Plasma Accelerators for Nuclear Applications and Materials Analyses (PANAMA)

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Understanding the (geo)chemical behaviour of nuclear materials and radionuclides is critical for safe operation at all stages of the nuclear fuel cycle, particularly in light of a renewed interest in nuclear energy to achieve the CO_2 emissions targets in the Paris agreement.[1] However, many nuclear materials are extremely dense and/or highly radioactive. Additionally, (geo)chemical reactions can occur on ultra-short time scales. These properties can severely limit analysis of these materials and processes.

Laser-driven plasma accelerators show great potential for the development of advanced analytical technologies that overcome such limitations. In such accelerators femtosecond (fs) laser pulses interact with a gas target to produce a plasma. The force of the laser pulse creates a plasma density wave in its wake, which accelerates electrons up to GeV energies in millimetres. These accelerated electrons can produce fs γ- and X-ray pulses (up to several MeV).[2] Similarly, laser interaction with solid targets can produce proton and ion pulses.[3]

In this presentation we will present the progress and case studies on research possibilities for the nuclear energy sector at the Scottish Centre for Applications in Plasma Accelerators (SCAPA).[4] At SCAPA we are developing capabilities exploiting radiation and particle pulses from laser-driven plasma accelerators. (1) For microstructural imaging, high energy radiation pulses can be used for γ- and X-ray tomography of dense and large objects, including radioactive samples. (2) At the molecular scale, ultrafast radiation pulses can be utilised for time resolved X-ray diffraction and absorption spectroscopy. (3) The ultrafast γ- and X-ray pulses can be synchronized with proton and ion beams for pump-probe studies on the (fs) mechanisms of particle induced material damage.[2,4] Such (combination of) capabilities will address fundamental research needs across nuclear sectors.

References

[1] Meeting the Energy Challenge, A White Paper on Nuclear Power. (2008). [2] Albert & Thomas *Plasma Physics and Controlled Fusion* **58** 103001 (2016). [3] Higginson et al. *Nature Communications* **9** 724 (2018). [4] www.scapa.ac.uk [5] Mahieu et al. *Nature Communications* **9** 3276 (2018).