DESIGN OF INPUT AND OUTPUT COUPLERS FOR LINEAR ACCELERATOR STRUCTURES

S.Yamaguchi, Y.Igarashi,* A.Enomoto and I.Sato
National Laboratory for High Energy Physics (KEK)
1-1 Oho, Tsukuba, Ibaraki, 305 Japan
* Mitsubishi Heavy Industries, Ltd. Nagoya Aerospace Systems
10, Oye-cho, Minato-ku, Nagoya, 455 Japan

Abstract

The input and output couplers for 2m-long S-band linear-accelerator structures for the KEKB linac upgrade have been designed and tested. The dimensions of the coupler cavities were estimated by a simulation of the Kyhl method using the MAFIA code, and determined by low-power tests using the Kyhl method. It has been shown that the coupler dimensions can be predicted with precision to be less than 0.5 mm. The asymmetry of the electromagnetic field (amplitude and phase) in the couplers has been corrected by a crescent-shaped cut on the opposite side of the iris. The total performance of the accelerator structures with these couplers is also described.

Introduction

A reinforcement of the PF linac at KEK is now under way for the KEKB project.[1] The beam energy of the linac is being upgraded from 2.5 GeV to 8.0 GeV. For this energy upgrade, about seventy new accelerator structures (54 cells, 2m-long, S-band, quasi-constant gradient, 2π/3-mode, electroplated and no dimpling) are to be fabricated. The input and output couplers for the new accelerator structures have been redesigned, because the existing couplers have insufficient performance concerning the reflection, phase shift, asymmetry of electromagnetic fields and RF breakdown limit. Fig. 1 shows a cross-sectional view of the coupler. The adjustable

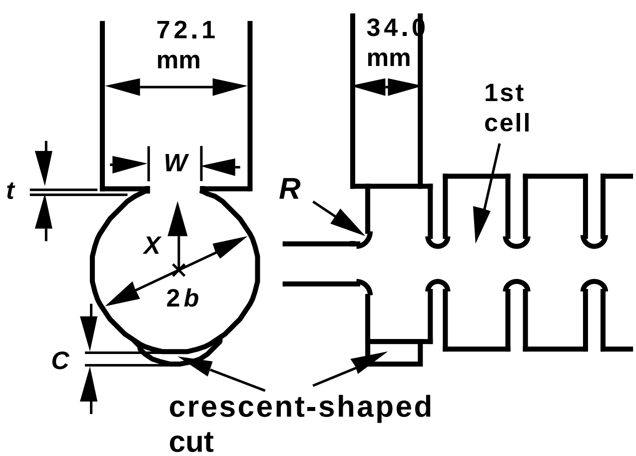

Fig. 1. Cross-sectional view of the coupler cavity (R=7mm and t=2mm).

parameters are W (iris width) and $2b$ (inner diameter). So far, the coupler dimensions have been determined by trial and error. A method for estimating the coupler dimensions by a numerical simulation using the MAFIA T3 module has been proposed [2]. In this paper, we present a new method to estimate the coupler dimensions by simulating the Kyhl method [4] using the MAFIA E module.

A correction for the asymmetry of the electromagnetic fields in the coupler cavities was performed by making a crescent-shaped cut on the opposite side of the iris.

Simulation of the Kyhl method

The simulation of the Kyhl method was carried out as follows:

1. Generate a mesh structure constructed with the coupler cavity, half cell and waveguide (Fig. 2). Although the curvature, (R) of beam hole edge (see Fig. 1) had been 3 mm for the existing couplers, it was changed to be 7 mm in order to improve the vacuum-breakdown limit.

