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Actinide ion beams by in-gas-cell laser resonance ionization, recoil sources, and on-line production at IGISOL

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The production of actinide ion beams has become a focus of recent efforts at the IGISOL facility of the Accelerator Laboratory, University of Jyväskylä, aimed at the measurement of nuclear properties of heavy elements using high-resolution optical spectroscopy [1]. Recently, off-line ion beam production of plutonium and thorium using laser resonance ionization combined with filament dispensers in a gas cell has been the subject of extensive studies. Additionally for thorium, which is of interest mainly because of the ^{229}Th isotope and its extremely low-lying isomeric state [2], development of a ^{233}U alpha-recoil source and on-line production activities have now commenced.

Both plutonium [3] and thorium [4] show unexpected phenomena during laser resonance ionization in a gaseous environment. A plutonium ionization scheme that has been reported to have high efficiency in vacuum (hot cavity) performed poorly in the gas cell due to significant collisional quenching of states. The high density of atomic states in actinide elements has also complicated the understanding of the laser ionization process. Therefore, the selective ionization of plutonium was investigated further with a tunable, grating-based Ti:sapphire laser developed by the Applied Quantum Beam Engineering group from Nagoya University [5]. For the filament dispensers of ^{229}Th, an additional challenge has been the low volatility of thorium, contaminants and scarcity of ^{229}Th material.

A gas cell with ^{233}U alpha-recoil sources is also a viable approach towards the production of a low-energy ^{229}Th ion beam. Two different sources have been characterized at IGISOL with gamma- and alpha-ray spectroscopy by taking measurements from the sources directly and via implantation foils. The Rutherford back scattering spectrometer of the local ion beam analysis facility was also used to characterize the sources. The findings of these studies emphasize the importance of having control over the source quality, thickness and contaminants.

The first on-line experiment for the production of ^{229}Th from a light-ion fusion-evaporation reaction on ^{232}Th targets has also been performed. Although the identification of ^{229}Th was not directly possible due to the long half-life (7932 years), several alpha-active reaction products were detected and a yield of about 400 ions/s/μA for ^{229}Th was deduced from the ^{227}Pa yield, known detection efficiency and cross section estimates. The challenge of on-line production is in the competing (and overwhelming) fission channel which produces a large number of fission fragments that are expected to cause strong ionization of the buffer gas. Also, significant target damage was seen to be a problem because the targets were kept as thin as possible. This has prompted new target manufacturing concepts which are current being considered.

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