

NIOBIUM QUARTER-WAVE CAVITY FOR THE NEW DELHI BOOSTER LINAC

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Abstract

This paper reports the completion of development of a 97 MHz niobium coaxial quarter-wave cavity to be used in a booster linac for the New Delhi 16UD pelletron electrostatic accelerator. A prototype cavity, which incorporates a niobium-bellows tuning device, has been completed and operated at 4.2 K at accelerating gradients above 4 MV/m for extended periods of time.

1 INTRODUCTION

Several recent heavy-ion booster linac projects employ superconducting quarter-wave coaxial-line (QWCL) resonant cavities [1 - 5]. The QWCL geometry is characterized by excellent mechanical stability and broad velocity acceptance. Also, QWCL resonators made with superconducting niobium have achieved high accelerating gradients [3]. The present project is aimed at developing a high-performance structure based on the QWCL geometry, with the design focussed on reducing construction costs and maximizing operational simplicity and stability. The superconducting accelerating structure discussed here is to be employed in a heavy-ion booster linac for the 16UD pelletron electrostatic accelerator at the Nuclear Science Center in New Delhi, India [6,7].

1.1 Cavity Design

Figure 1 shows the 100 MHz, two-gap resonant cavity which is optimized for particle velocity $\beta = v/c = .08$, but has a broad enough velocity acceptance that a single resonator geometry can be used for the entire booster linac, as presently envisioned [7].

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 both because of the cost of forming and welding the composite material, and also because this cost is further increased by the relatively large number of two-gap cavities required.

The high-voltage end of the coaxial line consists of a relatively large diameter section which capacitively loads the quarter-wave line and shortens the cavity nearly 20 cm. By using a cylindrically symmetric drift tube, large capacitive loading can be obtained while keeping

the peak surface electric field low. This both reduces the size of the resonant cavity and improves mechanical stability, which decreases rapidly with increasing length of the coaxial line. The niobium cavity is closely jacketed in an outer vacuum 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 vacuum and cryogenic vacuum being one common system. Such an arrangement is almost universally used in superconducting heavy-ion linacs, because it facilitates the large number of connections to room temperature required to operate an array of short,

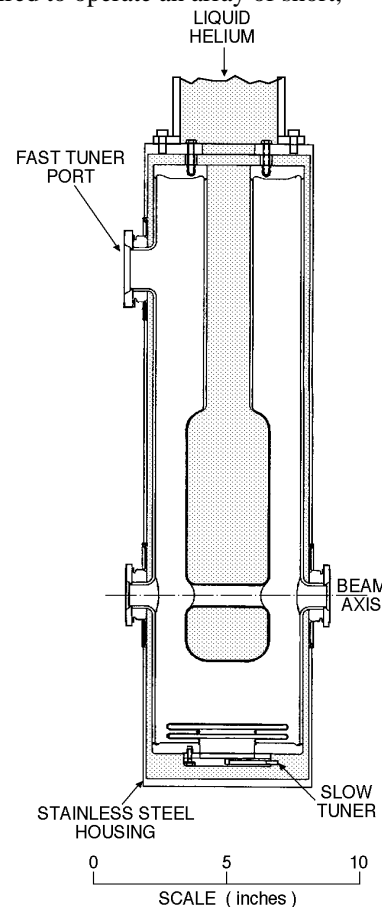


Figure: 1 Schematic figure showing the primary features of the 97 MHz, $\beta = 0.08$ coaxial-line cavity.

2 EXPERIMENTAL RESULTS



Figure 2: Major components of the niobium quarter-wave coaxial-line cavity prior to final weldment. Elements shown are the quarter-wave line and drift-tube, the 6.5 inch OD niobium outer housing and the 7.5 inch OD stainless-steel outer jacket

independently-phased resonant cavities. Where the outer jacket and niobium resonator join, i.e. at all beam ports and coupling ports, a flange made of explosively-bonded niobium and stainless steel is used to provide a welding transition between the two materials.

A pneumatic tuner, shown in Figure 3, is incorporated into the bottom end face of the resonant cavity and consists of a two-section niobium bellows. The end face moves about 2 mm with 1 atm of internal pressure, and provides a tuning range of approximately 70 KHz.

Resonator parameters (at an accelerating gradient of 1 MV/m) are:

Resonant Frequency	97.0 MHz
Synchronous Velocity	0.08 c
Drift Tube Voltage	85 KV
Energy content	.131
Peak Magnetic Field	100 G
Peak Electric Field	3.6 MV/m
Geometric factor QRs	17.3
Active Length	15.9 cm

Extensive cold tests have been performed on a final prototype cavity, which performs as shown in Figure 4. The minimum performance goal of 3 MV/m with 4 watts of rf input at 4.2 K has been substantially exceeded.

Multipacting in the cylindrically symmetric structure, although more severe than in the niobium split-ring and interdigital cavities employed in the current ATLAS accelerator, does not present any novel problems. The multipacting behaviour has been very repeatable. On repeated and numerous cool-downs, the cavity has required rf conditioning, with typically 1 watt of rf input, for a period of 14 to 18 hours in order to completely eliminate multipacting barriers. Under similar conditions, the split-ring and interdigital superconducting cavities employed in the ATLAS accelerator typically require one to five hours of rf conditioning. Although multipacting in the present cylindrically symmetric geometry is appreciably more severe, as manifested by the increased conditioning time, the multipacting does not reappear as long as the cavity temperature is kept below 100 K.

The cavity has been continuously operated at an accelerating gradient of at least 4 MV/m for a period of more than one week and exhibited no appreciable recurrence of multipacting.

The slow tuner bellows assembly has been tested at low temperatures and performs satisfactorily, providing the expected range of motion and causing no observable performance degradation at high field levels. The thermal stability of the slow tuner is excellent, even though it is cooled only by conduction to the main resonator body.



Figure 3: Niobium bellows tuner assembly. The tuner can be pressurized with helium gas and provides a two millimeter range of motion with 0 - 1 atmosphere internal pressure. A 70 kHz tuning range results.

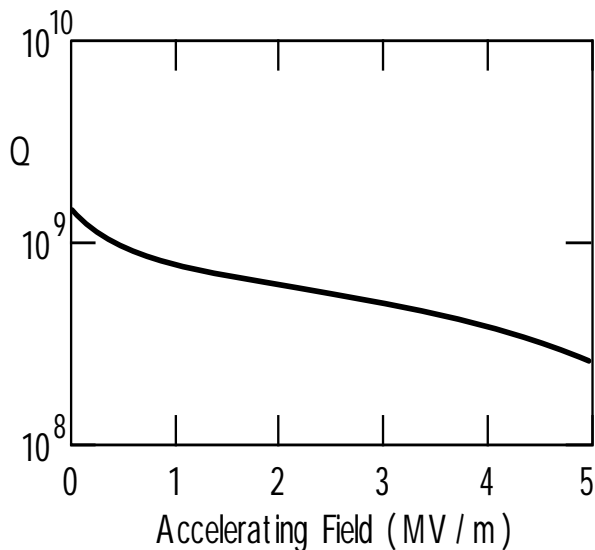


Figure 4: Resonator Q as a function of accelerating gradient at 4.2 k.

Rapidly filling the slow tuner with room temperature helium, a more severe test than would occur in normal operation, caused warming of the bellows above 9.1 K, the niobium transition temperature, for only a few seconds. Within 10-15 seconds the system entirely recovers.

3 CONCLUSIONS

The results described above conclude the development process for the New Delhi linac cavity. Production of an initial ten of an eventual thirty-two

cavities has been initiated, with completion of the initial group expected within two years.

4 ACKNOWLEDGEMENTS

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