QUARTER WAVE COAXIAL LINE CAVITY FOR NEW DELHI LINAC BOOSTER*

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Abstract

The quarter wave coaxial line cavity optimized for the linac booster at Nuclear Science Centre has now undergone several successful cold tests. The accelerating field gradient up to 5 MV/m at 7 Watts RF load has been attained. The novel feature of a pneumatically controlled niobium bellow forming a part of the cavity acting as a slow tuner has been successfully tested. All the design features of the resonator have performed well. Several cavities of this design are now under fabrication.

Introduction

Several laboratories around the world have installed or are in the process of installing superconducting linacs for heavy ions. All of them employ short, independently phased rf accelerating structures which are some variants of either a quarter wave coaxial line(QWCL) [1-5] or a half wave (HWR) [6] cavity resonator. The QWCL geometry is characterized by excellent mechanical stability and broad velocity acceptance. Thus a single resonator geometry would suffice for the entire booster linac since the range of velocities delivered by the 15 UD Pelletron at Nuclear Science Centre(NSC) in mass range A = 12 - 150 lies between 0.05 - 0.12[7]. Also, QWCL resonators made with superconducting niobium have achieved high accelerating gradients [3]. Our design was aimed at developing a high performance structure based on the QWCL geometry, with the design focused on reducing construction costs and maximizing operational simplicity and stability.

Cavity Design

Figure 1 shows the 97 MHz, two-gap resonant cavity which is optimized for particle velocity b = v/c =0.08. This design has a broad enough velocity acceptance, as shown in figure 2, so that a single resonator geometry can be used for the entire booster linac, as presently envisioned [7,8]. The cavity is entirely formed of niobium, rather than bonded niobium-copper composite as is used in the Argonne Tandem-Linac Accelerator System(ATLAS) and several other accelerators. This choice was made 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 capacitatively loads the quarter wave line and shortens the cavity nearly 20 cm. By using a cylindrically symmetric drift tube, large capacitative loading can be obtained while keeping the peak surface 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, 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 metals.

A pneumatic tuner, as shown in figure 1, 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 about 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	0.131 J
Peak Magnetic Field	100 G
Peak Electric Field	3.6 MV/m
Geometry Factor	17.3
Active Length	0.159 m

Experimental Results

Considerable effort was made for improvement in the quality of electron beam welding, specially for the central conductor to base plate weld, since major rf losses were observed in the previous test runs of the resonator [9]. The central conductor length was tuned and welded to the base plate. This welding was done in two steps, first from outside and then from inside, each in partial strength to obtain a smooth weld bead on the inside. Extensive cold tests have been performed on the final prototype cavity. The performance of the cavity at 4.2 K is represented by the Q-curve in figure 3. The minimum performance goal of 3 MV/m with 4 watts of rf input at 4.2 K has been substantially exceeded. This result shows that the design is good and the problems faced earlier were due to the faulty e-beam welding.

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 behavior has been very repeatable. On repeated and numerous cooldowns, 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 a week and exhibited no appreciable recurrence of multipacting.

The appearance of the Q-disease has been observed in this resonator when the resonator was kept for an extended period at 110 K and then cooled down to 4.2 K. The resonator Q improved on warming upto 300 K and then cooling it down rapidly over the temperature range of 150 K to 90 K. The results are shown in figure 4.

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 cooling to the main resonator. Rapidly filling the slow tuner with room temperature helium gas, 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. The system recovered entirely within 10-15 seconds.

Conclusion

The prototype cavity resonator optimized for the booster linac for the 15 UD Pelletron accelerator has been successfully developed. All the design features have been tested to work satisfactorily. The production of the required 35 such cavities have been initiated and the first batch of ten resonators is expected to be ready in two years.

