FABRICATION AND FINAL FIELD TUNING OF COPPER CAVITY MODELS FOR A HIGH-CURRENT SRF ERL AT 703.75 MHZ

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Abstract

Advanced Energy Systems is currently under contract to BNL to fabricate a five cell superconducting cavity and cryomodule for the RHIC eCooler SRF Energy Recovery Linac (ERL) program[1,2]. The cavity is designed and optimized for ampere class SRF ERL service. As part of this program, we have fabricated two low power copper models of the RF cavities. During the fabrication process a series of frequency measurements were made and compared to the frequency expected at that point in the fabrication process. Where possible, the cavity was modified either before or during, the next fabrication step to tune the cavity frequency toward the target frequency. Following completion of the cavities they were tuned for field flatness and frequency. This paper will review the measurements made, frequency tuning performed, and discuss discrepancies between the expected and measured results. We will also review the as fabricated field profiles and the results of the tuning steps. Further, the cost and benefits of extensive in process tuning will be discussed from an industrial perspective.

INTRODUCTION

Advanced Energy Systems is currently under contract to BNL to fabricate a five cell superconducting cavity and cryomodule for the RHIC eCooler SRF Energy Recovery Linac (ERL) program [1,2]. We have fabricated two low power copper models of the RF cavities which will be used by BNL for a variety of tasks including HOM measurements and evaluating configurations of a two-cavity string. AES was responsible delivering the cavities tuned for the correct frequency and field.

IN PROCESS TUNING OPERATIONS

Fabrication of the copper cavities consisted of a series of forming, machining, and welding operations. Interspersed with these operations were several sets of frequency measurements. In some cases frequency adjustments were made to the cavities during the machining operations.

Half-Cell Measurement and Pairing

Following forming of the half-cells and machining of the iris weld preps, the frequency of each of the mid and end half-cells was measured. Half-cell frequencies were compared to a target frequency calculated by modeling the individual half-cell part in SUPERFISH as it would be measured. The frequencies of the mid half-cells were used to select a pairing scheme for the welding of the half-cells into dog-bones. The pairing was arranged to match the half-cell frequencies as closely as possible so that during the dog-bone tuning operation each side of the dog-bone could be cut equally.

Dog-bone Measurement and Tuning

The frequency of each of the pre-welded dog-bones was measured prior to the iris weld. Pre-weld dog-bone frequencies were compared to a target frequency calculated by modeling the pre-weld dog-bone part in SUPERFISH as it would be measured. After the iris weld the frequency was again measured and compared to the target frequency calculated by modeling the finished dog-bone part in SUPERFISH. The dog-bones were tuned to correct any measured frequency errors by adjusting the cell length at the equator. This operation was performed during the equator weld prep machining operation.

End Cell Measurement and Tuning

Following completion of the end group/end half-cell assemblies, the frequencies were measured and compared to target frequencies calculated by modeling the parts in SUPERFISH. The end half-cells were tuned to correct any measured frequency errors by adjusting the cell length at the equator. This operation was performed during the equator weld prep machining operation.

MEASUREMENT RESULTS AND TUNING OF THE COMPLETED CAVITIES

Cavity 1 Frequency Measurement and Results

Following completion of fabrication of the first cavity a series of frequency measurements were performed the results of which are shown in tables 1 and 2. The π mode frequency was within the specified range and no frequency adjustment was required.

Table 1: Cavity 1 as built mode measurements.

Mode	Lab Frequency	Freq (70F,no air)
0	683.390 MHz	683.621 MHz
1	688.530 MHz	688.761 MHz
2	696.188 MHz	696.421 MHz
3	700.548 MHz	700.782 MHz
4 (π mode)	702.655 MHz	702.890 MHz

Table 2: Cavity 1 as built π mode detailed results.

