STATUS OF THE SUPERCONDUCTING BOOSTER LINAC FOR THE NSC PELLETRON ACCELERATOR

P.N.Prakash, T.S.Datta, B.P.Ajith Kumar, J.Antony, J.Chacko, A.Choudhury, G.K.Chaudhari, S.Ghosh, S.Kar, S.A.Krishnan, Manoj Kumar, Rajesh Kumar, A.Mandal, D.S.Mathuria, R.S.Meena, R.Mehta, K.K.Mistri, M.V.Suresh Babu, B.K.Sahoo, A.Sarkar, S.S.K.Sonti, S.Venkatramanan, J.Zacharias, A.Roy, R.K.Bhowmik & G.K.Mehta
Nuclear Science Centre, P.O.Box 10502, Aruna Asaf Ali Marg, New Delhi – 110067, India

Abstract

This paper reports the status of the construction of a superconducting linear accelerator as a booster to the 15UD Pelletron accelerator, at Nuclear Science Centre, New Delhi. The linac will use niobium quarter wave resonators to accelerate ions upto mass ~ 100 above the Coulomb barrier. Prototype resonator and resonators for the first linac module have been fabricated in collaboration with Argonne National Laboratory in USA. Resonators for the remaining two modules will be fabricated indigenously. For this a superconducting resonator fabrication facility is being set up. Details of the linear accelerator, cryogenics system, RF electronics, control system, beam transport system, and resonator fabrication facility are presented.

1 INTRODUCTION

The 15 UD Pelletron accelerator at Nuclear Science Centre (NSC) [1] is capable of accelerating ions upto mass 40 above the Coulomb barrier. In order to increase this mass range upto 100, a superconducting linear accelerator as a booster is presently under construction [2]. The linac will consist of one superbuncher cryostat containing one quarter wave resonator (QWR), three linac cryostats - each holding eight QWRs and one solenoid magnet (for transverse focussing), and a rebuncher cryostat containing two QWRs. We describe below the various sub systems and the present status of the project.

2 LINEAR ACCELERATOR

2.1 Resonators

The accelerating structure in the linac would be a superconducting niobium quarter wave resonator, which was chosen for its excellent mechanical stability and broad velocity acceptance. One single structure would be used in the entire linac. Prototype resonator for the linac was designed, fabricated and tested in collaboration with Argonne National Laboratory (ANL) in USA [3]. Figure 1 shows a schematic diagram of the quarter wave resonator. Detailed design features of the resonator have been presented elsewhere [4]. Resonators for the first linac module have also been fabricated in collaboration with ANL [5]. Figure 2 shows performance of two resonators from this production.

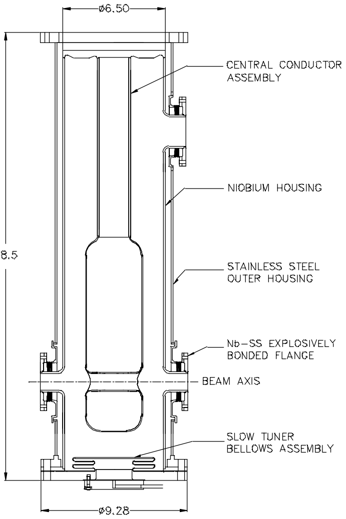

Figure 1. Schematic diagram of the quarter wave resonator. Dimensions are in inches.

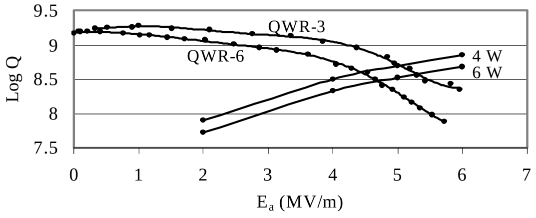

Figure 2. Resonator Q as function of accelerating electric field E_a at 4.5 K.

2.2 Cryogenics System

The estimated heat load of the linear accelerator - which consists of three linac cryostats, one buncher cryostat, and a rebuncher cryostat - with a total of 27 resonators, is 280 W at 4.5 K [6]. An expansion engine based helium refrigerator of capacity 600 W at 4.5 K is installed and is being operated. The helium refrigerator has been integrated recently with the buncher and first linac cryostats by indigenously developed liquid helium (LHe) distribution network [7]. This network has been designed for parallel feeding of liquid helium to all five cryostats independently by using the four valve boxes with long stem low heat load WEKA valves. The liquid helium supply and cold gas return lines are enclosed in 8 inch diameter vacuum jacket with intermediate liquid nitrogen shield and multilayer insulation and G-10 supports. The entire cryogenic network has been successfully tested by transferring LHe from the liquefier in close loop mode to the cryostats continuously for more than a week. The average heat load of the distribution line was measured to be ~ 1 W/m, in agreement with the estimated value.

