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The radioactive beam facility ALTO

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ABSTRACT

The Transnational Access facility ALTO (TNA07-ENSAR/FP7) has been commissioned and received from the French safety authorities, the operation license. It is allowed to run at nominal intensity to produce 10^{11} fissions/s in a thick uranium carbide target by photo-fission using a 10 μA, 50 MeV electron beam. In addition the recent success in operating the selective laser ion source broadens the physics program with neutron-rich nuclear beams possible at this facility installed at IPN Orsay. The facility also aims at being a test bench for the SPIRAL2 project. In that framework an ambitious R&D program on the target ion source system is being developed.

1. Introduction

Various production modes for neutron-rich radioactive nuclei based on induced fission in a thick target have been investigated for next-generation facilities. After an experiment [1], the production based on gamma induced fission was demonstrated to be technically feasible to obtain competitive yields of radioactive nuclear beams (RNB). This led to the building of the ALTO ISOL facility [2] which operates a 50 MeV electron linac. Even with a limited power, the facility can provide access at a low cost to a large range of interesting RNB. The whole ALTO facility supplies both stable and radioactive ion beams and develops ion sources and thick actinide targets for the production of RNB. In particular, the ISOL part of the facility is used as a test bench for R&D for SPIRAL2 and EURISOL projects [3].

2. Description of the facility

The ALTO facility is mainly powered by two accelerators: a 15MV-MP Tandem to provide stable beams as well as ^{14}C and clusters beams and a 50 MeV linear electron accelerator dedicated to the production of RNB. The delivered beams are dedicated to a large range of physics cases from nuclear structure to atomic physics, cluster physics, biology and nanotechnology. For the production and delivery of stable beams, the Tandem runs on average 4000 h/year which allows scheduling roughly 30 weeks for experiments. It provides beams of about 75 species ranging from proton to Au and cluster beams. They are typically distributed as follows: 20% of light ions (proton to ^{4}He), 60% of heavy ions (^{7}Li to ^{127}I) and 20% of cluster ions Cn, CnHm.

Regarding the RNB, the nuclei are produced by inducing fission reactions in a thick UC_X target heated upto 2000 °C and the beams obtained by the ISOL technique (Fig. 1). The driver is an electron linac delivering a 50 MeV/10 μA primary beam towards the production unit which is located inside a bunker. The fission fragments released from the target are ionized and the single-charged ions are extracted at 30 keV to the mass separator ($A/\Delta A = 1500$). The in-target production rate is about 10^{11} fissions/s. Three ion source types can be coupled to the target: Febiad ion source, surface ion source or laser ion source. The resonant ionization laser ion source has been installed recently at the facility.

After having performed off-line tests for the production of Sn, Cu and Ga, on-line beams of Ga have been selectively and efficiently produced and delivered to experiments. The laser system is based on the dye laser technology. It is equipped with a Nd:YAG (100 W, 532 nm) pump laser from EdgeWave operating at 10 kHz and powering two (540–850 nm) dye lasers from Radiant Dyes with their BBO doubling units (270–425 nm). In the on-line test to produce Ga beams, an ionization efficiency higher than 10% has been measured. We plan to upgrade the laser system by adding a third dye laser to achieve the three-step ionization schemes, in particular to ionize Ni, Ge, Sn, Sb and Te. In parallel we have designed a reference cell equipped with an oven and a detection system based on μ-channel plate. This cell will be used before on-line runs to tune the different laser wavelengths by measuring the current of the ions of interest obtained by the interaction of lasers and the evaporated atomic flow. This setup will be also used for the development of unknown laser ionization schemes.

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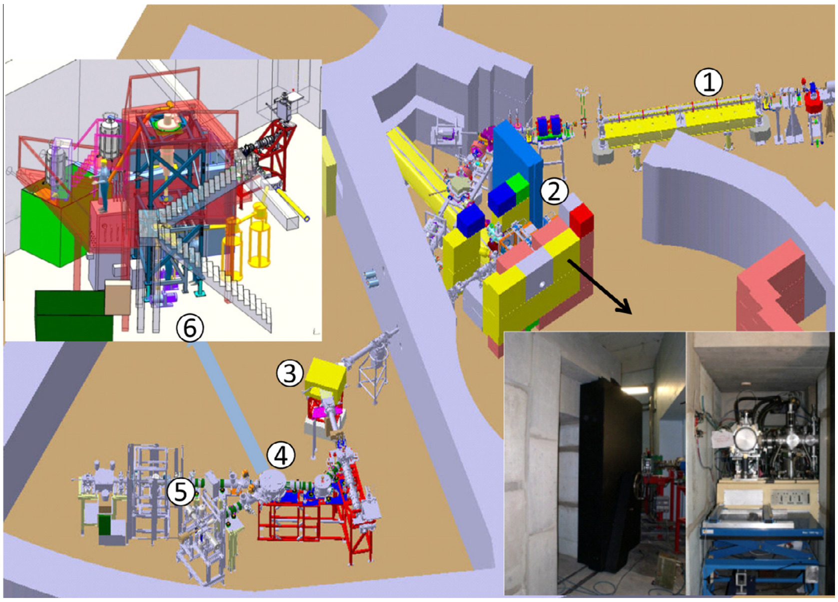

