A Cold Model Test of the CW-DTL for the Neutron Science Project at JAERI

Etsuji CHISHIRO, Hiroshi INO*, Nobuo OUCHI, Zensaburo KABEYA* and Motoharu MIZUMOTO
Proton Accelerator Laboratory, Japan Atomic Energy Research Institute,
Tokai-mura, Naka-gun, Ibaraki-ken, 319-11, Japan
*Mitsubishi Heavy Industries, LTD. Nagoya Aerospace Systems,
Oye-cho, Minato-ku, Nagoya, 455, Japan

Abstract

The RF characteristics of the DTL which accelerates proton beam from 2 to 10 MeV has been studied using a cold model. The cold model is fabricated of 60-cell made of aluminum and is assembled with post couplers to adjust and stabilize the accelerating field. In this study, the dependence of the RF characteristics on number of installed post couplers in the cold model has been investigated. Installing the post coupler every 1-cell, we can not obtain the uniform field distribution because some modes, which are neither cavity modes nor post modes, strongly perturb the field distribution. Decreasing the number of the post couplers, these modes disappear and the uniform distribution is obtained. The stabilization effects such as the field distribution, the detuning sensitivity and the mode spacing between TM010 and TM011 become weak with decreasing number of the post couplers.

1. Introduction

JAERI has planned the Neutron Science Project (NSP) for exploring basic researches and nuclear waste transmutation technology[1]. The NSP requires a high-intensity proton linac which consists of radio frequency quadrupole (RFQ) linac, drift tube linac (DTL) and superconducting linac. In this linac the DTL accelerates proton from 2 to 100 MeV.

The DTL has utilized post couplers to stabilize and adjust the accelerating field. In general, since the stabilized accelerating field has non-zero group velocity because two pass band (post band and cavity band) are confluent at the accelerating mode, the field distribution is almost insensitive to perturbations such as effects of stem, wall loss, detuning, and beam loading[2].

However, the stabilization using the post couplers is not simple at the low energy section of the DTL. This is because the cell length is short and varies rapidly along a tank[3]. The short cell length causes a strong coupling among post couplers that is dependent on the distance between the post couplers. The change of the cell length causes the differential resonance frequency of each post coupler that is dependent on the length of the drift tube.

To assist the design of the CW-DTL, the RF characteristics has been investigated using a cold model. In this paper, we describe the dependence of the stabilization effects on number of the post coupler in the cold model.

2. Experimental equipment

2.1 Cold model of CW-DTL injector

We have fabricated the cold model (2-10MeV, 60-cell) of which the geometrical size is reduced at factor of 1/3 for the CW-DTL. The designed parameters of the cold model is listed in Table 1 and the cross sectional view is illustrated in Fig.1. The cold model has been assembled with manufacturing tolerance of +/-0.3 mm. Post couplers are alternately inserted from side to side. A post length (L_p) which is a distance between the post coupler and the drift tube is adjusted with setting accuracy of +/-0.4 mm to tune the post coupler frequency for the stabilization. Each post coupler has an extension tab. In this study, the tab is kept to align in vertical. To investigate the dependence on number of post couplers, an installation interval of the post couplers for the cells is changed from every 1-cell to 5-cell. In each case, total number of post couplers corresponds to 59, 29, 19, 14 and 11 couplers.

Table 1
Designed parameters of the cold model

Frequency	600 MHz
Tank Radius	153.5 mm
Tank Length	3096.9 mm
Number of Cells	60-cell
Acc. Energy	2-10 MeV
Cell Length	32.9-72.7 mm
Drift Tube Radius	33.3 mm
Bore Radius	3.3 mm
Stem Radius	6.0 mm
Post Radius	5.0 mm
Material	Aluminum

2.2 Measurement

The axial field ($E(z)$) is measured by the bead perturbation method[4]. A radius of the bead made of Aluminum is 2 mm. Averaged field across i-th cell (E_i) and total averaged field $\langle E \rangle$ across the tank are given by following equations.

$$E_i = \frac{1}{L_i} \int_{i-cell} E(z)dz \ , \qquad (1)$$

$$\langle E \rangle = \frac{1}{L_{tot}} \int_{Tank} E(z)dz \ . \qquad (2)$$

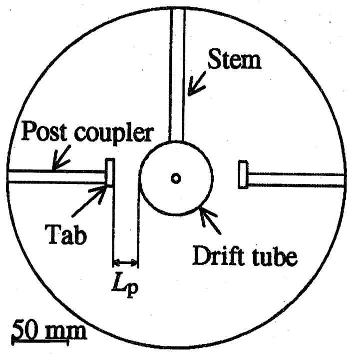

Fig. 1 Cross sectional view of the cold model.

where L_i and L_{tot} are i-th cell length and tank length, respectively. To evaluate filed distribution, distortion parameter (D_X) is defined as

$$D_X = \sum_{i=1}^{60} \left| E_i - \langle E \rangle \right| \Big/ \langle E \rangle \ . \qquad (3)$$

Also a network analyzer is used to measure the resonant mode frequency.

