DESIGN, FABRICATION, RF TEST AT 2K OF 1050 MHZ, B=0.49 NIOBIUM SINGLE CELL ELLIPTIC CAVITY FOR HIGH CURRENT PROTON ACCELERATOR

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Abstract

BARC is developing a technology for the accelerator driven subcritical system (ADSS) that will be mainly utilized for the transmutation of nuclear waste and enrichment of U^{233}. Design and development of superconducting medium velocity cavity has been taken up as a part of the ADSS project. The cavity design for β=0.49, f = 1050 MHz has been optimized to minimize the peak electric and magnetic fields, with a goal of 5MV/m of accelerating gradient at a Q > $5x10^9$ at 2K. After the design optimization two single cell cavities were fabricated from polycrystalline (RRR>200) and large grain (RRR>160) Niobium material. The cavities have been tested at 2K in a vertical cryostat at Jefferson Lab. and the results are summarized here.

INTRODUCTION

In the high energy section (> 100 MeV) of ADSS accelerator superconducting elliptical cavity will be used to accelerate protons up to 1 GeV [1]. For this purpose we have studied the RF properties of a β = 0.49, 1050 MHz single cell superconducting elliptical cavity.

CAVITY DESIGN

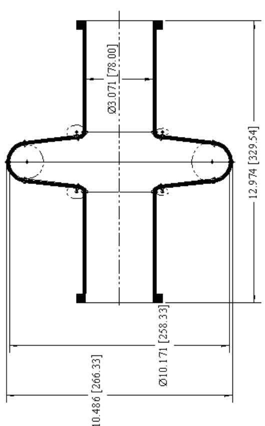

Figure 1: Drawing of the 1050 MHz, β=0.49 cavity.

RF parameters of 1050 MHz, β= 0.49 single cell Elliptical cavity has been optimized by means of 2D cavity tuning code SUPERFISH and 3D High Frequency Simulation code CST Microwave Studio for possible use in High Current Proton Accelerator[2].

A drawing of the single-cell cavity of 1050 MHz, β= 0.49 is shown in Figure 1. The main cavity parameters are summarized in Table -1.

Table 1: 1050 MHz, β = 0.49 Single Cell Cavity Parameters

	Value
Frequency	1050MHz
Geometrical β	0.49
Cavity Diameter	25.833 cm.
Iris Radius	3.9 cm
r/Q	9.162 Ω
G	144.578 Ω
E_{peak}/E_{acc}	4.26
B_{peak}/B_{acc}	8.02 mT/(MV/m)

CAVITY FABRICATION AND PREPARATION

Two prototype single cell Niobium cavities are fabricated with the designed parameters mentioned in Table 1. One of the cavities is made from sheet niobium of RRR > 250 and the other one is made with the large grain niobium of RRR ≥ 96 [3]. The schematic and the parts of the different components of the die are shown in Figure 2 and formed cavities are shown in Figure 3.

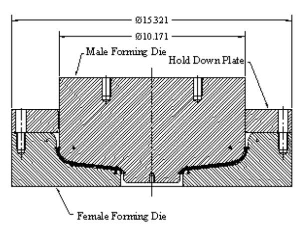

Figure 2(a): Schematic of the 1050 MHz cell forming die

Figure 2(b) : Components

Figure 3(a): Fine grain single cell Niobium Cavity.

Figure 3 (b): Niobium large grain half cells.

RF TEST

Both the cavities are pre processed with the standard cavity preparation for RF test at 2K. The vacuum at 2K was $5X10^{-9}$.

Fine Grain Cavity

The single cell fine grain niobium cavity RF test result of the cavity is shown in Figure-4. As can be seen, the low field Q was1X10^{10}.

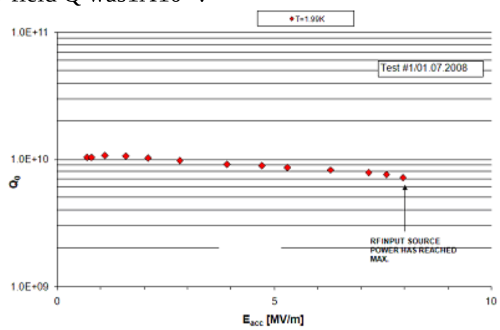

Figure 4: Q vs E_{acc} in TM_{010} mode of 1050 MHz, β = 0.49 fine grain single cell cavity.

