TUNING SUMMARY FOR THE 805 MHZ SIDE-COUPLED CAVITIES IN THE FERMILAB LINAC UPGRADE

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Abstract

Improved methods of manufacture and tuning were developed for Side-Coupled Accelerator Structures (SCS) for the Fermilab Linac Upgrade. With available CNC machines and numerical calculation programs, it was possible to machine cavities to a calculated shape with predictable accuracy. Minimal tuning was required after brazing. This paper summarizes the parameters measured at certain steps of the manufacturing process.

Introduction

Twenty-eight accelerating sections were manufactured for the Fermilab Linac Upgrade. The Sixteen accelerating cells of each section are of equal ß. The ß, hence length of accelerating cell increases for each section. Accelerating cells are connected via coupling slots through a coupling cell. Four sections, connected with bridge couplers, are mounted on a single girder. Each Girder, powered by a kystron, constitutes one of seven modules that will accelerate Linac beam from 116 Mev to 400 Mev. Also, there is a 16 cell and a 4 cell matching section at 116 Mev and a 4 cell debuncher at 400 Mev, a total of 31 sections. Accelerating cell spacing CL= $\beta\lambda/2$ which is the half RF wavelength spacing varies from 3.349 to 5.233 cm over the range of accelerating sections.

In each section all accelerating cells, coupling cells and slots are the same. End accelerating cells are terminated with a bridge coupler cell at both ends or a bridge coupler cell and terminating cell at each end. All internal segments are identical accelerating half cells.

A slot in the accelerating cells with the coupling cell brazed on the outside diameter provides coupling from one accelerating cell to the next. The coupling constant k1 is adjusted by depth of the slot (determined by the center to center spacing between the accelerating and coupling cavities). Mechanical considerations for the structure fabrication are detailed in Ref. 1

A standard five parameter model is used to describe the dispersion of the field modes in the passband. An adequate model description is given in Ref. 2. Final tuning of the structure makes use of the fact that all accelerating cells are tuned to a frequency $\omega 1$ and all side coupling cells are tuned to a frequency $\omega 2$. Three coupling constants, K1,K2,and K3 complete the model. Because of the existance of probes and shorts when actually measuring the cells, the frequencies are not the same as the values calculated by the dispersion equation. Details of the tuning procedures have been covered in Ref. 3&4.

This paper considers only the section tuning. Tuning of the completed module consisting of four sections and three bridge couplers is covered in Ref.5&6.

SUPERFISH (SF) Frequency

Prior to slotting the half cell segments they are tuned to a SF Goal frequency considerably higher that the operating 805 MHz. The mechanics of the coupling slot and a second coupling constant K2 lower the SF frequency to slightly below 805 MHz. Initially the correct SF frequency was determined by making aluminum models of segments at several modules. Initial values for SF Goal were determined by a curve fit of the models. As production proceded corrections were made to continuously update the SF Goal curve. Fig. 1 is a plot of SF Goal and the manufactured SF average frequency as a function of the cell spacing CL. The discontinuity in the curve at 4.400 cm (section 4-1) is a result of adjusting the nominal center to center spacing of the coupling and accelerating cells from 7.264 to 7.188 inches. this was done because the coupling constant K1, measured after slotting to the desired frequency, was drifting downward with increasing cell length, Fig.2.

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Stacking Order

High and low frequency half cells are paired in a stacking order to best equalize the interior accelerating cells. The goal was to have frequencies within ± 30 KHz. Fig.3 shows the Min-Max spread of the half cells before stacking and full cells after they were stacked in pairs.

Slotting

The coupling slot was made using a cutter arc identical to the inside radius of the coupling cell. The depth of the slot determines both the coupling K1 and the final frequency of the stacked cells. Once the SF frequency was machined, the final frequency and coupling K1 were not independent of each other. The target $\pi/2$ frequency for the section was 804.900 MHz. This allowed sufficient range to raise all cells while equalizing their frequencies as the section was tuned to 805.000 MHz. The $\pi/2$ frequency before and after brazing and after tuning are shown in Fig.4. Values of K1 were previously shown in Fig. 2.

