Field Flatness Tuning of Five-Cell SRF Elliptical Cavity

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1. Introduction

A basic study on the superconducting radio frequency (SRF) cavity with a geometrical beta of 0.42 has been performed for an extension of Proton Engineering Frontier Project (PEFP) [1]. As a prototype of the PEFP SRF cavity, a five-cell niobium cavity with the elliptical shape has been designed and fabricated as shown in Fig. 1. The major parameters of the developed cavity are like followings [2].

- Frequency:	700 MHz
- Operating mode:	TM010 pi mode
- Cavity type:	Elliptical
- Geometrical beta:	0.42
- Number of cells:	2
- Accelerating gradient:	8 MV/m
- Epeak/Eacc:	4.106
- Bpeak/Eacc:	8.28 mT/(MV/m)
- R/Q:	32.57 ohm
- Epeak:	32.85 MV/m (1.34 Kilp.)
- Geometrical factor:	124.58 ohm
- Cavity wall thickness:	4.3 mm
- Stiffening structure:	Double ring

Figure 1. Fabricated SRF cavity for PEFP

Before RF test in low temperature, we performed the field flatness tuning to make the field distribution in the cavity uniform along the beam axis. In general, the field distribution in the cavity is irregular because of several factors such as mechanical deformation during the cavity fabrication, the shrinkage due to the electron beam welding and so on. The field flatness in a multi-cell SRF cavity affects not only the net accelerating voltage but also the peak surface field, the Lorentz detuning effect and the coupling of the couplers. Therefore, the field distribution should be corrected after cavity fabrication. In this study, the field distribution was measured by using a bead-pull method and the field flatness tuning was performed by using first order perturbation theory based on the work done by Padamsee et al [3].

2. Field Flatness Tuning Setup

2.1 Tuning Principle

A uniform field distribution in the multi-cell cavity can be achieved by changing the individual cell frequency. A pair of cell jaws is used to stretch or squeeze the cell. Cell frequency can be decreased by squeezing the cell and increased by stretching the cell as shown in Fig. 2. The frequency change in a cell affects the field distribution, which can be estimated by using a perturbation theory [3].

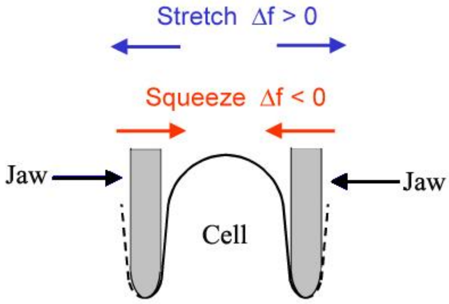

Figure 2. Tuning principle of multi-cell cavity

2.2 Warm tuner

To make the mechanical deformation required for tuning, we prepared a warm tuner as shown in Fig. 3. The warm tuner consists of a pair of jaw-carriage, two tailstocks to hold the cavity, a drive wheel to move the carriage and a supporting frame.

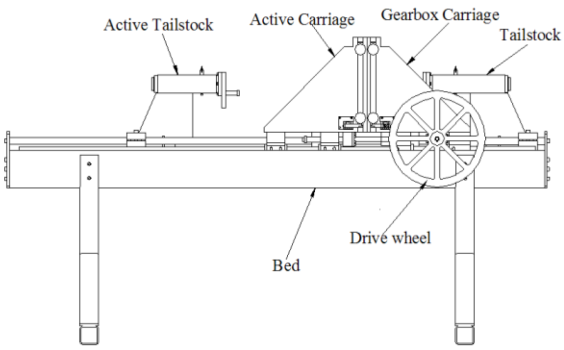

Figure 3. Warm tuner for cavity tuning

The field profile can be measured by using a bead-pull method based on the Slater's perturbation theory. For beam-pull measurement, we attached the stepping motor and several wheels to move a small metal bead through the cavity. The overall setup is shown in Fig. 4.