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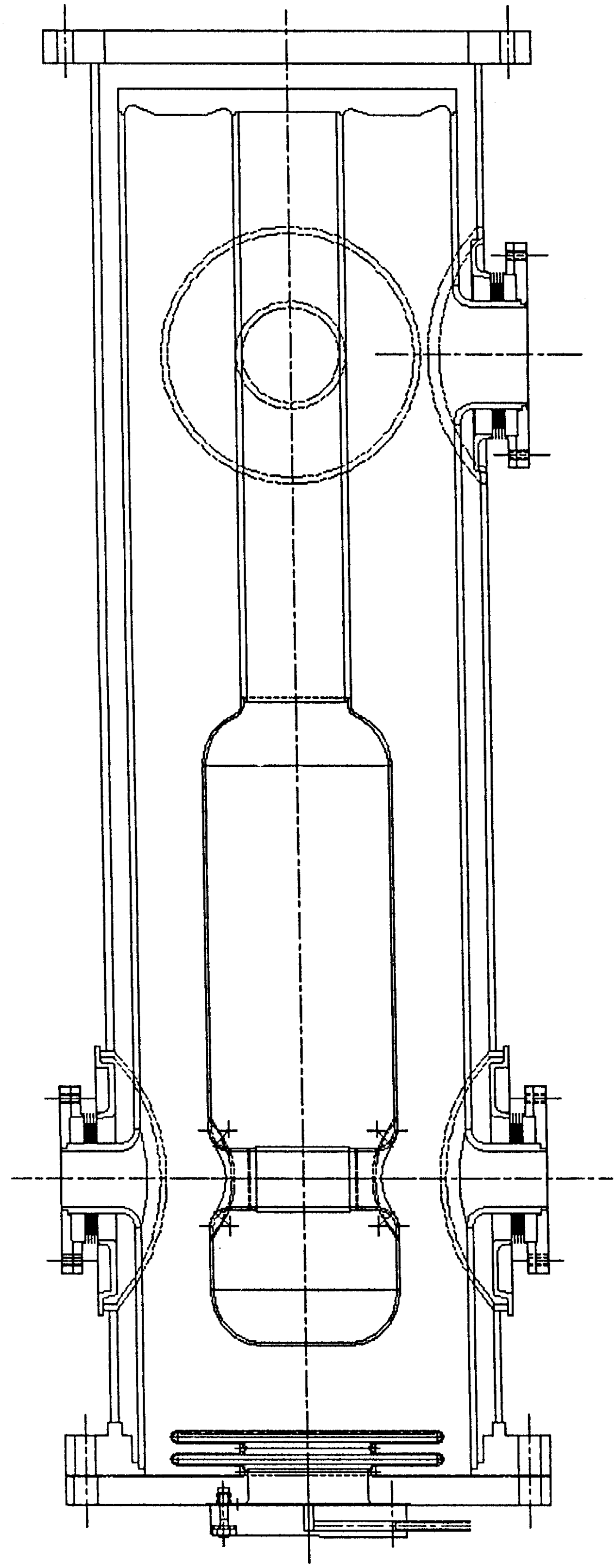

Fig. 1 Sketch of Coaxial line quarter wave cavity for linac booster.