The indigenously fabricated cylindrical buncher cryostat (ϕ900 mm × 2000 mm) and rectangular first linac cryostat (2800 mm × 1200 mm × 1950 mm) have been installed in the beamline. One of the special features of the linac cryostat is the support structure with alignment mechanism. With this mechanism it is possible to align individual resonators, magnet, as well as the entire cryostat structure. The vacuum achieved in both the cryostats at 4.5 K is $\leq 10^{-8}$ Torr and measured static heat loads are 3.5 and 8 W respectively. In both cryostats the resonators and liquid helium vessel are surrounded by 80 K copper sheet cooled by LN_2.

A helium gas recycling system consisting of a gasbag, recovery compressor, a high pressure cylinder bank and purifier has been built. A vacuum jacketed liquid nitrogen transfer line network connecting a 5000 litres capacity container and LN_2 plant is used for the shield cooling of cryostats, helium distribution line, and as a pre-coolant of helium refrigerator.

2.3 RF Electronics

The superconducting resonators will operate at 97 MHz frequency. The phase and amplitude of the RF fields in the resonators need to be stabilized with respect to a reference master oscillator. The resonant frequency variation of the resonator acts as the main disturbance to the stabilization process. The resonant frequency variation occurs on two time scales. The fast component is due to the vibration of central conductor of the resonator and the slow component is due to the pressure variation in the cryogenic system. A resonator control scheme has been developed for the resonator, which incorporates a fast and a slow tuner section. In the fast tuner section the resonator is made the frequency selective part of an oscillator. The phase of this oscillator is locked with the reference by dynamically inserting a phase shift in the oscillator by adding a quadrature signal in the oscillation loop [8]. The slow-tuner control mechanism has been incorporated to keep the average of the resonator frequency same as the master clock. The inclusion of the slow tuner mechanism reduces the load on the fast tuner and results in reduced power requirement for control. This control Scheme has been successfully tested with the resonator.

RF Amplifiers for the control have been designed and developed. The amplifier consists of MOTOROLA power MOSFETs in a push pull design and can deliver 200 W RF power continuously and has full protection against the reflected power.

2.4 Control System

A distributed control system has been developed for the Pelletron-LINAC accelerator system. It runs on a network of Pentium computers under the LINUX operating system. The devices of the accelerator are connected to several computers using CAMAC interface. The design is based on a client server model and the computers connected to CAMAC run the server code. Machines are provided on the same network for operator interface, by running the client program. The client computers use the X-window graphics and shaft encoder knobs interfaced to them to provide the operator interface. The system supports the monitoring and controlling of all the accelerator parameters including the Beam Profile Monitors, from any of the clients. Client programs can be written for any specific application like automatic beam tuning through a particular section of the machine, conditioning of resonators etc. The system has been running the Pelletron accelerator for the past two years.

2.5 Beam Transport System

The beam transport system consists of beam diagnostic devices (faraday cup, beam profile monitor etc.), quadrupole magnets, magnetic steerers, phase detectors (spiral cavity), vacuum components (valves, pumps, gauges etc.) and drift tubes. Several components of the beam transport system, such as the diagnostic box, quadrupole magnets, power supplies, magnetic steerers and phase detectors have been designed and fabricated indigenously.

The ion optics calculations for the linac were performed using a ray tracing computer program developed at NSC [9], to optimise the position of the superbuncher, linac modules and the rebuncher to deliver short time width or narrow energy width pulses on the target. In addition, element misalignment calculations have also been done.

3 SUPERCONDUCTING RESONATOR FABRICATION FACILITY

To fabricate resonators in-house for the second and third linac modules, and resonators for future projects, a Superconducting Resonator Fabrication Facility (SuRFF) is presently being setup. Three major facilities are planned:

1. Electron Beam welding facility.
2. Surface preparation laboratory.
3. High vacuum furnace.

The electron beam welding machine would be a CNC controlled, fully programmable, 15 kW, 60 kV machine with a vacuum chamber of size 2.5 m x 1.0 m x 1.0 m. The surface preparation laboratory would be used to electropolish the niobium resonators. For this an acid fume hood and other accessories are being setup. A class 100 clean room with a high pressure DI water rinsing system (80 bar) is also being planned. The high vacuum furnace would be used to anneal the niobium resonators upto 1200 C in vacuum ($\sim 10^{-6}$ T). The hot zone would be ϕ600 mm $\times$ 1000 mm chamber pumped by a turbo molecular pump.

