Ion Source for ADS Applications

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Abstract. The high power proton accelerators are being developed worldwide for ADS applications. The energy of the proton / deuteron required for this purpose is ~ GeV. The beam power requirements will depend upon the amount of nuclear power to be generated, the fissile material to be bred and the quantity of waste to be transmuted. Therefore, depending upon the task to be performed, requirement of beam power could vary anywhere from a few tens of MW to a few hundred of MW. To produce such powerful beams, one need reliable and efficient source. Generally, the intensities of these source lie in the range of 10 mA to 100 mA with energies varying anywhere from 50 keV to 100 keV. Their normalized emittances are found to be in the range of 0.15 to 0.2 π mm-mrad.

A high current electron cyclotron resonance (ECR) proton ion source at 50 keV, 50 mA has been designed and developed for the low energy high intensity proton accelerator LEHIPA. The ion source has been operated with 400 - 1100 W of microwave power at 2.45 GHz, with hydrogen as working gas. The total hydrogen beam current of 42 mA has been extracted at 40 keV of beam energy using three extraction electrodes. The characterization of the ion beam from the source is under progress. A five electrode ion source is under development. The details of design, fabrication and operation of the ion source are presented.

Keywords: ECR ion source, beam diagnostics
PACS: 52.50, 52.55, 52.70, 52.80

INTRODUCTION

The high beam power (MW) proton accelerators of GeV energy are now being built in several countries for ADS applications. As a first step towards this goal in India, a 20 MeV, 30 mA proton accelerators LEHIPA [1] (Low Energy High Intensity Proton Accelerator) is under development at BARC. LEHIPA consists of H^+ ion source at 50 keV will be accelerated to 3 MeV by Radio Frequency Quadrupole (RFQ) and to 20 MeV by an Alvarez type DTL.

High intensity cw ECR proton source with good beam quality and high reliability is the essential requirement of LEHIPA. A desirable property of such source is that the proton fraction of the extracted beam be as high as possible so as to avoid the need for selection of the desired ion i.e. to enable direct injection into RFQ accelerating structure.

The LEHIPA ECR proton source [2] has been designed and constructed for 50 keV beam energy and 50 mA beam current. The source plasma parameters have been measured using Langmuir probe. A beam line has been designed and under development to measure two important beam parameters i.e., beam emittance and proton fraction. The key components of ECR proton ion source are plasma chamber, vacuum system, microwave system, solenoid magnets, beam extraction electrodes, and beam measuring device. The plasma chamber was coupled to microwave circuitry through a ridge waveguide and a two layer microwave window of quartz and Boron

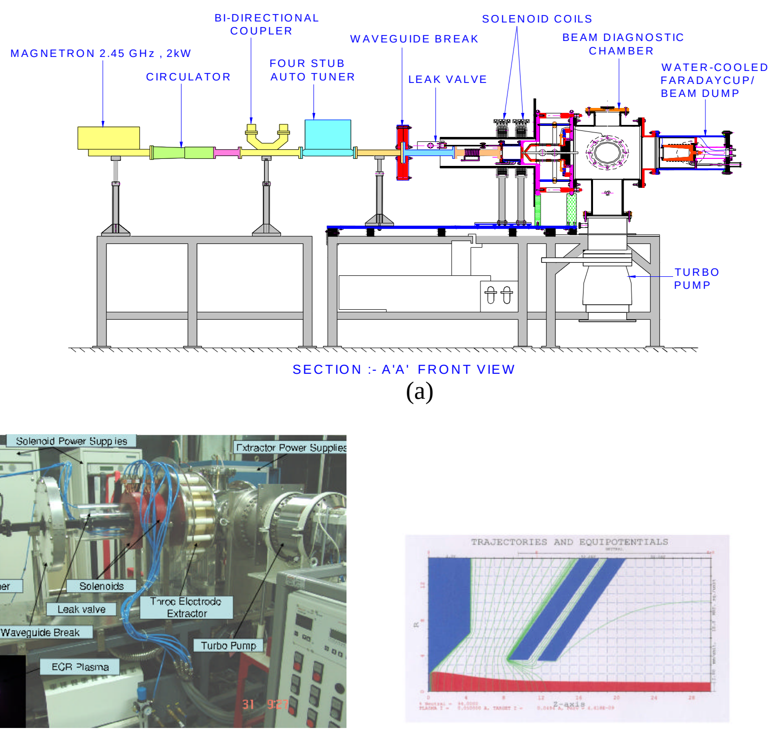
Nitride. ECR plasma was ignited with 400 - 1100 W of microwave power at 2.45 GHz, in the presence of hydrogen gas. The solenoid coils are used for confinement of plasma and to satisfy ECR condition at the plasma chamber extremities. Detailed description and operational experience of the source are presented in this article.

