/XUV interactions.

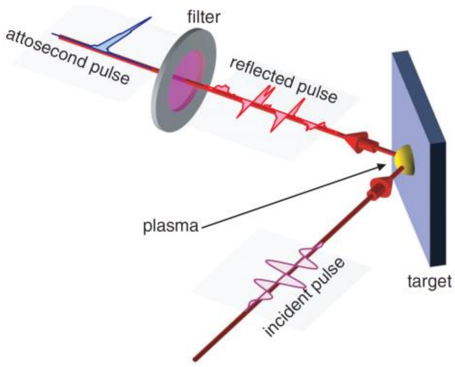

Figure 1 – Sketch of the basic scheme to generate high frequency radiation from a laser interaction with a solid density plasma. Removal of the residual laser energy using appropriate filters can also lead to attosecond scale (10^{-18}s) pulses - the shortest pulses that it is currently possible to produce. Figure from ref [2]

Project Description:

In this project we will use the EPOCH particle-in-cell code [1] to simulate high intensity laser-plasma interactions and the generation of coherent extreme-ultraviolet radiation. Here, the laser's electric and magnetic fields are solved using Maxwell's equations imposed on a numerical grid whilst the particles are modelled by a collection of "macro-particles" whose trajectories are solved using the equations of motion. The student will use this code to model this interaction to study some advanced schemes for optimising various parameters of the XUV radiation including its generation efficiency, temporal characteristics and polarisation.

Physics skills/knowledge gained

Lasers, plasmas, numerical simulations, programming, spectral analysis

References

[1]T. D. Arber *et al.* Plasma Phys. Control. Fusion, **57,** 113001 (2015)
[2]G. D. Tsakiris *et al.* New J. Phys., **8**, 19 (2006)