DESIGN AND MODEL CAVITY TEST OF THE DEMOUNTABLE DAMPED CAVITY*

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Abstract

Demountable Damped Cavity (DDC) has been designed in an ILC R&D. DDC has two design features. One is to use coaxial waveguide for strongly coupled out HOMs and apply choke filter to reflect accelerating mode. The axial symmetric RF design can reduce the beam kick effect. The other feature is demountable structure, which makes end group cleaning easy to suppress the Q-slope problem at a high field, and also could bring cost reduction in the cavity fabrication.

INTRODUCTION

It is important both strong HOM damping and high acceleration in the superconducting RF cavity for the ILC main linac. In multi-bunch operation, the long-range wakefields are excited by the forward bunches passing in the structure. If the wakefields are keeping existence, they deflect the coming bunches, and result in the multi-bunch beam breakup (or cumulative BBU) instability. The strong HOM damping is essential to suppress such effects. To obtain enough damping, the Q value of HOMs is to be lower than $1 \mathrm{x} 10^5$ for ILC machine [1].

OVERVIEW OF HOM DAMPERS

Various types of HOM dampers are used according to the purpose of the accelerator.

The coaxial antenna HOM coupler based on TESLA [2] is now adapted as ILC baseline design. The coaxial transmission line does not have the cutoff frequency and easily takes out HOMs. It can be designed compactly. Another merit is less cryogenic load, which is a cost driver in SRF machines, because the HOM power is taken out outside of the cryostat.

In the high-current accelerator like KEKB [3], HOM damping becomes much more serious. The RF absorber is mounted on the end of beam pipe (this method will be called "Beam pipe method"). As the beampipe is a cylindrical waveguide, it has the cutoff frequency. To damp HOM enough, a larger beam pipe is used for trapped HOMs to leak out the cavity and dissipate the power in the absorber. However, such a large beam pipe decreases the R/Q of the accelerating mode, which is unsuitable to the high-energy accelerator.

Cornell University has developed the special fluted beam pipe method instead of such a large beampipe for CESR-B [4]. It lets the trapped modes propagate out the cavity through the fluted waveguide, which decreases the Q_{ext} of the HOMs without decreasing R/Q of the accelerating mode.

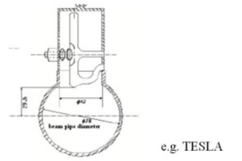
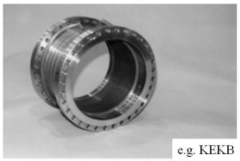
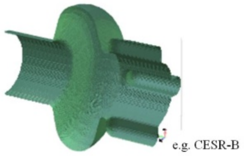
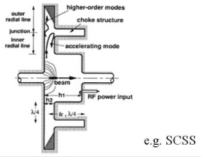
The concept of the choke mode cavity (e.g. SCSS [5]) has two devices: improved design in the transit line to take out HOMs easily like the special fluted beam pipe method, and choke cavity to reflect the accelerating mode at the transmit line, which makes the waveguide port imaginary short on the accelerating mode.

Table 1 compares the structure, the R/Q of accelerating mode, the Qext of HOMs, the fabrication cost, and the space factor.

RF DESIGN OF DDC

Fig.1 shows the DDC design on the Ichiro single end cell cavity. The RF design of the DDC is based on the upgraded choke mode cavity by Dr. Kageyama [6]. Keys of the RF design are followings. One is the coaxial waveguide, which takes out HOMs, especially trapped modes, at the end of the beam pipe, then damps in the absorber mounted there. On the other hand, TM010 mode (accelerating mode) propagats in the coaxial waveguide if no device is put. It is reflected back the cell using a choke cavity. The coupling constant between the cell and the coaxial waveguide can be adjusted by the length of the inner conductor. However a part of the accelerating mode is converted to TE01 mode at the joint of the choke structure and propagates out through the waveguide. This problem is reasonably solved using the cutoff frequency. The distance between the choke and the absorber is lengthened a little for this problem but the whole end

Table 1: Comparison by the Shape of Dampers.

	Coaxial antenna	Beam pipe	Special fluted beam pipe	Choke mode cavity
Figure				
R/Q(acc)	○	×	△	○
Qext(HOM)	△	○	○	○
Cost	×	○	△	△
Space factor	○	×	△	△

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group length is still same as ILC base line design.

Another key is the demountable end group. It has aimed to overcome a problem of high field Q slope observed in the TESLA type coupler [7]. Separating the end group from the cavity cell makes easy cleaning in such complicated end group. The separating point must be at a location where RF field is weak. We choose the point at outside of the choke cavity where the RF H-field is small about one sixth of that in the cell. The liquid helium base-plate is used as a part of the choke cavity to save the space. The demountable end group will be connected at the base-plate flange using MO seal.

