FABRICATION OF THE C-BAND (5712 MHz) CHOKE-MODE TYPE DAMPED ACCELERATOR STRUCTURE

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Abstract

The first high power model of the C-band (5712 MHz) accelerating structure for the e+e- Linear Collider project is under construction. This is a full spec version: equipped with the Choke-Mode cavity for the higher-order mode damping, the double feed coupler for the symmetric power feed at input/output, and RF-BPM for the beam-based alignment at both ends.

Fabrication of the total 91-cells and their frequency tuning were completed. The cells were assembled in one structure by the electroplating of copper.

The integrated phase shift were measured, it was within ±5 degree at operation condition. It was confirm that a Higher-Order-Mode (HOM, TM_{110}) is successfully damped by a choke-mode cavity with an SiC type rf absorber [1].

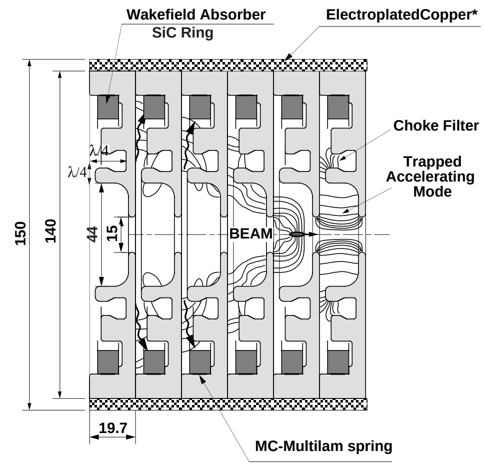

Figure 1: A cut of view of the C-band (5712 MHz) Choke-Mode structure.

Figure 2: C-band structure with SiC rf absorber.

1 INTRODUCTION

In the e^+e^- linear collider for 300-500 GeV C.M. energy region, one of the most important R&D issue for the accelerating structure is how to control the beam induced wakefield effects to achieve the nano-meter size beam at collision point.

From the beginning of the linear collider project, many ideas were proposed for damping the wakefield. However, most of those were not realistic; structure was very complicated, thus it was not suitable for mass production at a reasonable cost. In 1992, T. Shintake of KEK proposed a very simple HOM-free structure, so called Shintake-type “Choke-Mode” damped structure. [2] It is a kind of an open cavity. The beam induced power (HOM power) is strongly damped by the electromagnetic radiation through a radial line into open space, while the rf power necessary for the beam acceleration is trapped inside the cavity by a choke filter.

Its concept was confirmed by the experimental test performed at ATF-KEK in 1994, where the bunched electron beam was successfully accelerated in a prototype with S-band microwave power.

Figure 1 and 2 show the C-band model. The accelerating cavity, the annular slot for the choke and a room for the HOM absorber are machined on a copper disk on a turning lathe. The vacuum seal and mechanical structure is maintained by simply stacking them and plating copper layer from outside. The SiC ceramic ring is the HOM absorber, which is mounted in the disk with a metal spring insert (MC Multilum-contact). Since all parts are axial-symmetric, which can be machined on tuning lathe, the choke-mode type cavity has a big advantage on manufacturing than the other ideas proposed before.

The Choke-Mode concept has solved the multi-bunch problem. However, there is still another type of wakefield field problem. The short-range transverse wakefield causes the bunch shape deformation, resulting in loosing luminosity. This wakefield is a strong function of the iris aperture, its is proportional to $a^{-3.5}$, thus it becomes very strong at higher frequency bands. Considering the technical difficulties related to the tight tolerance, we did not use higher frequency, but chose the C-band (5712MHz) as the best frequency. The straightness tolerance is ±50 μm (maximum bow) for 1.8 m long structure. At the higher frequency bands, straightness becomes close to ±10 μm or less for 1.8 m-long structure.