Lab Frequency	702.650 MHz
Frequency (70F, no air)	702.885 MHz
Frequency (2K, no air)	703.920 MHz
SUPERFISH Frequency	703.781 MHz
π Mode Frequency Error	000.139 MHz

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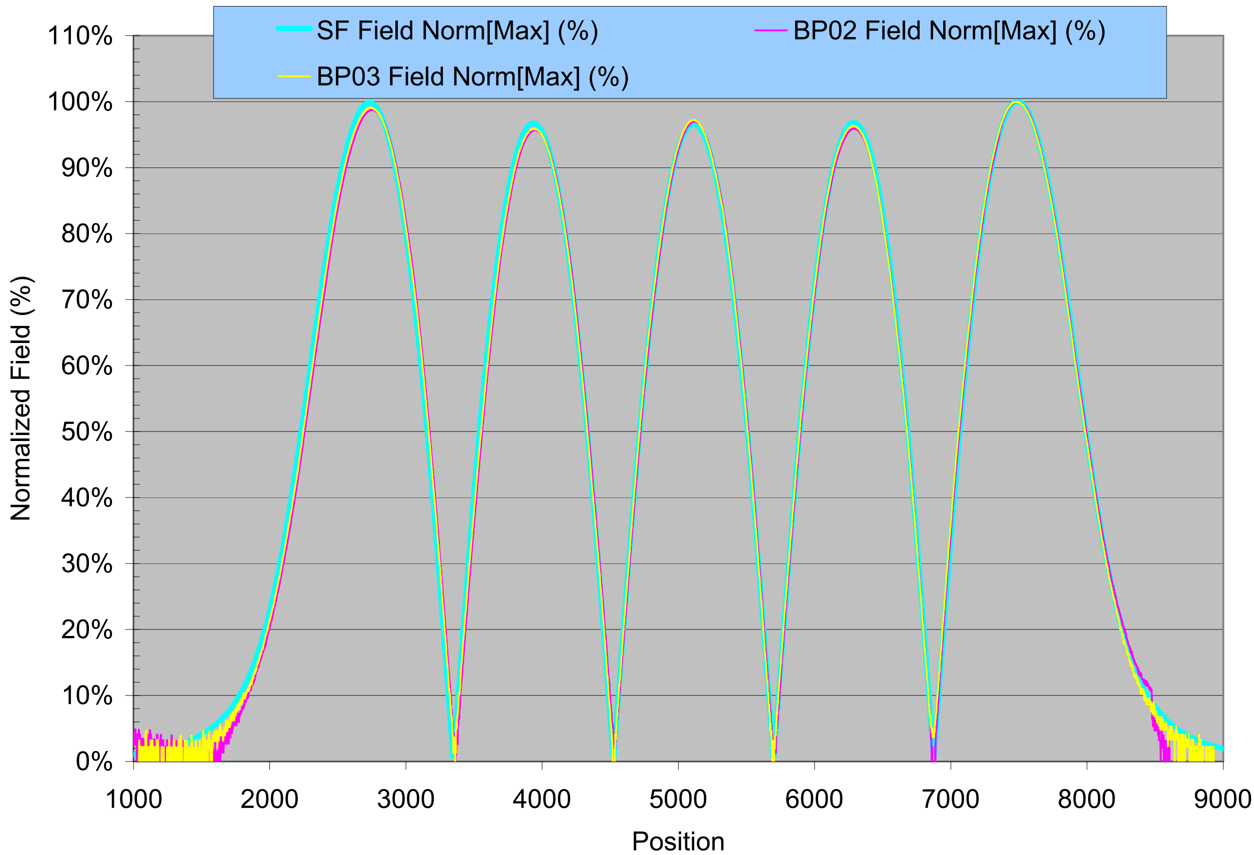

Figure 1: Beadpull results cavity 1 showing data for two beadpull measurements (BP02, & BP03) as compared to the field profile predicted by SUPERFISH (SF). (All point normalized to the maximum field.)

