MEASUREMENTS ON THE POST STABILIZED LINAC

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ABSTRACT

The Alvarez linac tank that is the model of the second tank at KEK is designed and fabricated to confirm the field stabilization by post couplers. A change of the on-axis electric field distribution due to the post insertion shows strong evidence of the stabilization. When the post mode overlaps the accelerating one, the on-axis field is distorted drastically. Investigating the stabilization, some parameters to find the stabilized point are obtained. It is possible to tune post couplers accurately using these parameters. Tab rotation at the top of a post coupler has a great effect on the field. We can use them to make a tilt on the field.

INTRODUCTION

At KEK, the second linac tank is designed to accelerate negative hydrogen ions from 20 MeV to 40 MeV. For the second tank above, post couplers are to be installed to stabilize the field. One of the reasons for installing post couplers is that the mechanical errors at fabricating the tank and the beam loading effect can be reduced by them. Post couplers make an energy flow in the tank to compensate a local disturbance. Another reason is as follows. It is necessary to adjust the resonant frequency to that of the first tank, and then two motor-driven tuners are provided. This tuning also causes a change of the field distribution, thus a field stabilizer is necessary.

The Alvarez linac with fifteen cells is fabricated and its characteristics are measured. To determine the parameters of the model tank, computer code, SUPERFISH and PARMILA, are used. The field distribution is measured by a standard bead perturbation method.

MECHANISM OF THE STABILIZATION

The mechanism of the stabilization by post couplers is as follows[1]. Usually an Alvarez linac operates at a lower edge of a dispersion curve. We call this zero mode operation. This operation has a disadvantage that mechanical errors of a tank and a beam loading effect directly affects a field distribution, because RF group velocity is zero. When post couplers are inserted into a tank, the capacitance between a post coupler and a drift tube and the inductance around a post coupler make an RF resonant circuit. All post couplers form a chain of oscillators and a new dispersion curve of post couplers arises. Then the length of post couplers is tuned to couple the post mode with an accelerating one. As a result of a confluence, the dispersion curve near the operating point has a finite slope and the mode spacing between an accelerating mode and higher modes becomes large. The slope of a dispersion curve represents RF group velocity. This means the existence of an energy flow in the tank and it becomes harder to excite higher modes. In this way the stabilization of a field is obtained.

CHARACTERISTICS OF THE MODEL TANK

The radius of the model tank is reduced to half the second tank, so the resonant frequency becomes 401 MHz. It has fifteen unit cells, corresponding to the 20.60 MeV to 28.78 MeV section. Main parameters of the tank are shown in Table 1.

First, the characteristics of the tank without drift tubes are measured. Figure 1 shows its Brillouin diagram. The calculated value and the measured one agree with each other within 0.07 %.

Table 1 Main parameters of the model tank

Number of cells		15
Frequency		401.5 MHz
Tank Length		2.51 m
	Inside diameter	0.45 m
Drift tube	Outer diameter	8.0 cm
	Bore diameter	1.5 cm
Energy		20.60 - 28.78 MeV
Beta		0.2062 - 0.2421

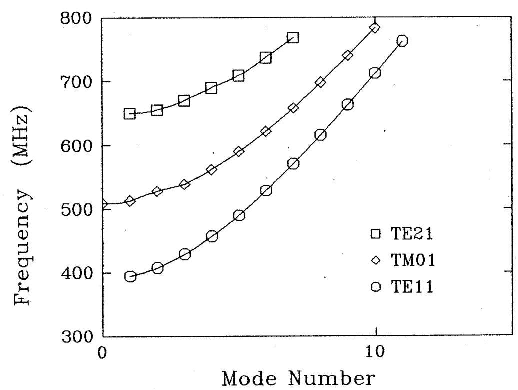

Fig.1 Dispersion curve without drift tubes

Second, Fig. 2 shows the Brillouin diagram with drift tubes. The resonant frequency of TM010 differs from the calculated value by SUPERFISH about 507 kHz or 0.1 %. This calculation is done with double precision. The difference between the measured value and the calculated one is small enough.

