STATUS OF THE RADIOACTIVE ION BEAM INJECTOR AT THE HOLIFIELD RADIOACTIVE ION BEAM FACILITY

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The Holifield Radioactive Ion Beam Facility (HRIBF) is a first generation radioactive ion beam (RIB) facility. Project construction commenced in FY'93 with the initial emphasis placed on conversion of a heavily shielded room from an experiment area to an area suitable for housing the RIB Injector. The RIB Injector is the central component of the RIB project. The Injector consists of two electrically connected high voltage platforms which are designed to operate at -300 kilovolts and which are separated by a shield wall. One platform houses controls, instrumentation, and power supplies. The second platform houses an ISOLDE type target/ion source (TIS) which will be bombarded with light-ion beams from the Oak Ridge Isochronous Cyclotron (ORIC). Additionally, this platform houses the first stage mass separator system which is designed for 1 part in 1000 mass resolution, electrostatic quadrupole lenses for beam transport, and a cesium charge exchange cell for conversion of positive ions to negative ions for injection into the Tandem Accelerator. This paper details the design and beam development aspects of the RIB Injector.

I. INTRODUCTION

The Holifield Radioactive Ion Beam Facility (HRIBF) is a first generation radioactive ion beam (RIB) facility which is currently under construction [2]. The primary mission of the HRIBF will be to provide RIBs as well as stable ion beams for nuclear physics and astrophysics research programs. The HRIBF utilizes two existing accelerators, the Oak Ridge Isochronous Cyclotron (ORIC) [3] and the 25 MV Tandem Accelerator. These accelerators, along with the RIB Target Ion Source (TIS) [4], the RIB Injector, and a high resolution mass separator system constitute the major components used to produce RIBs. High-intensity light-ion beams such as 50 microamps of 100 MeV alphas, 50 MeV deuterons, or 60 MeV protons from the ORIC will be transported to the RIB Injector to bombard the TIS. The resulting radioactive atoms will be ionized, mass analyzed, charge exchanged and accelerated to ground potential with a maximum beam energy of 360 keV. The RIB will then be transported to an on-line diagnostic station for radioactive ion species identification using a gamma ray tape system [5] and to a high resolution mass separator. The beam is then transported to the existing injection line of the Tandem Accelerator where it is accelerated, mass analyzed and transported to the experiment stations.

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II. DESIGN

The RIB Injector is the central component of the RIB project and its design was constrained by several factors. Calculations show that significant gamma and neutron radiation will result when the ORIC beam is stopped in the TIS. The Injector therefore had to be located in a room which has radiation shielding of sufficient thickness to reduce the prompt radiation to acceptable levels outside the room to minimize personnel exposure. The Injector had to be configured to minimize the radiation dose received by the electronic components of the system such as power supplies, controls hardware, etc. The Injector had to incorporate a mass analysis system capable of providing separation of adjacent mass units and for background reduction. Also, the Injector had to be designed to produce beams with energy similar to those supplied by the existing stable ion injector, nominally 200 to 300 keV, thus minimizing the modifications required for the Tandem Accelerator and providing efficient beam injection.

A plan view of the RIB Injector is shown in Figure 1. The Injector is located in Room C111, a heavily shielded room which was originally designed to house experiments utilizing 1 milliamp 75 MeV ORIC proton beams. The Injector includes two high voltage platforms which are separated by a shield wall. The Instrumentation Platform houses essentially all electronic equipment to minimize radiation damage. The 300 kilovolt power supply is mounted to the ceiling directly above the Instrumentation Platform. The Source Platform houses an ISOLDE type TIS which will be bombarded by intense light-ion beams from the ORIC. Additionally, the Source Platform houses the first stage mass separator system which is designed for 1 part in 1000 mass resolution, three electrostatic quadrupole lenses, beam diagnostics equipment, and a cesium charge exchange cell [6] for conversion of positive ions to negative ions. The two platforms are connected electrically by two high voltage conduits which carry signal and power cables.

The Injector is designed such that all control functions are carried out remotely. Effort was also made to provide maximum status information to the operator for all equipment and systems located on the Injector. The existing control systems for the ORIC and Tandem accelerators are unable to accommodate the additional controls requirements in a reasonable manner. As a result, a new control system has been implemented [7]. Controls for the Injector and, ultimately, the remainder of the HRIBF, are implemented through a new control system manufactured by Vista Control Systems, Inc. The controls platform for Vista is presently VAX/VMS/ELN. Operator interface is provided via X-terminals. The system is distributed with the

Injector controls being located on the Instrumentation Platform and connected to the remainder of the system via fiber optic ethernet. Specific I/O are implemented with a combination of VME and Allen-Bradley programmable logic controller modules.

