Project Title: High-quality positron and x-ray sources for EuPRAXIA

Supervisor(s): Prof. Gianluca Sarri (primary), Dr. Massimo Ferrario (secondary)

Email contact: g.sarri@qub.ac.uk

Type of Project: EXPERIMENTAL and COMPUTATIONAL

Helpful existing knowledge: 1st or 2:1 BSc or MSci degree in physics or related subjects.

Funding status: Funded

Project Description

Plasma-based particle accelerators can drive a wide range of secondary radiation and particle beams with spatiotemporal properties (typically in the micron and femtosecond scales) and brightness that are effectively unmatched by any other technology. These unique characteristics allow for unprecedented performance in probing and interacting with matter at different fundamental levels (e.g., nuclear, chemical, and biological). Their extreme versatility not only enables a precise control and fine-tuning of the beam parameters but also permits to select, by varying the interaction conditions, the type of particle or radiation (i.e., x-rays, gamma-rays, electrons, positrons, ions, and neutrons). Identified disruptive applications include ultra-fast electron diffractometry, high-resolution radiography of high-Z materials, phase-contrast imaging of biological tissue, and high-resolution detection of defects in materials even down to the nanometer scale.

Leveraging on proof-of-principle demonstrations of the unique potential of plasma-based accelerators, we established an international collaboration working towards the construction of the first plasma-based particle accelerator that will operate as an international user facility. After the recent publication of the Conceptual Design Report [1], the EuPRAXIA facility has been included in the ESFRI roadmap [2] and is currently under its preparatory phase funded by the European Union. The Laboratori Nazionali di Frascati (LNF), the largest laboratory of the Istituto Nazionale di Fisica Nucleare (INFN) in Italy, have been chosen as the host of the facility.

Flagship applications of the EuPRAXIA facility include the generation of coherent and bright x-ray betatron radiation [3,4] and the generation of ultra-short (~fs) and ultra-relativistic (~500 MeV) positron beams [5-8], areas in which our group at QUB is a recognised international leader. The main aim of the project is thus to design, install, and test, in close collaboration with LNF, beamlines and user end-stations for betatron x-rays and high-energy positron beams. The student will also contribute to the design and test of specific beamlines at QUB, using a recently funded state-of-the-art laser system [9]. The student will work on designing and testing compact, high-performance, and versatile laser-driven sources and user end-stations, joining a large-scale and vibrant collaboration and using state-of-the-art facilities and modelling software. The student will gain expertise and knowledge in emerging technological areas of fundamental interest to a broad sector of public and private stakeholders. It is envisaged that this work will result in high-profile publications and applications for patents, with the realistic expectation of significantly contributing to an impact case study.

Useful references

[1] R. Assman et al., 229, 3675 Eur. Phys. J. Special Topics (2020)

[2] https://roadmap2021.esfri.eu/projects-and-landmarks/browse-the-catalogue/eupraxia/

[3] B. Kettle et al., Comm. Phys. 7, 247 (2024)

[4] J. Cole et al., PNAS 115, 6335 (2018)

[5] G. Sarri et al., Phys. Rev. Lett. 110, 255002 (2013)

[6] G. Sarri et al., Nat. Comm. 6, 6747 (2015)

[7] G. Sarri et al., Plasma Phys. Contr. F. 64, 044001 (2022)

[8] M. Streeter et al., Scientific Reports 14, 6001 (2024).

[9] https://gow.epsrc.ukri.org/NGBOViewGrant.aspx?GrantRef=EP/Z533324/1