High-energy, laser-driven ion sources for advanced applications

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The acceleration of ions using laser-based techniques is currently attracting a very significant interest in the scientific community. Beams accelerated through these techniques have unique properties, particularly in terms of their ultrashort temporal profile, which are very distinctive and different from the characteristics of beams obtained from conventional accelerators. This is driving their use in innovative scientific applications which are currently being pursued in the major high power laser laboratories worldwide. Laser-accelerated protons can be used in advanced radiography techniques for investigating and characterizing the highly transient, large amplitude electric and magnetic fields appearing in dense, hot plasmas, or to generate, by irradiation of suitable samples, transient states of matter in between plasmas and solids (*warm dense matter*) of interest to astrophysical objects (planetary cores) as well as to fusion plasmas.

Our group at QUB has been at the forefront internationally in this area of research during the past decade. We have demonstrated novel mechanisms for ion acceleration, beyond the well-established TNSA (Target Normal Sheath Acceleration) process, as well as pioneering applications such as ultrafast radiobiology and high-resolution proton radiography.

This PhD project will be specifically focused on developing approaches for delivering optimized beams, with higher energies and flux, to allow new applicative capabilities in high energy density physics. For this purpose, we will explore novel acceleration concepts, theoretically capable of providing proton and ion beams with higher energies. Amongst those, we will explore the acceleration of ions by the very strong radiation pressure of laser pulses. This can be applied to ultrathin foils, in the so-called Light Sail regime of acceleration, but also in suitably preformed plasma profiles, which can be used to maintain the accelerating front in phase with the ions over an extended distance. In order to reduce the ion beam divergence, and enhance the particle flux, these mechanisms can be coupled to target-based approaches for selective collimation of the accelerated ion beams.

Employing beams with enhanced capability, we also plan to carry out proof of principle demonstrations of their use in proton radiography of dense hot materials and/or in irradiating suitable samples for warm dense matter creation.

The project is funded for 3.5 years by the Department for Economy NI and AWE plc, and is available to British nationals. It includes a top-up of £3.5K per annuum, above the standard studentship amount. The student will acquire skills in advanced optics, plasma physics, particle diagnostics and data analysis. They will be part of a strong experimental team and will have the opportunity of carrying out internationally leading research at state-of-the-art laser facilities. We envisage that this research will be carried out on world-leading large facilities such as ORION (at AWE), GEMINI /EPAC (at STFC's Central Laser Facility) and ELI Beamlines (Prague), and will be supported by dedicated modelling with relevant codes.

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