A RADIATION HARD ECR SOURCE FOR ISAC

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Abstract

The design of a radiation hard ECR source for the ISAC radioactive beam facility has been completed. The ion source with its 0-60 kV extraction system is coupled to the radioactive isotope production target via a small transfer tube. For a typical ISAC target the copper coils of the ECR source will be exposed to a dose rate of about 10^5 Gy/h for a 100 µA – 500 MeV incident proton beam. The whole assembly is located beneath a 2 m thick steel shielding structure. Construction details of the target-ion source system and auxiliary equipment are described. The source will be tested at the TRIUMF test bench during the second half of 2001 and will be installed in the ISAC facility by the middle of 2002.

1 INTRODUCTION

An isotope separator and accelerator (ISAC) has been constructed at TRIUMF [1].

The ISAC is an online based post-accelerator which uses 500 MeV protons of up to 100 µA from the TRIUMF cyclotron [2] to bombard the isotope production target. The radioactive ions are extracted from an ion source at an energy up to 60 keV for the single charged ions. A mass separator selects the beam of the wanted species. A radio frequency quadrupole (RFQ) linac accelerates the beam with an energy of 2 keV/u and e/m ratio from 1/6 to 1/30 to an energy of 150 keV/u. The beam, after traversing a stripper foil, is further accelerated by a series of five drift tube linacs (DTL's) to a final energy of 1.5 MeV/u for e/m ≥ 1/6.

A surface ion source is presently used to produce alkali metal ion beams for ISAC.

A radiation hard 2.45 GHz ECR source has been designed at TRIUMF to ionize radioactive gaseous species in a single charge state with emphasis on high 1^+ ionization efficiency and short ion transit time (less than 100 ms). These parameters are of utmost importance to many experiments requiring radioactive ion beams. Preliminary results obtained from a non-radiation hard prototype ECR source developed at TRIUMF on gas-ion transit time, ionization and extraction efficiency, beam emittance and energy spread are given in Ref. [3][4].

2 DESIGN

2.1 Production target

The production target consists of a 20 cm long x 1.9 cm OD tantalum tube with a 0.4 mm wall thickness. The target material is sealed inside the tube with welded 0.5 mm thick tantalum end caps. A second 4 cm long x 0.48cm OD tantalum tube with a 0.9 mm wall intersects the target tube orthogonally 1 cm above its central axis. This tube is the sole means of escape for products from the target and can serve either as a surface ionization source or as a transfer line to the ECR plasma chamber. Both target and transfer line are resistively heated to temperatures up to 2200° C. Independent power supplies (100A/10V for the target, 500A/10V for the transfer line) allow independent temperature regulation.

The target is mounted on ceramic insulators on a water-cooled copper support plate and surrounded by a water-cooled copper heat shield (Fig. 1). Target, support plate and heat shield comprise the exchangeable package that is then mounted on the extraction column situated at the bottom of the ISAC target module. An aluminum grip plate is attached to the package to facilitate remote handling using manipulators in the target hot cell. Operation of ISAC targets with proton beam intensities up to 10 µA is described in Ref. [5].

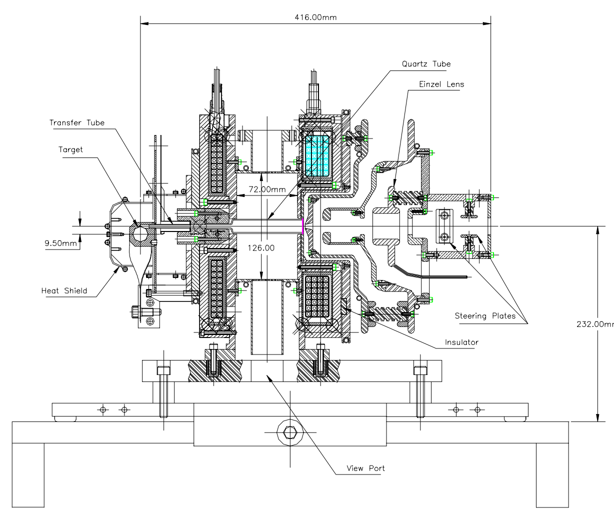

Figure 1: The radioactive isotopes produced at the target drift toward a quartz tube located inside the cavity of a 2.45 GHz electron cyclotron resonance (ECR) ion source. The quartz plasma chamber is considerably smaller (~80 times) than the resonant cavity in order to increase the efficiency for the extraction of short half-live isotopes. This ion source has a high efficiency for ionizing gaseous species in a single charge state. This source will be used to produce ion beams of nitrogen, oxygen, and neon from zeolite targets, as well as that of Xe, Kr, Ar, and Cl isotopes using Ta, Nb, and CaO targets, respectively.