We will establish the elemental technology in the single cell at first, then demonstrate on 9-cell cavity.

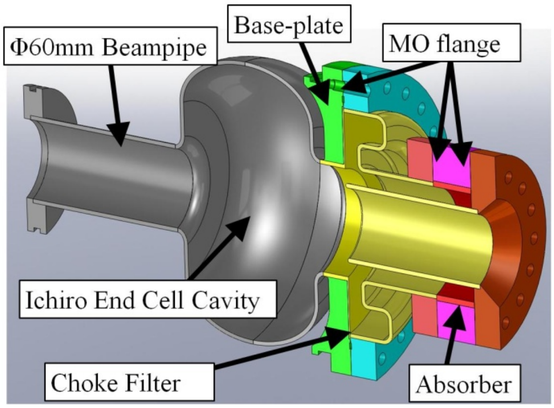


Fig. 1: Design of the DDC.

RF SIMULATION

We use Superfish and MW-Studio for calculating the RF characteristics of the DDC. Table 2 shows the comparison of Ichiro regular cell (both beampipe diameter are 60mm), Ichiro end cell (beampipe diameters are 60mm and 80mm), and the DDC. We can see the RF characteristics are even improved from Ichiro end cell because the choke cavity reflects the accelerator mode back to the cell.

Table 3 shows the Q_{ext} of HOMs which should be seriously damped both on the DDC (Fig.2) and the TESLA type HOM coupler (Fig.3 [8]). Superfish RF calculation is limited only for monopole modes, while MW studio can calculate all HOMs. For the DDC, we calculated the Q_{ext} of HOMs with MW studio. In this calculation, ferrite is supposed as the absorber material. We referred the TESLA like HOM coupler (KEK-STF baseline) from Dr. K. Watanabe's doctor thesis [8].

The Q_{ext} of the TESLA like type HOM coupler is higher than the DDC by ten times or more. In the TESLA type HOM coupler, TM110 (trapped mode) which has to be damped seriously, degenerates in two frequencies with different Q_{ext}s, while the DDC does not degenerate due to the axial symmetric configuration. The DDC can remarkably damp the trapped mode in an ILC cavity.

Table 2: Comparison of the RF Parameters.

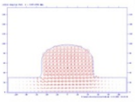
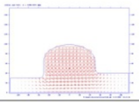
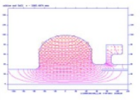
	Ichiro regular cell	Ichiro end cell	DDC
Shape			
Geometrical factor[Ohm]	281.8	286.9	282.4
R/Q[Ohm]	138.6	121.4	127.2
Ep/Eacc	2.07	2.22	2.17
Hp/Eacc[Oe/(MV/m)]	35.6	38.4	37.5
Max Eacc (critical field 1800[Oe])	50.6	46.8	48

Table 3: Q_{ext} of HOMs.

	TE111	TM110		TM011
		Low freq	High freq	
ISE cavity choke mode	negligible	$7x10^2$		$8x10^2$
Tesla Cavity STF I-type coupler	$2.0x10^4$	$3.5x10^4$	$5.3x10^3$	$1.0x10^5$

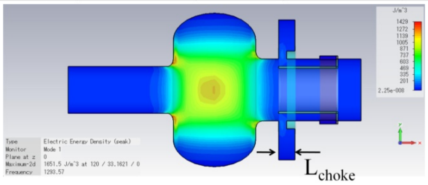


Fig. 2: DDC RF simulation model.

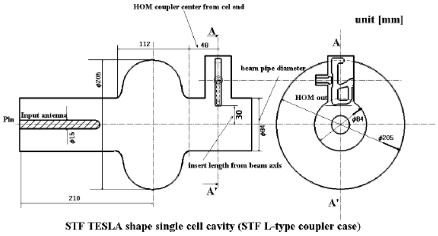


Fig. 3: TESLA type HOM coupler model [8].

MODEL CAVITY TEST

The purpose of the RF model cavity is to confirm that accelerating mode does not propagate to absorber while HOMs propagate out enough at absorber location. We measured the 2 type cavities: the DDC without absorber (Fig.4 left) and the simple Ichiro end cell cavity with the coaxial inner conductor inserted in the φ80 beampipe (Fig.4 right), which is referred as "Simple coaxial cavity". For both cavities, an input coupler is inserted in φ60 beam pipe and a pick up antenna locates between φ80 beam pipe and the inner conductor.

