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An Overview of the Radioisotope Electromagnetic Isotope Separation Capabilities at Idaho National Laboratory

July 2023

Changing the World's Energy Future

Jared J Horkley, Andrew John Zillmer, Kevin P Carney

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An Overview of the Radioisotope Electromagnetic Isotope Separation Capabilities at Idaho National Laboratory

Jared J. Horkley[a]*, Andrew J. Zillmer[a], Kevin P. Carney, Ph.D.[a]

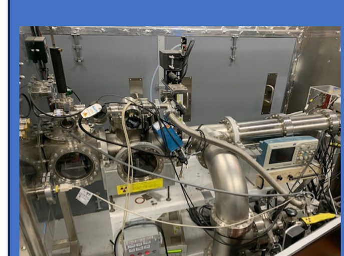
Introduction

Electromagnetic isotope separation (EMIS) has been an effective tool for the enrichment of isotopes for over 80 years. In the early 1990's the U.S. reduced or eliminated electromagnetic isotope separation capabilities, but in the last decade, increased demand for both stable and radioactive enriched isotopes have led to the reestablishment of small-medium scale EMIS capabilities in the U.S. National Laboratory Complex.

Radioisotope EMIS at INL

Upgrades: Collector, Ion Optics, Ion Sources

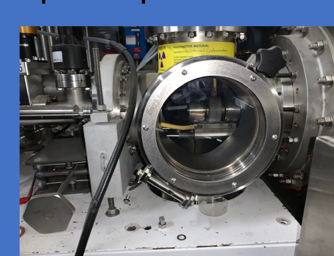
New collector chamber and movable stage installed in 2023



Old chamber

New chamber

Einzel Lens to be replaced with custom quadrupole mid-late 2023



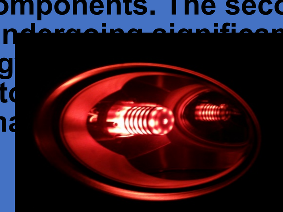
Einzel Lens

By: DTE Research and Design, LLC.

In the timeframe of approximately 2008 to 2013, Idaho National Laboratory (INL) refurbished and reconstructed two 90-degree sector isotope separators[1,2]. The first one completed was originally designated for stable isotope production but is now used primarily as a non-radioactive platform to test methods and components. The second separator is currently designated for radioisotope

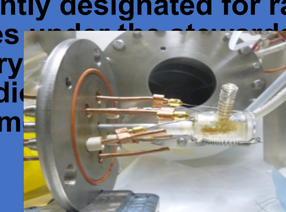
Ion sources

Colutron Q-100 hot cathode ion source



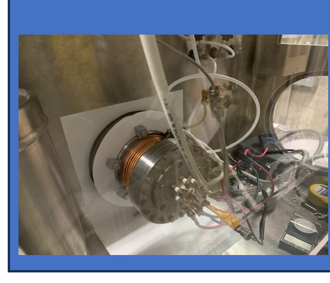
RF Ion source: Beam Imaging Solutions Inc.

