THE SUPERCONDUCTING MEDIUM BETA PROTOTYPE FOR RADIOACTIVE BEAM ACCELERATION AT TRIUMF

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Abstract

A 106.08MHz superconducting quarter wave resonator, based on the bulk niobium technology developed at LNL for low beta heavy ion linacs, has been designed, constructed and tested in a collaboration between INFN-LNL and TRIUMF.

This β=0.072 cavity is the medium β prototype for the superconducting heavy ion linac of ISAC-II, the future extension to the present ISAC radioactive beam facility. The extension will also include β=0.042 and β=0.105 sections. Cavity design characteristics and test results will be reported.

1 INTRODUCTION

The radioactive beam facility ISAC at TRIUMF [1],[2] can produce singly charged exotic ions by means of an ISOL type source and mass-separator. A room temperature linear post-accelerator, consisting of a 35.36 MHZ RFQ and a separated function DTL working at 106.08 MHz was recently commissioned to energies variable between 0.153-1.53 MeV/u for masses A≤30. TRIUMF has recently been funded to construct the ISAC-II upgrade to produce final energies E≥6.5 MeV/u for masses A≤150 to allow experiments above the Coulomb barrier. ISAC-II foresees the construction of a 43 MV superconducting booster of low, medium and high β sections consisting of cavities with β=0.042, 0.072 and 0.0105 respectively. The medium β section will be installed first requiring twenty, two-gap cavities each producing 1MV acceleration assuming a design gradient of 6 MV/m at 7 W.

The design concepts developed at LNL [3,4] for the bulk niobium quarter wave resonators of ALPI and PIAVE have produced cavities with the required performance [5] over a wide range of optimum velocity. TRIUMF chose to follow a similar scheme for its superconducting booster, and a collaboration agreement between INFN and TRIUMF has been set up for the development of the ISAC-II resonator prototypes.

2 CAVITY DESIGN AND CONSTRUCTION

We have designed and constructed a 106.08 MHz, β=0.072 superconducting quarter wave resonator for the radioactive beam facility ISAC-II at TRIUMF. The resonator belongs to the family of the bulk niobium, low beta cavities developed for the ALPI and PIAVE linacs at Legnaro. Their unifying characteristic is that different optimum velocities can be obtained simply by changing the resonator length, keeping all other design characteristics unchanged. Other important properties of these cavities are: the absence of an electronic fast tuner due to the presence of a mechanical damper in the inner conductor [6], the all niobium construction, and a simple machining and welding.

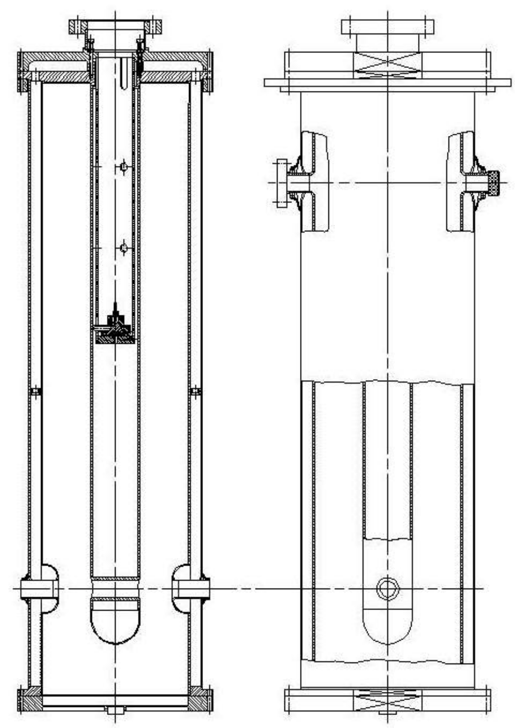

Figure1. The 106.08 MHz, β=0.072 cavity design.

In addition to the length, matched for the required frequency of 106.08 MHz, three slight modifications have been done in comparison to the ALPI type 80 MHz resonator design, i.e.: 1) the top flange was modified in order to increase the frequency stability against helium pressure changes; the stainless steel and the niobium plate on the top of the resonator are now more strongly connected by means of six additional screws near the inner conductor; 2) the top plate design was modified to allow a tube-to-tube, full penetration weld between the plate itself and the outer conductor; this procedure, although not strictly necessary, has lead to a simpler and faster operation and has reduced the risk of a welding accident; 3) instead of a Pb or Nb plated copper plate machined from a thick disk, the tuning plate is made of a 1.2 mm niobium sheet to simplify the construction and the surface treatment.

The cavity design and the rf characteristics are shown in Fig. 1 and in Table 1, respectively.

Frequency	f	106.08	*MHz*
Optimum velocity	β_o	0.072	
Transit time factor at β_o	T_o	0.9	
Stored Energy	U/Ea^2	0.09	*$J/(MV/m)^2$*
Peak magnetic field	Hp/Ea	≈ 100	*G/(MV/m)*
Peak electric field	Ep/Ea	≈ 5	
Geom. Factor $R_s \times Q$	Γ	19.1	*Ω*

Table 1. Cavity rf design characteristics

The mechanical construction proceeded as scheduled and the cavity was delivered by the manufacturer [7] in November 2000. During the following three months the cavity was first tested at room temperature and at 77K at Legnaro, then sent to CERN for the final chemical polishing before returning to Legnaro for rf testing at 4.2K.

