DEVELOPMENT OF A DISK-TYPE CAVITY INPUT COUPLER

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Abstract

A disk-type input coupler for the RF cavities has been developed and tested in PAL. The motivation for this work is to fabricate a coupler, which has the coaxial input port since PLS RF system utilizes the coaxial transmission line for RF power delivery. During the development, technologies like ceramic brazing, precision machining and coating were required. Computer modeling, fabrication, vacuum seal test, low power test were performed for the prototype. High power test is being performed on the PLS RF test stand with the cavity to be installed in the RF Test-Lab. Good performance are expected and better response to the cavity higher order modes are observed. We will present a whole procedure of the development and the test results.

1 MODELING

A loop coupler with a cylindrical ceramic window has been used for the PLS RF cavities. A new design with a disk-type window was strongly considered since this design would eliminate the unnecessary transition between waveguide and coaxial line. The same loop coupler design as the previously used one was adopted for obtaining similar coupling factor. A section with a disk-type window was redesigned for matching. To calculate the coupling factor, a 3D MAFIA model of the cavity incorporated with a coupler geometry was made as seen in Fig.1. Figure1 shows an electric field line for the fundamental frequency (500MHz) as well as the model geometry.

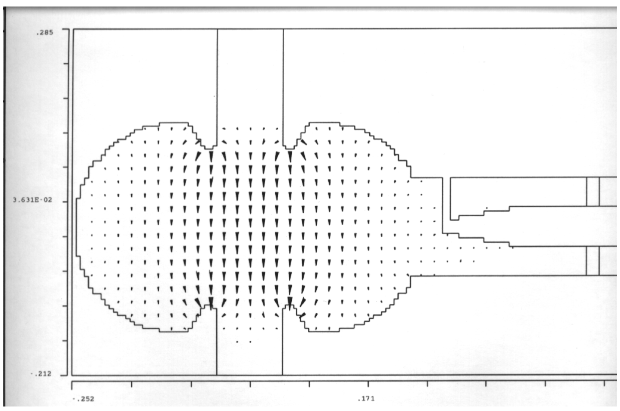

Figure 1: An electric field line for the fundamental frequency

Total number of meshes are over 400,000 and we only model a case in which the loop is aligned to the beam axis, giving a maximum coupling factor. We calculated the Q_{ext} as described in reference[2]. A calculation shows that the coupling factor is 3.1, however our measurement on the prototype is 4.5. This discrepancy might be due to the coarse mesh size around the loop position. Other cavity parameters such as the loaded and unloaded Q and the shunt impedance are in good agreement.

2 FABRICATION

2.1 Precision machining

Materials of the new input coupler consist of OFHC(oxygen free high conductivity) copper, SUS316L, and Al_2O_3 ceramic. The machining was very difficult to fabricate main component which is made of OFHC copper with diameter of 155mm, thickness of 1mm, length 100mm. The all components of input coupler have been allowed to have some machining error for carrying on assemblies and vacuum brazing. Otherwise, smooth difficulties in assembly and vacuum brazing could be taken place. The surface roughness of should be more than 1.6a(Ra). The machining have been accomplished with all the surface between 0.54a(Ra) and 1.30a(Ra).

2.2 High-vacuum brazing

The high vacuum brazing used in the development of input coupler divided as two stages in temperature. The first is middle temperature vacuum brazing from 780°C to 850°C, which is the interior temperature of vacuum furnace. And the second is high temperature vacuum brazing from 965°C to 1000°C. At here we describe on the high temperature stage.

2.2.1 Ingredient and characteristic of a material used for the high temperature vacuum brazing

The high temperature vacuum brazing has been used for joint of OFHC Cu with Al_2O_3 ceramic disk. A characteristic of material is shown in Table1.

2.2.2 Metallizing

The Al_2O_3 ceramic is widely used in various fields recently. Since it has a variety of good characteristics, such as the thermal endurance, the corrosion endurance and the abrasion endurance. But Al_2O_3 ceramic is fragile due to ion combination or joint combination, which it is a clear difference from a metal. Therefore, We metallize the brazing surface of ceramic, which compensate for the fragile characteristic. Major ingredients of metallizing paste are Mo and Mn. The thickness of metallizing is about 15µm up to 65µm.

Table 1: A characteristic of material

OFHC copper		Ceramic disk		Brazing alloy	
Ingredient	%	Characteristic		Characteristic	
Cu	99.99	Purity	95%	Extension Intensity	60 kg/ mm^2
H_2	0.4	Thermal Expansion Coef.	7.7× 10^{-6}/K	Increase Ratio	25%
O_2	3			Solid-state Temp.	877 °C
Oxyzen Content	≤5ppm	Thermal Conductivity	18W/ mK	Liquidity Temp.	921 °C

2.2.3 High-vacuum brazing

We have been assembly use brazing jig of ceramic disk and OFHC Cu. Figure 2 shows a state of combination ceramic disk and OFHC Cu. After, it was insertion in vacuum furnace. Temperature of vacuum furnace for this stage is 965°C to 1000°C. A temperature keep up roughly 50 min. A vacuum pressure of vacuum furnace for this stage is $3.2x10^{-5}$ Torr. And temperature of vacuum furnace made low to the normal temperature. And it would been testing for vacuum seal.

