source using a Faraday cup. The proton current v/s extraction voltage is shown in fig. A.5.2 (a) and pulse shape of beam is shown in fig.A.5.2 (b).

Fig. A.5.1 *ECR proton source*

In ECR source, plasma is produced by matching the frequency of the microwave source to the cyclotron frequency (2450MHz) of electrons, in the magnetic field (875gauss). The measured field profile is shown in fig. A.5.4. The magnetron is used as a source of microwave power and it can deliver maximum 2kW power at 2450MHz frequency. 5kV, 1A high voltage DC power supply is used to energize the magnetron. 5V, 20A AC power supply floating at 5kV is used to power the filament.

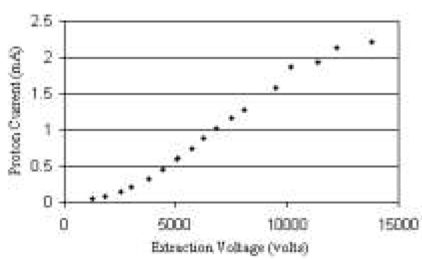

Fig.A.5.2(a) *The proton current v/s extraction voltage*

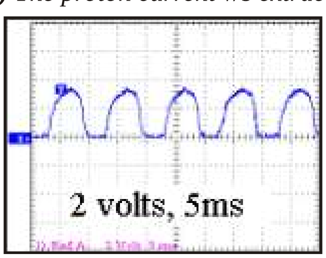

Fig. A.5.2(b) *The pulse shape of beam*

The microwave transfer line is developed using WR-284 rectangular waveguide section. The microwave power is coupled to the plasma chamber via ridged waveguide with window and DC break. The forward and reflected power is monitored using 50dB loop directional coupler. The plasma impedance is matched and reflected power is minimized using triple stub tuner. A high power isolator is used to protect the magnetron from load imperfections by directing the reflected power to the load. The isolation offered from reflected power is 25dB.

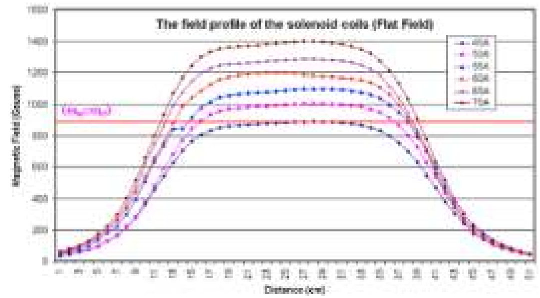

Fig. A.5.4 *The measured field profile (Flat Field)*

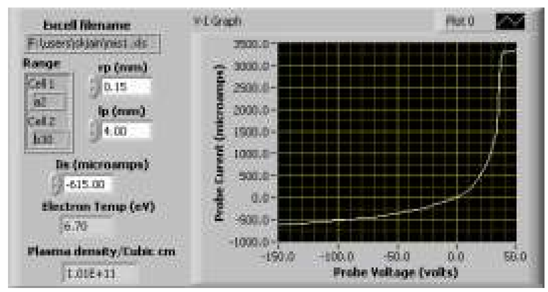

Fig. A.5.5 *The V-I characteristics of the ECR source*

Turbo molecular pump (400litre/sec.) is used for the evacuation of the plasma chamber (SS304) and $1x10^{-6}$mbar base pressure is maintained. Hydrogen gas flow is controlled through the precision needle valve. The source is operated at the hydrogen pressure at $2x10^{-4}$ mbar. The plasma parameters, plasma density and electron temperature is measured using Langmuir probe. The hydrogen plasma density in the order of $2\text{-}4x10^{11}cm^{-3}$ and electron temperature 3-7eV is obtained. The V-I characteristics of the Langmuir probe obtained from the ECR source is shown in Fig. A.5.5. The data obtained from the V-I characteristics, various plasma parameters are obtained.

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A.6 Fabrication of injection septum magnets for Indus-2

Septum magnet will inject the electron beam into the Indus-2 storage ring. Injection process will be completed in two stages firstly by bending the beam through (19+2)° in septum magnets and thereafter kicking the same in to the beam path using a kicker magnet Injection septum magnets were designed and developed at CAT.