The Q_{ext} value for the input and output couplers are 3.28X10^{10} and 2.07X10^{13} respectively. The high power RF test was limited by the input RF power source (15 W). No multipacting or field emission is observed till E_{acc} value 8MV/m.

Large Grain Cavity

Similar test was carried out with the large grain cavity at 2K and at 1.75K .The Figure-5 shows the Q Vs E_{acc} curve. But the cavity was quenching at 6MV/m for both the 2K and 1.75K measurements. This is not unexpected because while doing the BCP on this cavity we found lots of pits in the different locations of the surface in a definite trajectory. So the additional RF losses on those pits might lead to low field quench. The low field (~ 10 mT) surface resistance as a function of the He bath temperature was measured and the data were fitted [8] with the sum of the T-independent residual resistance, R_{res} and the Bardeen-Cooper-Schrieffer(BCS) surface resistance[9].

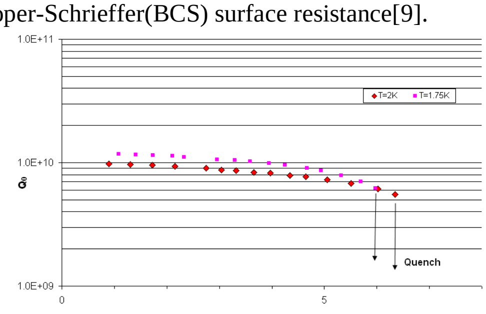

Figure 5: Q vs E_{acc} in TM_{010} mode of 1050 MHz, β = 0.49 large grain single cell cavity.

The critical temperature (*Tc* =9.25 K), coherence length (ξ=39 nm) and the penetration depth at 0 K (λ= 42 nm) are considered material constants for niobium. A plot of R_s as a function of 1/T is shown in Figure 6. The fit parameters show a residual resistance of 11 nΩ, the energy gap of 1.93 and normal electrons mean free path of 132 nm.

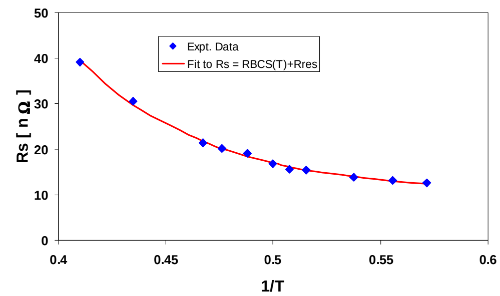

Figure 6: R_s versus 1/T for TM_{010} mode of the cavity. Data points are fitted with BCS theory plus residual resistance (solid lines).

RF power in the cavity produces radiation pressure that act on the cavity wall. These pressures deform the cavity wall and produce a frequency shift which depends quadratically on accelerating field E_{acc}. During the RF test we have measured the frequency variation Δf versus E_{acc} and is shown in Figure 7.

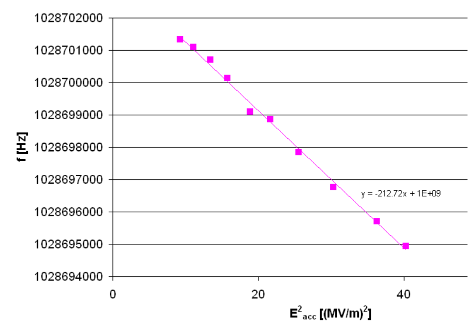

Figure 7: Variation of frequency with E_{acc}^2.

CONCLUSION

Both the cavities have shown an unloaded Q value of 1X10^{10} and well passed the design value of 5MV/m. The large grain cavity was quenching at 6MV/m for 2K and 1.75K measurement. The reasons for that are yet to be understood. The experimental value of Lorentz force detuning coefficient is significantly high and suggests a stiffening ring for multi-cell structure.

REFERENCES

[1] P. Singh et al., Accelerator development in India for ADS programme, Pramana **68** (2007) 331.

[2] "RF Properties of 1050 MHz, β = 0.49 Elliptical cavity for High Current Proton Acceleration" Amitava Roy , J. Mondal, K. C. Mittal, Journal of Instrumentation, 3 P04002, 2008 (IOP Publication).

[3] J. Mondal, G. Ciovati, P. Kneisel, K.C. Mittal, G.R. Myneni, Proc. of the 14th SRF Workshop, dBB Forum, Berlin, Germany, September 2009, Paper THOAAU01.