Fig. 1. 3D-view of the ISOL facility at ALTO. (1) Electron Linac 50 MeV; (2) target-ion source vault; (3) mass separator; (4) kicker-bender; (5) beta decay spectroscopy line Bedo; (6) new beam line (under construction) for the nuclear orientation experiments.

Presently, the facility can deliver the radioactive nuclear beams to five different experimental set-ups. One of them is equipped with a beta-decay spectroscopy set up [4]. A second one, under construction, is dedicated to the nuclear orientation measurements on-line [5].

In 2012, French safety authorities gave the green light to run the ISOL facility at nominal primary electron beam intensity (10 μA, 50 MeV). A routine production at the ALTO facility allows the delivery of various ion beams depending on the chosen ion source. Experiments are scheduled according to an irradiation cycle corresponding to 2 weeks of irradiation and 3 weeks of decay. In this cycle, the use of the target ion source set is limited to 2 weeks to avoid aging which lowers the production. In the Fig. 2 are plotted the expected yields with a 60 g UC_X target irradiated by the electron beam at nominal intensity. Measurements have been performed at 100 nA) using a Febiad ion source [6] and additional data have been obtained at nominal intensity with a W surface ion source. The extrapolation of the whole measured yields at low intensity is in agreement with the expected yields [7].

3. R&D at the ALTO facility

The IPN-Orsay has a long experience in the production of RNB by ISOL technique [8]. In recent years, developments on targets and ion sources have been achieved mainly for the future SPIRAL2 facility and the European projects EURISOL and ActILab [9]. An active R&D program is underway on both the target and ion source systems at the ALTO facility. The objective is to build up an efficient and reliable system operating in a strong ionizing environment.

3.1. IRENA ion source

A new Febiad-type ion source, named IRENA, has been developed to operate efficiently and steadily under strong radiation conditions [10]. It has been designed with a radial configuration of the anode–cathode set to allow both efficient ionization and the confinement of the positive ions for efficient extraction. In such a configuration no magnetic field is required; the design involves few components to assure a reliable long-term operation under hard radiation and to reduce the amount of radioactive waste. The feasibility prototype was designed as close as possible to the EBGP [11] ion source to compare their performances.

To optimize the anode–cathode set and to improve the mechanical and electrical reliability, the second prototype was completely modeled with 3D-Lorentz simulation code (Fig. 3a) [12].

Due to the difficulty in the manufacturing process, the strip structure of the anode used in the first prototype was modified into a grid one. In addition, 3D Thermal simulations were carried out using the NX-IDEAS code to improve the temperature homogeneity all along the cathode at high temperature (Fig. 3b and c). First off-line tests of the second prototype have shown very competitive performances in comparison to the classical plasma ion source Febiad-MK5 commonly used nowadays at ALTO (Table 1). These tests are still in progress to get the best configuration for the production of radioactive nuclear beams on-line.

3.2. Off-line tests of lanthanide fluorination

To study the low-spin states of the neutron-rich lanthanide nuclei located near the mass 160, another R&D work is underway to improve efficiently the production of lanthanide beams by using the fluorination process. Due to their high melting point and chemical reactivity, the lanthanides are known to release slowly. Some isotopes such as ^{156}Pm, ^{159,160}Sm and ^{161}Eu could be released at 2500 °C and ionized as Ln^+ [13]. Such a target temperature is not yet reachable at ALTO since the running temperature for standard target cannot exceeds 2200 °C. However the release of lanthanide can be favored by injecting CF_4 in the integrated target/ion-source [14]. Off-line tests have been carried out with stable lanthanide isotopes in order to determine the best running conditions for the production of lanthanide beams. A target obtained from a mixture of lanthanide and graphite has been developed in order to simulate the release of Ln in the UC_X targets. CF_4 has been injected by an adjustable micro-leak in the target which is connected to the ion source. The addition of CF_4 favors the formation of lanthanide fluorides which are volatile molecules. These molecules are extracted from the ion source in the form of LnF_2^+, LnF^+ or Ln^+ ions. The first tests have demonstrated the feasibility of the investigated technique. The current of different masses corresponding to Ln^+, LnF^+ and LnF_2^+ ions has been measured as a function of the various