Liquid metal ion source

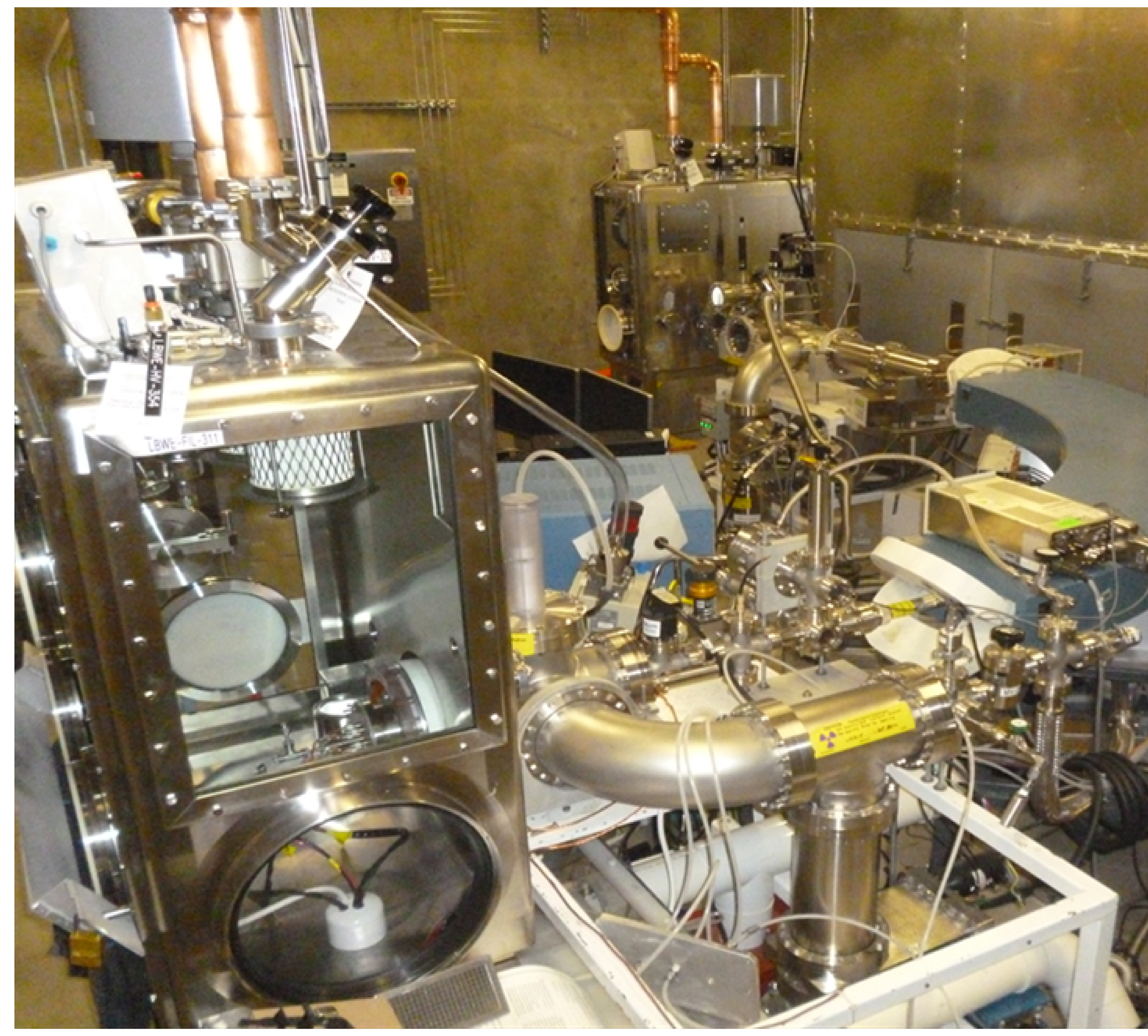


Customized hot cathode ion source loaded with NpClx

High temperature electron bombardment ion source.[3]



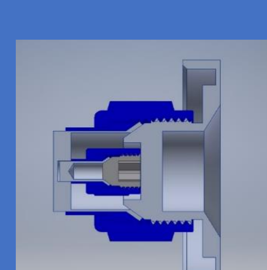
Outer flange of hot cathode ion source mounted to high voltage flange in the source glovebox.

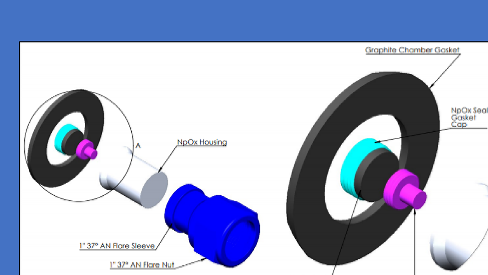


Radioisotope electromagnetic isotope separator set up at INL's Materials and Fuels Complex Analytical Research Laboratory

Source Material Preparation

Irradiated ^{237}Np





- 0.5 g NpO_2
  - Test Sample
- Irradiated June 2018
  - 5 hours at 38 MeV
  - ~5x10[14] total fissions
  - Contact dose (+8 days): 450 mR/hr
  - ^{236m}Np: 97 ± 9 mCi (measured)
  - ^{236g}Np: ~0.17 µg (estimated)
  - ^{236}Pu: 97 ± 9 mCi (measured)

- 2.5 g NpO_2
  - Production Sample
- Irradiated May-July 2020
  - 5 hours at 38 MeV
  - ~5x10[14] total fissions
  - Contact dose (+8 days): 450 mR/hr
  - ^{236g}Np: ~100 µg (estimated)
  - ^{236}Pu: 97 ± 9 mCi (measured)