A. Beam Optics

The Target/Ion Source produces a beam which is round and has an energy of up to $\pm$ 60 keV. The first optics element is a pair of electrostatic quadrupole doublets which focus the beam to a vertical line at the object of the first stage mass analyzing magnet with dimensions of 1 mm wide in the energy plane by 10 mm high. A slit system is located at the object location to clean up the beam prior to injection into the analyzing magnet. The beam at the magnet object is mass analyzed and focused to a vertical line at the image of the magnet with unit magnification. However, the various mass components in the beam are spread out in a series of vertical lines allowing adjacent mass units to be resolved easily with a slit system; the separation between masses 80 and 81 is approximately 25 mm. A quadrupole triplet focuses the beam from the image slits to a round spot at the center of the cesium charge exchange cell. The cell charge exchanges the positive ion beam into a negative ion beam. A quadrupole triplet focuses the beam which emerges from the cell to a round spot at the entrance to the high voltage platform acceleration tube. The negative ion beam is accelerated to ground potential at an energy high enough for efficient Tandem injection. Stringent requirements were placed on the 300 kilovolt power supply used to bias the RIB Injector due to beam energy stability considerations. The supply has a ripple and noise specification of less than .004% or about 12.5 volts peak to peak at 300 kilovolts. Acceptance tests show that the actual ripple and noise is 9 volts peak to peak.

B. Beam Optics Components

The first stage mass analyzing magnet is the central optics component of the RIB Injector. It is a symmetric split-pole double focusing configuration with a total bend angle of 151.5 degrees and a bend radius of 558.8 mm. Its design is based on a maximum ion beam rigidity of 0.558 T-m and a maximum ME/q^2 of 15.0, corresponding to bending a singly charged 50 keV mass 300 ion. The effective field boundaries of the magnet poles are separated by approximately 203 mm. This small separation coupled with relatively short image and object focal lengths of 558 mm results in a compact mass analysis system which is crucial to the space limited design of the Injector.

The quadrupoles used on the RIB Injector are electrostatic units of a new design. The electrodes are mounted on a support tube which extends through the center of the electrodes. Four support tubes are used for mounting all of the electrodes in a triplet or quadruplet assembly. The elements are mounted on the support rods using precision ground annular ceramic insulators and the spacing of the elements along the beam axis is set during assembly using gage blocks. The result is an accurate and reproducible alignment of the electrodes within each singlet and from one singlet to the next. Each element of the quadrupoles is

