Benchmarking collisional rates and hot electron transport in high-intensity laser-matter interaction

Supervisors:

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When high-intensity lasers interact with opaque target materials they rapidly ionise the target creating a hot plasma. These plasmas are compact sources of bright secondary radiation including MeV proton beams which exhibit highly desirable characteristics for applications such as high-dose rate radiobiology. During the interaction, the laser energy transfer to the proton beam is mediated by electrons within the plasma which respond quickly to the laser electric field due to their low mass. As a consequence, the characteristics of the proton beam strongly depend on the electron population. Understanding of the evolution of the electron population and its dependence on the laser parameters is therefore crucial in order to create tailored proton sources for applications.

During this project the student will visit state-of-the-art international research facilities in UK and Germany to study the transfer of laser energy to high-energy electrons, using extreme-brilliance X-ray Free-Electron Lasers (XFELs) to directly probe the target evolution. The student will then exploit this enhanced understanding of laser-heating and computer-guided data-acquisition tools developed at QUB to explore the optimisation of laser-to-target energy transfer using automated diagnostic feedback in order to enhance laser-plasma radiation sources for applications.

This 4-year, fully-funded EPSRC PhD position, includes additional travel funding to support research visits and training at European XFEL Hamburg. This billion-euro research facility provides the unique combination of a bright high resolution x-ray source and new high-power laser facility necessary for this work. The student would work with experts on XFEL science and laser-driven particle accelerators within an international collaboration of scientists. By participating in experiments at XFEL and laser facilities, the student will learn how to design and operate a high-intensity laser experiment as part of a team before taking the lead as well as developing diagnostics and analysis tools. Local laboratory facilities at QUB will also be used for experimental preparation and in-house studies.

In addition to experiments, the PhD will also involve travel to international schools and conferences (to share the 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 of Modern Physics, 85, 571, (2013)

Applications of MeV energy protons: Aymar et al., Frontiers in Physics, 8, 567738 (2020), Passoni et al., Scientific reports, 9, 9202 (2019)

Automated feedback: Shalloo et al., Nature Phys., 11, 6355 (2020)

XFEL science: Vinko et al., Nature, 482, 59-62 (2012)