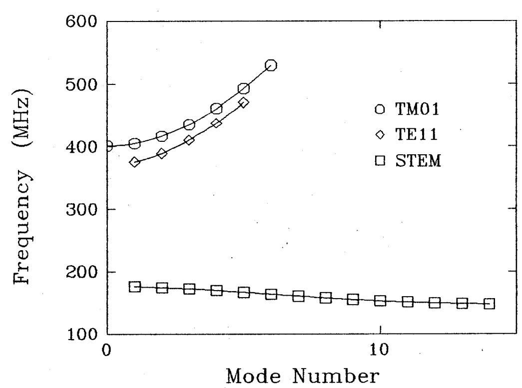

Fig.2 Dispersion curve with drift tubes

Furthermore, considering the dependence of a SUPERFISH calculation on its mesh size, this difference can be reduced. Figure 3 shows the dependence of the resonant frequency on the mesh size. In this figure, "A" points out the value we use. Taking account of the difference between "A" and "B", which points out the ideal value of infinitesimal size, the measured value approaches the calculated one, and 507 kHz reduces about 100 kHz. On the other hand, the mechanical error of the radius is within 0.1 mm. Since the resonant frequency of TM010 is in proportion to the inverse of the radius, the frequency error due to the mechanical error becomes about 100 kHz. This shows the calculation is quite accurate.

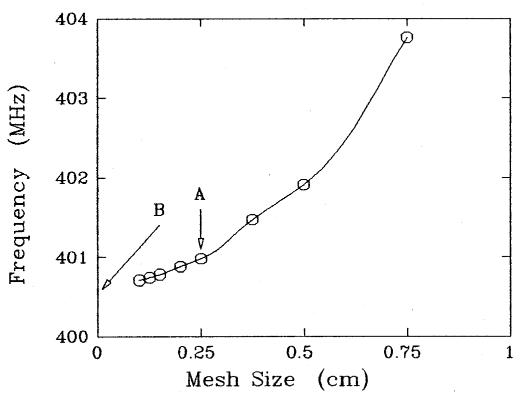

Fig.3 Mesh size dependence in SUPERFISH

EFFECT OF POST COUPLERS

To observe the effect of post couplers, intentional perturbation of moving both of the end plates toward the same direction is given. It causes a change of the resonant frequency in first and last cells. Table 2 shows the detail of it.

Table 2

Three kinds of perturbation to the end plates

		Increase of cell length	Change of frequency
Case 1	Δ1 mm		
	first cell	- 1 mm	- 1.5 MHz
	last cell	+ 1 mm	+ 1.0 MHz
Case 2	Δ3 mm		
	first cell	+ 3 mm	+ 3.5 MHz
	last cell	- 3 mm	- 3.0 MHz
Case 3	Δ5 mm		
	first cell	- 5 mm	- 6.0 MHz
	last cell	+ 5 mm	+ 4.0 MHz

In each case, Brillouin diagram, shift of operating frequency, and field distribution are measured.

In this experiment, the introduced frequency shift as perturbation is about 1 to 6 MHz. In the case of the second tank, it is about 0.9 MHz.

Field distribution

Figure 4 shows the measured field distribution before and after the stabilization. In this figure, "unperturbed" expresses the condition that the end plates are not perturbed and the tank is not stabilized, "perturbed" expresses that the end plates are perturbed of case 1 and the tank is not stabilized, and "perturbed and stabilized" expresses that the end plates are perturbed and the tank is stabilized. Without the stabilization, the field decreases as a cell number increases when the resonant frequency of first cell decreases and that of last cell increases. Post couplers have a strong effect on such a field distribution, and we can make a flat field with the stabilization. On the other hand, post couplers also have an effect to distort the field when the post mode overlaps the accelerating one. Figure 5 shows the distorted field. When the perturbation is Δ1 mm or Δ3 mm, the same results are obtained.