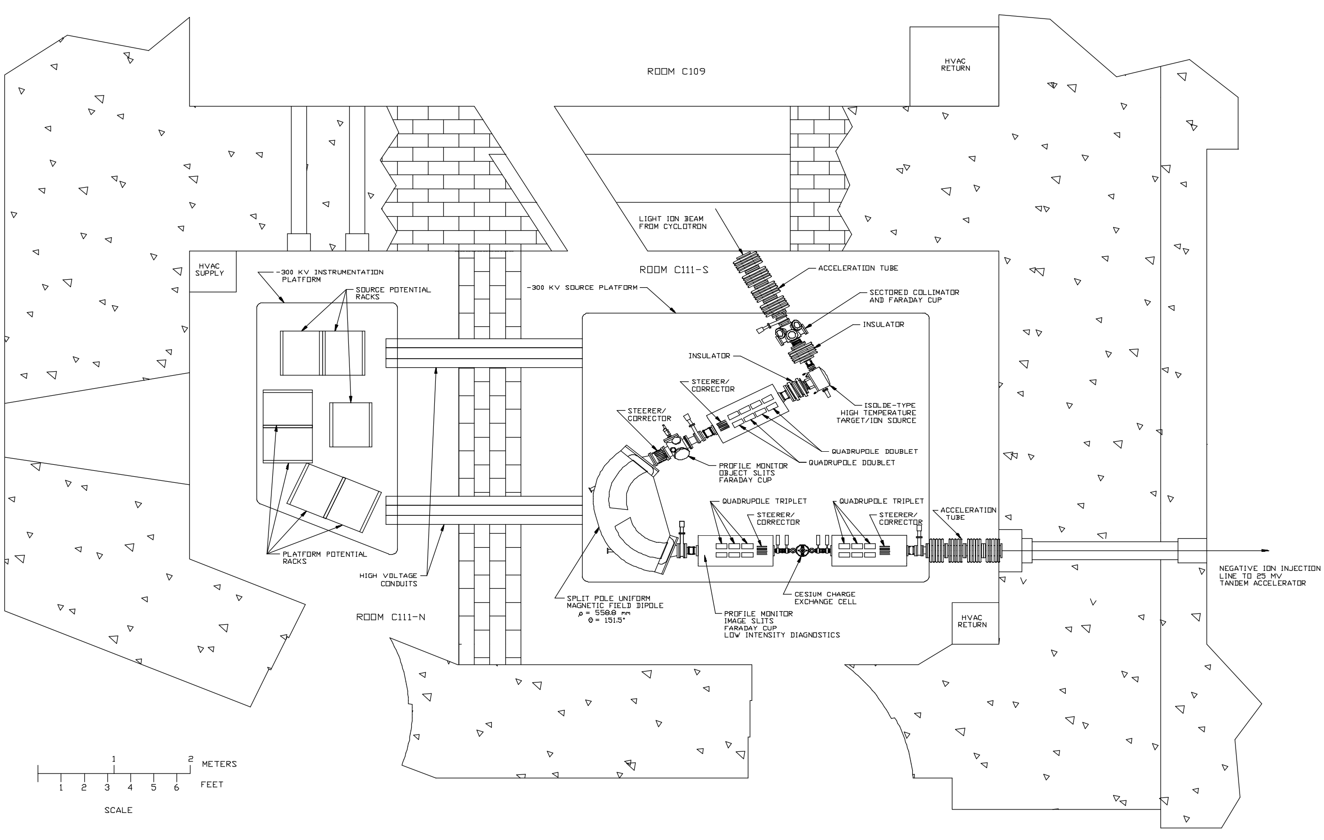

Figure 1. The Radioactive Ion Beam Injector

biased by an individually controlled 5 kilovolt power supply. This allows the quadrupoles to also be used as steerers. A resistor was installed on each electrode to provide a quick diagnostic check that the desired voltage is actually present. A 32 pole electrostatic element has been installed at the exit of each quadrupole assembly for future use as a steerer and as a sextupole and octupole corrector.

B. Beam Diagnostics Components

The majority of beam diagnostics are installed at the mass analyzing magnet object and image positions. Both the object and image position have a beam profile monitor, a slit system and a Faraday cup. Additionally, the image position has provision for a low intensity diagnostic assembly which is currently being developed [8]. The beam profile monitor installed at the object position is an oscillating vane unit which provides an x and y scan of the beam intensity. The monitor installed at the image position is an oscillating pin unit which provides a single axis scan in the energy plane of the magnet.

Each slit system has a series of fixed apertures mounted on a rotationally adjustable disk. Each slit system also has an adjustable aperture which can limit the vertical size of the beam. The Faraday cups are suppressed units and are designed to fit in a cylindrical space of approximately 35 mm diameter while providing an entrance aperture of approximately 14 mm. Faraday cups identical to these are installed at the entrance and exit of the charge exchange cell.

Additional beam diagnostics provide information regarding the ORIC light-ion beam. The first component is a 4 sector collimator which is used to determine beam position. The beam is focused to a waist at the collimator thus ensuring that it is not focused too tightly at the target. Following the collimator is a water cooled Faraday cup which is used in conjunction with a second water cooled Faraday cup mounted after the target assembly on the ion source to determine the amount of beam stopped in the ion source.

III. OPERATIONS AND DEVELOPMENT

The installation of the RIB Injector has been completed and initial operations and development activities have begun. Voltage tests of the Injector with all equipment installed were successfully completed at -275 kilovolts. All of the optics elements have been successfully tested with stable ion beams and the operational settings are in good agreement with the calculated values. The charge exchange cell has been tested and characterized on the Ion Source Test Facility.

Initial commissioning of the Injector using stable ion beams commenced in October of 1994. This effort resulted in successful transport of a stable mass 28, 20 keV, 16 nanoamp beam off the high voltage platform to the 300 keV diagnostic station. Several periods of beam development have since been utilized to study the operational characteristics of the Injector, to improve the beam transmission, to debug beam diagnostics and controls, and to gain operational experience using the RIB Target/Ion Source. Recent efforts have produced a mass analyzed xenon beam with 6% combined ionization and transmission efficiency.

Current development activities are focused on several areas. The Target/Ion Source and its sub-systems are being radiation hardened where possible. Work is continuing on the control system to complete the remote control interfacing of all essential components. Several controls functions as are being added to aid beam tuning. Operational aids and help screens are being added as on-line references. Ion source and beam transmission parameters are being studied using a xenon gas feed into the Ion Source, and the Target/Ion Source is being prepared to receive a light-ion beam from the ORIC.

IV. SUMMARY

The RIB Injector at the Holifield Radioactive Ion Beam Facility has been completed. Successful operation has been demonstrated with stable ion beams resulting in beam transport to the 300 keV diagnostic station. Efforts are currently underway to prepare the Target/Ion Source to receive a light ion beam from the ORIC resulting in the first RIB production at the facility.

V. REFERENCES

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