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TARGET AND ION SOURCE DEVELOPMENT FOR BETTER BEAMS IN THE ARIEL ERA

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Abstract

Any ISOL facility pushing the boundaries of nuclear physics must be able to provide cutting-edge ion beams to its users - beams of isotopes far from stability, with few contaminants, that may be difficult to extract from an ISOL target. The development of these pure, exotic beams must be supported by continuing research and development on targets and ion sources. In the ARIEL era, new target/ion source geometries and operational modes will provide new opportunities which can only be exploited with time for development.

To prioritize this, TRIUMF proposes to build a dedicated test stand for target and ion source research which will model the critical features of the new ARIEL target stations. This stand will provide a testing ground for methods of increasing efficiency and selectivity, such as investigations of new surface ion source [1,2] and Forced Electron Beam Induced Arc Discharge (FEBIAD) ion source [3] designs. In addition, this will provide a development environment for new beams, either from new target materials, or through techniques such as extracting molecular beams. In order to maximize the gain from these investigations in on-line operation, the ion optical properties of the final beam will be investigated concurrently.

INTRODUCTION

In order to continue to provide new radioactive ion beams to experiments, an ISOL facility needs to continue to develop targets, ion sources and extraction methods. However, little time is available on-line for development and there are nearly no options for custom diagnostics, modifications to the installation, or inspection of the physical devices. This lack of access makes an off-line test stand a necessity for continued operational success. Many facilities have such setups, however they are normally devoted to target conditioning and preparation, and are not readily available for testing prototypes, nor are they available for modifications. For this reason, a test stand dedicated to research and development of targets and ion sources is desirable. This would be a modular setup that could be modified to suit the investigation at hand and would provide opportunities for a range of diagnostic devices, such as Faraday cups, multichannel plates, wire scanners, emittance meters and thermal readouts.

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OPTIMIZATION OF ARIEL TARGETS AND ION SOURCES TEST STAND

To reach the goals of the Advanced Rare IsotopE Laboratory (ARIEL, [4]), TRIUMF's flagship research facility, continuing research and development into targets and ion sources will be necessary. Several test stands are currently being used to characterize untested components and methods that will be crucial to the success of this project. In development now is the Optimizaton of ARIEL Targets and Ion Sources (OATIS) test stand, which will be built out of a test stand previously designed to study the possibility of producing Mo and Re beams for life sciences [5]. Figure 1 shows the current state of OATIS, which consists of an ion source floated up to 40 keV, transport optics and a magnetic mass separator. Since the original test stand was designed for beam currents in the tens of milliamps, some aspects will have to be re-designed for OATIS to enable the transport and detection of lower current beams, down to the picoamp range. On-line, ions of interest are often produced at the rate of picoamps or lower, so it will be valuable to be able to investigate the properties of these low current beams at OATIS.

The Faraday cage will be reused, as will the HV biasing power supply and isolation transformer. The original ion source will be replaced with an ARIEL target vessel and back plate, modified to be mounted on the OATIS beam line. A rack which already exists inside the Faraday cage will provide services to the target and ion source and a moveable extraction electrode will be incorporated. The ion beam steerers and quadrupoles currently available will be used for preliminary tests, though the Faraday cups will have to be modified to read the low beam currents (pA - µA) expected. The slits in front and behind the magnet will be retained. The beam box following the magnet is capable of accepting a variety of diagnostics, and the beam line upstream of the magnet has multiple ports in which diagnostics can be introduced to satisfy different studies.

The separator magnet is a dipole magnet with a bend radius of $\rho = 37.4599$ cm and a pole gap of 6.35 cm. The magnet can reach a field of 1.3 T, theoretically allowing the transport of singly charged beams of up to mass 286 at 40 keV. Figure 2 shows a recent measurement of the magnetic field as a function of current at the midplane of the magnet. Work on the OATIS test stand now focuses on refurbishing the vacuum system.

