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The Booster Linac for the New Delhi Pelletron*

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Abstract

This paper describes the heavy ion booster linac project for the New Delhi tandem Pelletron accelerator. The superconducting linac will consist of all niobium quarter-wave coaxial-line cavities. A prototype of the accelerating structure has been designed and a room temperature model is tested for the electromagnetic and mechanical properties. Three prototype niobium cavities are nearing completion at the Argonne National Laboratory.

I. INTRODUCTION

The Nuclear Science Center is an autonomous organization of the University Grants Commission of Government of India to provide research facilities to universities and other educational institutions in the areas of nuclear and atomic physics, materials and bio sciences etc. The facility at present has a 15 UD tandem Pelletron accelerator upgraded to take the terminal voltage to 16 MV [1]. The present accelerator is capable of accelerating up to mass 40 above the Coulomb barrier. Efforts to add a booster accelerator to push this limit around mass 120 to explore exciting areas in nuclear physics began in early 1990. Furthermore, the area of superconducting resonant cavities offers new avenues in accelerator physics and technology.

II. THE LINAC

The choice of a superconducting linear accelerator was decided for its modular structure and also the success of such linacs at other laboratories [2]. Design for housing the linac and experimental beam hall started in mid 1990 so that the civil construction could start as quickly as possible. A collaborative project with Argonne National Laboratory to design and fabricate a suitable prototype accelerating structure started in late 1991.

II.1 Resonant Cavity Design

Several recent heavy-ion booster linac projects employ superconducting quarter-wave coaxial-line (QWCL) cavities as the accelerating structure [3-5]. The QWCL geometry is characterized by excellent mechanical stability and broad velocity acceptance. Niobium superconducting QWCL resonators have achieved very high accelerating gradients [5].

A. General Approach

The design begins with a 100 MHz two gap resonant cavity optimized for particle velocity $\beta = v/c = 0.08$. Such a structure has a large enough range of velocity acceptance that a single resonator geometry will suffice for the entire booster linac, as presently envisioned [6]. Two cavities as described above are being constructed as prototypes and will be tested first individually, and then as a coupled pair in order both to test the superconducting coupler and also to ascertain the feasibility of operating the cavities in strongly coupled pairs and thus combining the advantages of two gap and multigap cavities.

B. Quarter-Wave Coaxial-Line Cavity

The cavity is formed entirely of niobium, rather than bonded niobium-copper composite as is used in the ATLAS linac and several other accelerators. This choice was taken because of the cost of forming and welding the composite material and also because the cost is increased by the relatively large number of two-gap cavities required. Figure 1 shows a coupled pair of cavities. For the moment, we consider half of the coupled pair which constitutes a single QWCL, and note several features:

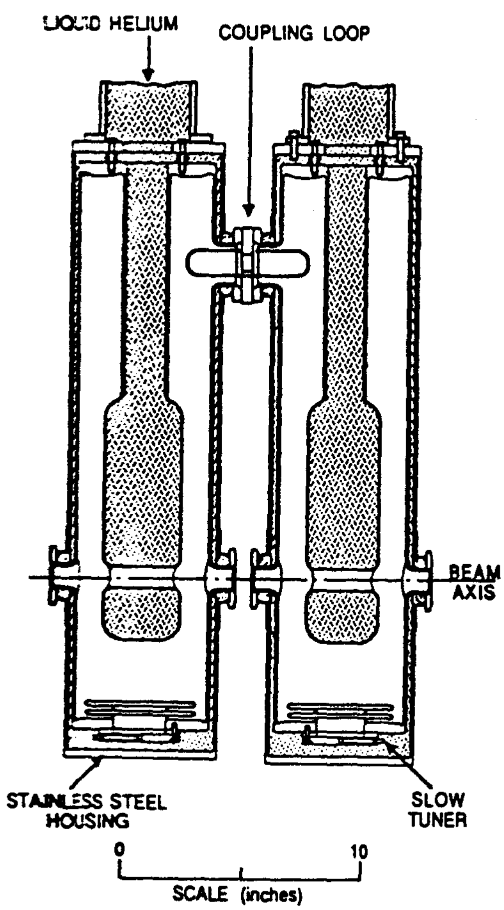

Figure 1. Coupled pair of 100 MHz quarter-wave coaxial-line cavities. The shaded region shows the volume occupied by liquid helium.

1. The high voltage of the coaxial line consists of a relatively large diameter section which capacitively loads the quarter wave line and shortens the cavity near 20 cm. This is done to reduce the size of the resonant cavity, and therefore the cost, and to improve the mechanical stability while keeping the peak surface electric field low.

2. The niobium cavity is closely jacketed in a vessel of stainless steel which contains the liquid helium required to cool the superconducting structure. This design permits an array of cavities to operate in a cryostat with the beam-line and cryogenic vacuums being one common system. A small amount of niobium-stainless steel bonded composite material is used to provide welding transitions where beam and coupling ports penetrate the stainless steel jacket.

3. A pneumatic tuner is incorporated into the bottom end face of the resonant cavity and will consist of a three-section niobium bellows. The end face will move about 3 mm with 1 atm of internal pressure, and provide a tuning range of approximately 200 KHz, substantially more than required for single cavity operation, but necessary for operating the cavities in coupled pairs.

C. Electrodynamic Parameters

The QWCL resonant geometry has been modeled numerically and measurements have been performed on a copper model to determine the electromagnetic and mechanical properties of the design, which proved entirely satisfactory [6].

