Project Title: Relativistic attosecond sources from intense multi-colour laser pulses

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Type of Project: EXPERIMENTAL (primary) / COMPUTATIONAL (secondary)

Helpful existing knowledge: Electromagnetism and optics, laser/plasma physics useful but not necessary

Funding status: This project is fully supported with a studentship funded in collaboration with Helmholtz Institute Jena (GSI GmbH) and will include a stipend enhancement over the standard studentship baseline. Funding is subject to standard UK residency eligibility.

Project Description

Short-pulse, high power laser technology, based on the 2018 Nobel prize winning chirped pulse amplification technique [1], continually races towards increasingly brighter pulses of light with peak powers reaching up to 20 Petawatts planned for future facilities such as Vulcan 20-20 [2]. The extreme intensities of these pulses can, among many other applications, generate intense, attosecond duration bursts of coherent X-ray radiation. Attosecond science was the subject of the recent 2023 Nobel prize in Physics [3] but understanding the mechanisms associated with solid density plasmas will be necessary to access the brightest possible attosecond pulses for full attosecond pump-probe experiments [4].

Theoretical and experimental work has demonstrated that the addition of a finely controlled second harmonic pulse (so-called two-colour field consisting of an infrared and a blue coloured laser pulse) can give exceptional efficiencies [5]. Figure 1 shows the typical beam structure of the radiation in the XUV regime and the experimentally measured dependence of the radiation's intensity as a function of harmonic order and 2^{nd} harmonic phase. To date, this has only been seen on comparatively lower power systems. This project will involve predominantly experimental work with the option for conducting supporting simulations to explore methods to extend this to petawatt class power systems to unlock a coherent X-ray source of beamed radiation with unprecedented brightness.

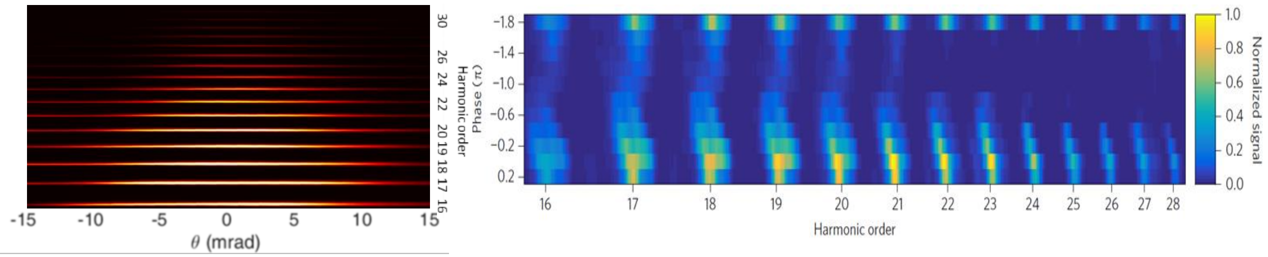

Figure 1 - Left: Experimentally measured beams of high frequency harmonic radiation (as a point of reference, 20^{th} harmonic is 40nm wavelength) generated from laser irradiation of a solid density plasma surface at the JETI40 laser facility in Jena, Germany. Right: Harmonic spectrum as a function of the relative phase of the added 2^{nd} harmonic pulse. Phase was varied by rotation of a glass plate in the beam tuning the effective thickness of glass hence the overall dispersion between the two colours. [5].

Skills gained by student

The successful applicant will have the opportunity to travel and work alongside at laboratories both within and outside the UK and will develop skills in advanced optics, X-ray spectroscopy and numerical modelling. Additionally, the student will be based, for at least 3 months over the project, in the Helmholtz Institute Jena in Germany where they will run experiments on the state-of-the-art JETI200 laser system. The student will receive focused training from experienced laser and target area staff.

Useful references

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

[2] https://www.clf.stfc.ac.uk/Pages/Vulcan-2020.aspx

[3] https://www.nobelprize.org/prizes/physics/2023/summary/

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

[5] M. Yeung et al. "Experimental observation of attosecond control over relativistic electron bunches with two-colour fields", Nat. Photonics, **11**, 32 (2017)