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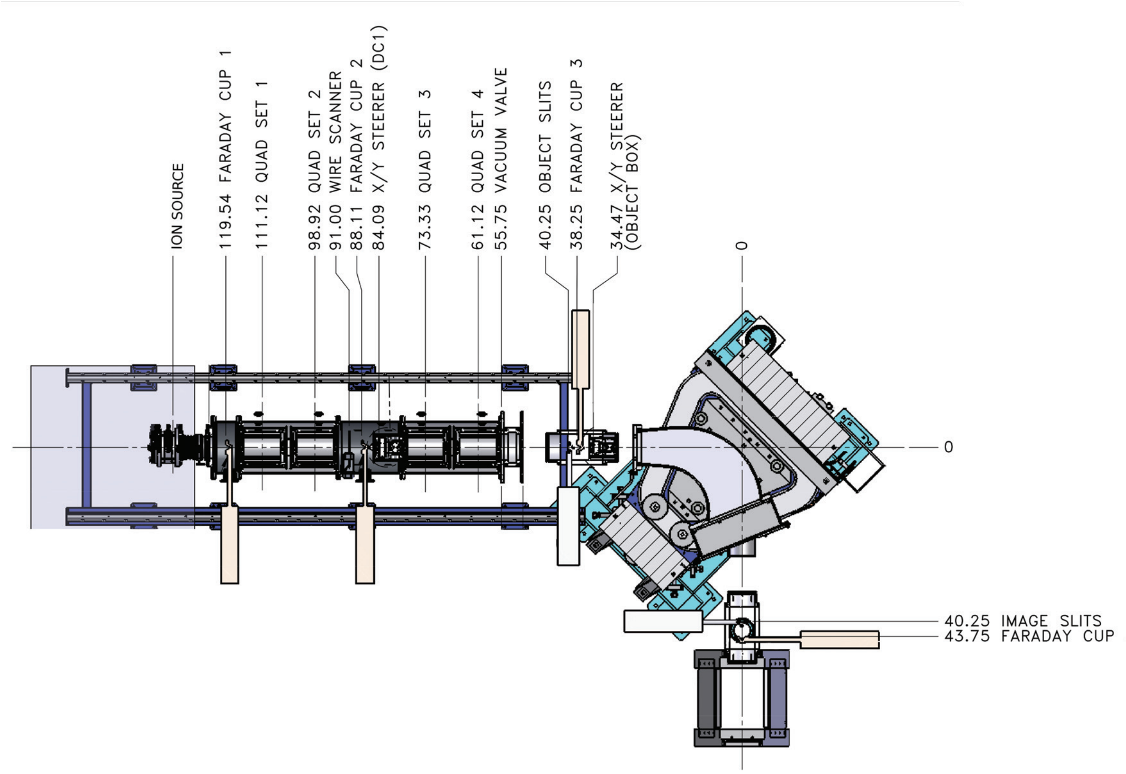

Figure 1: Layout of the current OATIS test stand, showing the ion source and the separator magnet, as well as the locations of 4 Faraday cups, 4 sets of quadrupoles, 2 XY steerers, a wire scanner and 2 sets of slits. The position of each element relative to the origin at the 90° magnet is given in inches before the element name.

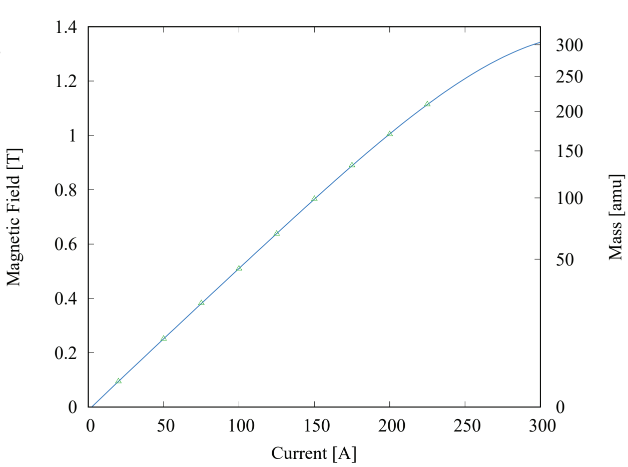

Figure 2: Magnetic field as a function of current in the coils for the OATIS separator magnet, measured at the magnet midplane. The mass theoretically able to be transported with this magnetic field is shown on the right.

TEST STAND DEVELOPMENT PLAN

The main purpose of the OATIS stand is to develop or improve methods of ion production and extraction, specifically for use at ARIEL. The ion sources planned for use at ARIEL are a surface source, a FEBIAD and a laser ion source. Initially, it will be possible to test both surface and FEBIAD sources at OATIS; laser integration is a possibility that will be investigated in the future. Relative ion source efficiency from the surface and FEBIAD sources can be measured with a Faraday cup or multichannel plate. OATIS will also provide a system on which to validate simulations of ion sources to be operated within the ARIEL target stations [6] and test new designs of FEBIAD and surface ion sources. Characterization of the ISAC [7] FEBIAD design is a project currently underway, with the goal of improving its robustness and efficiency for ARIEL. A test stand dedicated to these types of measurements will allow for the quick turnover of new prototypes, and the ability to customize diagnostics to suit the measurement.

OATIS will also provide a facility for studying the production and transport of atoms to the ion source. For instance, the formation and extraction of molecules provides a promising method of delivering beams that are otherwise difficult to extract from the target. OATIS, like ARIEL, will have a gas injection system at the target which will allow some investigation of the high-temperature chemical production of interesting molecules. Initial tests will be done with S, F and SF_6, which have already been shown to produce extractable molecules for ISOL-type systems (see for example [8, 9]).