3. Experimental results

3.1 Field distribution with a post coupler installed every 1-cell

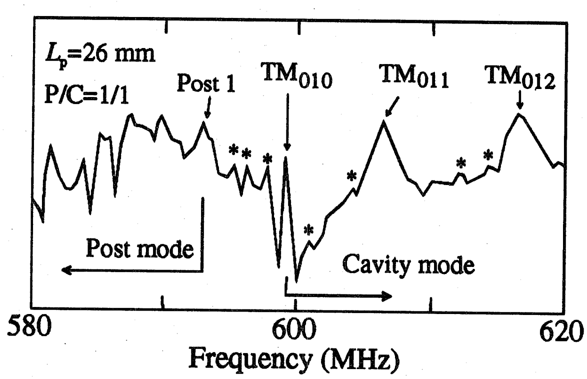

Fig.2 Resonant modes of the cold model
Post couplers are installed every 1-cell

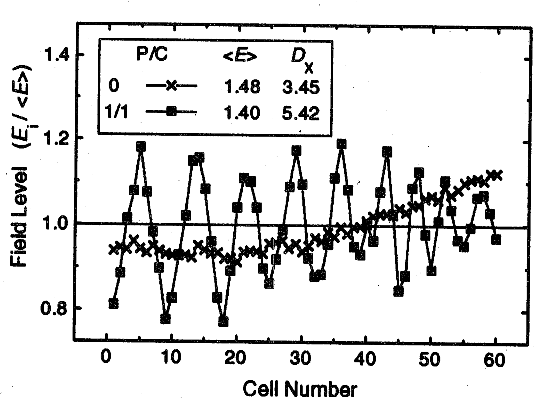

Fig. 3 Field distribution with post coupler every 1-cell (P/C=1/) and without post coupler (P/C=0)

We had attempted the stabilization of the cold model with a post coupler installed every 1-cell. Here we express this installation interval with P/C (Post/Cell)=1/1. Tuning the post couplers, a minimum D_X was obtained at L_p = 26 mm, but undesirable modes were excited around TM010 mode (Plotted by "*" in Fig.2). These modes were neither

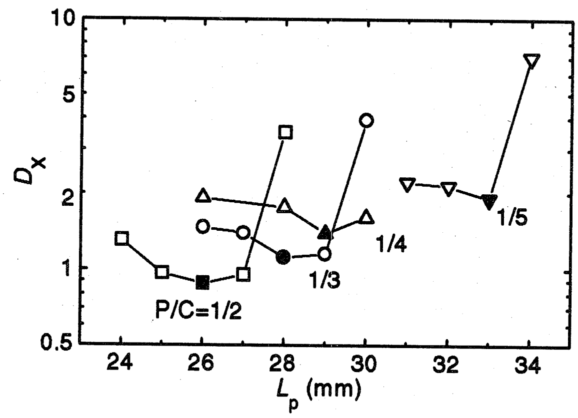

Fig. 4 Dependence of D_X on L_p. P/C=1/n indicates a installed post coupler every n-cells

