DEVELOPMENT OF 2.45 GHZ HIGH CURRENT MICROWAVE ION SOURCE AT VECC

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Abstract

A 2.45 GHz microwave ion source (100kV, 20mA) has been developed at VECC and is presently under testing for performance improvement. Beam from source will be transported by a low energy beam transport line and will be injected axially into a 10 MeV, 5-10mA compact cyclotron. This paper reports the development work and the initial test results of the ion source.

SOURCE DESCRIPTION

The ion source consists of a plasma chamber, two solenoids and a triode ion extraction system. The diameter of the apertures in the plasma electrode, accelerating electrode and de-accelerating electrode are 6mm, 8mm and 8mm (new one) respectively. The plasma chamber is a double walled water-cooled cylindrical stainless steel chamber of 100 mm length and 90 mm diameter. The microwave power from the 2.45 GHz, 1.2 kW magnetron is coupled to the chamber through a three stubs tuning unit, an auto tuner and water cooled ridged wave-guide. Ion source with adjustable solenoid, its power supplies, microwave generator (2.45 GHz, 1.2 kW), a high precision gas flow system etc., all are kept at a high voltage deck ~100 kV. High voltage deck is separated from the ground through polypropylene insulators. A two-segment ceramic insulators (Al_2O_3) column, which supports the beam extraction electrodes, separates the high voltage deck and the beam line at the ground potential. Power to the various subsystems on the deck is supplied using a 150kV, 30kW isolation transformer.

The injection beam line consists of two magnetic solenoids (SOL1: 40 cm, 3.6 kG) (SOL2: 40 cm, 3.3 kG), with some diagnostic elements slits, faraday cup and emittance monitoring box. The beam from the ion source is expected to contain a substantial fraction (~10 to 20 %) of molecular hydrogen ion. Two motor controlled independent slits, one set for the *x*-plane and other set for the *y*-plane is used to control the size of the beam and to reject the molecular hydrogen beam. We have also provided another water cooled fix slit of 4 cm dia after the first solenoid and before the waist position of proton. Beam current measuring equipments used in the beam line are; a water-cooled faraday cup (up to 10 mA only) with secondary electron suppresser and a DCCT. Three turbo pumps having pumping speed of 520 l/s are used to evacuate the entire system. We have achieved vacuum of the order of 1.5 x 10^{-7} Torr near the extraction zone and in the beam line. Control units for adjusting current in the solenoids, movement of solenoids, tuning of microwave power, adjustment of gas flow etc. is placed on the high voltage deck and control and monitoring of the various voltages and current is done with a PC at ground potential through optic fibre.

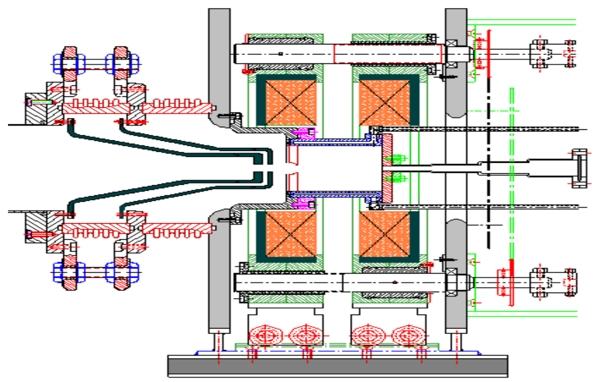

Figure 1: Drawing of the ion source and three-electrode ion extraction system.

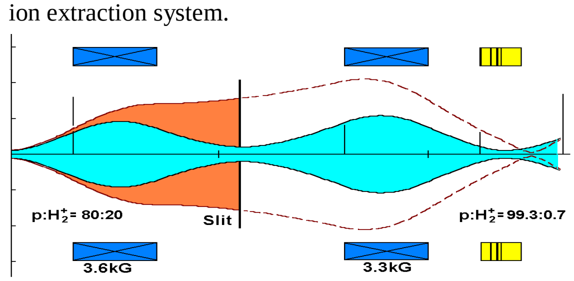

Figure 2: Beam envelope for 20 mA proton beam with a normalized emittance of 0.8π mmmrad.