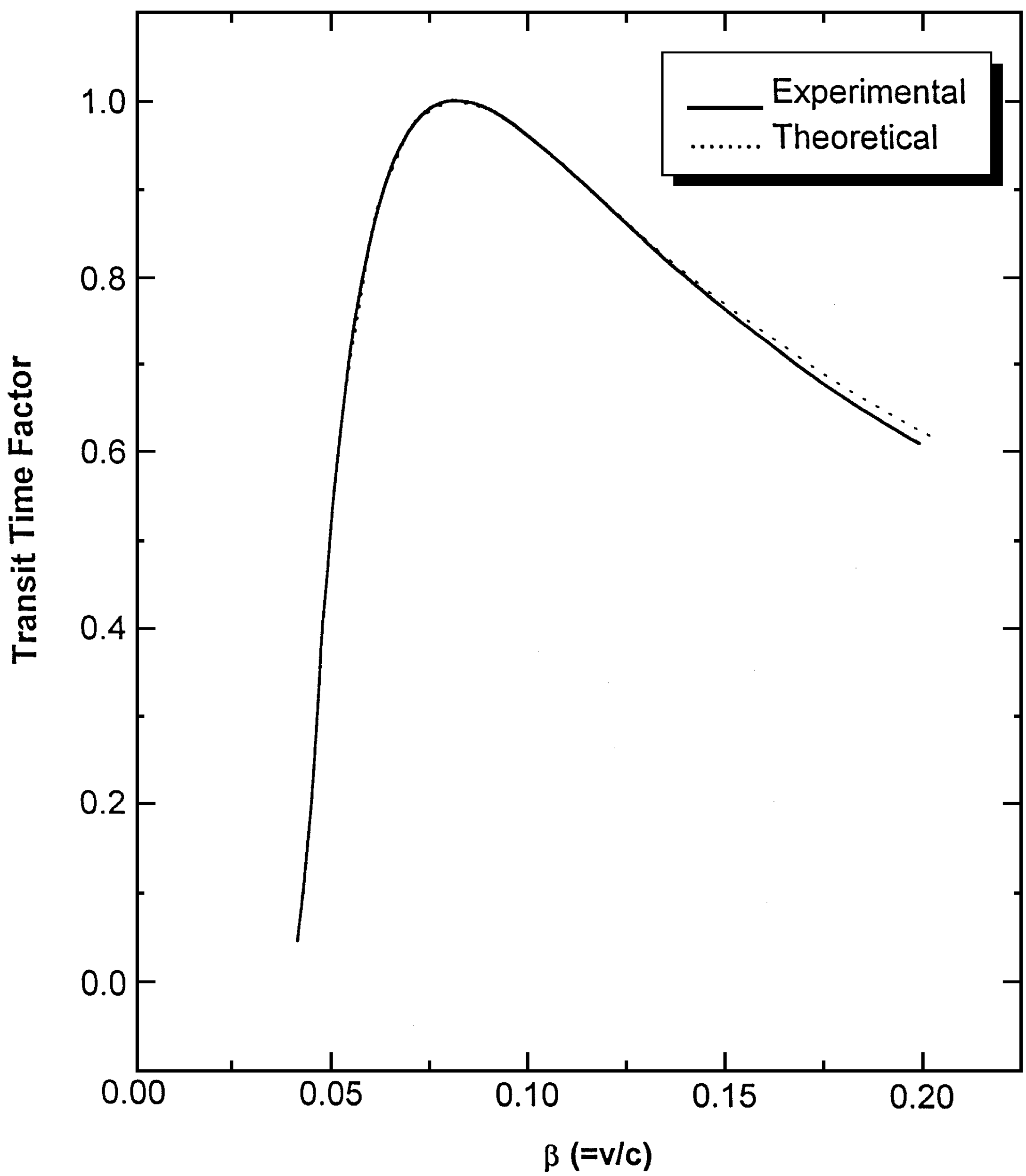

Fig. 2 Transit time factor of the QWCL cavity.

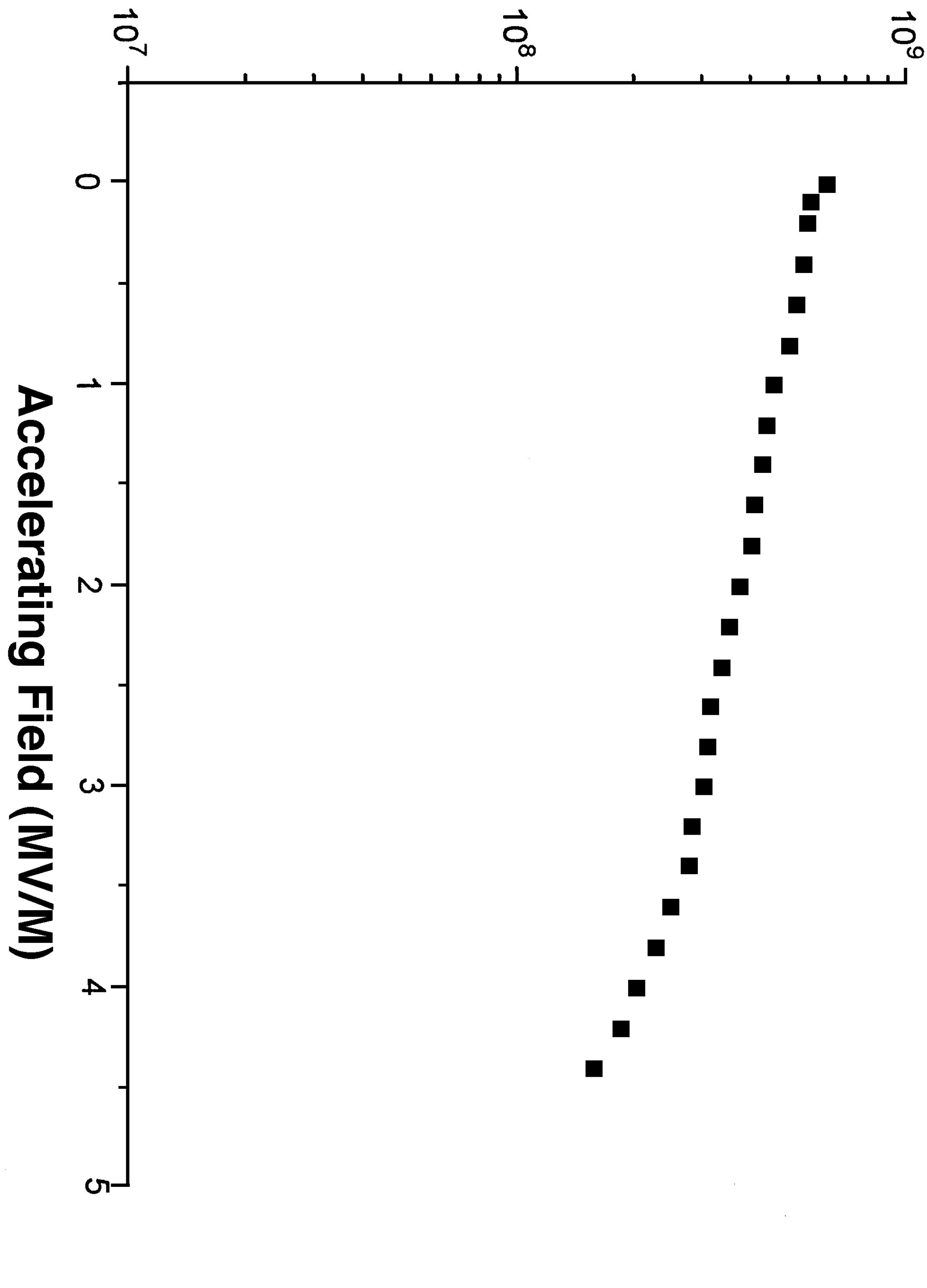

Fig 3 Q curve for the cavity after rf pulse conditioning.