CP600, *Cyclotrons and Their Applications 2001, Sixteenth International Conference,* edited by F. Marti

2.2 *Ion source – Extraction*

The ion source chamber consists of a microwave cavity and a quartz plasma chamber (see Fig. 1). The microwave cavity is a well-tuned single mode (TE_{111}) resonator at 2.45GHz with no parasite modes within 50MHz. A unique feature of this source is that the plasma chamber is considerably smaller (80 times) than its resonance cavity therefore minimises the transient time. The computer code POISSON was used to design the coils and the yoke (made of steel C-10-10) to ensure that the ECR zone is in the quartz tube. The axial magnetic field along the axis of the source is shown in Fig. 2. The excitation of the downstream coil is 7500 Ampere-turn and 4000 Ampere-turn in the opposite coil. The static magnetic field required for an ECR condition at 2.45GHz is 0.0875 T. The coils are excited independently to achieve a 1 to 1.3 mirror ratio. The fibreglass-insulated coils are epoxy encapsulated in a leak tight copper container at atmospheric pressure. The purpose of this approach is twofold: a) since the operation of the source requires a base pressure in the low 10^{-7} Torr, out-gassing problems are not present and, b) because the rest volume in the coil container is tightly filled with epoxy, the expected high radiation dose rate of about 10^5 Gy/h for a 100 µA – 500 MeV incident proton beam [6] will not impair the functioning of the coils even if the epoxy is destroyed. An axially symmetric three-electrode extraction system is used to extract the beam (Fig. 3).

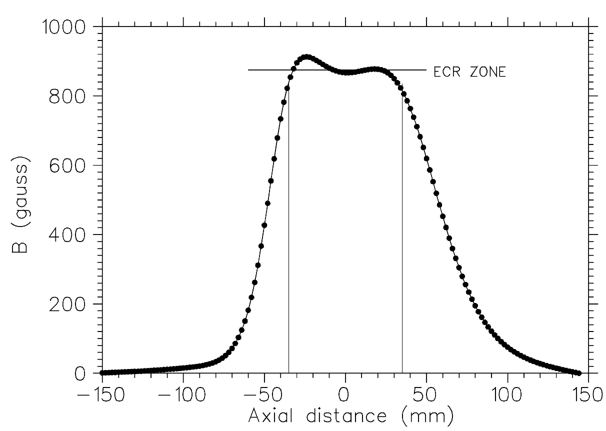

Figure 2: Magnetic field intensity profile along the axis of the resonant cavity. The vertical lines indicate the inner walls of the cavity.

Microwave power of up to 1kW is transported to the cavity through a circulator, an automatic four stub tuner and a microwave guide system (Figs. 4 and 6). The wave guide is at ground potential over most of its length. Furthermore, it is operated at atmospheric pressure to ensure no plasma formation inside the guide. An Al_2O_3 window is certanium-soldered to the guide. A second Al_2O_3 window provides the electrical insulation; it rests loose under the R.F. choke. This window is also a primary barrier (that can be discarded) if radioactive contamination emerges from the ion source cavity.

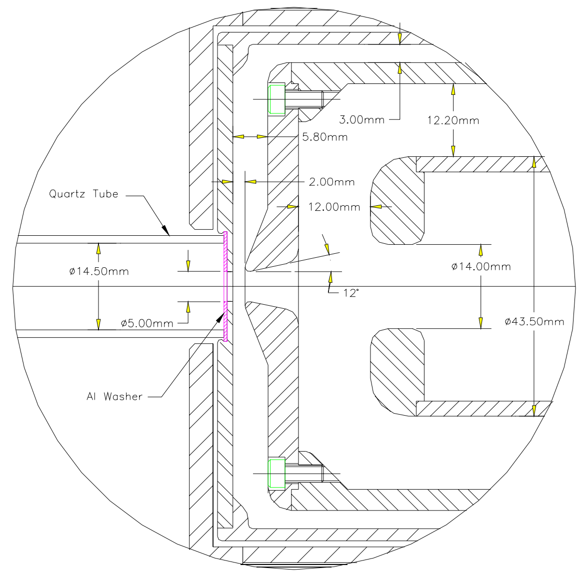

Figure 3: Extraction geometry. For a 60 keV operation the intermediate (extraction) electrode is biased at about 54 kV. An aluminum washer, pressed by the quartz tube against the Molybdenum plasma electrode, is used as an electron provider because of its high secondary electron emission characteristics.