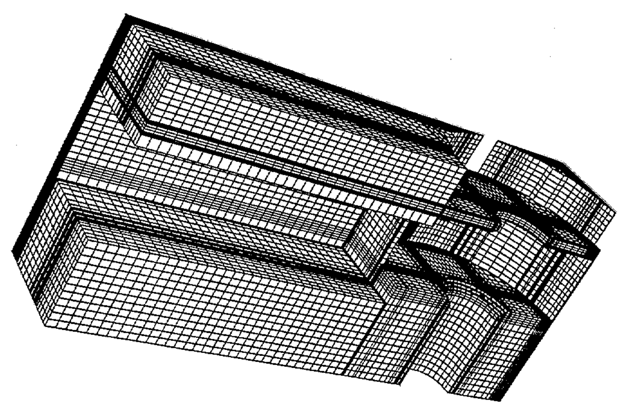

Fig. 2. MAFIA geometry for the Kyhl method simulation.

2. Obtain the resonant frequency (f_{res}) and external Q (Q_{ext}) for this structure by simulating the Slater's tuning curve method[4].
3. Determine f_{res} and Q_{ext} for various W and $2b$. Fig. 3 shows $f_{res}(W,2b)$ and $Q_{ext}(W,2b)$.
4. Obtain W and $2b$ at the cross point of two lines (Fig. 4): one is

$$f_{res}=f_{ave}\equiv(f_{2\pi/3}+f_{\pi/2})/2. \tag{1}$$

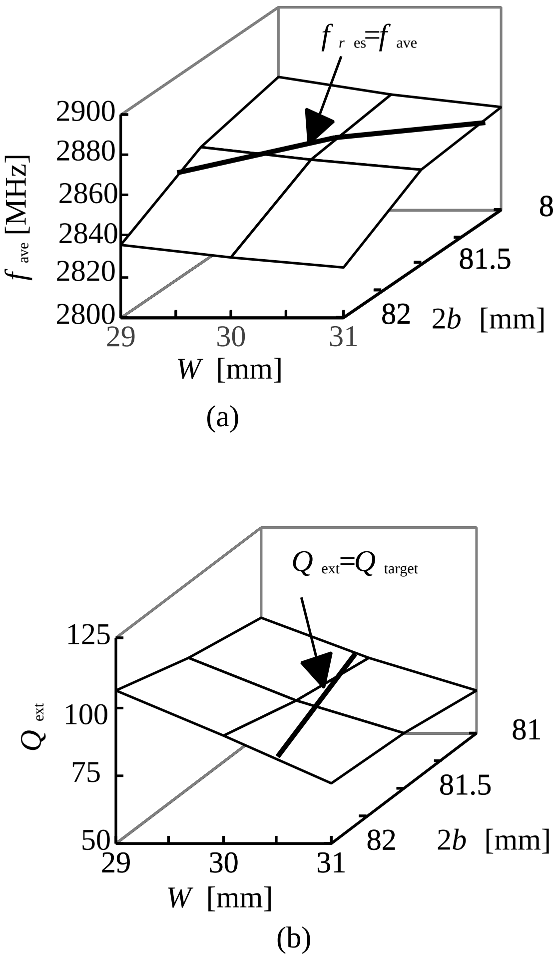

Fig. 3. (a) $f_{res}(W,2b)$ and (b) $Q_{ext}(W,2b)$.

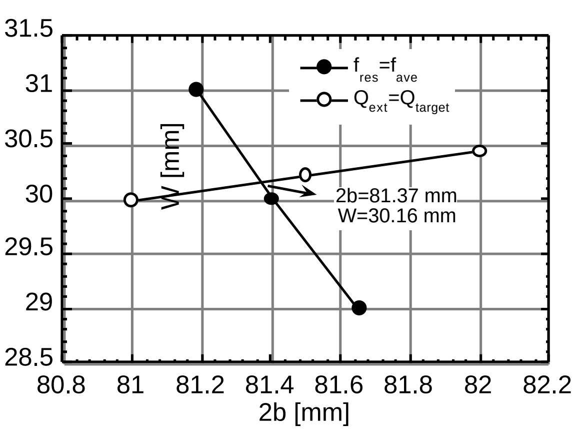

Fig. 4. Lines of f_{res}=f_{ave} and Q_{ext}=Q_{target}. The values at the cross point gives the designed values of W and $2b$.

