Superconducting Linac Booster for NSC Pelletron*

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Abstract

This paper reviews the progress made in the heavy ion superconducting linac booster project for the Nuclear Science Centre Pelletron accelerator. Prototypes of the accelerating structure have been fabricated at Argonne National Laboratory and undergone several diagnostic tests. Preliminary designs for the buncher and linac cryostats have been made. Several prototypes of rf electronics and control modules have been fabricated and tested.

Introduction

The superconducting linac booster for the 16 MV 15 UD Pelletron accelerator at Nuclear Science Centre (NSC) has now been planned in two phases due to resource crunch[1]. In the first phase heavy ions upto mass 80 will be accelerated to energies above the Coulomb barrier and in the second phase the mass limit would be increased to 120. The subsystems of the project which need to work together are the basic accelerating structures, the rf instrumentation and control, the cryogenic system and the beam optics. We describe below the current status of each subsystem.

The Resonant Cavity

The accelerating structure of the linac is a niobium superconducting quarter wave coaxial line (QWCL) cavity which was chosen for its excellent mechanical stability and broad velocity acceptance . The prototype structure optimised for the NSC Pelletron has been designed and fabricated under a collaboration between NSC and Argonne National Laboratory [2]. Two such prototypes have been fabricated. The first is without beam ports but is fully jacketed in stainless steel shell and can be tested in vacuum environment at 4.2 K. The cavities are formed entirely of niobium and standard sheet metal forming techniques and electron beam welding procedures were used . Several cold tests were performed on the first prototype cavity and the results were reported earlier [3]. Various diagnostic tests have been carried out to determine the low Q-value of 1.7×10^7 of the resonator , which indicated defective e-beam welds near the shorted end of the coaxial line. These tests, however, established several important properties of the present design :

1. Multipacting in the cylindrically symmetric design do not pose any novel problems and were overcome by rf conditioning for a period of 14-18 hours.
2. The structure has excellent mechanical stability as demonstrated by the vibration induced rf eigenfrequency jitter of only 10-20 Hz even when connected to the ATLAS recirculating helium refrigeration system.
3. The explosively bonded niobium to stainless steel welding transition proved reliable in exhibiting no observable vacuum leaks under repeated cycling over the temperature range 4 K to 358 K.
4. The precooling and warming of the resonator by circulating gas through two small channels welded to the outer stainless steel jacket proved quite efficient with a thermal relaxation time of 4 hrs via convection in helium gas at 1 atm.

The second cavity was tested without putting the stainless steel jacket and the slow tuner bellow. In this configuration, cold test in vacuum was not feasible and the whole cavity was immersed in liquid helium in a large sized (24" dia and 72" depth) dewar. A 4" dia glass view port was designed for the top plate of the dewar through which the interior of the cavity could be directly viewed or seen on a video monitor using a video camera. On putting rf power the lossy regions could be identified by the formation of bubbles in the liquid around these regions. The cavity could be tested upto a field level of 0.7 MV/m beyond which arcing in liquid helium was observed. The Q value obtained for this structure was 1.05 x 10^8. The major losses were confined to the welding of the central conductor to the base plate at the shorted end. The entire cavity was heat treated at Cornell University, without any improvement of the Q. In fact the value of Q was lower than before heat treatment. Efforts are underway at ANL to redo the weldings and improve the Q of the cavity. The production of the cavities would start as soon as the prototype achieves high enough Q-value and is tested for high fields.

The first phase of the linac calls for the fabrication of 32 cavities, which would be housed in four cryostats.

Cryogenics and cryostats

The 600 W helium reliquefier from CCI, U.S.A. has been delivered at NSC and is in the process of installation. In the first phase this system will provide 330 W cooling capacity without liquid nitrogen. The warm gas piping has been completed and the interconnections between cold box, dewar and other components are being checked. The installation is expected to be completed by the end of this year.