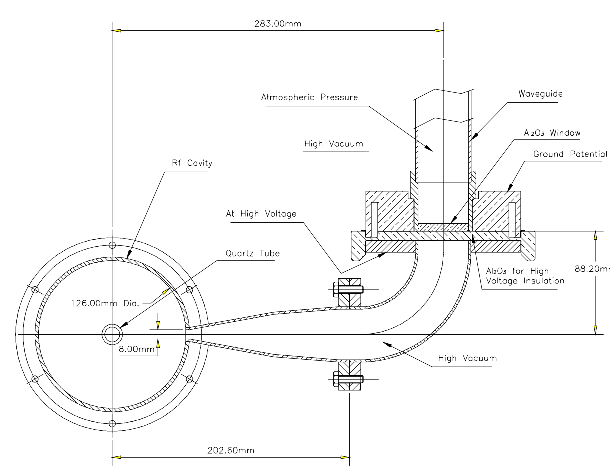

Figure 4: It shows the microwave guide arrangement at the bottom of the target-ion source containment module. An Al_2O_3 window is soldered to the microwave guide. The wave-guide is, for most of its length, at ground potential and at atmospheric pressure. A second Al_2O_3 window resting on the flange of the 90° bend provides the high voltage insulation. To remove the target-ion source assembly the wave-guide is lifted and the tray holding the source is moved out sideways.

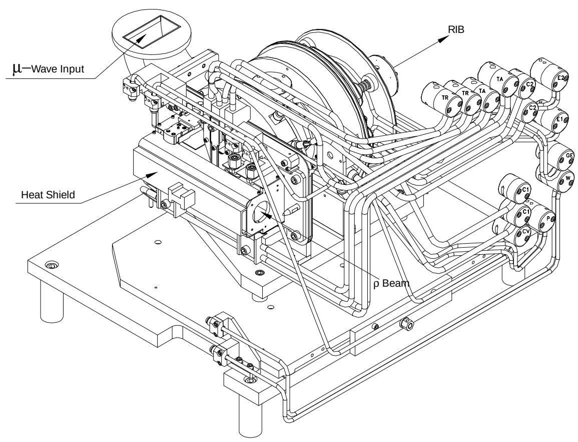

Figure 5: The target-ion source-extraction assembly on a self-align tray. This figure shows the combined current, voltage and cooling quick disconnect feeder lines. The target-ion source is serviceable via remote handling.

The target-ion source-extraction assembly rests on a self-align tray (Fig. 5) placed in a 60cm x 60cm x 90cm box at the bottom of the target module. Remote handling equipment removes the assembly from the box. Current, voltage and cooling water is supplied via quick disconnect copper blocks using metal seals pressed on stainless steel seats. Each of these feeders has a net copper contact surface of 7 cm^2. A quick disconnect unit was tested at 1000 A showing a contact resistance of about $5x10^{-6}$ Ohms.

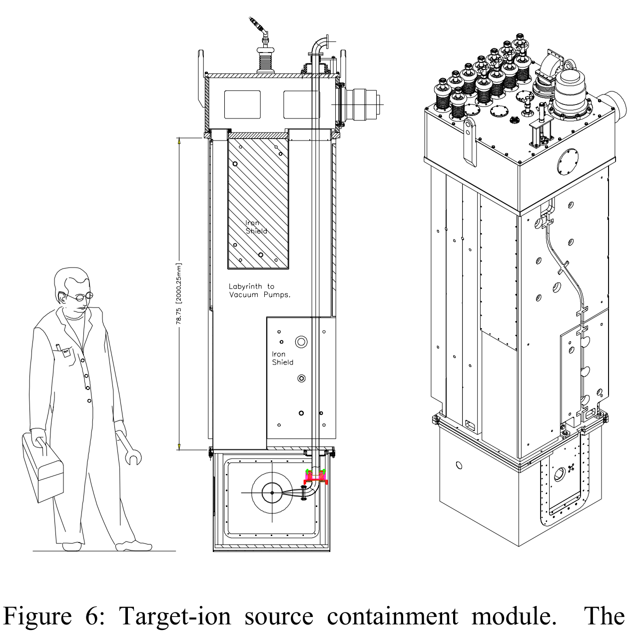

Figure 6: Target-ion source containment module. The target-ion source tray is in a box suspended below approximately 2 m of copper plated steel shielding. Services to the ion source are routed through a duct in the shielding, except for the microwave guide, which is brought down separately.

3 CONCLUSIONS

The radiation hard source will be tested at the TRIUMF test bench for beam quality, stability and reliability during the second half of 2001 using stable gaseous elements. Emphasis will be put in exercising the service of the source using remote handling equipment prior to its operation in a high radiation environment, which is foreseen by the middle of 2002.

4 ACKNOWLEDGEMENTS

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