Stop Band

The stop band was adjusted high for stability and because the coupling cells shift down in frequency under vacuum. An additional slow drift of the coupling cells is expected over time. Fig.5 shows the stop band at atmospheric pressure and at vacuum. All measurements are corrected for vacuum at 25 Deg.C. The difference in the two curves is attributed to the mechanical deflection of the coupling cells under vacuum.

Dispersion Parameters

After tuning the sections, all modes were measured and the five parameters of our model were calculated. $\omega 1$ and $\omega 2$ are plotted in Fig. 6. K1, K2 and K3 are plotted in Fig. 7.

Conclusions

A rather straight forward method of tuning and fabricating Side Coupled Sections was developed. By constant comparing of manufactured parts with models and adjusting SF frequencies as production progressed desired tuning and coupling could be controlled. Production did not require measurments at the machining location and so several vendors could be manufacturing parts at the same time. Stacked and measured parts could be shipped across country and brazed with little shift in the structure tuning.

References

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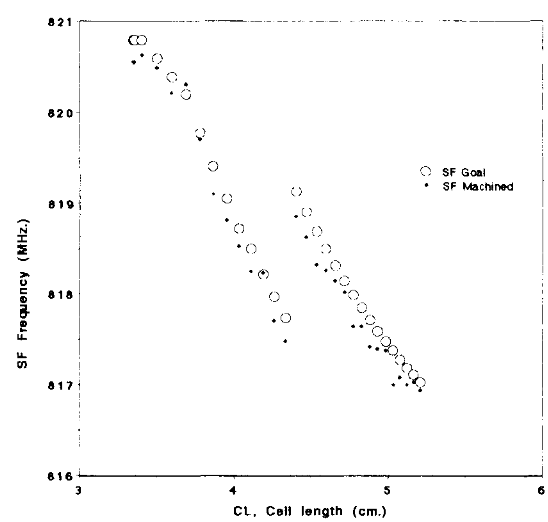

