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Studies of radio-isotope production relevant for medical imaging using laser-driven ion beams

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Medical imaging based on the radiation emitted by unstable nuclei is used on a daily basis as a fundamental tool in medical diagnosis, particularly thanks to techniques such as PET (Positron Emission Tomography) or SPECT (Single-Photon Emission Computed Tomography). This has led to an increase in the demand of nuclear radio-isotopes, with the production typically being done at conventional accelerators (cyclotrons) and dedicated nuclear reactors. However, due to the large footprint and associated cost of these production facilities, their feasibility and economic viability relies on the mass-scale production of supplies that cover large areas, typically regional or national scale. As a result, a single production facility must provide nuclides to health centres in distances that range up to 100s of km. In the particular case of the β^+ emitters used in PET imaging, this approach has limited the range of isotopes to ^{18}F. With a half-life of $\sim$ 110 min, ^{18}F can endure the time required for the production, post-processing and distribution. Other radio-isotopes of interest in medical imaging, such as ^{11}C, ^{13}N, or ^{15}O, have lifetimes too short to be commercially available.

In this context, there has been a growing interest in compact accelerators that can be used for the production of isotopes. A particularly promising alternative is the use of ultra-intense lasers as drivers of energetic ion beams, with advantages such as flexibility, compactness and cost-effectiveness. Although there are several mechanisms for laser-based ion acceleration, Target Normal Sheath Acceleration (TNSA) is arguably the most interesting mechanism. In TNSA, an ultra-intense laser pulse ($I > 10^{18}$W\,cm^{-2}) interacts with a thin (few micron), metallic target, leading to the acceleration of light ions to energies in the MeV range with appealing properties, such as ultra-short duration, small source size, and low emittance. Thanks to the closely-coupled setup, with the laser-plasma interaction being limited to a region of a few micron, the shielding requirements are significantly lowered with respect to conventional accelerators. Such a laser-based accelerator would therefore constitute an affordable option for hospitals, clinics, and research centres, enabling the on-demand production of radio-isotopes, including those with shorter lifetimes.

Here, we present some recent results and technological developments achieved using the STELA system, a 30\,TW laser deployed at the Laser Laboratory for Acceleration and Applications (L2A2), in the University of Santiago de Compostela (Spain). These developments in targetry, diagnostics, and secondary production of radio-nuclides open the path for this technology to become a real alternative to the commercial generation of medical radio-isotopes.

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