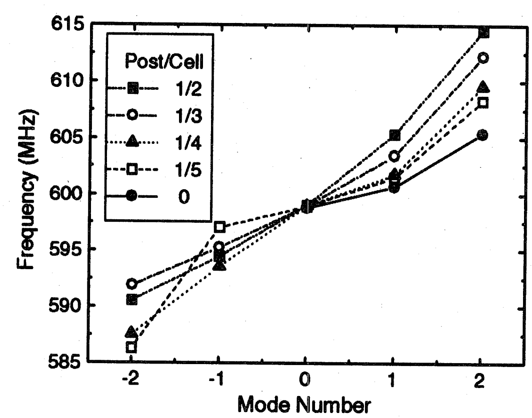

Fig. 5 Dispersion curves of TM and post modes

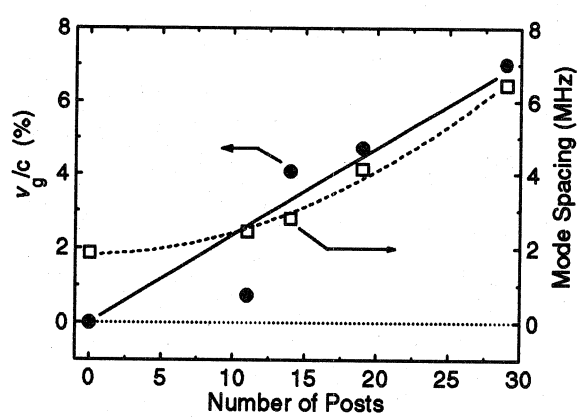

Fig.6 Group velocity (v_g) and mode spacing vs. number of post couplers

the cavity (TM) modes nor the post modes, and arose when the post band closed the cavity modes. The field distributions with P/C=1/1 and without post coupler (P/C=0) are shown in Fig.3. At the P/C=0, the field level gradually varies. On the other hand, the distribution at the P/C=1/1 periodically oscillates. Nevertheless the cold model was tuned by the post couplers, the D_X is larger than that of P/C=0. It seems that the distribution is perturbed by the undesirable modes, but the excitation mechanism of the modes has not been clarified.

3.2 Dependence on number of post couplers

Expanding the installation interval of the coupler, we reduced the total number of the post couplers to eliminate the contribution of the undesirable modes. At the interval of P/C=1/2, these modes were not excited around the TM010 mode and stabilized field was obtained. Fig.4 shows the dependence of D_X on L_p at conditions of P/C=1/2,1/3,1/4 and 1/5. When a minimum value (D_{Xmin}) of D_X was achieved at a L_p, we regard that condition as the cold model with the L_p was stabilized. Narrowing the interval, that is to say, increasing number of the post couplers, smaller D_{Xmin} was produced. The smallest D_{Xmin} was measured at the P/C=1/2. The group velocity (v_g) and the mode spacing between TM010 and TM011 were calculated from dispersion curves (Fig.5) of the stabilized cold model. Fig. 6 shows the v_g and the mode spacing as a function of total number of the post couplers. Both v_g and mode spacing became largest for all conditions at the P/C=1/2.

In the stabilized cold model, the detuning sensitivity was measured by shifting a resonant frequency of TM010 mode, which was accomplished by pulling out a half-drift tube of the low energy end. Fig. 7 shows the dependence of D_{Xmin} on the detuning frequency. As shown in the figure, D_{Xmin} is linearly increasing at all conditions and the tilt is gradual at the narrow interval condition. At the P/C=1/2 detuning perturbation slightly influenced the field distribution. We defined a detuning sensitivity as perturbation growth against detuning frequency. In this evaluation it indicates an enhancement factor of D_{Xmin} per detuning frequency of 1 MHz. Fig. 8 plots the sensitivity as a function of total number of posts. The detuning sensitivity exponentially decreases with increasing number of post couplers.

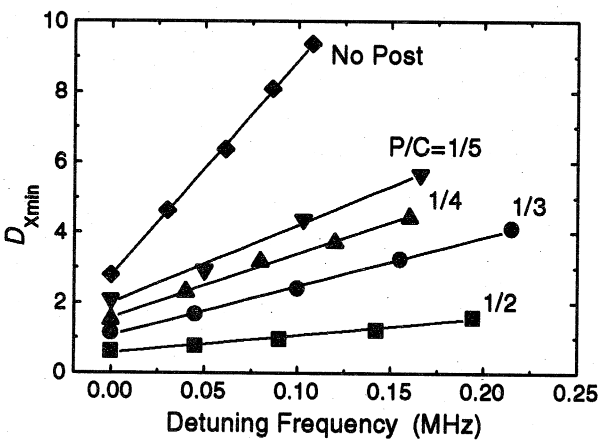

Fig.7 Dependence of D_{xmin} on detuning frequency

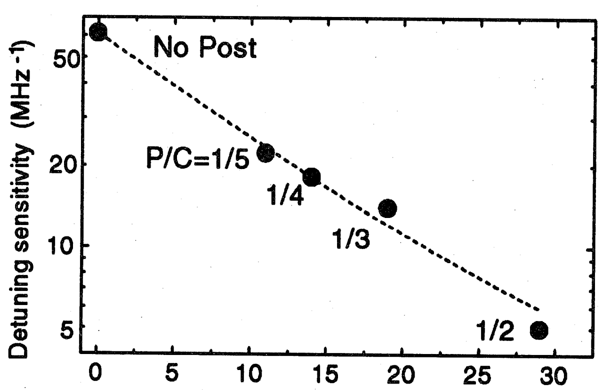

Fig. 8 Detuning sensitivity vs. number of post couplers

4. Conclusion

The stabilization effects become large with increasing number of post couplers. However, too many post couplers, or too closing post couplers causes the excitation of the undesirable modes. These modes seriously affect the field distribution.

Reference

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