ECR PROTON ION SOURCE

A high intensity three electrode ECR proton ion source has been developed and a five electrode ion source is under development. The parameter of the ion source is shown in Table 1.

Table 1: Parameters of the Ion Source

Parameters	Required	Status
Beam energy (keV)	50	40
Beam current (mA) (hydrogen)	50	42
Discharge Power (kW)	< 2	1
Frequency (GHz)	2.45	2.45
Magnetic field (G)	875 - 1000	875 – 1000
Duty factor (%)	100	100
Gas flow rate (sccm)	< 2	0.4 – 1.3
Proton fraction (%)	> 80	To be measured
Beam emittance (π mm-mrad)	0.2	To be measured



(a)

(b) (c)

Figure 1. (a) Schematic (b) hardware and (c) simulation of three electrode ECR proton ion source

The three electrode proton ion source is shown in Fig. 1. In the operation of the ion source, a base pressure of 6 x 10^{-7} mbar was maintained for several hours, prior to the commencement of plasma generation. The working gas was then introduced in the plasma chamber in a controlled fashion using a precision leak valve and maintained in the pressure range ~ 10^{-4} - 10^{-3} mbar in the plasma chamber and ~ 10^{-6} - 10^{-5} mbar in the extractor region. The current in the solenoid coils were adjusted to obtain the desired magnetic field configuration. The microwave generator was then energized for initiating discharge. The microwave power (400 – 1100 W) was then coupled to the plasma chamber. The reflected power was minimized using four stub auto-tuner. Once the plasma discharge was established, the extractor electrodes power supplies were energized to extract the ion beam. The total ion beam current (unanalyzed) of 20 mA to 40 mA were routinely extracted from the ion source. It has been observed that the microwave window (6 mm thick quartz plate) was punctured after half an hour of source operation at the above current ratings due to the back-streaming electrons. The microwave window has been shifted from the line of sight of back-streaming electrons and located after the H-plane bend. In the new location of microwave window, stable plasma has been generated and characterized.

BEAM PARAMETER MEASUREMENT

A beam has been designed and under development to measure the beam emittance and proton fraction. The beam line consists of solenoid magnets, dipole bending magnet and steering magnets. The beam diagnostics incorporated in the beam line are DCCT, ACCT, emittance measurement unit, Faraday cups, CCD cameras and spectrograph. The beam line is shown in Fig. 2. The solenoid magnets, bending magnet, steering magnets, DCCT and ACCT and the two slit emittance measurement unit are shown in Fig. 3.

