STATUS OF THE TRIUMF-ISAC FACILITY FOR ACCELERATING RADIOACTIVE BEAMS

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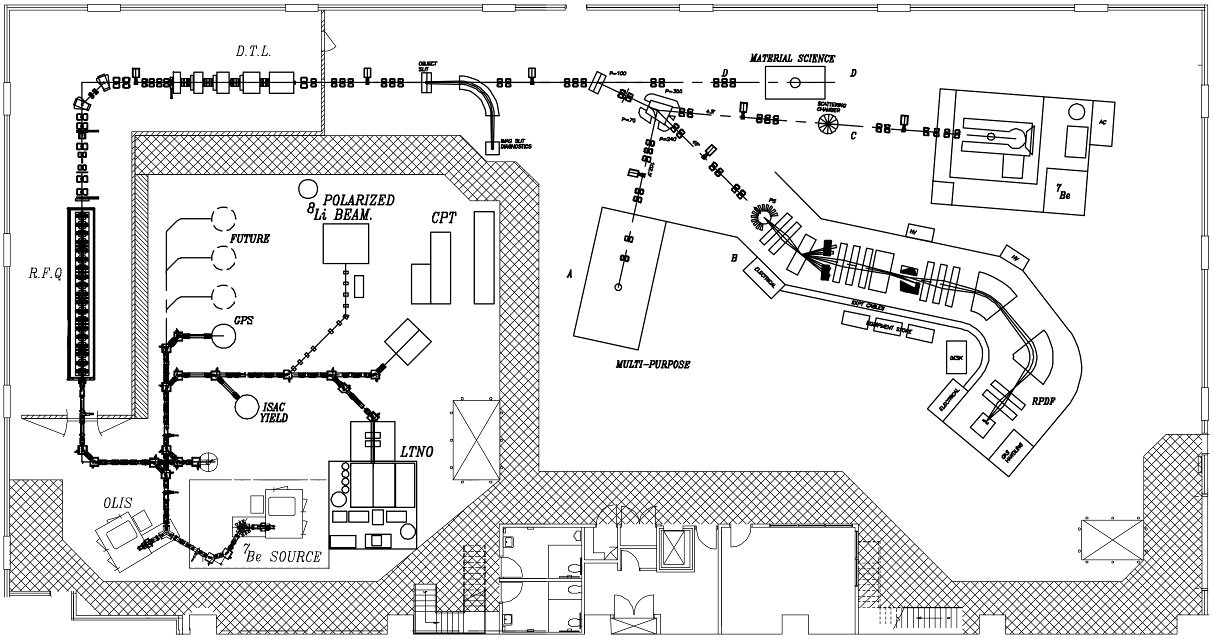
Abstract

ISAC, a new facility for accelerating intense beams of unstable ions, is under construction at TRIUMF. The radioactive nuclei will be produced by up to 100 A of 500 MeV protons impinging on one of two target/ion source stations located in an underground vault. The ionized beam will be transported by electrostatic ion optics to a high acceptance, high resolution mass analyser. Following mass selection the beam is transported vertically to grade level and then horizontally to either a low energy experimental area or to a system of accelerators. First, a 35 MHz cw RFQ accelerates isotopes with q/A >1/30 from 2 keV/u to 150 keV/u. Following the RFQ the beam is passed through a stripper and magnetic bend to select a charge state with q/A 1/6 prior to rebunching and injection into a cw drift tube linac (DTL) operating at 105 MHz. The output beam, with energy continuously variable from 0.15 to 1.5 MeV/u, is transported to one of a number of experimental stations. This paper briefly outlines the plans, schedule and status of the project.

1 INTRODUCTION

A five-year plan, designed to provide TRIUMF with an intense radioactive ion beam facility by the year 2000, was approved in June 1995. The plan includes (i) The extraction of a high intensity (100 A) proton beam from the 500 MeV H- cyclotron into a dedicated beam line (2A) transporting the beam to a new 5000 m^2 facility; (ii) A remotely handleable 50 kW target/ion-source beam - dump system for the production of low energy radioactive beams up to 60 keV for singly charged ions; (iii) A high resolution (1/10000) mass selection system; (iv) A low energy transport system (LEBT) and experimental area; (v) a linear accelerator system, consisting of an RFQ and an interdigital H- DTL, accelerating ions with A 30 to energies between 150 keV/u and 1.5 MeV/u; and (vi) a transport system for the accelerated beams (HEBT) and corresponding experimental area (see fig. 1).

