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Field Flatness Tuning for PEFP 100 MeV DTL

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1. Introduction

A conventional 100 MeV drift tube linac is under development for Proton Engineering Frontier Project. Currently the proton linac up to 20 MeV, which consists of injector, 3 MeV RFQ and 20 MeV DTL is completed. To accelerate the proton beam up to 100 MeV additional 7 DTL tanks are required.

The DTL should be tuned after fabrication and alignment of the drift tube inside the tank to meet the requirements from the beam dynamics. Tuning process includes the resonant frequency tuning, field flatness tuning and tilt sensitivity tuning. The tuning goal for the field flatness tuning is less than ±2% in field uniformity throughout the DTL tank with less than ±1% standard deviation. A non-uniform field profile caused by the machining errors and alignment errors can be made uniform through the slug tuner adjustment. This procedure requires the field profile measurements and several iterations between the field profile measurements and adjustment.

The methods and the results of the DTL field flatness tuning will be reported in this presentation.

2. Methods and Results

2.1 Field Profile Measurements

The field profile through the DTL tank can be measured by using bead pull method, which is based on Slater's perturbation theory [1]. When a small bead is sent through the DTL tank, it causes the resonant frequency shift. This frequency shift is proportional to the square of the field intensity in the region where the bead is passing. Therefore we can calculate the field profile from the measured frequency shift.

For near the resonance, the frequency shift is proportional to the phase shift. The time required for the phase shift scan is far less than that for frequency shift scan, which means that the measurement errors caused by temperature drift during the scan is smaller for the phase scan. If we measure the phase of the DTL tank as a function of frequency near the resonance, we can convert the phase shift to the frequency shift. In the field flatness tuning, we actually measured the phase shift rather than the frequency shift.

2.2 Field Flatness Tuning Setup

For the bead pull measurement, we used an aluminum spherical hollow bead with 9.4 mm in diameter. The bead is sent through the tank by using step motor and the sweep time through the tank is adjusted to make a spatial resolution better than 0.3 mm. It takes about 5 minutes for a bead to sweep the tank. A vector network analyzer and LabVIEW program were used to measure the phase shift of S21 parameter. To minimize the error caused by temperature drifting, we installed the heating cable around the tank and controlled the tank temperature as constant as possible. The overall tuning setup can be seen in Fig. 1.

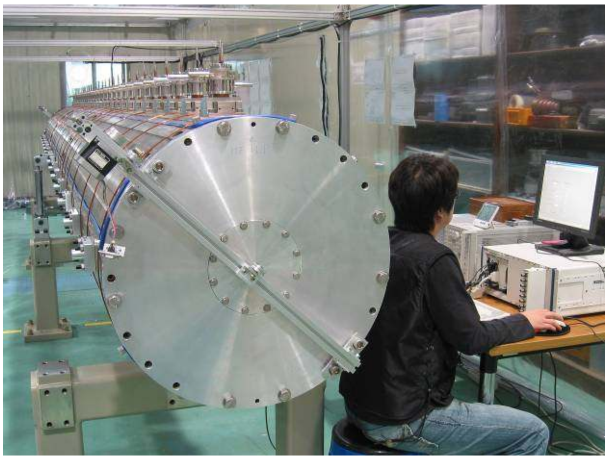

Fig. 1. Overall field flatness tuning setup. A step motor to drive the bead, vector network analyzer to measure the phase shift and PXI for data acquisition can be seen.

2.3 Field Profile before Tuning

Before the field flatness tuning, we measured the spectrum of the DTL tank as shown in Fig. 2. We installed the post couplers as well as the slug tuners. The gap between the post coupler tab and drift tube wall is as small as about 18 mm, so the post mode frequency is very low and not shown in Fig. 2. Figure 3 shows the measured phase shift before slug tuner adjustment. As can be seen in the figure, the filed profile is far from uniform distribution. The field error (peak to peak) was about ±10% with the standard deviation of 6.7%.

2.4 Field Profile after Tuning

To make the field distribution flat, we adjusted the slug tuners. Each DTL tank is equipped with 12 slug tuners. The amount of displacement of each slug tuners is determined by using a weighted delta function type perturbation model [2-3]. The measured phase shift after the slug tuner adjustment is shown in Fig. 4. The measured field error (peak to peak) after tuning was less than ±2% with the standard deviation of 0.6%.

