SUPERCONDUCTING LOW BETA RESONATOR FOR THE HIGH CURRENT INJECTOR AT IUAC

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Abstract

A High Current Injector for the superconducting linac at Inter-University Accelerator Centre (IUAC) is under development. The injector will consist of several accelerating structures including a superconducting low beta module. A niobium resonator, optimized for β=0.050 and operating at 97 MHz, has been designed for the same. Copper model of the resonator has been built and rf measurements have been performed. This paper briefly presents the resonator design and status of the project.

INTRODUCTION

Currently the 15 UD Pelltron accelerator injects heavy ion beams into the superconducting booster linac at IUAC. In order to provide larger beam currents at high charge states, a high current injector (HCI) is being developed, which would work as follows. An ECR ion source will inject the heavy ion beam of A/q=6 at an energy of ~8 keV/n into a room temperature RFQ which would accelerate it to 180 keV/n. The beam would be further accelerated through the DTL section, which will have half a dozen tanks. The expected energy at the end of the DTL section is around 1.5 MeV/n. In order to match the beam properly into the booster linac, a superconducting low beta module is planned after the DTL section. The module will be positioned in such a way that it can accelerate beams from HCI as well as the Pelletron accelerator. The low beta module will contain superconducting niobium resonators. In the following we briefly present details on the low beta resonator design.

LOW β RESONATOR DESIGN

TEM class superconducting niobium resonators are used in linear accelerators for accelerating heavy ions [1]. Several variants of this class of structures have been designed and developed [2]. The two gap quarter wave co-axial line resonator is characterized by its excellent mechanical stability and broad velocity acceptance. It is simpler to fabricate compared to the other structures, although larger number of resonators are required to reach the final beam energy. However, over the past one and a half decades several techniques, especially in post fabrication processing, have been developed to achieve high accelerating gradients in niobium resonators [3]. It is also well known that quarter wave resonators (QWR) achieve higher gradients as compared to, say half wave structures. So, overall the QWR structure offers an excellent choice for the low beta resonator design.

The low beta module will be located in phase-I beam hall where the ceiling height is less than the booster linac vault. The overall height of the resonator is therefore an important parameter. With this in mind we have decided to keep the resonator frequency the same as the booster linac. The electromagnetic parameters were optimized using Microwave Studio [4], which is a 3D electromagnetic simulator based on the finite integration technique. The main goal of the optimization was to reduce the peak magnetic and electric fields while maintaining high values for the shunt impedance and geometric factor. To achieve this, the central coaxial line has been tapered. This has the additional advantage of providing better mechanical stability while reducing electron multipacting. In the next step of the optimization, the diameter of the outer housing was sufficiently increased to increase the shunt impedance and geometric factor. This further reduced the peak magnetic field. For frequency tuning, the resonator will use the existing slow tuner design, which has been well tested and suitably modified for reliable performance. In table 1 the resonator parameters are shown.

Resonance frequency f_0	97 MHz
Synchronous velocity β_0	0.050
Effective length L_{eff}	~11 cm
Stored energy U_0 @ 1 MV/m	26.1 mJ
E_{Peak} @ 1 MV/m gradient	3.4 MV/m
B_{Peak} @ 1 MV/m gradient	62.5 G
Shunt impedance R_{sh}/Q	650 Ω
Geometry factor QR_s	16.1 Ω
Frequency tunability Δf_{ST}	100 kHz

Table 1: Design parameters for the low beta resonator.

The mechanical design of the resonator was studied using ANSYS multiphysics [5] software, which aimed at increasing the mechanical frequency of the lowest mode of the central conductor as high, and as far away from 50 Hz, as possible. At the same time, stiffness of the various components of the resonator were also studied to reduce eigenfrequency shifts from liquid helium induced pressure fluctuations. The resonator would be closely jacketed in an outer stainless steel vessel. Over the past several years many improvements have been made on this clamp-shell design on the existing resonators in the booster linac [6]. It is therefore logical to extend it to the low beta resonator design also so as to benefits from the present experience. In figure 1, the low beta resonator is shown.

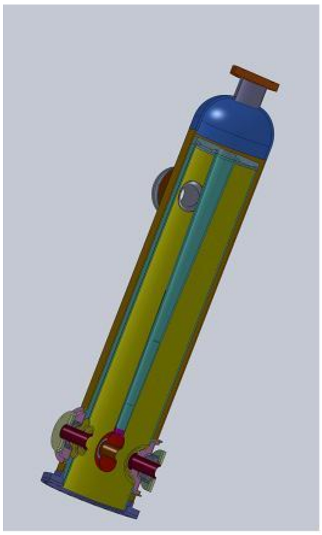

Figure 1: Cut away 3D view of the low beta quarter wave resonator. The overall height is about 85 cm.

In order to validate the electromagnetic parameters of the low beta resonator, a room temperature copper model was built (see figure 2). The copper model was an exact copy of the design except for the drift tube, which was rolled into a cylinder without the rounded corners. This minor change was made because fabricating a drift tube of the actual design required a proper forming die which was not necessary for the bead pull measurements. This change, however, meant that the expected frequency would be slightly lower than the design frequency. Bead pull measurements were performed on the copper model to measure the on-axis electric field profile, stored energy, energy gain, transit time factor and shunt impedance. In addition, the frequency tunability using a mock slow tuner was also measured. In figure 3, the on-axis field profile and transit time factor are shown. In table 2 the various parameters measured on the copper model are shown.

Figure 2: Copper model of the low beta resonator.

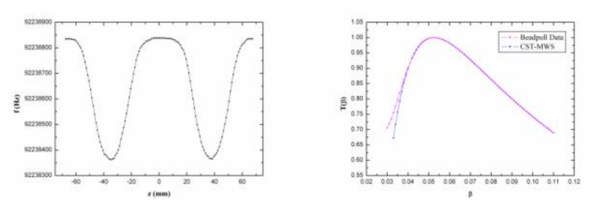

Figure 3: Bead pull (left) and transit time factor (right) measurements on the copper model. The red curve is from the bead pull measurement and the blue curve is from Microwave Studio calculation.

Parameter	Measured value
f_0	92.25 MHz
β_0	0.050
U_0	27 mJ
R_{sh}/Q	658 Ω
V_{Gain} @ 1 J	0.62 MV
Δf_{ST}	110 kHz

Table 2: Parameters from the bead pull and other measurements on the copper model.

PRESENT STATUS

The niobium prototype resonators are presently under fabrication. All the major dies required for forming the components, have been made and trials are underway. The other tooling required for the fabrication is also being developed. We plan to complete the prototype resonator fabrication in the next few months.

ACKNOWLEDGEMENTS

The authors would like to thank K.K. Mistri for his help in fabricating the copper model, R. Mehta with the bead pull setup and measurements, and J. Sacharias with the engineering design of the resonator and in making the drawings.

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