Figure 2. The 106.08 MHz prototype before testing.

3 TEST RESULTS

The cavity was first tested at room temperature and at liquid nitrogen temperature, to assess mechanical and rf properties and to verify the good behaviour of the newly designed top flange. The frequency, according to our plans, was slightly higher than the target value, and the final adjustment was obtained by plastic deformation of the cavity in the beam port region.

The thermal contraction after cooling to 77K agreed with the calculated value, and no hysteresis was observed after bringing the resonator back to room temperature. The improved connection between top niobium plate and stainless steel flange reduced by 50% the frequency pressure sensitivity, which is now about 0.9 Hz/mbar. The mechanical damper was optimized at room temperature and required a 37 g load, about half the weight chosen for the ALPI 80 MHz cavities. The dangerous mechanical mode at 85 Hz could be damped by about 20 dB.

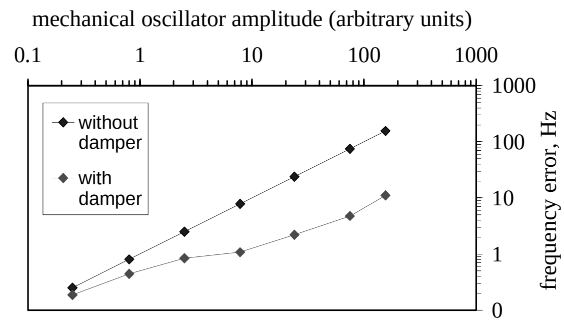

Figure 3. Results of the mechanical stability measurement at room temperature. The lowest mechanical 85 Hz mode was excited by a mechanical oscillator.

The first test in the superconducting regime at 4.2K was done at Legnaro, after final chemical polishing performed at CERN. The multipacting conditioning started at room temperature and it was completed during resonator precooling with liquid nitrogen. Conditioning proceeded without problems and took approximately four hours. After cool down to 4.2 K, the cavity showed significant field emission at about 6 MV/m. Cavity conditioning of one hour at a pulsed rf power of 100 W (the maximum we could have from our amplifier) in a $3*10^{-5}$ mbar Helium atmosphere completely conditioned the cavity and allowed a maximum accelerating gradient of more than 11 MV/m (see Fig. 3). The 7W gradient was 6.7 MV/m.

No problem was observed with the thin niobium tuning plate, and the tuning range was 20 kHz.

The lower mechanical mode frequency at 4.2K was about 89 Hz, not far from the calculated value. In spite of the relatively low overcoupling allowed by our amplifier, the cavity could be locked safely to the ISAC frequency of 106.08 MHz at the design gradient of 6 MV/m.

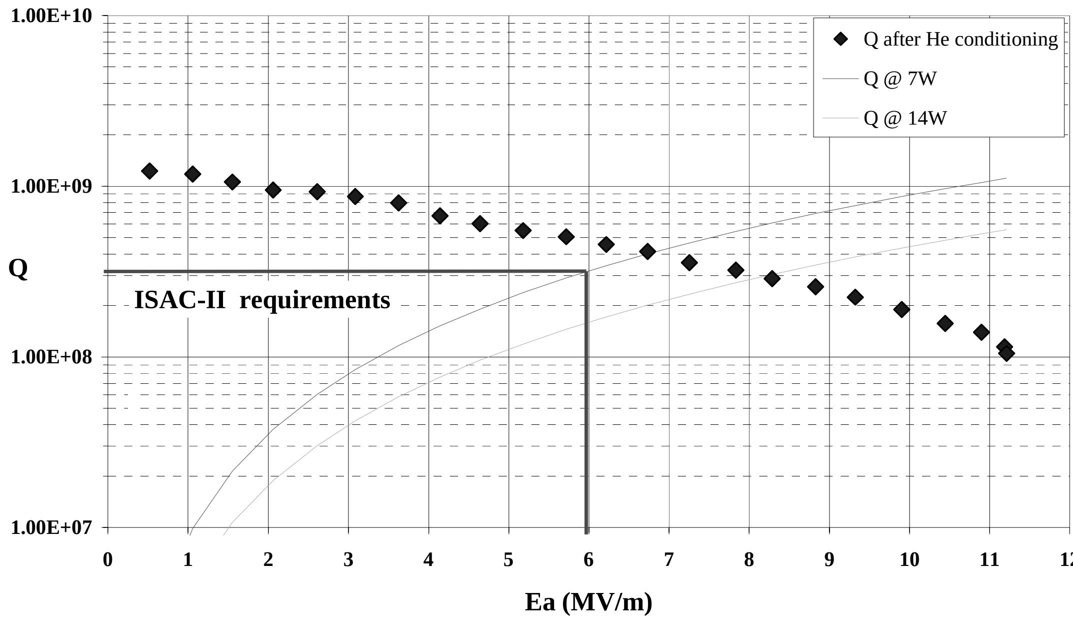

Figure 3. Performance of the ISAC-II medium beta cavity prototype at 4.2 K.

4 CONCLUSIONS

The medium-β cavity prototype of the ISAC-II superconducting linac at TRIUMF was designed, constructed and successfully tested. The cavity more than fulfilled the required specifications, exceeding the design gradient of 6 MV/m at 7W and reaching more than 11 MV/m at maximum power.

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