Radiobiology with laser-driven ions at ultra-high dose rate

Supervisors: Prof. M. Borghesi (m.borghesi@qub.ac.uk), *Centre for Light-Matter Interaction*
Prof. K. Prise (k.prise@qub.ac.uk), *Patrick Johnston Centre for Cancer Research*

Background: Cancer ranks as a leading cause of death worldwide, motivating research in developing more advanced and effective forms of therapy. Treatment of cancer using radiation (radiotherapy) is particularly important in this context, and is delivered most commonly employing x-ray- photons, but also, in its more advanced form, employing high energy protons or carbon ions. An emerging radiotherapy concept currently attracting a phenomenal amount of research interest is the so-called FLASH approach, where radiation dose is delivered to the patient in short pulses, at a dose rate of 10 to 1000s Gray/second. In animal models, FLASH delivery has been seen to result in significant sparing of the healthy tissues surrounding the tumour and a remarkable decrease in side effects, while maintaining a pronounced effectiveness in destroying the cancerous cells. These results have triggered a broader fundamental interest in the investigation of the biological effects of highly pulsed radiation beams. Laser-acceleration of ions, a technique pioneered by our group at QUB, provides particle pulses with an intrinsically ultrashort (typically of picosecond order or less) temporal duration. This offers the opportunity to irradiate samples at extreme dose rates never reached before, many orders of magnitude higher than even in the FLASH regimes discussed above. This opens to investigation unexplored regimes of radiobiology, where preliminary data highlight a complex scenario which challenges established understanding of radiation interaction with cellular media and requires new hypotheses and models, highlighting this regime as particularly promising for future radiotherapy.

Project description: The project offer the student the unique opportunity for training at the interface between physics and biology, which will be enhanced by specific expertise available at the partner's institution (e.g. in particle transport, numerical modelling, radioprotection and laser operations) . There is potential for acquiring skills and knowledge in a broad range of areas, including laser-plasma interaction experimental techniques; particle diagnostics and dosimetry; cell culture and handling; cell exposure techniques; biological assays; data analysis techniques in physics and biology; Montecarlo modelling of particle transport. Throughout the project, the student will have access to research capabilities and facilities at the leading edge internationally. We envisage that a large fraction of the research will be carried out at the ELI Beamlines facility, which is emerging as the leading European centre for the provision of laser-accelerated particle beams. At ELI Beamlines, the student will contribute to the flagship experimental activities carried out within the framework of the EU-funded IMPULSE project. Research will also be carried out in the UK, mainly at the STFC Central Laser Facility (CLF), of which our group is a major user. CLFs' VULCAN Petawatt and GEMINI lasers are also internationally leading systems which will provide unique capabilities to the student's research.Throughout the project, the student will have access to research capabilities and facilities at the leading edge internationally. We envisage that a large fraction of the research will be held at the ELI Beamlines/ELIMAIA facilities, which is emerging as the leading European facility for the provision of laser-accelerated particle beams. Research will also be carried out in the UK, mainly at the STFC Central Laser Facility (CLF), of which our group is a major user.
There will be broad training opportunities at ELI (e.g. through the annual ELI Summer School, which provides an overview of the state-of-the-art in the field, and of the activities in the ELI facilities), and in the UK, through the participation to dedicated training programmes at the CLF (e.g. the PhD Training Weeks and the Target Area operator course). These provide hands-on training in experimental techniques, advanced topical lectures in laser-plasma science, as well as in safety and team management.

Funding: The studentship has a duration of 3.5 years, and stipend and fees will be funded directly by ELI Beamlines.

Background reading:

P. Chaudhary *et al*, *Radiobiology Experiments With Ultra-high Dose Rate Laser-Driven Protons: Methodology and State-of-the-Art*, Front. Phys., **9**, 624963 (2021)

F. Hanton *et al*, *DNA DSB Repair Dynamics following Irradiation with Laser-Driven Protons at Ultra-High Dose Rates*, Sci.Reports. **9**, 4471 (2019)

P. Chaudhary, *et al*, *Cellular irradiations with laser-driven carbon ions at ultrahigh dose rate*s, Phys. Med. Biol. **68** 025015 (2023)

D. Margarone *et al*, *ELIMAIA: A Laser-Driven Ion Accelerator for Multidisciplinary Applications*, Quantum Beam Sci., **2**, 8 (2018)