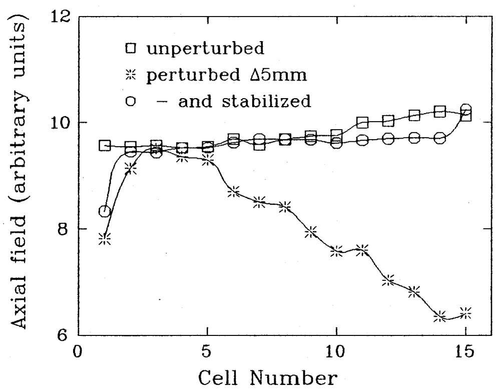

Fig.4 Field distribution
before and after post stabilization

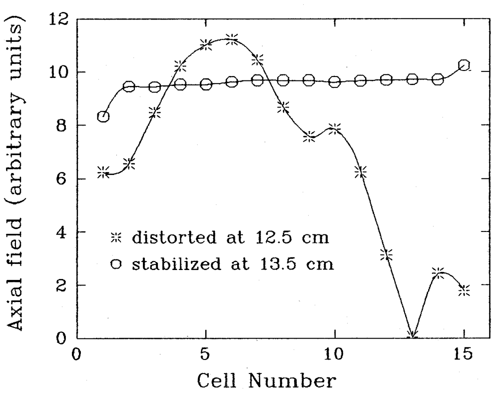

Fig.5 Post couplers effect
on the field distribution

To represent the flatness numerically, a distortion parameter Dx is introduced[2].

$$Dx = \sum_i |\overline{F}_i - F_i|$$

In Ungrin's paper, $\overline{F}_i$ is defined in each cell, but here $\overline{F}_i$ is taken as the average of fifteen cells. Figure 6 shows the dependence of Dx on the length of a post

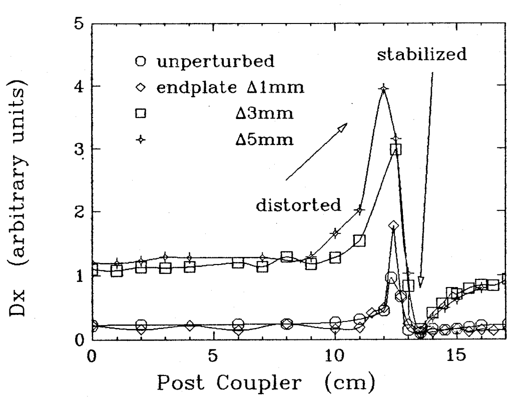

Fig.6 Distortion parameter defined
by Ungrin, et al.

coupler in three cases of perturbation. In each case, we can observe a peak due to the distortion of a field at 12.5 cm. At 13.5 cm a dip exists and it shows the field is stabilized. Using this parameter, we can determine a stabilized point accurately.

Brillouin diagram

Figure 7 shows the dependence of Brillouin diagram on the post length. As post couplers are inserted into the tank, the capacitance and inductance increase and its resonant frequency decreases. When the post length is 13.5 cm, dispersion curve near the operating point has a finite slope and the mode spacing between operating point and next one becomes large.

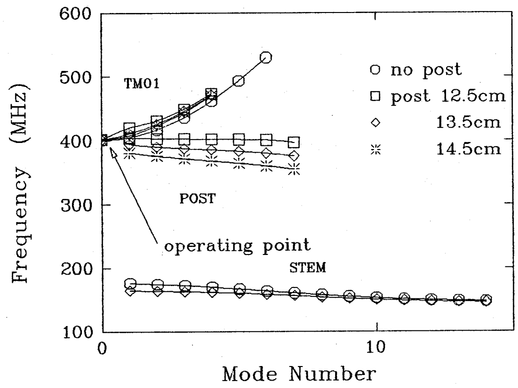

Fig.7 Dispersion curve, changing post length

Resonant frequency

Figure 8 shows the dependence of the resonant frequency on the post length. There is a critical transition point at 12.5 cm. This frequency transition corresponds to the field distortion as shown in Figs. 5 and 6. At the left of this point, the frequency decreases because the post mode pulls down an accelerating one. At 13.5 cm, the stabilized point, the frequencies for three kinds of perturbation agree.