The other is

$$Q_{ext}=Q_{target}. \tag{2}$$

This set of W and $2b$ is the design value of coupler cavities. Here, $f_{\pi/2}$ (resonant frequency for the $\pi/2$ mode) were obtained by a dispersion curve measured using 6 cell accelerator structures (standard cavities). Q_{ext} was determined as follows: Let Q_{ext} be inversely proportional to v_g,

$$Q_{ext} \quad 1/v_g . \tag{3}$$

The relation between $2a$ and v_g is given by the following equation, which is obtained by the dispersion curves for several standard cavities:

$$v_g/c=0.959887\text{x}10^{-5}(2a)^3-0.514516\text{x}10^{-3}(2a)^2 +0.0105696(2a)-0.0735666. \tag{4}$$

From equations (3) and (4), and data for a coupler with good matching and tuning characteristics ($2a$=26.3 mm, and Q_{ext}=96.195), Q_{ext} is given as a function of a as follows:

$$1/Q_{ext}=4.31109\text{x}10^{-6}(2a)^3-2.31082\text{x}10^{-4}(2a)^2 +4.74707\text{x}10^{-3}(2a)-0.033040. \tag{5}$$

From this equation, the target value of Q_{ext} can be obtained.

The coupler dimensions were determined by cold tests based on the Kyhl method. A very few iterations of machining were required before an optimal configuration could be obtained. A comparison between the measured and predicted values of the coupler dimensions is shown in Fig. 5 for three types of couplers with different $2a$.

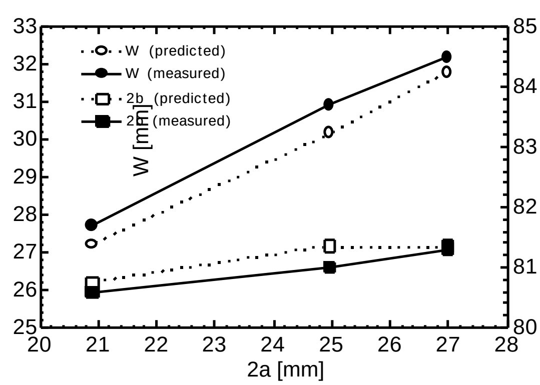

Fig. 5. Comparison between the predicted and measured values of W and $2b$.

It is shown that the coupler dimensions (W and $2b$) can be predicted with an accuracy of less than 0.5 mm.

Correction of the Field Asymmetry in Couplers

The asymmetry of the electromagnetic field (amplitude E and phase) in a couplers was corrected by a crescent-shaped cut (depth of the cut is C) on the opposite side of the iris (see Fig. 1) using following procedures:

1. Measure the electric-field distribution for two couplers with different values of C. The field distribution has been measured by the bead pull method based on the non-resonant perturbation theory [7].
2. Obtain a relation between C and the factor k, defined as follows: (Fig. 6)

$$k=\Delta E/E_{X=0}\ [\%], \quad (6)$$
$$\Delta E=E_{X=X0}-E_{X=0},$$
$$X0=4,8,12\ [\mathrm{mm}].$$

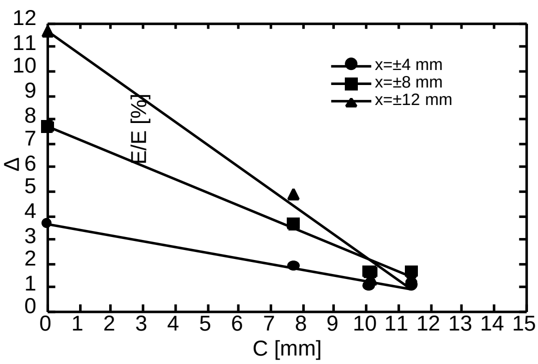

Fig. 6. $\Delta E/E$ as a function of C.

