Design of High Power Model of Damped Linear Accelerating Structure using Choke Mode Cavity

Tsumoru Shintake
KEK: National Laboratory for High Energy Physics
1-1 Oho, Tsukuba-shi, Ibaraki-ken, 305 JAPAN

Abstract
A high power model of a damped linear accelerating structure using the choke mode cavity has been designed.

1. INTRODUCTION

In the course of design study of the e+e- linear collider[1], a new type HOM damped cavity: the choke mode cavity was proposed by the author[2]. Using a cold model of this cavity at S-band, it was demonstrated that most of all the higher order modes were fully damped, while small effect on the dominant accelerating mode. In the frequency spectrum measurement, since the damped Q was very low, no any peak was observed around the most dangerous TM110 mode. By means of the time domain simulation using TBCI-code, the damped-Q of TM110 mode was estimated to be less than 10. [3]

Since this cavity is a simple structure, and it has perfect cylindrical symmetry around the axis, it is quite suitable for mass production of large number of cells for traveling wave accelerators requested for e+e- linear colliders. Since, wall dissipation power density is uniform around the axis, and there is no heat concentration at any point, this structure is also suitable for high-power CW accelerating cavity in storage rings, especially for B-factories[4,5].

In order to study practical problems of this cavity, we started design study of S-band high power model. In this paper, current status of this design study is reported.

2. ACCELERATING MODE

Schematic drawing of the high power model is shown in Fig. 1. Since the structure has many slots for HOM damping, it will be installed in a vacuum vessel. It consists of 14 cells: 12 regular cells of the choke mode cavity, input and output coupler cells.

A. Accelerating Mode : Phase Advance per Cell

In order to get enough space for the choke structure, we use the $3\pi/4$ mode, rather than $2\pi/3$ mode. Cross-sectional dimension is shown in Fig. 2. The disk-to-disk spacing: D in $3\pi/4$ mode is 39.364 at 2856 MHz. This is 4.4 mm longer than the $2\pi/3$ mode. The Brillouin diagram of this mode is shown in Fig. 3 comparing with the $2\pi/3$ mode. The group velocity is 0.01c for both modes. Since the $3\pi/4$ mode is near to π-mode, the rise time of pulse microwave propagating along this structure becomes slower than in $2\pi/3$ mode. The estimated rise time from the band width ($\tau = 1/\pi(f\pi - frf)$) is 64 nsec for this mode and 41 nsec for $3\pi/4$. This is sufficient value for practical application of S-band linear accelerator. The shunt impedance of $3\pi/4$ mode is almost same as the $2\pi/3$ mode.

B. Degradation of Q-factor due to the Choke HOM Damping Structure

The damping slot, radial transmission line and the choke structure dissipate microwave power due to wall loss. This is 25% of the wall dissipation power per cell of conventional disk-loaded structure. Therefore, the shunt impedance of this structure becomes 25% lower due to attaching this choke HOM damper. Design parameter are listed in Table-1. Since the stored energy in the damping structure is 10% of the total, R/Q parameter becomes 10% lower. The Q-factor becomes 85% of conventional disk-loaded structure.

Since the choke is a kind of a notch filter, the power stop-band is limited. If the operating frequency moves from the design center frequency, or the choke resonance is different from the rf frequency due to dimension errors, some fraction of the accelerating microwave power can leak-out from the cavity. Figure 4 shows degradation of Q-factor due to this power leakage as a function of relative frequency detuning. Q_{leak} denotes the power leakage effect. If we accept a degradation of a few % of Q-value, that is 98 % of Q_0, the tolerance on the choke center frequency becomes ± 0.16 %. Therefor, the dimension tolerance for the choke depth is approximately ± 40 μm for 25 mm choke depth. This is easy value to realize by machining on a turning lathe.

The frequency bandwidth required for the traveling wave structure(v_g=0.01) is around ±0.5 %. Since the Q-factor is higher than 10000 within this bandwidth, the pulse response will not be disturbed.

C. Dimension Tolerance & Tuning

Sensitivity of the resonance frequency on dimension errors and their tolerances for 100 kHz frequency error are listed in Table 2. Tolerances on 2a, 2b and D dimensions are same as that in the conventional disk-loaded structure. The tolerances on choke dimensions are not so tight. Since 2b dimension tolerance is tight, conventionally it is tuned by pussing the body from outside after braising.

However, we can not access to 2b dimension after the braising. Therefore, firstly we will measure the center frequency ($\pi/2$-mode) using two detuned dummy-cavity and slightly machine the 2b dimension for coarse tuning, and

D dimension (spacer length) for fine tuning. Since the tolerance on D dimension is not tight, it will not be necessary additional tuning after the braising process.