Fig. 1. Comparison of SF Goal and Machined Frequency

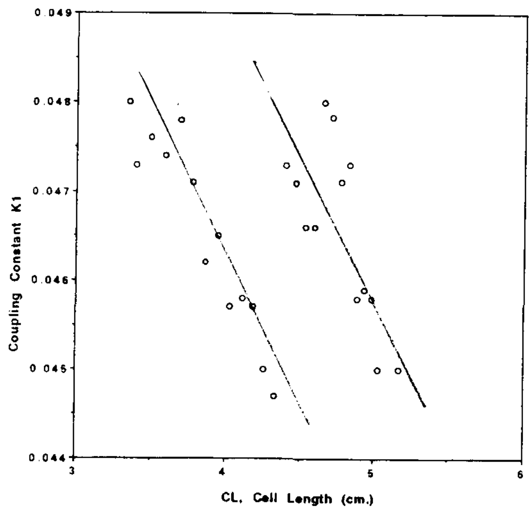

Fig. 2. Production Coupling K1 Vs CL

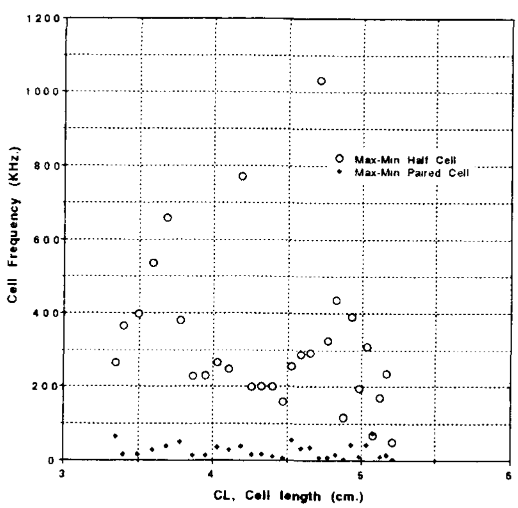

Fig. 3. As Machined Cell Frequency Spread

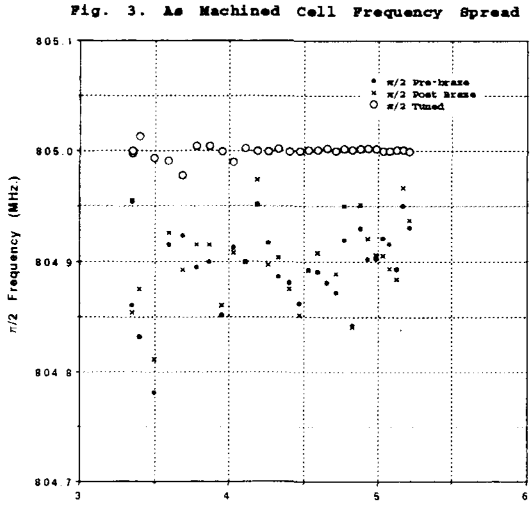

Fig. 4. $\pi/2$ Frequency vs CL

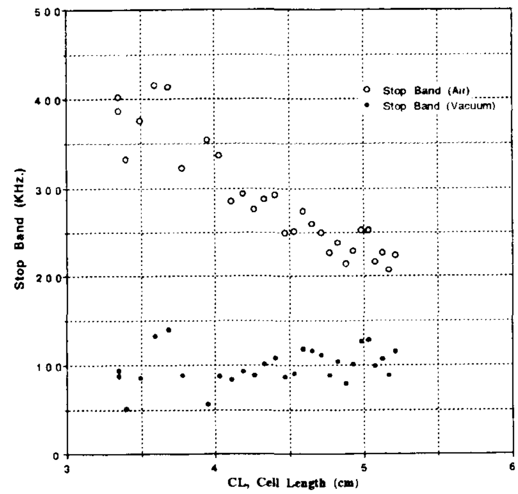

Figure 5. Stop Band vs CL

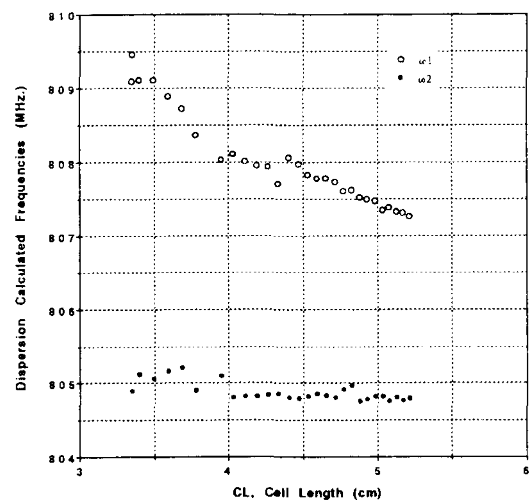

Fig. 6. Cell Frequency Calculated From Dispersion Measurements.

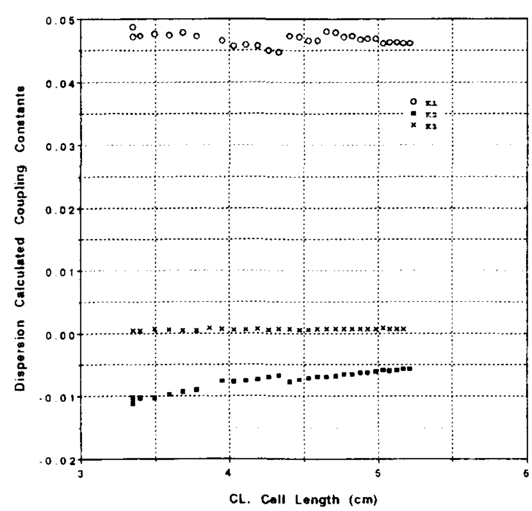

Fig. 7. Coupling Constants Calculated From Dispersion Measurements.