Project title: Next-Gen Pulsed Therapeutics — Compact Laser-Driven Ion Accelerators for Future Medicine and beyond

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Helpful existing knowledge: UG degree in Physics, Plasma physics, accelerator physics, Experimental skills and Python

Funding status: Awaiting funding

Project Description:

Recent advances in ultra-intense, high-repetition-rate laser systems are opening a new frontier in compact particle accelerators—an alternative to conventional RF-based acceleration—for both established and innovative applications. This PhD project will investigate a promising all-optical approach to ion acceleration based on laser-driven helical coils, enabling miniature, high-repetition-rate ion sources with potential applications in cancer therapy, radioisotope production, and industry.

The helical coil target is a novel approach pioneered at QUB [1,2], which, by harnessing laser-generated impulsive electromagnetic pulse (ps-EMP) in a miniature and versatile setup, offers guided post-acceleration at a rate of GV/m, several orders of magnitude higher than that feasible at conventional accelerators, acting effectively as a travelling-field accelerating module. The highly collimated, quasi-monoenergetic ion beam produced by this scheme enables more efficient transport and delivery of high-energy ions to an application/irradiation site. Building on the initial results, the PhD project will aim to design, develop and characterise a compact ion beamline for the irradiation of secondary samples, thereby enhancing ongoing activities in laser-driven radiobiology, radiolysis, material damage and the generation of secondary particles, as well as opening new opportunities in other areas. Ultimately, this research will help bridge the gap between table-top laser systems and clinically relevant therapeutic accelerators, paving the way for affordable, hospital-scale proton and ion therapy systems of the future.

The United Kingdom has been at the forefront in developing high-intensity lasers and laser-based radiation sources. With a recently funded £80M grant by UKRI, MoD and industries, the Central Laser Facility (CLF), STFC, UK, is currently commissioning a state-of-the-art 10 Hz Petawatt laser system, EPAC (Extreme Photonics Applications Centre) [3], which is aimed to provide a step-change in capability for laser-driven accelerator research in the UK. The PhD student will work towards developing a high-rep ion beamline for the EPAC by capitalising on expertise available at QUB and CLF. In particular, the PhD student will explore the underlying physics of ps-EMP generation and its coupling into the helical coils, study coil and target optimisation through particle-in-cell (PIC) and Multiphysics simulations. The approach will be developed and tested on a single-shot basis at QUB's TARANIS laser system, with the goal of establishing scalable solutions for high-repetition-rate operation so the beamline design can be deployed at large-scale facilities at the EPAC and the Extreme Light Infrastructure (Czech Republic and Romania) [4] operating at 1–10 Hz. The student carrying out this project will develop a varied range of skills in experimental laser-matter interaction physics, particle acceleration and detection, dosimetry and extensive particle-in-cell and Multiphysics simulations.

Useful references

[1] S. Kar et al., Guided post-acceleration of laser driven ions by a miniature modular structure, Nature Communications, 7, 10792 (2016).
[2] H. Ahmed et al., High energy implementation of coil-target scheme for guided re-acceleration of laser-driven protons, Sci. Reports., 11, 699 (2021)
[3] https://www.clf.stfc.ac.uk/Pages/home.aspx; https://www.clf.stfc.ac.uk/Pages/EPAC.aspx
[4] https://www.eli-beams.eu; https://www.eli-np.ro