With the limited availability of on-line development time, tests performed at OATIS will be crucial for understanding and prototyping new ideas for ARIEL. The utility of these tests can be increased by modeling the OATIS ion delivery method as closely as possible on the on-line system. This

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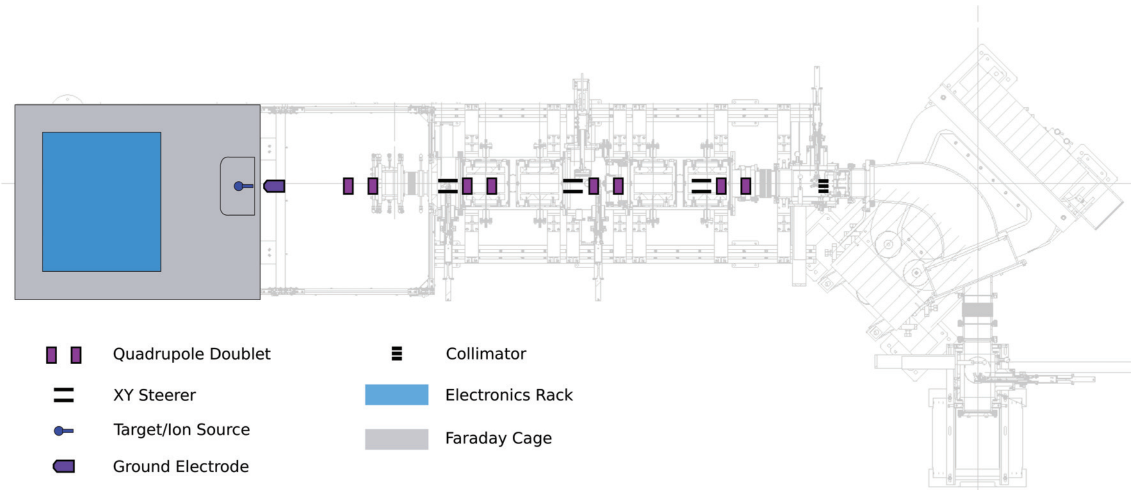

Figure 3: The basic layout of the ARIEL optics between the ion source (here a surface ion source is used) and the pre-separator magnet, overlaid on a drawing of the OATIS beam line.

ensures the applicability of the results achieved at the test stand to on-line ARIEL operation.

As mentioned above, the existing ion source at OATIS will be replaced with an ARIEL target and ion source combination inside a hermetic target vessel, mounted on a simplified connector flange which will mimic the important aspects of the ARIEL target module. Beam can be extracted from the ion source through the use of a stable atom source feeding the transfer line of the target. Since the transfer line and ion source will be a replica of the one used on-line, the resulting stable ion beam should have very similar properties to the radioactive one produced at ARIEL [10]. The optics going from the ion source to the separator magnet will be modified to follow the ion optical design between the ARIEL ion source and the first pre-separator magnet. Space at the OATIS test stand is limited by the location of the ISAC test stand at one end and the mounting point of the separator magnet at the other. We are considering the magnet immovable, but by sliding the OATIS Faraday cage as far back as possible on its mounting rails, and reducing the space between the electronics rack and the target/ion source (both of which are held at high voltage), it will be possible to include the ARIEL optical design in the beam line.

Figure 3 shows the current design of the ARIEL optics overlaid in their proposed locations inside the OATIS beam line. Since the properties of the ARIEL pre-separator magnet cannot be reproduced at the test stand, the drift distance before the entrance to the magnet has been modified from the ARIEL design to accomodate the different bending radius of the OATIS magnet. Ion optical simulations will be required to confirm the proposed layout.

The first task will be to verify the ARIEL ion source requirements are met. The design specifies a longitudinal energy spread of less than 1 eV and a 90% transverse emittance of less than 3 μm at 60 keV for the extracted beam. It is clear that these parameters will be difficult to meet with a FEBIAD source and will require development. An Allison-style device [11] can be used to measure the transverse emittance.

The measurement of the energy spread with a Retarding Field Analyser (RFA) [12] presents a larger challenge because the RFA must be floated to match the beam energy of 60 keV, and because the transverse velocity component of the beam must be very well controlled to accurately measure less than 1 eV. These measurements will be possible by using a low-noise ground and floating the emittance station using the same power supply that provides the HV bias to the ion source. A collimator will be used to discard the majority of the beam, retaining only ions with at most $\Delta E_{\perp}/E = 1.7 \times 10^{-6}$. The ARIEL ion source design also requires beams to be produced with energies between 12 keV and 60 keV, with no more than a 50% loss of efficiency at 12 keV [13]. The ion source efficiency at different energies can be tested as described above for the FEBIAD/surface source investigations.

SUMMARY

A plan has been outlined for the construction of a test stand dedicated to target and ion source development. This test stand will follow the ARIEL design as closely as possible between the target and pre-separator magnet in order to make new developments easily applicable to the on-line system, however the test stand will have many options for modifications that will allow close study of the beam properties of interest.

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