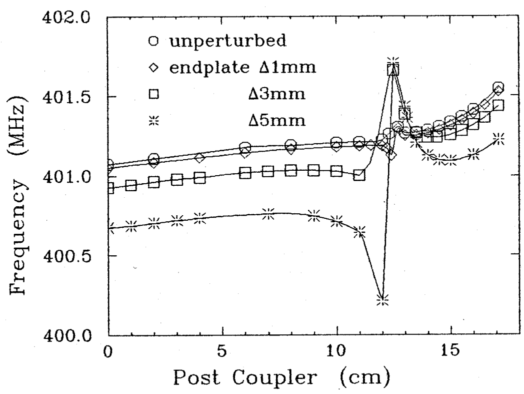

Fig.8 Frequency shift by insertion of post, taking endplate perturbation for parameter

TAB ROTATION AND ITS SIZE

At the top of a post coupler, a tab is attached as shown in Fig. 9. When all tabs point to the same direction, up or down, symmetry of a post coupler and a drift tube is conserved. Experiments mentioned above are done on that condition. Then these tabs are rotated to point right or left to change the coupling between unit cells. Asymmetry of this geometry influences an energy flow in the tank and makes a tilt on the field. Figure 10 shows the field distribution in three cases. The field decreases in the direction that post couplers point to.

To determine the tab size, two kinds of tabs with areas 1.7 and 3.0 times a post coupler cross section are prepared. The field stabilization is achieved with each tab and in the case of no tab the field is stabilized as well. The post length at the stabilized point is 13.5 cm for large tabs, 14.4 cm for small tabs and 15.9 cm for no tab. To prevent a post coupler discharge, we select large tabs for the second tank. In addition, large tabs effectively influence the tilt on the field when they are rotated.

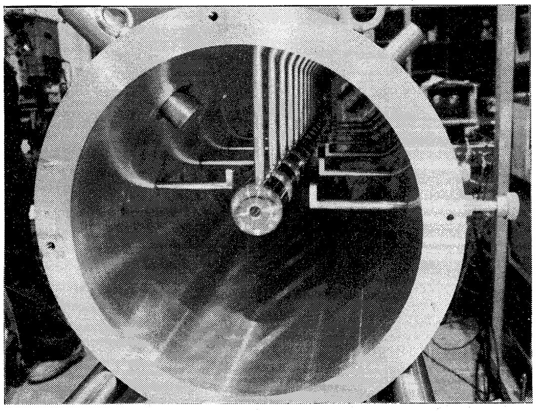

Fig.9 The model tank with post copulers

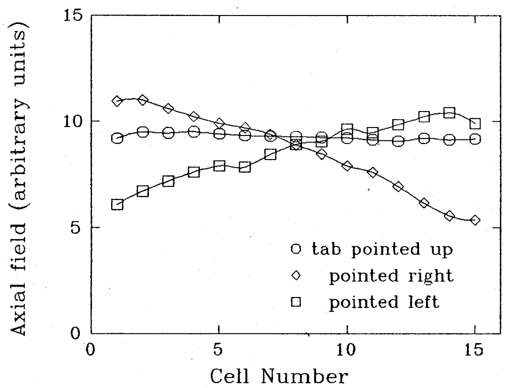

Fig.10 Field distribution vs. tab rotation

CONCLUSION

The stabilization by post couplers is achieved. As shown in Fig. 4, it is possible to correct the field distribution disturbed by mechanical errors. However, we should note that post couplers distort the field when the post mode overlaps the accelerating one. Since there is a little distance between the stabilized point and the distorted one, it is necessary to adjust post couplers carefully. Some information about this problem is obtained as follows.

It is confirmed that the distortion paramter is useful to determine the stabilized point of a post coupler. As shown in Fig. 6, there is the sharp dip that represents the stabilized point, so we can tune the length of a post coupler accurately.

At the stabilized point, the resonant frequency remains constant for every kinds of perturbation. This suggests the possibility that the frequency can be used as a parameter to tune the post length as well as the distortion parameter.

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