Status Report of Development of High Current Front End H^- Injector Linac for SNS at RRCAT

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Abstract. RRCAT has initiated development activities of a 100 MeV, 30 mA H^- injector Linac. The system consists of H^- ion source, Low energy beam transport (LEBT), Radio frequency quadrupole (RFQ), Drift tube linac (DTL) and Separated function DTL (SFDTL) accelerating structures, RF power sources, Controls, Beam dump and Beam diagnostics. This linac system will serve as low energy section for building 1 GeV proton accelerator for the ultimate goal of a pulsed Spallation Neutron Source (SNS) at RRCAT. In the first phase of the plan, development of front end linac operating at 3 MeV energy and 30 mA current along with prototype fabrication of DTL and SFDTL structures is envisaged.
Keywords: Ion source, LEBT, RFQ, DTL, Beam Dumps, Faraday Cup, SNS, Klystron, Linac
PACS: 41.75.Cn, 41.85.Ja, 41.85.Qg

INTRODUCTION

Development of a 3 MeV H^- ion linac has been initiated at RRCAT to serve as a front end for the 1 GeV proton accelerators for a pulsed Spallation Neutron Source [1]. The front-end system will comprise of a filament driven multi-cusp H^- ion source, Low Energy Beam Transport (LEBT) system, Radio Frequency Quadrupole (RFQ), RF power sources, Controls, Beam dump and Beam diagnostics. Prototype of a Drift tube linac (DTL)) accelerating structures are also being designed and developed for their RF power testing. The physics and engineering design will ensure minimum loss during transport of the 3 MeV, 30 mA, beam. A brief description of each sub-system is as follows.

DEVELOPMENT OF H^- ION SOURCES

In order to meet the requirement of H^- ion front end linac system, a multicusp filament based 50 keV, 30 mA, low emittance H^- ion-source operating in pulsed mode with a repetition rate of 25 Hz has been initiated. Physics design of the multicusp source was carried out analytically and using computer simulations based on finite element method. Subsequently the results were verified by conducting experiments of magnetic field mapping inside the cylindrical geometry using 3-D Hall probe measurement technique [2]. The results have corroborated the simulations. Similarly thermal studies were carried out using computer simulations to study the heat removal from plasma chamber to protect the permanent magnets. The cusp loss width parameter was studied to determine the total power requirement of the source. The role of geometrical factor was found to play major role in the calculation and it was derived using rigorous mathematical treatment [3]. Based on above studies a prototype engineering design of the multicusp plasma chamber and 3-electrode ion extraction chamber has been made [4]. This system has recently been tested for extraction of hydrogen ion current of 0.75 mA at 5 kV accelerating field. Figure 1, shows the multi-cusp H- ion source system.

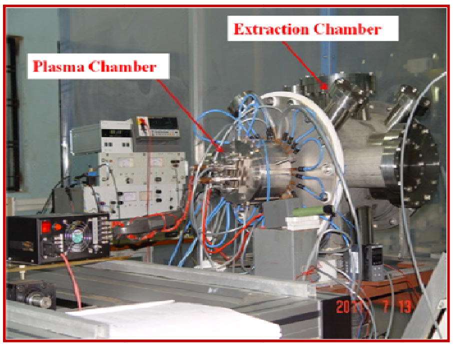

FIGURE 1. Prototype multi-cusp filament based pulsed H^- ion source.

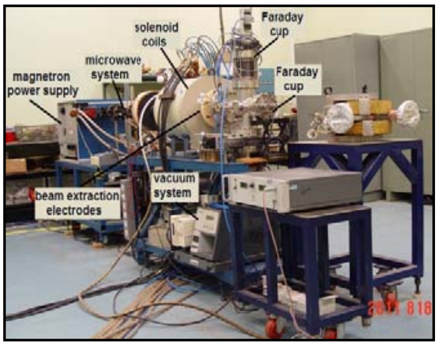

FIGURE 2. ECR ion source

ECR ion source at 2.45 GHz operating frequency has been designed, fabricated and operated [5]. Three electrode ion extraction system was used in flat geometry to study the ion beam extraction. Hydrogen ion beam was extract up to 7.8 mA at 25 kV accelerating voltage between the plasma and ground electrode.

PHYSICS DESIGN OF LEBT, RFQ AND DTL

Physics design has been completed for a 352.2 MHz, 3.47 m long, four vane type RFQ that will accelerate the 50 keV, 30 mA pulsed H^- ion beam with 1.25% duty factor to 3 MeV [6]. The intervane voltage has been chosen to be 80 kV, the optimized value of the minimum aperture radius is 2.31 mm and modulation parameter has been varied in the range 1 – 1.95. The synchronous phase is initially kept at -90 degree to maximize the capture efficiency, which is ramped to -30 degree. Design of vane-end cut-back has been completed and it has been planned to use dipole stabilizer rods for operating mode stabilization against deflecting dipole modes [7]. An Alvarez type, 5.62 m long, Drift Tube Linac (DTL) has been designed to accelerate the 3 MeV beam to 10 MeV [8]. The DTL has 60 cells and the structure parameters have been optimized for high effective shunt impedance, while keeping space provision for housing quadrupoles in drift tube in FOFODODO configuration. The synchronous phase has been varied from -45 degree to -30 degree and Quadrupole gradient is varied in the range 55-35 T/m. CST-MWS simulations have been done to fix the postcoupler diameter and penetration to stabilize the field.