3. HIGHER ORDER MODES

Since the choke is a quarter-wavelength line, it has higher order resonances at 3f0, 5f0.. If we use a simple straight choke, the 3rd resonance can trap some higher order modes in the accelerating cavity. In the previous measurement[2], a peak of trapped TM021 mode was observed at 8.5 GHz. In order to eliminate this peak, we reduced the choke length and widened the bottom as shown in Fig. 2. With this modification, the 3rd resonance becomes 9.5 GHz, while the dominant frequency does not move. Since the gap width of the radial line is 13 mm at the choke, and 24 mm at outer region, the 3rd resonance field can propagate along the radial line by higher order mode as shown in Fig. 5(b). Therefore the 3rd resonance does not trap cavity modes. Fig. 5(c) is parasitic resonance of the choke at 10.7 GHz. Because of the same reason as 3rd mode, this mode does not disturb the HOM damping.

Fig. 6 shows the calculated wake potential of single cell of this cavity. The estimated damped Q-value from the decay time was approximately 14 for TM110 mode. Since only the TM010 dominant accelerating mode is trapped inside this cavity, the longitudinal wake potential shows coherent oscillation at 2856 MHz.

4. CONCLUSIONS

We will fabricate this high power model in this year, and examine the high power test.

In the second model, we will implement the microwave absorber made of SiC for the HOM damping.

ACKNOWLEDGEMENTS

The author would like to thank Tatsuya Kageyama, Kazunori Akai and Yoshishige Yamazaki for stimulating discussions. The author would like to thank Hiroshi Matsumoto and Hitoshi Baba for useful suggestions on fabrication process.

[1] JLC Group, "JLC-I", KEK Report 92-16, December 1992 A/H/M

[2] T. Shintake, "The Choke Mode Cavity", Jpn. J. Appl. Phys. Vol. 31 (1992) pp. L1567-L1570, Part 2, No. 11A Nov. 1992

[3] T. Shintake, "HOM Free Linear Accelerating Structure using Choke Mode Cavity", Proc. 17th Linear Accelerator Meeting in Japan, Sendai, Japan (1992); KEK Preprint 92-66, July 1992 A

[4] B-factory Accelerator Task Force, "Accelerator Design of the KEK B-factory", KEK Report 90-24.

[5] "An Asymmetric B Factory based on PEP", conceptual design report, Feb. 1991, LEL PUB-5303

Table-1

Operating Frequency	f_0	2856	MHz
Wavelength	λ_0	104.969	mm
Phase Shift per Cell		$3\pi/4$	
Cell Unit Length	D	39.364	mm
Structure Length	L	511.7	mm
Cell Number	N	14	cells
(2couplers + 12 regular cells)			
Impedance	CI: constant impedance		
Aperature	$2a$	24.0	mm
Cell Diameter	$2b$	82.94	mm
Disk Thikness	t	8.0	mm
Q-factor	Q_0	12000	
Group velocity	V_g/c	0.0096	
Shunt Impedance	r	42	MΩ/m
Attenuation Parameter	τ	0.13	
Filling Time	T_F	171	nsec
Accelerating gradient at 100 MW rf input.			
at input	Ea1	45.7	MV/m
at output	Ea2	40.1	MV/m

Table-2 Dimension Tolerance

Dimensions	Target	Sensitivity	Tolerance
(mm)	(mm)	(kHz/μm)	(μm)
2a	24.00	4.0	± 25
2b	82.94	- 36	± 3
D	39.36	- 5	± 20
t	8.00	10	± 10
Lchoke	(26.25)	- 4.4	± 23
Rchoke	(66.1)	- 11	± 10