Cavity 1 Beadpull Results

Field profile measurements were performed using a beadpull. The results of two beadpull measurements are shown in figure 1 and compared with the field profile calculated with SUPERFISH. Agreement with SUPERFISH was observed to within ±0.5%, no field tuning was required.

Cavity 2 Frequency Measurement and Results

Tables 3 and 4 show results of frequency measurements for the second cavity. The π mode frequency was within the specified range and no frequency adjustment required.

Table 3: Cavity 2 as built mode measurements.

Mode	Lab Frequency	Freq (70F,no air)
0	683.501 MHz	683.753 MHz
1	688.543 MHz	688.797 MHz
2	695.203 MHz	695.459 MHz
3	700.423 MHz	700.681 MHz
4 (π mode)	702.626 MHz	702.885 MHz

Table 4: Cavity 2 as built π mode detailed results.

Lab Frequency	702.628 MHz
Frequency (70F, no air)	702.887 MHz
Frequency (2K, no air)	703.905 MHz
SUPERFISH Frequency	703.781 MHz
π Mode Frequency Error	000.124 MHz

Cavity 2 Beadpull Results

Field profile measurements were again performed using a beadpull. For cavity 2 however, the fields were tilted by 13.4%, field tuning was therefore required

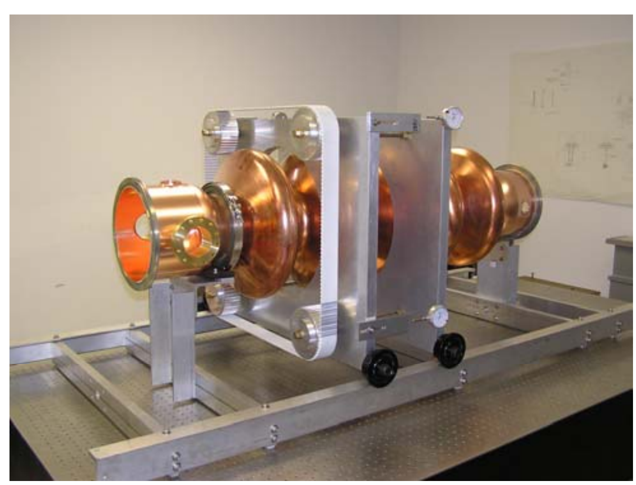

Figure 2: Cavity tuning fixture with cavity installed.

Field Tuning Procedure

Field tuning was accomplished by adjusting the individual cell frequencies. Deforming the cells in a