In 1996, hardware R&D on the C-band rf system was started at KEK. The first high power 1.8 m-long Choke-

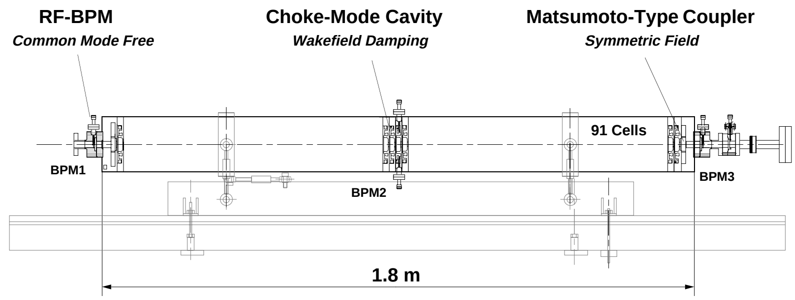

Figure 3: 1.8 m long high power C-band choke-mode structure.


Figure 4: Machined copper parts of field symmetric double feed coupler. They will be brazed together and mounted at both ends of the structure by the electron-beam welding.

mode structure is under fabricating at MITSUBISHI HEAVY INDUSTRIES Ltd. The structure to be tested at ASSET in SLAC in December this year.

This paper describes details on fabrication of the cell and tuning on the acceleration mode. Optimization on the HOM damping performance is described in a separate paper [1].

2 CHOKE-MODE STRUCTURE

The first high-power model of the C-band choke-mode structure is composed of the regular section (89 choke-mode cells), input/output couplers attached at each end, two common-mode-free RF Beam-Position-Monitor (RF-BPM) as shown in Fig.3. A wake-field monitor is prepared in the center cell, by which we can observe the beam induced HOM spectrum, and determine the beam position. To avoid unwanted transverse kick due to asymmetric field, the double-feed coupler using J-shaped waveguide is used in the input/output couplers as shown in figure 4.

2.1 Main Parameters of the structure

The main parameter of the accelerating structure designed for 500 GeV C.M. energy linear collider is listed in Table 1. To increase the shunt impedance, we changed the disk-thickness from 4 mm of initial design to 3 mm. It improved the shunt-impedance by 13%.

3 MANUFACTURING AND ASSEMBLING

3.1 Machining of the cavity

The choke-cell, and the coupler cavity are made of the high purity Oxygen Free High Conductivity (OFHC, >99.99%) copper. The final machining uses a very high-precision tuning lathe with a diamond cutting-tool of rounded shape (R0.5). The dimensional accuracy of the accelerator cavity was kept within 2 μm, except for the rounded part of the beam hole, where it is 5 μm, which provides the frequency valuation of within ±100 kHz.

The surface roughness was kept to 30 nm at cavity inner surfaces and within 500 nm around the beam hole [3]. Since the stored energy in the choke slot is much smaller than that in the acceleration cavity, the dimensional tolerance is much looser than that in the cavity cell, it is around ±30 μm. The electric field gradient is also lower in the choke slot, thus the surface roughness of 3-6 μm is enough. Therefore, machining of choke can be made on ca standard turning lathe, and it does not increase the fabrication cost

Table 1: Main parameters of the accelerating structure

Frequency	5712	MHz
Phase shift per cell	$3\pi/4$	
Field distribution	C. G.	
Number of cells	91	cell
Active length	180	cm
Iris aperture (2a) : up-stream : down-stream	1.74 1.254	cm cm
Cavity diameter : up-stream : down-stream	4.53 4.33	cm cm
Disk thickness: t	0.3	cm
Quality factor: Q	10.7-10.3	$\times 10^3$
Group velocity : up-stream : down-stream	0.035 0.012	c c
Average shunt impedance: rs	53-67.3	MΩ/m
Attenuation parameter	0.53	
Filling time: T_f	286	nsec

3.2 Assembling the SiC RF Load

In order to mount the rf load on the cavity, we decided to uses a thin metal spring, which was inserted between the SiC- ring and the outer-groove as shown in figure 6. The reason why the brazing was not used is to eliminate the high temperature bonding process, which causes dimensional changes in the structure, resulting in a big error on straightness, which can exceeds the 50 μm limit.

The cooling of SiC-ring is not a big issue in this case, since the estimated wakefield power per cavity is as low as 2 W only. The leakage power of the accelerating field is also quite low, because the choke has enough isolation gain as high as -90 dB.