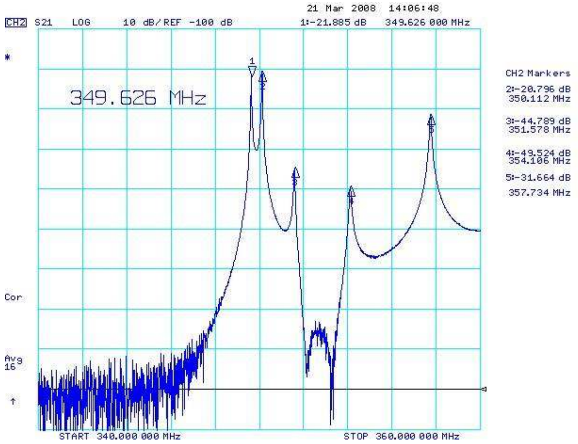

Fig. 2. Spectrum with post couplers and slug tuners. The resonant frequency of TM010 accelerating mode was 349. 626 MHz at 27℃ with air inside the tank.

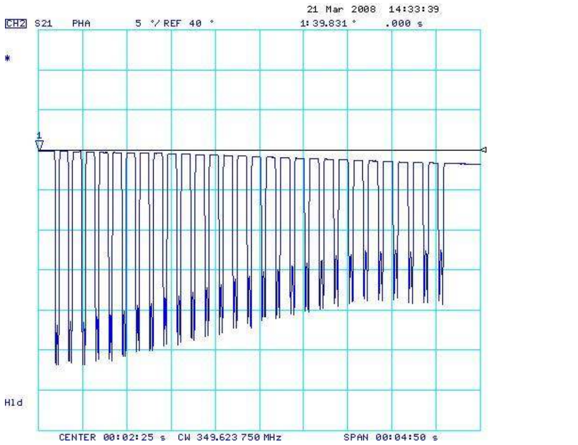

Fig. 3. Measured phase shift before tuning. The measured field error was about ±10% with the standard deviation of 6.7%.

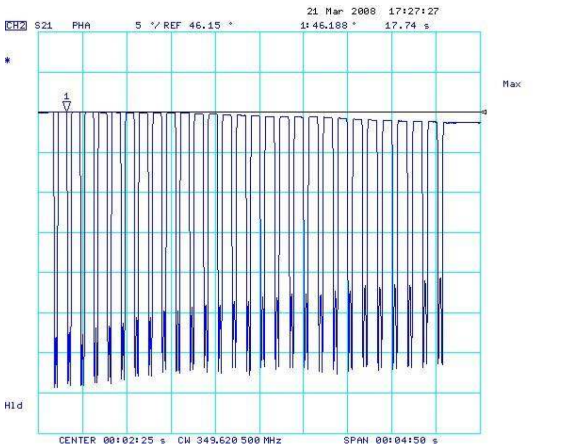

Fig. 4. Measured phase shift after tuning. The measured field error after tuning was less than ±2% with the standard deviation of 0.6%.

3. Conclusions

The tuning results can be summarized as shown in Fig. 5, where the field profiles before and after tuning are compared. With tuning of slug tuner displacement, the field flatness can be adjusted to meet the requirements. In the tuning process, the weighted delta function type perturbation calculation was very useful to determine the slug positions.

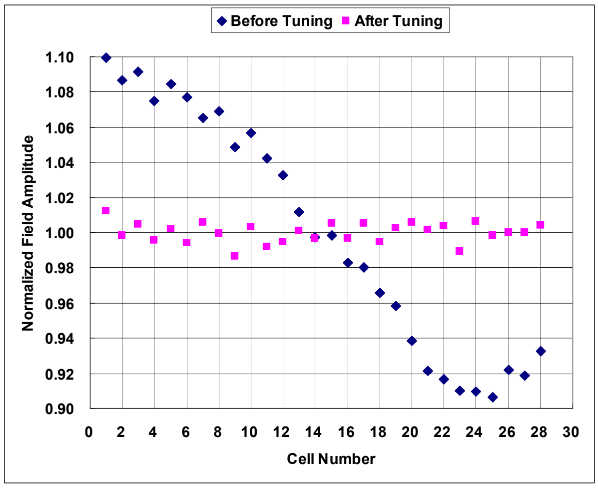

Fig. 5. Comparison between the field profile before the tuning and the field profile after tuning.

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