Synthesising Extreme Light Pulses for Applications in Intense Laser-Plasma Interactions

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Proposal

The internal mechanics of electrons in atomic and molecular systems operate on a timescale of attoseconds (10^{-18}s) which require sources of intense bursts of light on this same timescale to act as an ultrafast "camera flash" to probe and potentially control such ultrafast dynamics [1]. Pulses this short are beyond what is possible via "conventional" femtosecond laser technology (which was recently the subject of a Nobel prize [2]), however one promising route to such a source is the intense interaction of a laser pulse with a solid density plasma surface which leads to relativistic electron motion and nonlinear modulation of the incident field corresponding to the presence of ultrahigh frequencies confined to attosecond scale bursts [3]. Recent work in this area from our group highlights the huge gains possible from precise spatiotemporal tailoring of the incident laser pulse [4]. Some of these results are highlighted in figure 1 below.

This project will focus on the development and optimisation of the techniques used to achieve this including generation and control of additional frequency components in the laser pulse using non-linear processes in crystals and advanced schemes for manipulation of the polarisation and spatial properties of the driving beam. This will involve working at some of the most intense lasers in the world (e.g., the Central Laser Facility in the UK and the JETI200 laser at the Helmholtz Institute Jena in Germany) and the use of cutting-edge numerical simulation codes to model the interaction. As such, the successful applicant will have the opportunity to travel and work alongside researchers from across the world and develop skills in advanced optics, X-ray spectroscopy and numerical modelling.

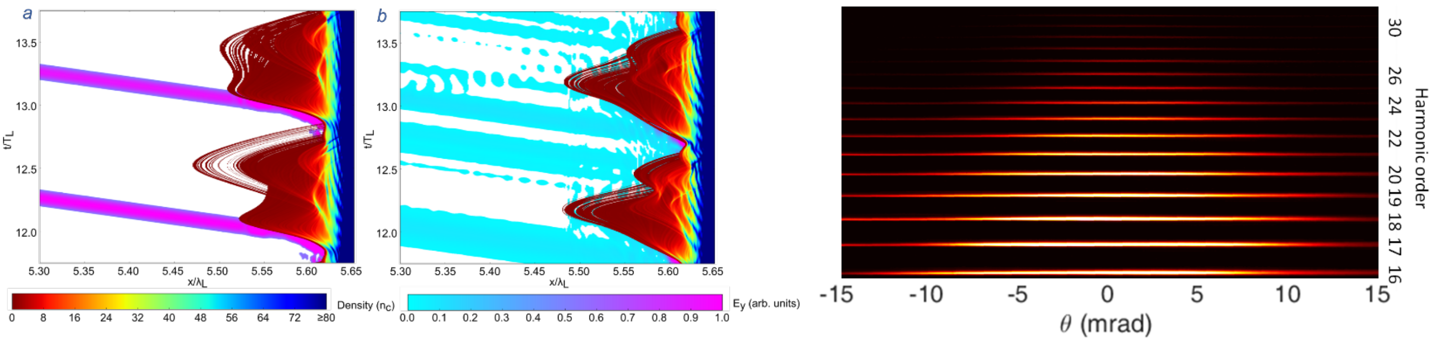

Figure 1 – Left: Simulations of bright, coherent, ultrashort pulses of light when a synthesised multi-harmonic driving pulse is (a) optimised and (b) deoptimized. Right: Experimentally measured beams of high frequency harmonic radiation (as a point of reference, 20th harmonic is 40nm wavelength) generated from laser irradiation of a solid density plasma surface at the JETI40 laser facility in Jena, Germany.

References

[1] F. Krausz and M. Ivanov "Attosecond Physics", Rev. Mod. Phys., **81**, 163 (2009)

[2] https://www.nobelprize.org/prizes/physics/2018/summary/

[3] G. Tsakiris et al. "Route to intense single attosecond pulses", New J. Phys., **8**, 19 (2006)

[4] M. Yeung et al. "Experimental observation of attosecond control over relativistic electron bunches with two-colour fields", Nat. Photonics, **11,** 32 (2016)