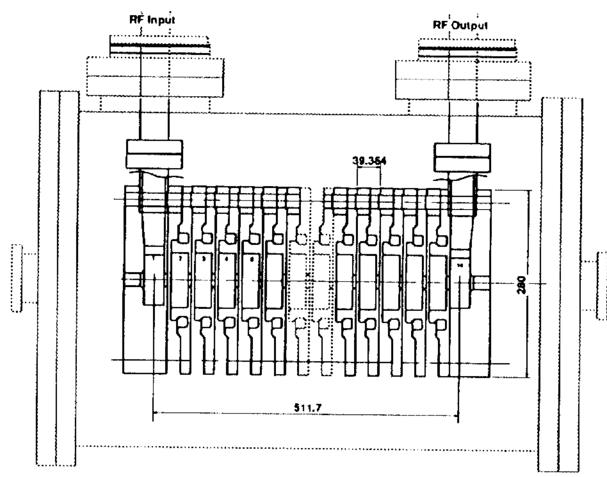


Fig. 1 S-band High Power Model

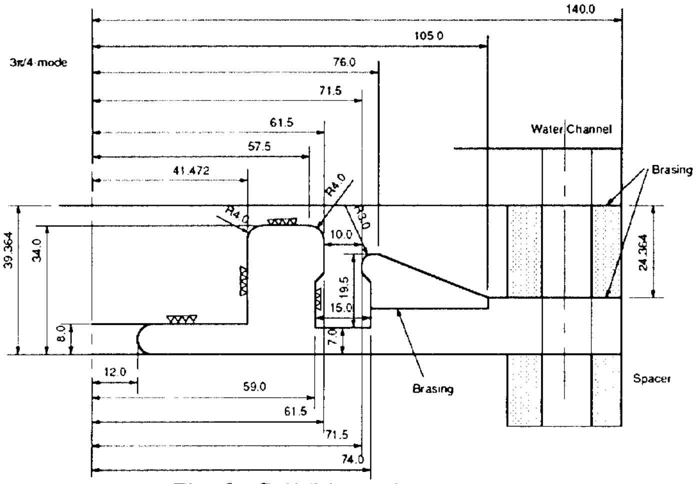


Fig. 2 Cell Dimensions

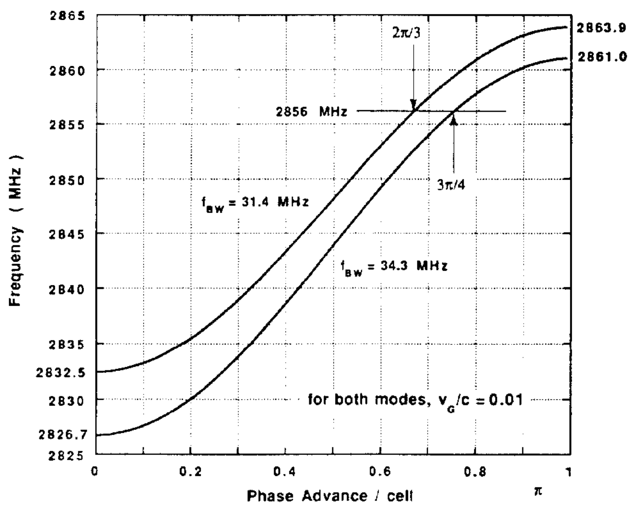


Fig. 3 3π/4-mode and 2π/3-mode.

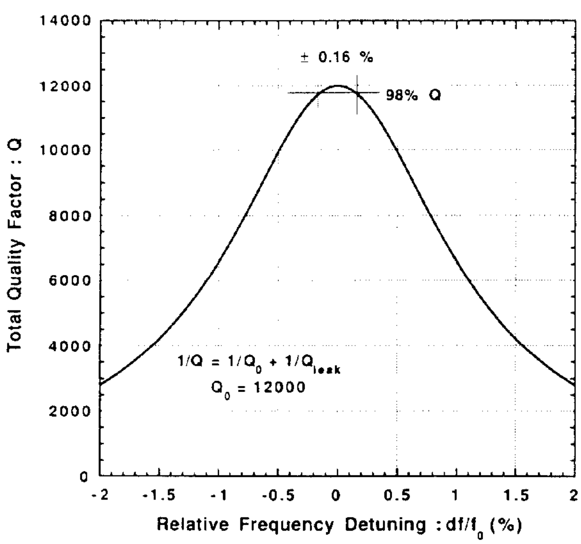
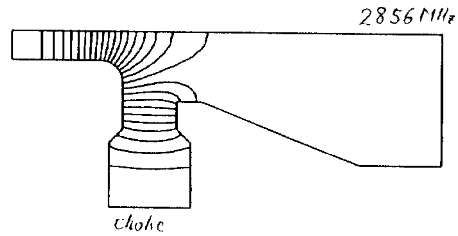
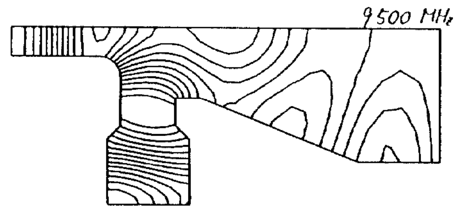


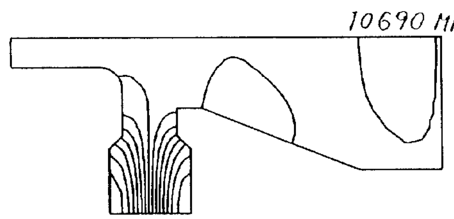
Fig. 4 Frequency dependence of Q-factor. Calculated by network model.



(a) Dominant mode, 2856 MHz.

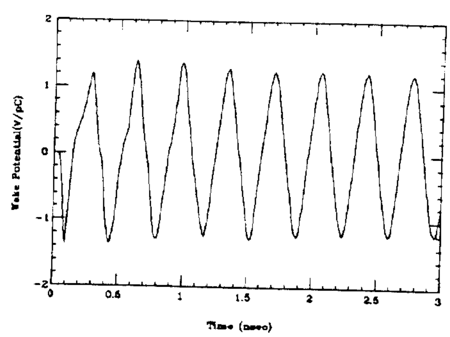


(b) 3rd resonance at 9.5 GHz

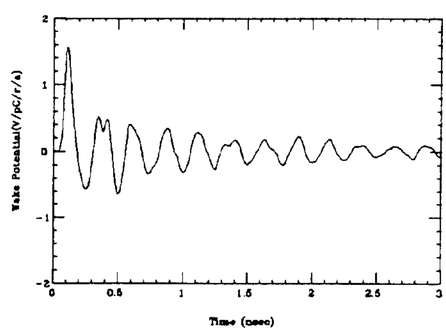


(c) Parasitic resonance at 10.7 GHz

Fig. 5 Choke Resonances



(a) Longitudinal



(b) Transverse

Fig. 6 Wake potential calculated by TBCI code.