Due to the high cost of liquid nitrogen in India, we have decided to procure a captive system which has also been designed as a closed loop system reliquefing the return gas. A nitrogen plant of cooling capacity 5000 W at 82 K has been designed and ordered with M/s Stirling Cryogenics and is expected to be commissioned by middle of next year.A sketch of the entire refrigeration system is shown in figure 1.

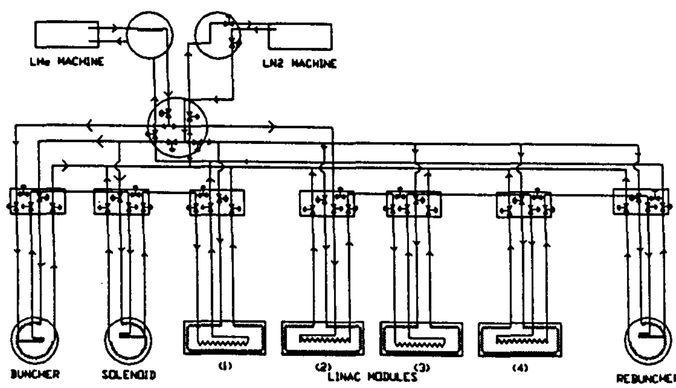

Fig. 1

Preliminary designs for the buncher and linac cryostats have been made. The buncher would consist of a single QWCL cavity whereas the rebuncher would require two QWCL cavities. The linac cryostat would house eight cavities and a superconducting solenoid for tranverse focussing. The cryostat design incorporates many important features of the cryostats in both the high energy end and the positive ion injector section of ATLAS. These include e.g. the support and alignment system for the resonators, the feedthrough design, cryogenic connections etc. A test cryostat, 0.9 m in diameter and 1.8 m tall has been designed, fabricated and leak tested upto 78 K and would be used for cold tests of resonators and solenoids.

RF Instrumentation and Control

The resonators will be all independently phased and the phase of rf in each cavity would be controlled through voltage control reactances (VCX) for the fast frequency excursions and slow variations through a pneumatically controlled niobium bellow. Prototypes of resonator control module, the power amplifier, the slow tuner module and PIN diode pulser required for the QWCL cavities have all been fabricated and tested with resonators on line at ATLAS. These would be reproduced in the required number at New Delhi. A clock distribution system to provide phase reference signals at 97 MHz and its subharmonics has been designed.The existing single harmonic buncher for the Pelletron, purchased along with the machine, has only 10% efficiency for bunching the dc beam and is in the process of being replaced by a single gap multiharmonic buncher of ANL design [4].

A control system running on a network of PC/AT 486 computers has been developed for the Pelletron -Linac system. The design is based on a client server model with server directly connected to the accelerator by using a CAMAC serial highway which maintains an on-line database of all the accelerator parameters. All other computers are connected to the server by an ethernet link . The server would service the requests from all the client computers to access the machine parameters and keep the database periodically updated. Database integrity is maintained by allowing only one program to access the database and thus avoiding any conflicting requests.The client computers can run any program and they will have access to the runtime database through the server program. Several of them will act as operator consoles with some special hardware interfaced to it for supporting the assignable knobs and meters. The assignable control knob is an incremental input device connected to the PC ISA Bus. A system with two consoles and the server has been tested by running the beam.

Beam Optics

The beam optics has been worked out using two computer codes, LINRAY from ANL and NSCRAYdeveloped at NSC. The program NSCRAY treats the QWCL cavity as a two gap structure with the electric field produced by three coaxial cylinders and takes into account the higher order derivatives of the electric field inside the cavity for calculating the ion trajectories. The placement of the buncher, linac modules and the rebuncher has been optimized from the consideration of close packing and the beam quality in both longitudinal and transverse phase space on target.

Conclusion

The prototype resonator fabrication and testing is nearing completion and we expect to start production of the resonators early next year. The civil construction for housing the linac and beam hall is complete. The cryogenic facilities comprising of liquid helium and liquid nitrogen systems would be ready by middle of next year. Beam optics studies are in the final stage and the linac layout is being frozen. The details of the rf instrumentation and control system have been worked out.

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