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200MHz superconducting RF cavity development for RLAs[1]

R.L. Geng*, H. Padamsee*, D. Hartill*, P. Barnes*, J. Sears*,
R. Losito†, E. Chiaveri†, H. Preis† and S. Calatroni†

*LEPP, Cornell University, Ithaca, NY 14853-5001, USA
†CERN, Geneva, Switzerland

Abstract. A 200MHz single-cell superconducting Nb-Cu cavity has been fabricated and tested at 4.2 K and at 2.5 K. The low field Q_0 reached 1.5×10^{10} at 4.2 K. The accelerating gradient (E_{acc}) reached 11 MV/m at a Q_0 of 6×10^8. Two multipacting barriers show up at E_{acc} = 3 and 1 MV/m. Helium processing is effective in reducing field emission and improving accelerating gradients. The Q-drop is observed with a much stronger field dependence as compared to what is expected. Results on the radiation background near the cavity and the external magnetic field effect on the Q of a cold cavity are also reported.

INTRODUCTION

The proposed neutrino factory and muon collider ask for RF cavities operating at a frequency near 200 MHz for rapid acceleration of muons [1]. One scenario is to use superconducting RF cavities [2]. The desired accelerating gradient is at least 15 MV/m at a Q_0 of 6×10^9. Since there is no superconducting RF experience at 200 MHz, R&D in this regime should be started early. Cornell and CERN collaborated to fabricate and test a 200 MHz single-cell elliptical Nb-Cu cavity.

DESIGN AND FABRICATION

The cavity is fabricated with the standard film niobium sputtering technique that has been used for LEP2 cavities. The cell has a length of 750 mm and a major diameter of 1370 mm. The entire cavity, including the 400 mm diameter beam tubes, is nearly 2000 mm long. RF parameters are listed in Table 1.

The two half cells were formed by spinning two 8 mm thick OFE copper sheets. The RF surface was polished electrolytically for a 400 μm surface removal to reduce the imperfections induced by the mechanical process. The cavity was welded with an electron beam from the inside. Further mechanical smoothing has been done by grinding locally all the sharp points of the RF surface. Chemical polishing (SUBU) was performed twice on the whole cavity to remove 20 μm + 20 μm. The deposition was

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TABLE 1. Cavity RF parameters

Parameter	Value	Unit
G	250	Ω
R/Q	121	Ω
E_{pk}/E_{acc}	1.69	-
B_{pk}/E_{acc}	4.34	mT/(MV/m)
$E_{acc}/\sqrt{U}$	0.518	(MV/m)/$\sqrt{J}$

made by using the existing infrastructure developed for LEP2 cavities. The cavity was rinsed at 100 bars with ultra pure water.

PERFORMANCE

The cavity was tested in a vertical dewar fitted in a radiation shielded pit. The pit was lined with sheets of low carbon steel, attenuating the earth magnetic field to 0.2 G in the cavity space. Two multipacting barriers were identified at 3 and 1 MV/m [3], corresponding to first and second order two-point multipacting in the equator region respectively. These barriers were observed consistently during each cavity test and could be surmounted after a few hours of RF processing. Field emission was found to be rather strong during initial cavity tests. Additional high pressure water rinsing was applied and a significant improvement was achieved. Gas helium processing was found to be very effective in attacking field emitters and the accelerating gradient was improved by a factor of two in some cases. The achieved cavity performance is shown in Fig. 1. At 2.5 K, the low field Q reached 2.5×10^{10} and E_{acc} reached 11 MV/m. The cavity itself did not limit us from reaching higher gradients, but the RF coupler did.

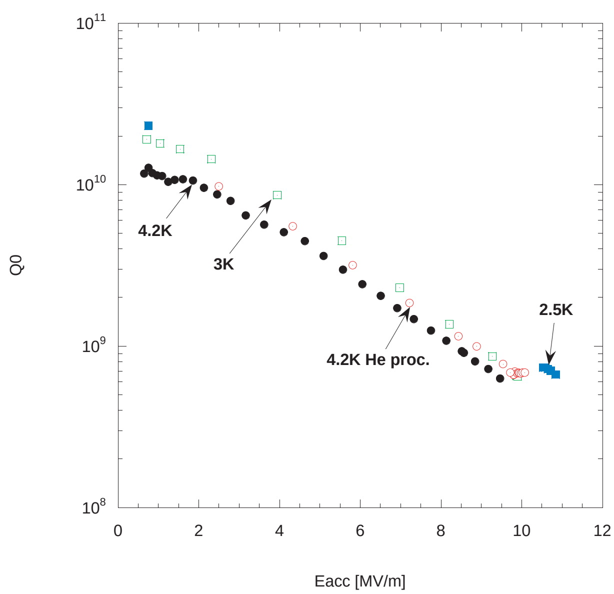

FIGURE 1. Performance of the 200 MHz superconducting Nb-Cu cavity.