OPERATIONAL EXPERIENCE

During the initial operations of the source, we faced few problems and taken appropriate actions:

1. Initial promising operations were halted several times due to failure of the electronic components at the high voltage deck induced by HV sparking. To solve these problems we have grounded most of the floating conductors inside the deck and also done some modification by connecting a high resistance between isolation transformer and the deck. We placed appropriate filters and tested the system up to 90 kV with negligible leakage current (200 μA).
2. There was a serious problem in microwave coupling to the plasma. We observed very high reflected power and lots heating in the ridged wave-guide. Locally made control of manual tuner did not work properly. We inserted an auto tuner in the system. We designed and fabricated a new water-cooled ridged wave-guide and replaced it with the existing one.

3. We faced lots of glow discharge and internal arcing during initial operation in the extraction region. We have added one more turbo pump having pumping speed of 520 l/s closed to the extraction electrode to reduce the magnetic discharge in the system. We are planning to add some iron sheets in the extraction region to reduce the field in the extraction zone.
4. The thermal fracture of microwave window from the back streaming electrons and source plasma heating was another problem. We have now placed a 5 mm thick boron nitride plate behind the water-cooled plasma chamber. A RF quartz window is now placed for vacuum sealing just before the 90 deg bent in the waveguide. This will save the system in case of fracture of boron nitride microwave window.

STATUS REPORT

During the first operation we achieved around 130 μA beam current at the FC at very nominal microwave power at an extraction voltage of 80 kV. We found increase in beam current with the increase in microwave power; however, microwave reflection was the major problem. After incorporating few changes as mentioned above we achieved around 4.7 mA beam current at an extraction voltage of 75 kV at the DCCT, placed half a meter away from the extraction electrode and 2 mA at the faraday cup through a 1cm x 1cm slit, placed just before the second focusing solenoid. Further optimisation of the coil positioning around the plasma chamber and gas flow yielded 6.4 mA beam current on FC and 8.5 mA on DCCT at 400 watt of microwave power and extraction voltage of 80 kV. We transported this beam up to the last beam dump near the diagnostic chamber. We observed increase in the beam current (I > 10 mA) at the DCCT with increase in microwave power. At present we are testing the source for performance and beam quality improvement. Beam spot of 80 keV, 5 mA on alumina plate is shown in Fig. 4.

Figure 3: Ion source on high voltage deck and LEBT. Added to the system is fluorescence beam profile measurement device, diagnostic box two CCD cameras and associated software. At the end of beam line we see locally made water-cooled beam dump cum faraday cup.

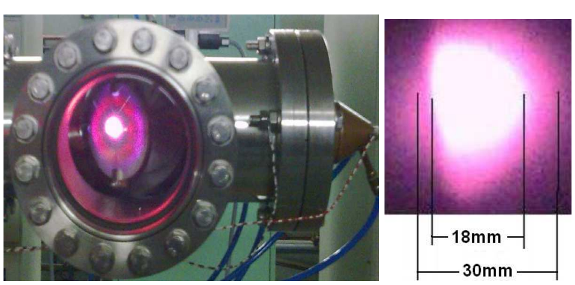

Figure 4: Beam spot of 80 keV, 5 mA on water cooled alumina plate. Most of the ring type shadow around the hot spot is due to other beams and neutrals generated in the extraction region.

FUTURE PLAN

At present a diagnostic box has been placed after the second solenoid together with a beam dump. The beam profile will be measured using fluorescence beam profile measurement technique employing two CCD cameras and associated software. Estimation of the beam emittance will be done from this profile measurement. We have already fabricated a small magnet. It will be connected at the end of the beam line to test the space charge dominated beam inflection with spiral inflector.

REFERENCES

[1] V.S. Pandit et al., Symposium on Ion Beam Technology and its Applications (SIBTA-2007) 109