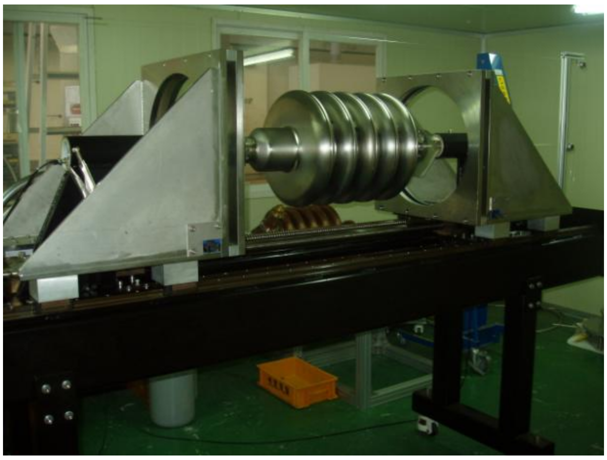

Figure 4. Overall setup for field flatness tuning

3. Results and Conclusions

The initial field measurement result is shown in Fig. 5. As can be seen from Fig. 5, the field distribution is far from uniform. The fields in a 4th and 5th cell are almost negligible compared with 1st cell field. Before applying the perturbation theory, we performed manual tuning based on the fact that the local field is increased by increasing the local frequency (stretching the cell) and vice versa. By manual tuning, we obtained a field distribution better than initial profile as shown in Fig. 6. Following the manual tuning, we applied the perturbation theory and obtained almost uniform field distribution after twice iterations. The final measurement result is shown in Fig. 7 and the normalized field distribution is summarized in Table 1. The final field flatness is uniform within ±4%, which good enough considering the requirement is about 8%.

Table 1. Normalized field in each cell after tuning

Cell Number	Normalized Field [%]
1	99.1
2	102.4
3	101.0
4	101.2
5	96.2

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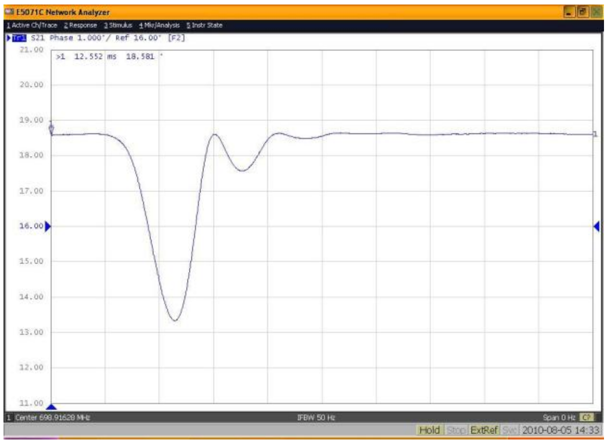

Figure 5. Initial field distribution

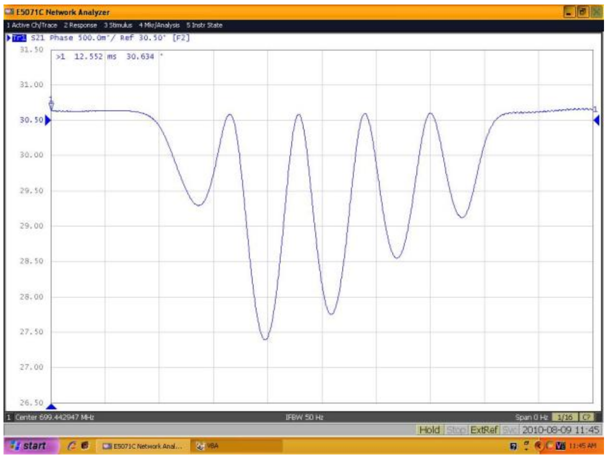

Figure 6. Field distribution after manual tuning

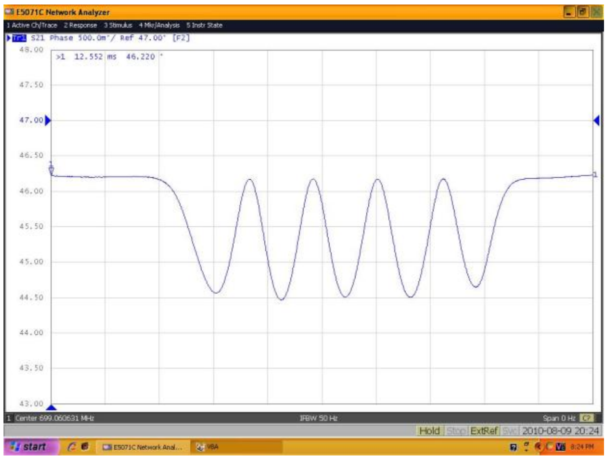

Figure 7. Final field distribution after tuning