The facility will allow strengthening of the radioactive beam research initiated ten years ago (using a 1 A 500 MeV proton beam) on the TISOL facility [1]. It will also allow new astrophysics, material science, life science and other fundamental research to take place at energies up to 1.5 MeV/u for light (A 30) ions. The limit in mass and energy was dictated by budget limitations and experimental priorities. However, the new building was



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designed to be compatible with acceleration to 6.5 MeV/u. A new plan to expand the mass range and energy range beyond present limits is being developed for the period after the year 2000. For energies less than 60 keV, all isotopes produced by the target/ion source system can be delivered to the low energy experimental area.

2 FACILITY

When fully commissioned, beam line 2A will direct a 100 A proton beam to the ISAC targets and will be one of four primary beam lines into which beam may be extracted simultaneously from the H- cyclotron. Low intensity beam has already been extracted into the front end portion of 2A over an energy range from 472 to 510 MeV. Simultaneous low-intensity extraction into lines 1A and 2A has also been demonstrated to be feasible, despite intrinsic vertical oscillations of the internal cyclotron beam in the extraction region.

The new ISAC building, is divided into a shielded building and an experimental building. The sealed, heavily shielded section, houses the highly radioactive and potentially contaminated target/ion source assemblies, extraction systems, the pre-separator magnet, and ancillary systems (cooling, vacuum, decontamination and storage facilities). A remotely controlled 20-ton crane and two hot cells are integral parts of this building. Construction is well advanced with concrete pouring nearly complete. The structural steel erection is well under way. The installation of services is in progress. The buildings will be available starting this summer.

3 TARGET/ION SOURCE SYSTEM

All highly activated and potentially contaminated components such as production targets, beam dump, ion sources and initial focusing devices will be located at the target station within the target hall along with the primary radiation shield and services required to operate the target station components. Hot cells, assembly area and a decontamination and storage facility will be included within the target hall. The target facility is located in a canyon surrounded by steel and concrete shielding, and consists of a large vacuum tank with five separate modules: entrance, target, beam dump and two exit modules housing beam-optics components. The target module is made up of a 2m long shielding plug on the bottom of which are the ion source and the extraction system. The target/ion source assembly will be biased to give extraction voltages up to 60kV. The target station modules are all designed to be handled remotely. The shielding is designed to allow access by personnel into the target hall with beam on target.

4 MASS SEPARATOR

The mass separator front end includes an electrostatic triplet followed by an electrostatic doublet. Preliminary mass selection will be done using a 60 magnet having a resolving power around 300. The focal plane of this magnet accepts a large portion of the beam within a ±10% mass range. The slit-selected beam is then transported to the main mass separator which is designed to provide mass separation with energy spread focusing at the focal plane. This is based on two magnetic sectors, placed at different electrostatic potentials. The design will allow good mass separation even with an ion source having several tens of eV energy dispersion.

Table 1-Separator Specifications

Separator Specifications	
Mass range	< 238 amu
Ion beam energy	≤ 60 keV
Mass dispersion	5m or 5 cm/%
Resolving power	≤ 10000

5 LEBT

The ion beam from the mass separator is transported vertically to grade level and is to be switchable between the low energy experimental area (LE) and the accelerator. A switchyard allows an off line source to supply beam to either the RFQ or the LE experimental area while simultaneously, the mass separator can supply beam to the LE or the RFQ, respectively. All the optics in the LEBT are electrostatic: quadrupoles are typically 50 mm long by 25mm bore radius, bends are each 45, with spherical electrodes, 250mm in radius. The RFQ, having no bunching section, accepts bunches ±30 in length. A sawtooth rebuncher (four harmonics) located 5m upstream of the RFQ operates at 11.67 MHz, yielding bunch separation of 86ns and 80% of the beam within the RFQ longitudinal acceptance for acceleration. More details can be found elsewhere in these proceedings [3].