When a HV-discharge is happen in a choke, the acceleration field will flow into the SiC. However, it also causes the detuning of the cell frequency and the traveling

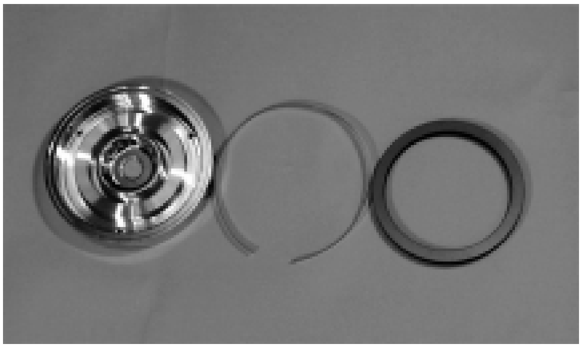

Figure 5: An SiC rf absorber components. Left: choke-mode cavity. Center: metal spring belt. Right: SiC rf absorber ring. An SiC rf-absorber ring is inserted smoothly into the outer groove by using a simple jig with pressure around 30 kgf.

rf power is reflected back to upstream. Only the stored energy in one cell will be dissipated on the SiC, which is only 0.2 J or less.

4 RF MEASUREMENT

After the precision machining, each cavity was stacked, and resonance frequency was measured. Since the relation between $\pi/2$ and $3\pi/4$ modes are known in advance, the $\pi/2$ mode frequency (cell resonance) was used for this check. The deviation from the target frequency of each cell was adjusted by slightly machining the inner dimension (2b) of the disk.

4.1 Choke Slot

The center frequency of the choke filter was measured with a special rf jig. The acceleration cavity part is electrically shorted by a metal disk, then a rf-signal is fed from the center terminal. The transmitted power through the choke is monitored by two pick-up antennas. Figure 6 shows the typical frequency response. The deviation of the center frequency from the target of all the cavities were within the specified values of ±1 MHz.

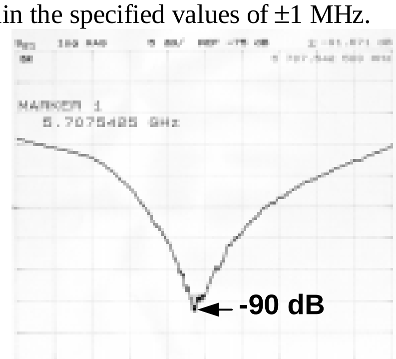

Figure 6: Frequency response of choke cavity.

4.2 Accelerating cavity

The cell resonance frequency was measured by a special jig, which detunes the neighboring cells and resonates at $\pi/2$ mode. Figure 7 show the frequency deviations from the operating point of 5712 MHz in vacuum. As can be seen in figure, all the data obtained within the specified frequency of ±200 kHz.

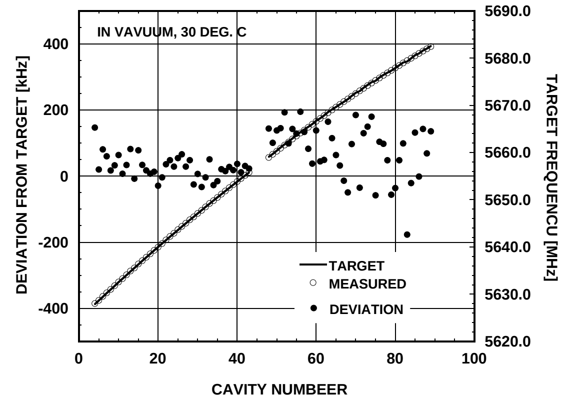

Figure 7: Frequency deviations from the target of each acceleration cavity.

5 ELECTROPLATING

To meet the straightness tolerance, we decided to uses the "Electroplating Method" (not to be confused with the prior electro-forming method), which plates a thick copper layer of 5 mm on the outer surface of stacked cavities. During this process, temperature of the structure raises, but only around 40 °C, which does not cause the dimensional changes in copper material and keeps the structure straightness [4].

6 SUMMARY

The deviation frequency from the target of the choke and accelerating cavity were obtained within each target value of ±1 MHz and ±200 kHz. An integrated phase error is around ±5° for 87 cavities.

It was confirmed that the conventional hardware technique, which has been used in fabrication of S-band accelerating structures, is enough to develop the C-band structure.

The fabrication will be completed in this fall, and its HOM performance will be tested with ASSET beam line at SLAC end of this year.

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