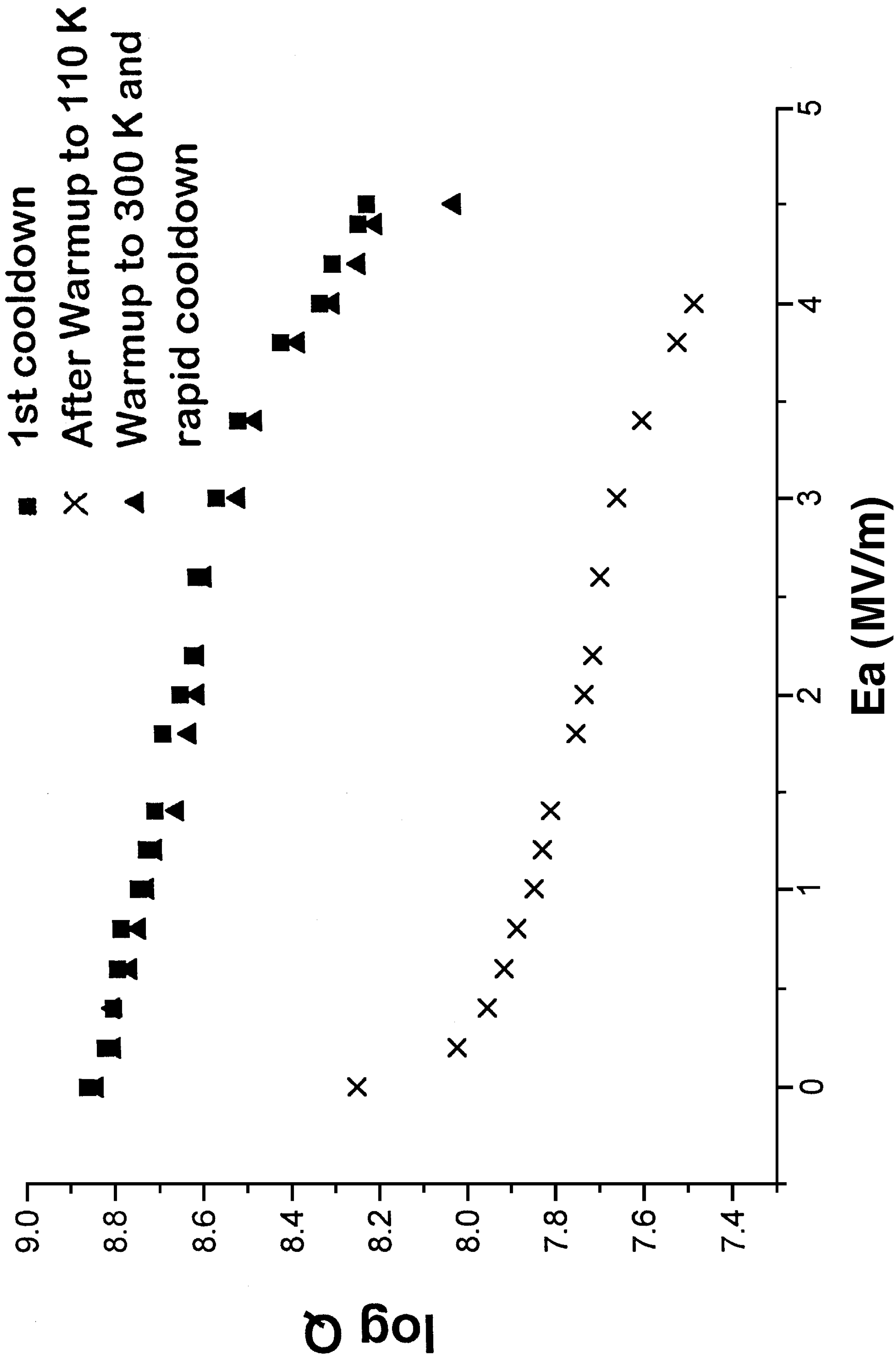

Fig. 4 Q curves for the resonator under quick cooldown and after holding the resonator at 110 K for several hours .