A Low Energy Beam Transport (LEBT) line, consisting of solenoid magnets of maximum strength 3.5 kG and steering coils having a maximum field of 100 G has been designed for transporting the beam from Ion Source to RFQ with the matched beam parameters at RFQ entrance, and with minimum emittance growth.

RFQ, BEAM DIAGNOSTICS & RF SYSTEMS

RFQ will be an octagonal shape integrated four vane cavity type structure, will be fabricated in smaller modules of length of 1.1~ 1.2 meter.

Thermal Analysis and Prototype Fabrication of RFQ Cavity and DTL Tank

The total power loss in the RFQ structure is ~ 9.6 kW at 3% duty factor. The power loss for the analysis has been considered 40% more than the power loss calculated by SUPERFISH. The thermal structural coupled analysis of RFQ has been carried out (Fig 5.a) to ensure the thermal and structural stability of the RFQ structure [9].

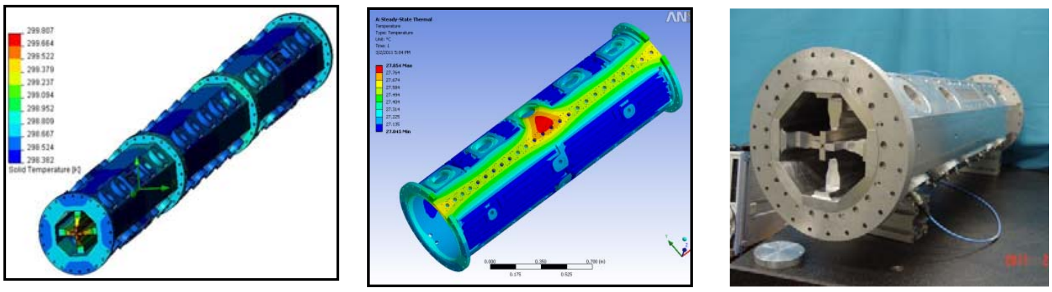

FIGURE 3. Temp plot **(a)** RFQ, (b) DTL tank. **(c)** RFQ segment in Al

Each segment of the RFQ structure would have 24 circular cooling channels A coupled thermal structural analysis for DTL tank was also carried out to evaluate thermal deformations and stresses induced in the structure (Fig 5.b). Prototype fabrication of 1st segment of RFQ structure (unmodulated) was carried out (Fig 5.c).

Beam Diagnostic equipments: The beam diagnostic devices will be used for the measurement of beam parameters such as beam emittance, beam position, profile, size, current, beam loss etc in H- Linac. Basic beam diagnostic devices to be installed in the LEBT include: beam emittance monitor, beam profile monitor, beam current monitor, fluorescent screen etc. A photograph of the Faraday cup is shown in figure 4.

FIGURE 4. Faraday cup

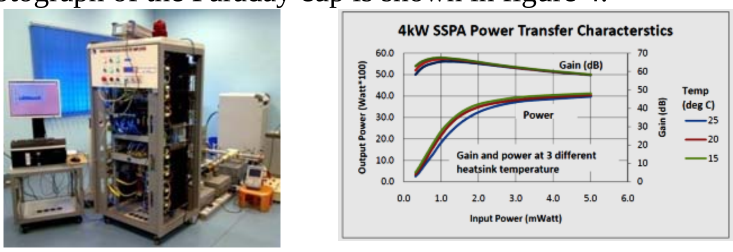

FIGURE 5. Solid state 4 kW amplifier and its performance

RF Power System for RFQ & DTL: A 4kW Solid State Amplifier at 352 MHz with high power 16-way radial power divider /combiner, 2-way combiner and directional coupler has been developed in-house. At the core of this unit, 16 numbers of 270W Amplifier modules have been power combined using 16-way radial power combiner as shown in figure 5. The low power and high power directional couplers have been used for measurement of RF power at various stages. The coaxial and waveguide components have been fabricated to test the solid state RF power systems.

100kV, 25Hz, Solid state pulse modulator for 1MW Klystron and WR 2300 waveguide components for 3MeV Pulsed RFQ: A 100kV, 20A, 600 μsec pulse duration solid state bouncer compensated puluse modulator has been constructed for 1MW klystron for powering RFQ(Fig 7 a). WR 2300 waveguide transmission line is designed incorporating dual directional coupler, harmonic filter, three port waveguide circulator, waveguide E and H plane bends, full height to half height waveguide transition, magic tee power dividers & flexible waveguides [10].

(a) (b) (c)

FIGURE 7. a) 100 kV solid state modulator, b) 1MW352.2MHz circulator, (c) magic T power divider.

SUMMARY

Developmental activity for the front end 3 MeV H^- linac has started and testing of filament heated multicusp plasma and ion extraction system of H^- ion source and ECR ion source was carried out. The physics and engineering design of LEBT, RFQ and DTL has been completed and prototype fabrication of RFQ segment is made in Al. The solid state RF amplifier based power source have been designed and built up to 4kW power at 352 MHz frequency. The 100 kV solid state bounce modulator and waveguide components have been developed in house and tested using 1MW, 352.2 MHz klystron and three port circulators obtained from CERN. In the first phase the front end linac will be tested using various beam diagnostics e.g. Faraday Cup, double slit beam Emittance monitor and beam dumps being developed in house.

ACKNOWLEDGMENTS

We sincerely acknowledge the contributions of all the team members under PLSCD, RFSD, BPL, PHPMS and BDS divisions and sections of RRCAT.

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