4 PRESENT STATUS

Construction of the linear accelerator has advanced sufficiently. All the designing & prototyping aspects have been completed. The linac beamline has been laid upto the first linac cryostat, and the superbuncher and linac cryostats are installed in the beamline. Liquid helium and liquid nitrogen plants have been installed and are run regularly. The cryogenic distribution system has been designed, fabricated and installed for transferring liquid helium to the cryostats. A resonator control module, suitable for the NSC linac, has been designed and tested with the resonator. Several RF amplifiers and other electronic items for control have been designed and fabricated. A number of beam transport items have been fabricated indigenously. A multiharmonic buncher has been installed in the low energy section of the Pelletron accelerator.

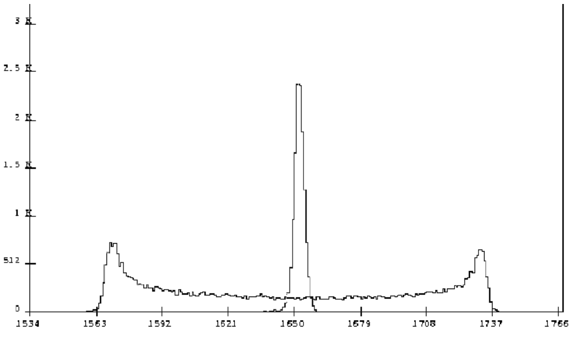

Figure 3. The monochromatic beam splits into a broad band with two peaks when the superbuncher is turned on.

The superbuncher has been tested with both DC and pulsed beams. Figure 3 shows results from the DC beam test. It shows the elastic peak from a ^{16}O beam scattered from a gold target with the resonator switched off. When the resonator is turned on, it broadens and separates into two peaks - one accelerating ions, and the other decelerating ions. The difference between the centroids gives twice the energy gain.

In the test with pulsed beam a ^{16}O beam of 1.3 ns FWHM from the pre-tandem multiharmonic buncher was compressed by the superbuncher to 185 ps (see figure 4) near the entrance of the linac module (~ 8.2 m). The measurement was limited by the resolution of the cooled surface barrier detector (-3 °C), which was separately measured to be of the same order.

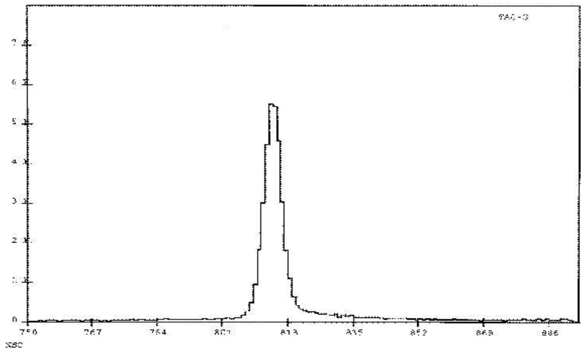

Figure 4. TAC spectrum of the bunched beam from the superbuncher (FWHM = 185 ps).

REFERENCES

[1] D.Kanjilal et. al., NIM A328, 1993, p97

[2] A.Roy et. al., Proceedings of the 8th International Conference on Heavy Ion Accelerator Technology, Oct. 5-9, 1998, Argonne, IL, USA, p267

[3] K.W.Shepard et. al., Proceedings of the 1997 Particle Accelerator Conference, May 12-16, 1997, Vancouver, BC, Canada, p3072

[4] K.W.Shepard et. al., Proceedings of the 1993 Particle Accelerator Conference, May 17-20, 1993, Washington, DC, p1045

[5] P.N.Potukuchi et. al., Proceedings of the 1999 Particle Accelerator Conference, March 29 – April 02, 1999, New York, p952

[6] T.S.Datta et. al., Proceedings of the 18th International Cryogenic Engineering Conference, Mumbai, India, 2000, p131

[7] Anup Choudhury et. al., Proceedings of the 18th International Cryogenic Engineering Conference, Mumbai. India, 2000, p459

[8] I.Ben Zvi et. al., NIM A245, 1986, p1

[9] P.N.Prakash et. al., NSC Technical Report, Ref.: NSC/TR/PNP/96/132