3. Obtain the optimum value of C by interpolation or extrapolation.

Fig. 7 shows the field distributions (amplitude and phase) for a coupler with an optimum value of C.

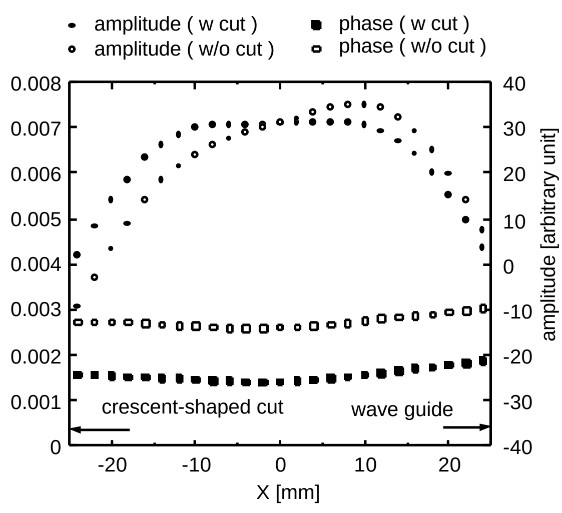

Fig. 7. Effect of the correction of an electromagnetic-field asymmetry by a crescent-shaped cut.

With this correction, the asymmetry of amplitude ($\Delta E/E$) and phase was reduced from 8% to 1% and 1.3° to 1.1°, respectively at X=8mm.

RF characteristics of the accelerator structure

The phase distribution for the accelerator structure with new couplers was measured using a nodal-shift technique (Fig. 8). A standard deviation of 0.9° was achieved (note that our accelerator structure was fabricated without dimpling). The SWR was 1.07.

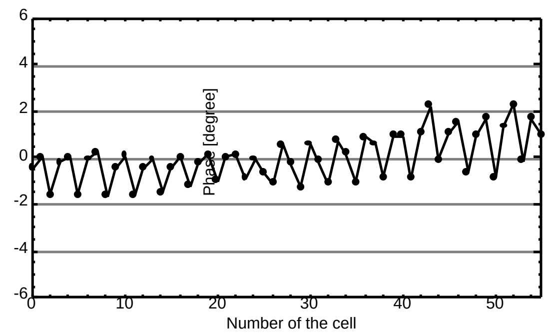

Fig. 8. Phase distribution for the accelerating structure after electron-beam welding of the couplers.

Summary

The design of the coupler dimensions was achieved by a simulation based on the Kyhl method. The dimensions obtained by this method are in good agreement with that determined by cold tests. It has been proven that the asymmetry of the electromagnetic fields in the coupler can be corrected by a crescent-shaped cut.

Acknowledgments

The authors wish to thank S.Takeda, H.Matsumoto T.Higo and S.Miura for their valuable comments on this work.

References

[1] A.Enomoto, "Upgrade to the 8 GeV Electron Linac for KEKB," these proceedings.

[2] C.-K. Ng and K.Ko,"Numerical Simulations of Input and Output Couplers for Linear Accelerator Structures," SLAC-PUB-6086.

[3] E.Westbrook, " Microwave Impedance Matching of Feed Waveguides to the Disk-Loaded Accelerator Structure Operating in the 2π/3 Mode," SLAC-TN-63-103, 1963.

[4] J.C.Slater, *Microwave Electronics* (D.Van Nostrand, New York,1950).

[5] H.Deruyter, et al. "Symmetrical Double Input Coupler Development," Proceedings of 1992 Linac Conf., Ottawa (1992) 407.

[6] N.P.Sobenin, et al. "DESY Linear Collider Accelerating Section Coupler," Proceedings of 1994 Linac Conf., Tsukuba (1994) 74.

[7] C.W.Steele, MTT-14,,No2, Feb. 1966, p.70.