Since septum magnets are placed in UHV environment hence its construction is entirely different than rest of the magnets of Indus-2. This segment has a parallel edge type core housed in a split body made of 316L SS. Selection of proper tool, machining sequence and in-process monitoring was necessary to achieve high geometrical accuracies and surface finish.

Material selection

The magnet core material is selected based upon its high magnetic field strength, low magnetic reminance, vacuum compatibility of both bulk, and surface, insulation property and its ability to be die-punched with minimum burrs. SoftMAG B-36 (ferrite steel with 36% Nickel) has been selected as core material as it meets all of the above requirements. 316L SS has been selected as construction material for magnet body owing to the fact that it has very low out-gassing rate and low magnetic permeability. Further it also gives high rigidity (compared to Al / Cu) desired for stringent flatness requirement. We have selected SS316L grade because this grade has shown low Austenite to Martensite transformation (magnetic transformation), which is detrimental for circulating beam. Oxygen free copper (C-10100) has been used for septum coil. This coil is insulated from core by high purity aluminum oxide coating.

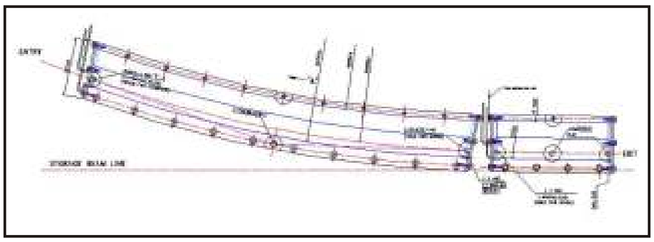

Fig A.6.1 *Layout of injection into Indus-2*

Fig A.6.2 *Magnet body during machining at HBM-AZ-11*

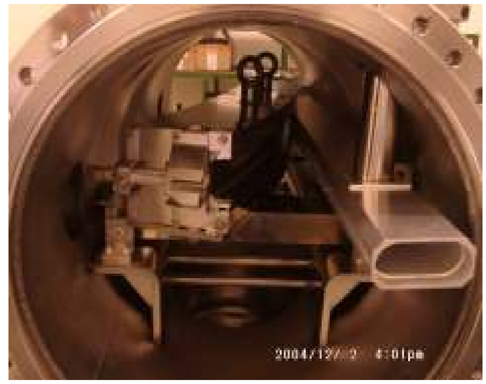

Fig A.6.3 *Mockup assembly of injection system*

Fabrication

Vertical milling machine BMV-40 with OMI CNC control was used to machine 250mm long thin septum body at R-7162mm. While HBM AZ-11 with TNC 155 control was used for scooping as well as final machining of 855mm long thick septum body at R-2593.4mm. Austenitic SS requires more sophisticated machining skills as compared to other Steels, Cu and Al alloys. If SS is not machined at right speed with sufficient cutting fluid, cold working can substantially harden it. Work hardening provides a thin layer of high hardness on work piece, which promotes tool wear at a faster rate. Using correct clamping location, optimum cutting parameters and proper cutting sequence controlled distortion. The two halves were stress relieved before final machining to achieve dimensional stability.

Magnet core is made of laminations of thickness 0.1mm. They are prepared on pillar with ball cage type die punch set. The cutting edge of die and punch were machined using CNC wire-cut machine. The seating surfaces of this set were hardened and ground to obtain dimensional & geometrical accuracies within $\pm 5\mu$m. During stamping on 25 Ton capacity mechanical press spring loaded pressure pads were used with reduction in burr. These laminations were thereafter oxidized (@20μm) for insulation and annealed in hydrogen furnace to maximize its magnetic strength.

Septum Coil was machined out of OFE copper solid stock using CNC BMV-40milling machine. Multilayer coated carbide tools with high rake angle and built-in chip breaker geometry were used to obtain surface finish of better then 0.8μm. The coils were chemically cleaned immediately after machining and wrapped in aluminum foil to avoid staining. The coils were finally coated with aluminum oxide using detonation plasma coating (@100μm on all sides) at ARC Technical Park in Hyderabad. This process gives porosity less than 4% which in turn reduces out gassing rate.

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