Irradiated ^{238}U

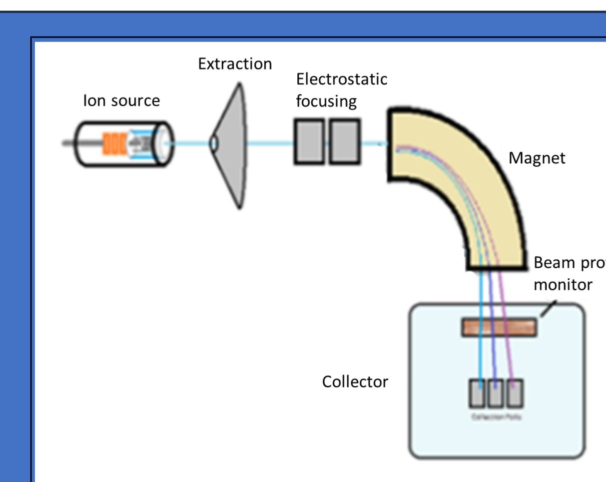
-32 g depleted uranium target irradiated at Los Alamos National Laboratory Isotope Production Facility.

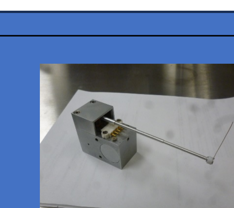
-Proton irradiation (^{238}U (p,3n)) for 103.9 hours to produce an estimated 44 µg ^{236g}Np.

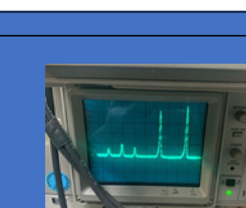
-The target was shipped to INL for chemical processing to recover the and analyze Np to determine ^{236}Np:^{237}Np ratio.

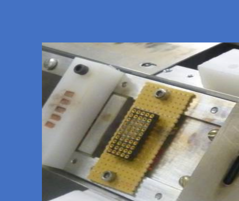
-Possible feed for isotope separation pending ratio results.

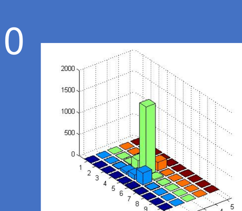
Isotope Separation

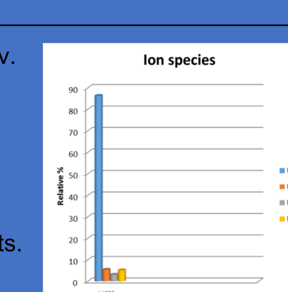












-Ions are produced in the source and accelerated at a variable potential of 30-40 kv.

-An extraction lens referenced to the acceleration potential, as well as electrostatic focusing lenses shape the ion beam before it enters the magnet.

-The magnet separates isotopes according to mass.

-The separated beam is monitored via profilometer and Faraday cup measurements.

-Ion species from a given feed material can be determined by scanning mass ranges by adjusting the magnetic field.

Recovery and Analyses

-Isotopically separated nuclides are collected simultaneously on V-shaped Faraday cup collectors fitted with high purity foils (Al, Ti, W, Au).

-The foils are removed, and the product is leached into acid solution to be analyzed for purity and enrichment.

Conclusions and Future Work

References:

1). Carney, K.P, Horkley, J.J., & McGrath, C. A., et al (2013). Advancement of isotope separation for the production of reference standards. *Journal of Radioanalytical and Nuclear Chemistry, 296*, 383-387.

2). Horkley, J.J., Carney, K.P., Gantz, E.M. et al (2015). Production of highly-enriched Ba-134 for a reference material for isotope dilution mass spectrometry measurements. *Journal of Radioanalytical and Nuclear Chemistry, 305*, 267-275.

3). Johnson, P.G., Bolson, A., Hendersen, C.M. (1973). A High Temperature Ion Source For Isotope Separators. Nuclear Instruments and Methods, 106, 83-87.

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Isotope Program
U.S. Department of Energy

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Battelle Energy Alliance manages INL for the U.S. Department of Energy's Office of Nuclear Energy

Idaho National Laboratory

Efforts are underway to enhance ion beam extraction and focus to maximize efficiency and beam quality. Collector upgrades are near completion and will provide enhanced beam diagnostics for optimum target placement. Various ion