6 ISAC ACCELERATOR

A description of the various components of the ISAC accelerator system has already been reported elsewhere [3]. Recent progress, design definitions or improvements will be summarized below. Basic specifications are given in Table 2 and the layout in Figure 1.

6.1 RFQ

The reference design for the RFQ [4] is a four-rod split ring structure operating cw at 35 MHz. Full power tests on a single ring were completed last summer [5] and on a three ring module assembly last fall [6]. The 8 metre long vacuum tank and the RFQ components have been released for manufacturing, allowing the low energy seven-ring portion of the final RFQ to be assembled and tested with beam in its final location by spring 1998. The final RFQ is 760 cm long with 19 rings in 40 cm long modules. The cross section of the vacuum tank is rectangular to facilitate alignment of the modules and copper plating of the vacuum tank. The alignment philosophy is to construct a solid base, maintain tight manufacturing tolerances, construct the modules using precise jigs and fixtures and edm-machine the critical mounting surfaces for the electrodes after assembly [6].

Table 2-Accelerated Beam Specifications for ISAC

Input Beam	
Injected energy	2 keV/nucleon
Ion mass	A 30
Ion charge	1 (initially)
Beam emittance (100%)	50 mm mrad at injection
Output energy range	0.15 E 1.5 MeV/u
Resolution E/E	0.1%
Duty factor	100%

6.2 MEBT

The MEBT is made up of three sections. In the first section, the beam from the RFQ is focused in three dimensions on to the stripping foil to minimize emittance growth due to multiple scattering and energy straggling. Five quadrupoles provide the transverse focus and a two-gap, 105MHz spiral resonator between the second and third quadrupoles will focus the beam in time. There is also provision to incorporate a chopper to eliminate beam from the adjacent two sparsely populated 35 MHz buckets. The quadrupoles act optically like a typical 4Q system but the third quadrupole is replaced by two quadrupoles separated by a drift space to allow the chopper to be placed where the beam is parallel in x. The chopper slits would be placed just upstream of the foil. The second section consists of a 90 achromatic bend (QQDQQDQQ) with charge selection slits at the symmetry plane. The section is very compact to reduce beam debunching. The last section includes a 35 MHz folded /4 rebuncher, at the image point of the charge selection section, and four quadrupoles to provide a three dimensional match at the DTL entrance. This buncher is now being developed in collaboration with LBNL.

6.3 *Drift-tube Linac*

The separated function ISAC DTL [7] will accelerate ions of 1/3 q/A 1/6 to a final energy fully variable from 0.15 to 1.5 MeV/u. Five independent 105 MHz interdigital H-mode cavities provide the acceleration, while quadrupole triplets and three gap split-ring resonator bunchers between IH tanks provide transverse and longitudinal focusing. To reduce final energy the high energy IH tanks are turned off sequentially and the voltage and phase in the last operating tank is varied. Beam simulations show that the DTL can accelerate beams with little or no emittance growth over the complete energy range. Design of the first IH tank is well under way with fabrication to be completed by the end of the year. We are collaborating with INR Moscow on the design and fabrication of a working prototype for the split-ring resonator bunchers [8]. The complete DTL is scheduled to be fully commissioned by the end of 1999.

7 HEBT

The HEBT comprises three sections. In the first section the beam is captured from the DTL and matched to the HEBT with five quadrupoles. The 5Q system allows the insertion of a chopper if required. A 90 analysing magnet can be positioned in the periodic section to check the beam energy and energy spread off line during commissioning and accelerator tuning. The beam is directed to the various experimental areas with an asymmetric QQDQQDQQ achromatic system where the last bend is a large switching magnet. At present four areas are envisaged but there will be capability for more areas as the science program evolves. To maintain the bunched structure of the lowest velocity beams (=1.8%) 35 MHz rebunchers are positioned every 8-10m.

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