Fig. 4: DC (left), Simple coaxial cavity (right).

Fig.5 shows the results of network-analyzer measurement (S21) in the Simple coaxial cavity and the DDC without absorber. We can see that the TM010 mode (fundamental mode 1300MHz) is rejected in the DDC (red solid line in Fig.5) while it propagates to the end of beampipe in the Simple coaxial cavity (blue dot line in Fig.5). A lot of HOMs appears in Fig.5 because both cavities do not equip absorber. The mode assignment was done with the frequency by RF simulation. We labeled the HOMs as cavity modes, choke modes and coaxial modes, which show where the fields are mainly exited. From the simulation results, we have confirmed that both choke and coaxial modes propagate to the absorber and damped enough with the DDC, for instance their Q_{ext}s are between100 and 1000.We will measure the DDC with absorber soon.

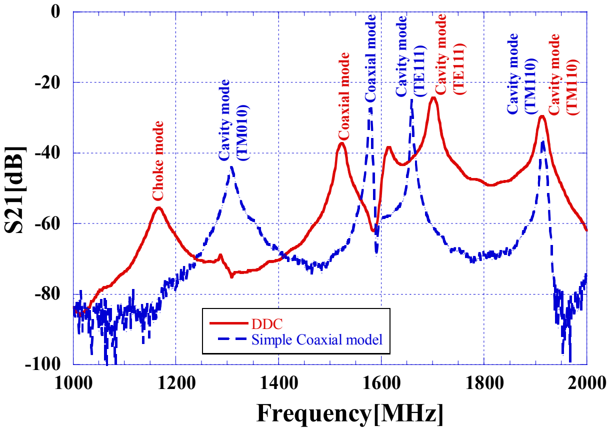


Fig. 5: Comparison between the DDC and the simple coaxial cavity.

TECHNICAL CHALLENGE

We have many technical challenges to realize the DDC. Followings are issues to be technically solved.

Demountable Structure

This will be solved by applying the MO seal which is a zero impedance vacuum sealing method. It is under developing in our group [9]. The seal location is at the choke cavity flange where the RF field is weak. The surface electric and magnetic fields on this location are ~96kV/m and ~305Oe when the theoretical maximum fields (Eacc=48MV/m and Hp=1800Oe) are excited in the cell.

Thermal Structure

The choke cavity and the inner conductor parts close to the cell have to keep at 2K. The RF dissipation there must be removed efficiently. However, the end group is out of the He vessel and not immerse to liquid He. Therefore we need a design the RF dissipation easily taken out to thermal anchors. The Nb/Cu film coating technology will be suitable for the requirement [10].

The Sensitivity of Choke

The choke cavity is highly sensitive with mechanical tuning. We calculate the sensitivity as shown in Fig.6: relation of L_{choke} (see Fig.2) and $Q_{absorber}$, which means the RF loss of accelerating mode in damper. If required $Q_{absorber}$ to be 10^{12} or more, L_{choke} has to be controlled within a submicron. This accuracy could be achieved by the piezoelectric tuner but it increases the end group cost.

To lower only the Q of the choke cavity would be other way. For instance, Ti/N coating is a candidate, which is well known as unti- multipacting. If coated it on the SRF surface of the demountable choke cavity, the Q would be reduced due to the increased surface resistance.

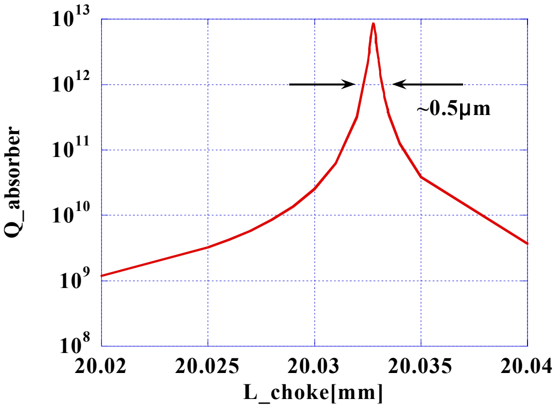


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Fig. 6: Relation L_{choke} and $Q_{absorber}$.

Absorbing Material

We will adapt the AlN-glassy carbon as the absorber, which is working well in CEBAF, JLAB [11].

Multipacting

As mentioned above, Ti/N coating on the SRF surface of the demountable choke cavity could be effective. We will start simulation on multipacting soon.

SUMMARY

We have designed the DDC to improve the problems of TESLA type HOM coupler. There are many technical challenges. We will prove one by one using the single cavity, then step up to the 9-cell cavity.

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