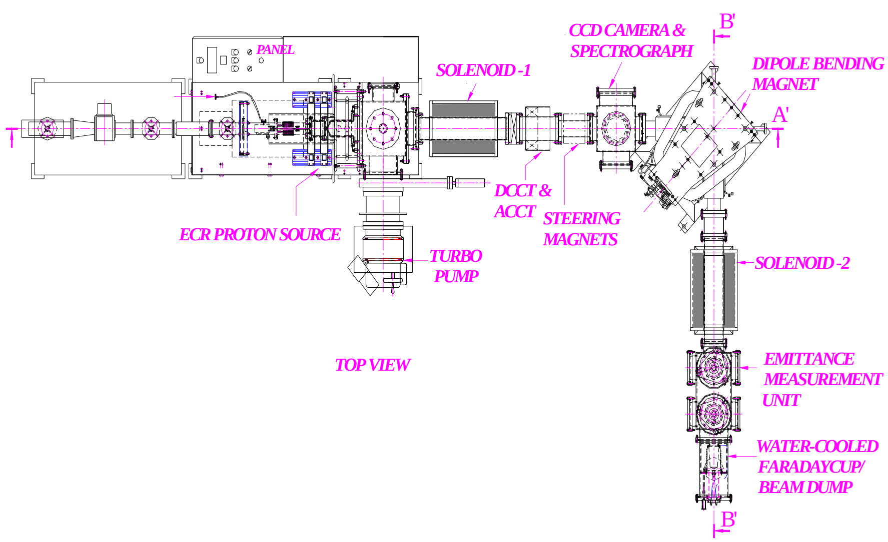


Figure 2. Beam line for emittance and specie measurement

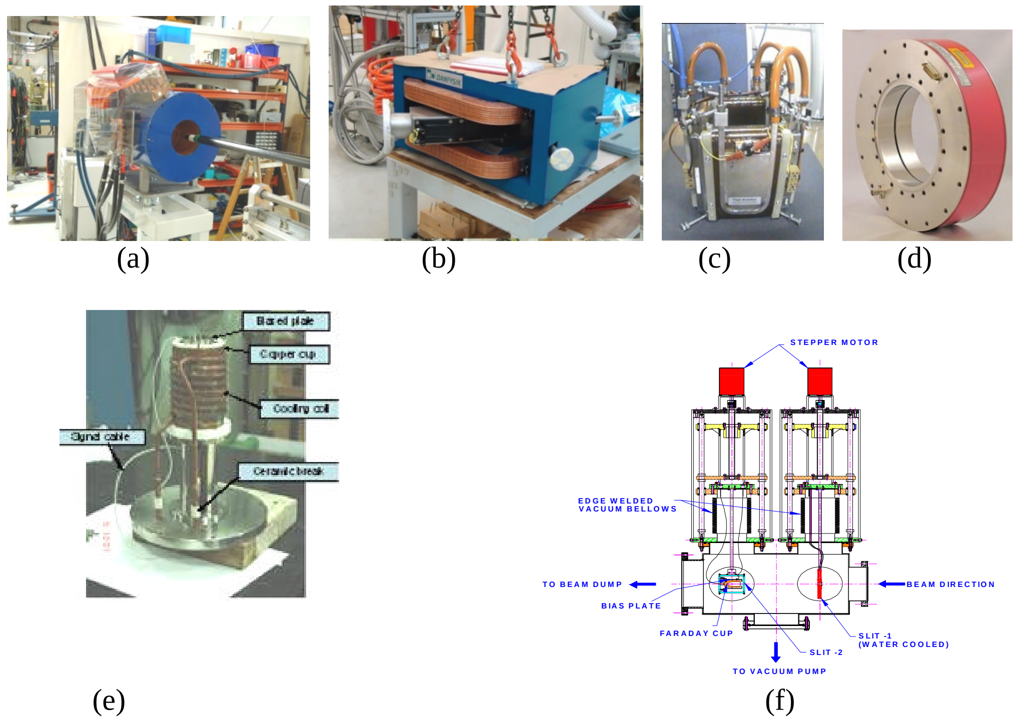


Figure 3. The beam line components (a) solenoid magnet, (b) dipole bending magnet, (c) steering magnet, (d) DCCT and ACCT, (e) Faraday cup and (f) two slit emittance measurement unit.

The above beam line components in Fig. 3 have been procured. The vacuum chamber and other components of the beam line have been fabricated. The emittance meter is under development. The assembly and testing of beam line will start soon.

CONCLUSION

A three electrode ECR proton ion source has been developed at BARC for LEHIPA. 42 mA of hydrogen beam current has been extracted at 40 keV. A beam line is under development to measure beam parameters i.e., emittance and proton fraction. A five electrode ion source is under development.

ACKNOWLEDGEMENTS

The authors wish to thank Dr. L. M. Gantayet, Director, BTDG, BARC, for his keen interest and support for this work.

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