A Penning Ion Source for Stable Isotope Beam Production at TRIUMF-OLIS

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Abstract

The Off-Line Ion Sources (OLIS) facility at TRIUMF is considering replacement of its existing microwave ion source to increase the breadth of available beams for experiments at the Isotope Separator and ACcelerator (ISAC) complex. A Penning ion source is one potential new candidate source, with requirements for beams having A/q < 7 for masses under 30 AMU. Additionally, the Penning source lifetime, beam currents, and beam quality must achieve equal or better performance than the existing microwave source. A new Penning source is being collaboratively developed between SIRC and TRIUMF, utilizing a stand-alone Penning ion source test stand with an adjustable magnetic field up to 1 Tesla. The candidate ions chosen to assess the efficacy and utility of the Penning source are: ^{6}Li 1+, ^{12}C 2+, ^{18}O 3+, ^{24}Mg 4+, and ^{30}Si 5+. Here we describe the initial set-up of the Penning test stand and commissioning status. In addition, a study utilizing IBSimu is reported where the magnetic field is varied to maximize separation between the desired isotope and charge state, and others also extracted from the source. For example, for the case of a high purity Oxygen feed-gas, good separation between ^{18}O 3+ and (^{18}O 2+, 4+) , and (^{16}O 2+, 3+, 4+) is necessary.

Penning Ion Source Test Stand

Fig. 1: The test stand donated by D-Pace in its current state at the SIRC. Power supplies, pumps, and logic controllers are on order and will allow the test stand to begin operation in 2026.

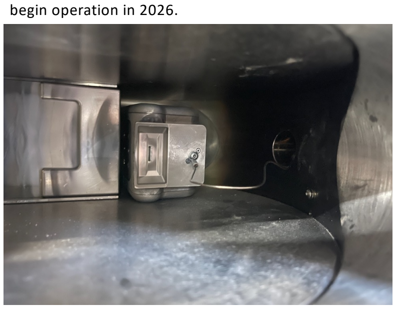

Fig. 2: An inside view of the vacuum box and extraction slit from the ion source.

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Methods

Numerical Methods

Ion Beam Simulator or IBSimu is a codebase used for modeling beam trajectories developed by Dr. Taneli Kalvas. The Penning test stand model was created using the IBSimu library to explore whether the candidate ions would be resolvable against other isotopes and charge states present after a half turn, and if so, what magnetic field strength would maximize separation while keeping the beam trajectory within the size of the Penning vacuum box and on the pole of the magnet. In this paper we consider the O 3+ and Mg 4+ trajectory and separation cases as representative examples.

Experimental Methods

Experimental data will be collected using a Penning Ion Source test stand donated by D-Pace to Selkirk College's SIRC located at the STAC. The ion source inside the vacuum box is pictured at left. Beam currents will be measured after a half turn using a Faraday cup and the objective will be to achieve currents typical from OLIS. A representative ion at OLIS surface source such as Sodium at 46.92 kV should expect a beam current between 10-20nA electric.

Initial Results

Results of the Oxygen beam simulations are below. The graph on the left represents the beam trajectories in the XZ plane while the plot on the right is a histogram of beam intensities along the x-axis direction. The magnetic field is flat at 0.25T. The source beam of naturally occurring Oxygen is composed of 99.8% ^{16}O and 0.2% ^{18}O.

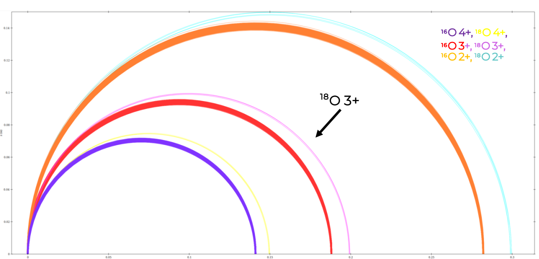

Fig. 3: IBSimu modeled beam trajectories of naturally occurring Oxygen. From left to right after the half turn on the x-axis they are ^{16}O 4+, ^{18}O 4+, ^{16}O 3+, **^{18}O 3+,** ^{16}O 2+, ^{18}O 2+.

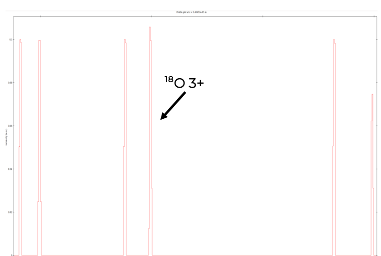

Fig. 4: Histogram of beam intensities along the x-axis after the half turn. Note the good separation of the target ion, **^{18}O 3+**. A separation of 10mm is observed with ^{16}O 3+ to the left and a separation of 81mm is observed with ^{16}O 2+ to the right. This is good separation and should be resolvable with a sliding slit Faraday cup for current measurement.

Magnesium 24, 25, and 26 simulations are below. The magnetic field strength is flat at 0.2T. ^{24}Mg makes up 79% of naturally occurring magnesium while ^{25}Mg and ^{26}Mg make up 10% and 11%, respectively. Note the separation of the target ion ^{24}Mg 4+ is not as good as Oxygen but overall key elements look promising for measurement with a sliding slit Faraday cup and charge states appear separable. If there is an overlap of the tails, particularly with 24Mg 4+ and 25Mg 4+, a decoupling algorithm may be utilized for parsing out the target beam current.

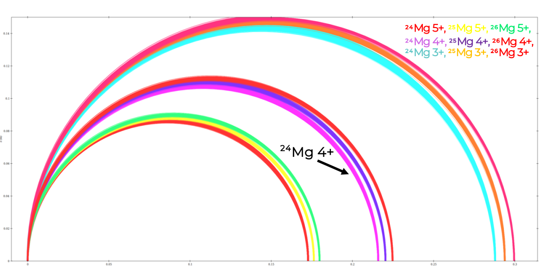

Fig. 5: IBSimu modeled beam trajectories of Magnesium. From left to right after the half turn on the x-axis they are ^{24}Mg 5+, ^{25}Mg 5+, ^{26}Mg 5+, **^{24}Mg 4+**, ^{25}Mg 4+, ^{26}Mg 4+, ^{24}Mg 3+, ^{25}Mg 3+, ^{26}Mg 3+.

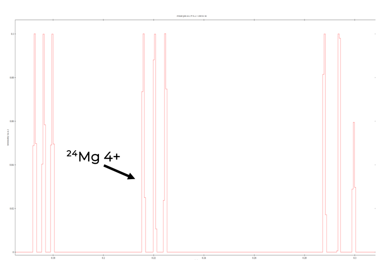

Fig. 6: Histogram of beam intensities along the x-axis after the half turn. Separation of target ion from ^{26}Mg 5+ to the left is 36mm and separation from ^{25}Mg 4+ to the right is 3mm.

Acknowledgement

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