Project Title: The Coherent Harmonic Focus - High Harmonic Generation in the Multi-Petawatt Regime.

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Type of Project: EXPERIMENTAL

Helpful existing knowledge: Knowledge of Matlab environment, Particle in Cell codes

Funding status: Awaiting funding.

Project Description

With the worldwide emergence of high-power laser facilities with multi-Petawatt (PW, 10^{15} Wcm^{-2}) performance, and plans in place for the Vulcan 20 PW laser at the Central Laser Facility in the UK, exciting new horizons for high energy density science are emerging. A key element of these advances will be understanding and harnessing the generation of bright sources of high harmonic radiation in the XUV and X-ray regions of the spectrum from these intense interactions.

This project will focus on two major mechanisms: Relativistically Oscillating Mirrors [1] and Coherent Synchrotron Emission [2] and examine how the shape of the plasma surface can be controlled to permit focusing of the emitted harmonics [3]. Recent work has shown how this focusing can boost the intensity of the driving laser by orders of magnitude to begin to explore exotic effects such as pair production from the vacuum at the so-called Schwinger Limit predicted by Quantum Electrodynamics [4].

The project work will be undertaken at laboratories in both Europe and the U.S. while preparatory work will be performed using the TARANIS laser system in Queen's. Whilst this will predominantly be a lab-based experimental project, the use of Particle In Cell codes will also form a key element of the research to support and guide the detailed experiments.

Skills gained by student

The skillsets developed as part of this project fall under two categories.

Firstly, lab-based skills. As this project will involve the use of high-power laser systems a broad range of skills essential for working safely and efficiently in a laboratory environment will be developed and honed. Communication and working with international teams of scientists and working with technical staff to develop and animate detailed ideas will form the basis for an transferable skillset that is essential for any tech-focused career.

Secondly, simulation-based skills. A significant fraction of this project will be devoted to thoroughly investigating the multi-petawatt laser matter interaction to form the theoretical framework for the associated experiments. This will develop skills in the use of high-power computing, writing proposals for accessing large clusters and the use of particle in cell codes (EPOCH and WARP-X) to simulate and model the interactions.

Useful references

[1] B. Dromey et al. High harmonic generation in the relativistic limit, ***Nature Physics*** 2, 456–459 (2006)

[2] B. Dromey et al. Coherent synchrotron emission from electron nanobunches formed in relativistic laser–plasma interactions. ***Nature Physics*** 8, 804–808 (2012)

[3] B. Dromey, et al. Diffraction-limited performance and focusing of high harmonics from relativistic plasmas, ***Nature Physics*** 5, 146–152 (2009)

[4] S Gordienko, **A Pukhov**, O Shorokhov, T Baeva *Coherent focusing of high harmonics: A new way towards the extreme intensities* Physical review letters **94**, 103903 (2005)