Project Title: Spatio-temporal coupling in high intensity lasers

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Type of Project: EXPERIMENTAL/COMPUTATIONAL

Helpful existing knowledge: Physics degree, python, lasers and optics

Funding status: Awaiting funding

Project Description

By focusing ultra-short pulse length lasers to micron-scale spot sizes it is possible to achieve such high electromagnetic field strengths that electrons are ripped from their atoms and accelerated close to the speed of light. This allows for a variety of interesting plasma phenomena as well as the development of compact particle accelerators [1]. Furthermore, by interacting such laser pulses with a relativistic electron beam, it is possible to generate highly energetic x-ray pulses through inverse-Compton scattering [2] and to explore the fundamental behaviours of quantum electrodynamics (QED) in the strong-field regime where analytical theories become extremely challenging [3].

In this project, the student will investigate the use of spatio-temporal coupling in laser pulses to enhance particle acceleration and inverse-Compton scattering. This technique, known as the 'flying focus', provides control of the velocity of the focal region of the laser, such that it can be made to move faster than the speed of light, or even counterpropagating relative to the laser direction [4]. In theory, careful tuning of the focus velocity allows for huge enhancement in laser particle acceleration and x-ray generation processes, making this an exciting approach for next generation light sources and particle colliders.

The student would join a team of researchers and students working on high power lasers, plasma acceleration and applications of intense x-rays at the Centre for Light Matter Interactions at Queen's University Belfast. This project is also part of an international collaboration and would involve travel to high power laser facilities to perform experiments within a multi-disciplinary team of scientists and engineers. The work is both computational and experimental. The student would also have opportunity to travel to conferences to present their work, and to apply their developments at the new Extreme Photonics Application Centre at the Central Laser Facility in the UK.

Useful references

1. Mangles, S., Murphy, C., Najmudin, Z. *et al.* Monoenergetic beams of relativistic electrons from intense laser–plasma interactions. *Nature* 431, 535–538 (2004). https://doi.org/10.1038/nature02939
2. Ta Phuoc, K., Corde, S., Thaury, C. *et al.* All-optical Compton gamma-ray source. *Nature Photon* 6, 308–311 (2012). https://doi.org/10.1038/nphoton.2012.82
3. K. Poder, et al. Experimental Signatures of the Quantum Nature of Radiation Reaction in the Field of an Ultraintense Laser Phys. Rev. X 8, 031004 (2018) https://link.aps.org/doi/10.1103/PhysRevX.8.031004
4. Froula, D.H., Turnbull, D., Davies, A.S. *et al.* Spatiotemporal control of laser intensity. *Nature Photon* 12, 262–265 (2018). https://doi.org/10.1038/s41566-018-0121-8