D. Coupled Cavity Pair

Coupling a pair of QWCL cavities creates a structure in which the two lowest frequency rf eigenmodes consists of the fundamental rf eigenmode in each of the independent cavities, the two of which can be either in phase or π radians out of phase. As is discussed in Ref. [6], if each half of the pair can be independently tuned, both the modes can be used for beam acceleration, providing a wide range of velocity acceptance.

E. Multipacting Test

To provide an early test of the multipacting behavior of the design, an existing QWCL cavity was modified to mimic the drift tube gap and resonant frequency of the prototype QWCL cavity [7]. Multipacting tests were performed after (a) cooling down the resonator to 4.2 K and (b) after warming the resonator to room temperature for several days and cooling down without exposing to air. Although the multipacting in the present geometry seems appreciably more severe than, for example, the ATLAS split-ring and interdigital superconducting cavities, the conditioning process seems entirely effective and no operational problems are foreseen at present.

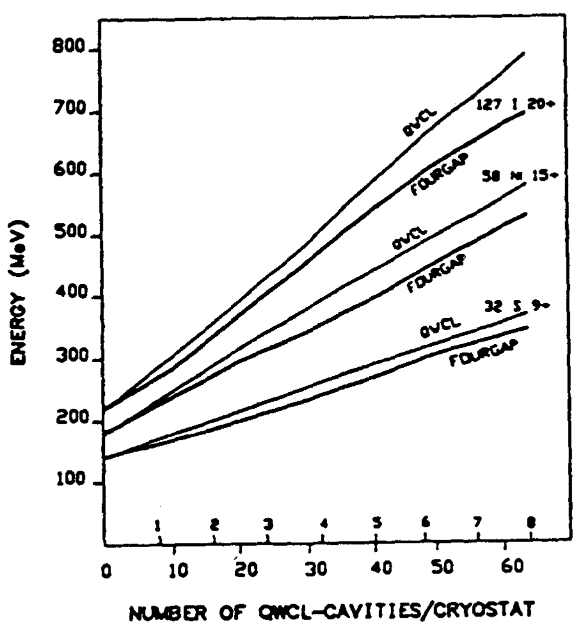

Figure 2. Energy gain versus the number of QWCL-cavities. Each cryostat will have 8 single or 4 coupled QWCL-cavities. The upper number on the x-axis shows the number of cryostats.

II.2 Energy Gain

We plan to have 8 independent or 4 coupled QWCL cavities in a cryostat. The expected energy gain as a function of the number of resonators when operated as (1) independent QWCL cavities and (2) coupled cavities (fourgap), at an electric field gradient of 3 MV/m for 3 different ion species is shown in Figure 2. The energy gain in the coupled mode is typically 10% lower than the independent mode. Strongly coupling two cavities splits the rf eigenmode into two modes, each of which covers a portion of the full velocity acceptance range of the original single cavity mode, resulting in slightly lower energy gains [6].

III. CRYOGENICS AND CRYOSTATS

An order with Cryogenic Consultants Incorporation (CCI), USA, for a 600 W liquid helium plant has already been placed. Commissioning of the plant is expected to begin in mid 1994. Due to the high cost of liquid nitrogen in our country we are forced to buy a LN_2 plant to meet our needs. The entire cryogenics for the booster linac is planned in such a way that we can expand as we add more cryostats. The cryostat design for the linac will start as soon as we finish testing the prototype resonators. The design for helium plumbing and distribution system is also expected to be taken up at that time. A superconducting solenoid magnet with a field value of 7 Tesla using Nb Ti wire has been designed and wound. A test cryostat for cold tests of the solenoid and resonators is under fabrication.

IV. FINAL COMMENTS

Construction of the first prototype quarter wave cavities is in advanced stage. We hope to have the first cold test before the end of the year. The civil construction for housing the linac and beam hall are near completion. Figure 3 shows the time scale as envisioned at present for the completion of the project.

The booster project is still in its initial stages. We expect to embark on a cryostat design after the prototype tests. A few RF amplifiers working at around 4 and 100 MHz have been designed and fabricated.

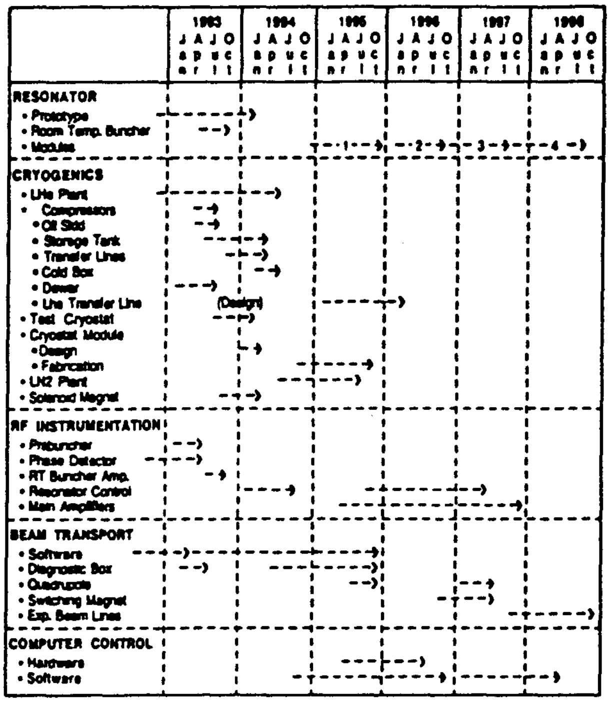

Figure 3. Time scale as envisioned at present for the completion of the project.

Some preliminary beam optics studies have also been started. This would be taken up more seriously once the prototype tests are over.

V. ACKNOWLEDGMENTS

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