Ion Sources used in the Production of Radioactive Ion Beams at the HRIBF

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Radioactive ion beams are produced at the Holifield Radioactive Ion Beam Facility (HRIBF) using the ISOL technique where the atoms are produced in a thick target, transported to an ion source, ionized, and extracted from the ion source to form an ion beam. At the HRIBF, the radioactive ion beams thus produced are accelerated to 200 keV for injection into a tandem electrostatic accelerator, further accelerated up to a few MeV per nucleon, and then delivered to experimental stations for use in nuclear physics and astrophysics studies. The radioactive nuclei are produced via light ion (p, d, ^{3}He, α) induced reactions on the target nuclei. These production beams are provided by a K=100 cyclotron. To date, the production beam intensities have been limited to 12 μA by the ability of the production target to withstand the deposited power.

The types of ion sources used to produce radioactive ion beams vary considerably. Since negative ions are required for injection in the tandem accelerator, most of the ion source development effort has been focused on improving the efficiency and durability of sources that produce negative ions directly. Three such sources have been used at the HRIBF to produce radioactive ion beams, either on the RIB Injector Platform or during tests with low-intensity production beams at the UNISOR Facility. In some cases, where the electronegativity of the element is relatively low, it is more efficient to make positively charged ions and then create negative ions by passing the low-energy positive-ion beam through a charge exchange cell containing a metal vapor. At the HRIBF a cesium-vapor cell is used. The ion sources used at the HRIBF are listed below.

- Kinetic Ejection Negative Ion Source (KENIS) [1] – used to produce beams of ^{17,18}F from targets of aluminum oxide and hafnium oxide fibers.
- Electron Beam Plasma Ion Source (EBPIS) [2] – used to produce positive-ion beams of proton-rich isotopes of As, Ga, and Cu using liquid metal targets and F from fibrous oxide targets. Also used to make beams of many fission fragments produced in a uranium carbide target.
- Batch-mode Cs-sputter ion source [3] – used to produce beams of long-lived nuclei from solid targets.
- Negative Surface Ionization Source [4] – utilizes a LaB_6 surface to produce negative ions of bromine and iodine from a uranium carbide target.

The poster presentation will provide more information on each of these sources, including the unique capabilities of each and their usefulness to the HRIBF.

[1] G.D. Alton, Y. Liu, C. Williams, and S.N. Murray, *Nucl. Instr. and Meth.* **B 170**, 515-522 (2000).

[2] Carter, H.K., et al., *Nucl. Instr. Meth.* **B 126**, 166 (1997). (Lists of extracted beams and the measured intensites are available at www.phy.ornl.gov/hribf/users/beams/).

[3] G.D. Mills, G.D. Alton, D.L. Haynes, and J.R. Beene, *Physics Division Progress Rpt. ORNL-6957, Sept. 1998* (available at www.phy.ornl.gov/progress/hribf/randd/hri031.pdf).

[4] H. Zaim, Y. Liu, S.N. Murray, and G.D. Alton, to be published in *Application of Accelerators in Research and Industry*, edited by J. L. Duggan and I. L. Morgan, AIP Conference Proceedings, New York: American Institute of Physics, 2001.

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