Development and characterisation of high-repetition rate proton sources using novel targets

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High-intensity lasers can be used to accelerate protons to high energies over very small distances when they are focused on sub-millimetre targets. These proton beams exhibit highly desirable characteristics including very short durations (a million, millionth of a second) that cannot be achieved with conventional particle accelerators. This characteristic means they have a very high current and so, amongst many other applications, can be used to study the propagation of strong currents.

Due to the enormous potential of these proton beams for a wide range of applications (covering fundamental physics, to medicine and material science) many experiments have been performed to explore how the characteristics of the accelerated particles are influenced by the laser and target conditions. Traditionally, these experiments have provided tens to hundreds of data points due to the limited shot rate of very high intensity lasers.

In recent years a new generation of high-intensity lasers, that can fire multiple times a second, have driven a revolution in data gathering and interpretation within the field, including the integration of machine learning techniques. This will be combined with progress in target and diagnostic technology in order to support high data acquisition rates which not only enable deeper understanding of the laser-matter interactions but will enable many new uses of these tiny high energy particle accelerators.

This project will explore the generation of proton beams using novel high-repetition rate targets, characterisation of the beam quality throughout the parameter space and tunability of the beam characteristics for particular applications.

This 3-year, fully-funded DfE PhD position would support a student to join with an international collaboration of scientists developing novel high-repetition rate targets, diagnostics and analysis methodology suitable for multi-Hz experiments. These will be utilised at international facilities including the Central Laser Facility near Oxford and new high-repetition rate laser facilities in Europe and the US. By participating in these experiments, the student will learn how to design and operate a high-intensity laser experiment as part of a team before taking the lead. Local laboratory facilities at QUB will be used for target and diagnostic development.

In addition to experiments, the PhD will also involve travel to international schools and conferences (to share their results with the community through poster and oral presentations), computer simulations to support experimental planning and data analysis. This PhD will provide the student with broad research experience and a suite of highly transferable skills for research and industry.

Suggested references for further details on relevant topics:

Laser driven proton acceleration:

- Macchi et al, Review Modern Physics, 85, 751 (2013)
- Roth and Schollmeier, Proceedings of the CAS-CERN Accelerator School: Plasma Wake Acceleration (CERN-2016-001)
- Schreiber et al., Review of Scientific Instruments, 87, 071101 (2016)

Applications:

- Proton radiography: Borghesi et al., Laser and Particle Beams, 20, 269-275 (2002)
- Hadron therapy:Bulanov et al., Physics Letters A, 299, 240-247 (2002)
- PIXE: Passoni et al., Scientific reports, 9, 9202 (2019)

High repetition laser plasma interactions and diagnostics:

- Morrison et al., New Journal of Physics, 20, 022001 (2018).
- Huault et al., High Power Laser Science and Engineering, 7, 660 (2019)
- Ma et al., Plasma Physics and Confined Fusion, 63 (2021)