Project: Laser energised travelling-wave accelerator for interdisciplinary applications

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Project Description

Laser-acceleration of ions is an emerging technique, alternative to conventional RF-based acceleration, which promises compact delivery of high energy ions, not only for the pursuit of scientific frontiers but also making proton therapy more affordable to fight against Cancer [1]. In particular, laser-driven sheath acceleration (TNSA) and hybrid mechanisms delivers protons approaching therapeutic energies [2].with unprecedented ultra-short burst duration and laminarity. However, large intrinsic divergence and broad energy spectrum of the TNSA beams pose a significant bottleneck towards beam transport and delivery to an application/irradiation site.

A radically different approach pioneered at QUB employs helical-coil targets [3]. By harnessing laser-generated impulsive electric fields, the helical-coil target forms a miniature travelling-wave accelerator offering guided post-acceleration at a rate GV/m, several orders of magnitude higher than that feasible at conventional accelerators. Based on the recent developments to this approach in terms of high-energy implementation [4]. and multi-staging, the PhD project will aim to design, develop and characterise a first-ever "all-optical" beamline for irradiation of secondary samples, which will enhance ongoing activities in laser-driven radiobiology, radiolysis, material damage and generation of secondary particles, as well as opening new opportunities in other areas.

The United Kingdom has been at the forefront in developing high-intensity lasers and laser-based radiation sources. The Central Laser Facility (CLF), UK, is currently building (scheduled operational in 2024-25) a state-of-art 10Hz Petawatt laser system called EPAC (Extreme Photonics Applications Centre)[5], which aims to provide a step-change in capability for laser-driven accelerator research in the UK. The PhD student will develop a high-rep ion beamline for the EPAC by capitalising on the expertise available at QUB and CLF, which aligns nicely with the timeline of the EPAC project. The proposed project is also closely aligned with the part of the Horizon2020 "IMPULSE" project led by QUB for developing a compact, high repetition source at pan-European laser infrastructures (ELI) [6].

While the core studies will be carried out on a single-shot basis at QUB's TARANIS laser system[7], we will aim to explore and design solutions for high–repetition operation, so that the beamline design can be exported to external facilities (e.g. CLF, ELI Beamlines), operating at 1-10 Hz repetition rates. The student will access the leading experimental and computational resources available at QUB, CLF and ELI. The student carrying out this project will develop various skills in experimental laser-matter interaction physics, particle acceleration and detection, dosimetry, particle transport and Monte-Carlo modelling. The student will spend a significant amount of time (3-6 months each year) at the CLF working alongside the design and technical teams of the EPAC project, which will help to mitigate and circumvent any technical issues along the way and so significantly speeding up the research.

Funding

The studentship is awarded through Queen's Collaborative Studentship scheme for a duration of 3.5 years. The tuition fees and stipends will be paid as per Department for the Economy (DfE) guidelines and there will be a salary top-up of £2k per annum. Travel and accommodation costs during student's time at the CLF will also be fully covered.

References

[1] V. Malka *et al.*, *Principles and applications of compact laser-plasma accelerator*, Nat. Phys. **4**, 447–453 (2008)

[2] F. Wagner *et al.*, *Maximum proton energy above 85 MeV from the relativistic interaction of laser pulses with micrometer thick CH_2 targets*, Phys. Rev. Lett. **116**, 205002 (2016); A. Higginson *et al.*, *Near-100 MeV protons via a laser-driven transparency-enhanced hybrid acceleration scheme*, Nat. Comm., **9**, 724 (2018).

[3] S. Kar *et al.*, *Guided post-acceleration of laser driven ions by a miniature modular structure*, Nature Communications, **7**, 10792 (2016).

[4] H. Ahmed *et al.*, *High energy implementation of coil-target scheme for guided re-acceleration of laser-driven protons*, Sci. Reports., 11, 699 (2021)

[5] https://www.clf.stfc.ac.uk/Pages/EPAC-introduction-page.aspx

[6] https://eli-laser.eu

[7] https://www.qub.ac.uk/research-centres/CentreforPlasmaPhysics/ProjectsFacilities/TARANISLaser/