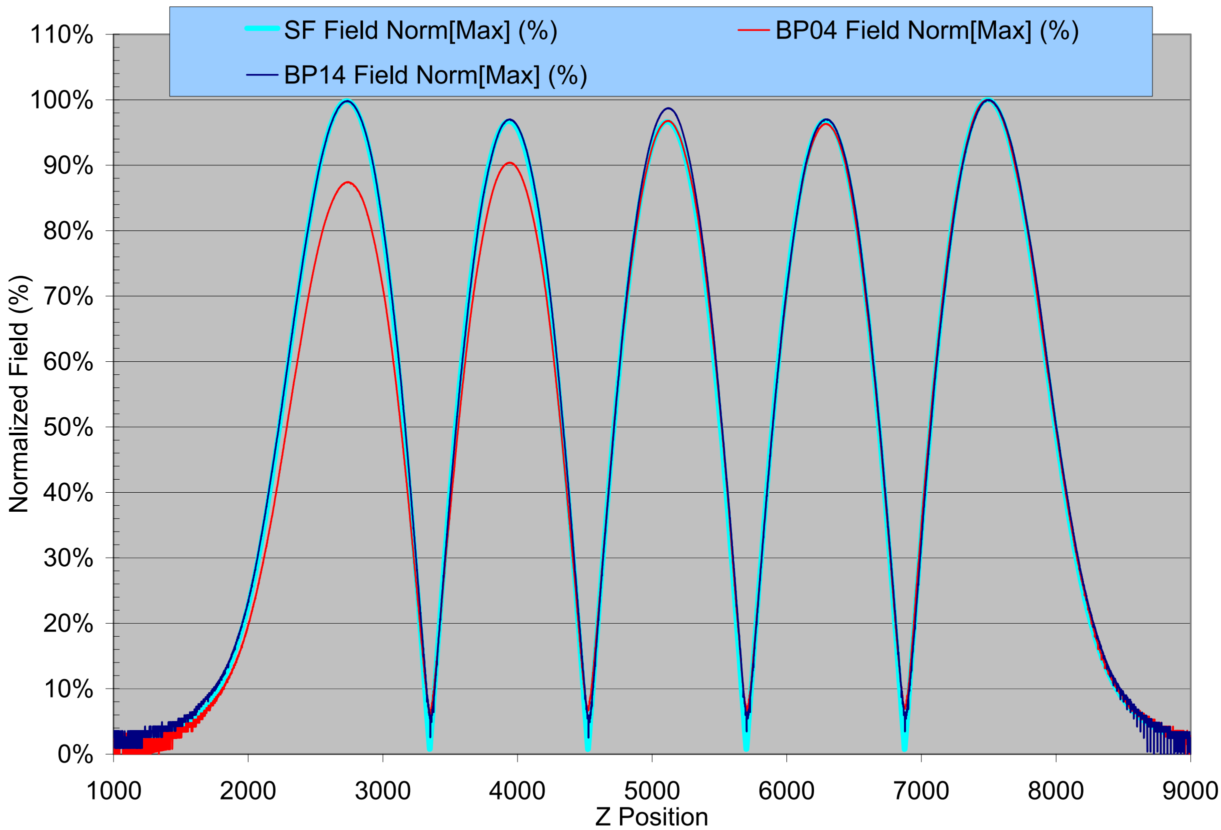

Figure 3: Beadpull results for cavity 1 for measurements before (BP04) and after (BP14) tuning as compared to the field profile predicted by SUPERFISH (SF). (All point normalized to the maximum field.)

tuning fixture caused the cell frequency adjustment. This fixture and the cavity are shown in figure 2.

Field Tuning Results

Results of the field tuning operation are shown in figure 3. Field profiles before tuning, after tuning, and calculated by SUPERFISH are shown. After tuning agreement with SUPERFISH was observed to within ±1.1%

Final Frequency Results

Tables 5 and 6 show results of frequency measurements for the second cavity following field tuning. The π mode frequency was kept within the specified range.

Table 5: Cavity 2 mode measurements following tuning.

Mode	Lab Frequency	Freq (70F,no air)
0	683.454 MHz	683.705 MHz
1	688.594 MHz	688.847 MHz
2	695.251 MHz	695.507 MHz
3	700.561 MHz	700.819 MHz
4 (π mode)	702.656 MHz	702.915 MHz

Table 6: Cavity 2 π mode detailed results following tuning.

Lab Frequency	702.661 MHz
Frequency (70F, no air)	702.920 MHz
Frequency (2K, no air)	703.934 MHz
SUPERFISH Frequency	703.781 MHz
π Mode Frequency Error	000.153 MHz

CONCLUSION

Fabrication, frequency tuning, and field tuning of two copper low power test cavities has been completed. The first cavity met all frequency and field specifications in the as-built condition, no tuning following the last welding step was required. The second cavity required tuning of the field profile but was within spec on the frequency. In process measurements and tuning consisted of half-cell frequency measurements and a tuning operation on the cell equators following the iris welds. The equator tuning step was included in the machining of the weld preparations. As long as these preparations are required this is an easy stage at which a tune operation can be added.

REFERENCES

[1] Extremely High Current, High-Brightness Energy Recovery Linac, Ilan Ben-Zvi, These Proceedings
[2] High Current Energy Recovery Linac at BNL, Vladimir N. Litvinenko, These Proceedings

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