The Q-slope (a characteristic of sputtered Nb-Cu cavities) of the 200 MHz Nb-Cu cavity is found to be about 10 times steeper than what is projected from the previous results at other frequencies. The fact that the cavity Q changes as the bath temperature changes (see Fig. 1) indicates that the Q-slope is resulted mainly from the intrinsic property of the niobium film. However, it should be pointed out that field emission remains to be a contributing factor to the Q-slope, even after helium processing.

RADIATION BACKGROUND

The radiation in the test pit is generated in the form of Bremsstrahlung x-rays when field emission or multipacting electrons hit the cavity wall. Measurements were made by a γ probe and a NaI detector on the top plate of the dewar. The detectors are roughly aligned with the cavity axis to allow the best detection of high energy γ's generated by electrons accelerated by the full cavity voltage. Fig. 2 shows the gradient dependence of the dose rate. The peak near 3 MV/m is a result of multipacting which generates a large number of low energy electrons. Above 4 MV/m, the radiation is mainly due to field emission electrons originated from the iris of the cavity and its field dependence fits very well into the modified Fowler-Nordheim theory. The field enhancement factor β is found to be in the range of 600 - 900.

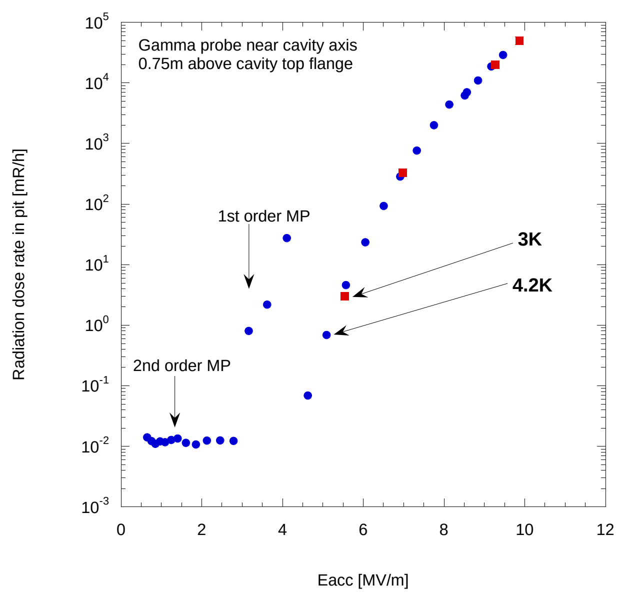

FIGURE 2. γ radiation near the 200 MHz superconducting cavity.

The energy of γ rays shows a low energy peak below 1 MeV. This can be attributed to the Compton effect when photons go through the cavity wall and the top plate of the dewar. The end point energy of the spectrum corresponds reasonably well to the full voltage of the cavity. No neutron radiation was detected at the highest achieved accelerating gradient.

EFFECT OF EXTERNAL MAGNETIC FIELDS

The envision of fitting a strong solenoid and a cavity into one cryostat motivated the study of the external magnetic field effect on a cold cavity. A rather simple configuration was adopted, in which a superconducting coil (the end face diameter being 40 mm) was installed against the cavity equator. The cavity was cooled down prior to turning on the magnet. As shown in Fig. 3, the cavity is not affected by an external magnetic field of $\leq$ 1200 Oe. Above 1200 Oe, a non-reversible power loss due to the external field is observed. These results are consistent with the fact that niobium is a type-II superconductor with its H_{c1} being close to 1200 Oe at 4.2 K.

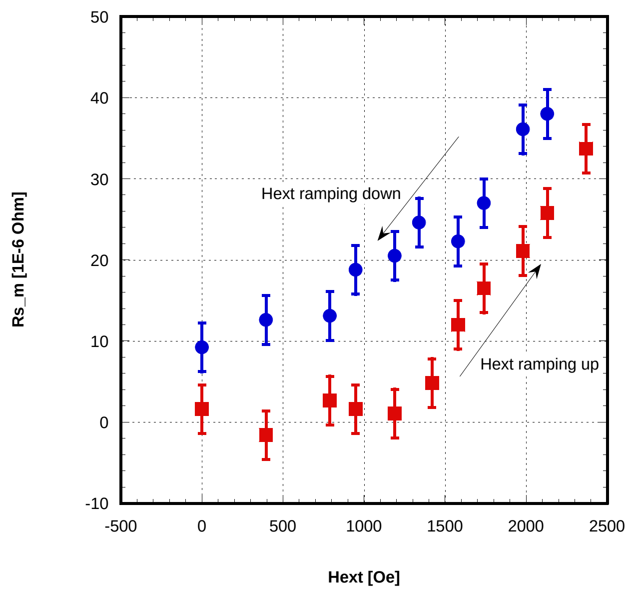

FIGURE 3. External magnetic field effect on the additional surface resistance of the 200 MHz cavity. The cavity is cooled down to superconducting prior to turning on the magnetic field.

CONCLUSION

The first 200 MHz superconducting elliptical cavity was successfully fabricated and tested. The accelerating gradient reached 11 MV/m. The low field Q reached 2×10^{10} at 2.5 K. The film is not responsible for the gradient limitation, but is responsible for a strong Q-drop, for which further work is needed.

REFERENCES

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