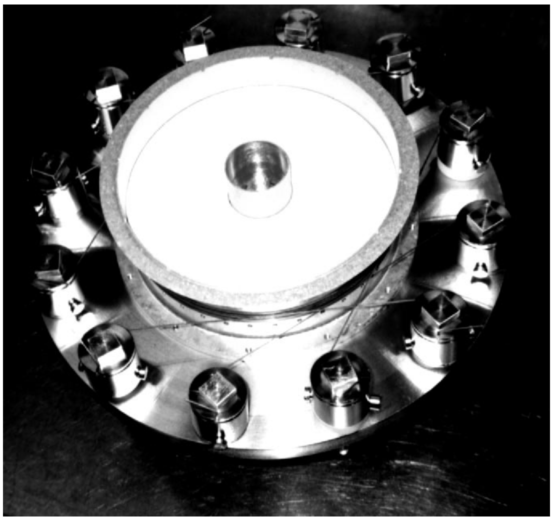

Figure 2: A state of combination ceramic disk and OFHC Cu (a preceding insertion in vacuum furnace)

3 TEST OF THE PROTOTYPE

3.1 Brazing test

After high temperature vacuum brazing of ceramic disk with OFHC Copper, we have tested to evaluate the brazing process. The first one is the vacuum seal test for spray the He on vacuum brazing point, when will reveal the leak point if there is any. The results was good and at that time vacuum condition was $3x10^{-8}$Torr.

The second test, after cutting the interface of vacuum brazing, is to analyze the ingredient at interface by using the EPMA equipment. Figure 3 shows the interface of vacuum brazing.

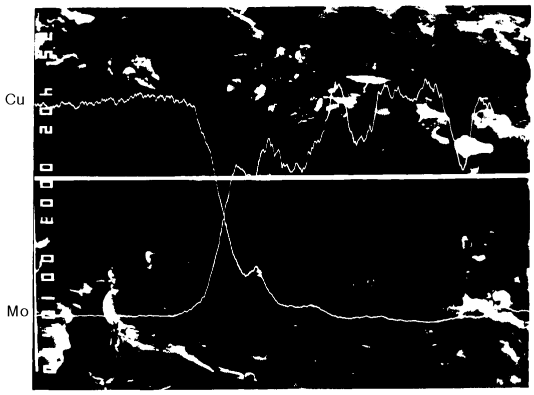

Figure 3: EPMA(Electron Prove Micro Analysis) Cu-Mo peak in Al_2O_3-Cu interface joint

3.2 Low power test

At the resonance of the cavity mode, the coupling is proportional to the input cavity impedance, which is proportional to the square of the mutual inductance between the coupling loop and the cavity mode. This mutual inductance is proportional to the integral of the cavity magnetic field through the coupling loop ; the overall integral,

$$\beta \propto Z_{cavity} \propto \left[\int_s \vec{H} \bullet d\vec{a}\right]^2 .----(1)$$

From this form the variation of coupling with a change in the loop position and the rotation angle can be determined. For a magnetic field which is uniform access width of the input port and which decays exponentially with distance away from the cavity the variation of coupling with a change in angle or a change in penetration into the input port are given by ;

$$\beta(Z) = \beta_0 e^{-2\delta(Z-Z_0)} .--------(2)$$

At ϕ=0°,
The measured values for two different loop positions are

Relative loop position (mm)	β
0	8.97
23.05	2.014

From equation (2) the attenuation constant is obtained as

$$\frac{1}{\delta} = 3.08\text{cm}^{-1} .----------(3)$$

Bellow the loop, the input coupler port forms a circular waveguide with 12 cm of diameter. The dominant mode TE_{11} and the attenuation lengths of this mode is

$$\frac{1}{\lambda_e} = \frac{1}{\sqrt{k^2 - k_0^2}},$$

$$k^2 = \left(\frac{1.842}{6}\right)^2,$$

$$k_0^2 = \left[\frac{2\pi\left(500.082\times10^6\right)}{3\times10^{10}}\right]^2,$$

$$\frac{1}{\lambda_e} = 3.47\mathrm{cm}^{-1} \text{ ----------- } (4)$$

Since (3) and (4) agrees well, TM_{010} mode, fundamental mode of the cavity would be expected to couple most strongly to the TE_{11} mode in the circular input coupler port.

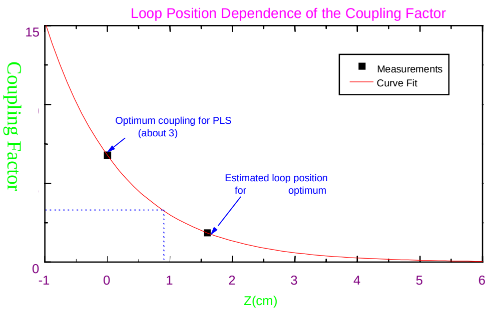

Figure 4: Loop position dependence of the coupling factor

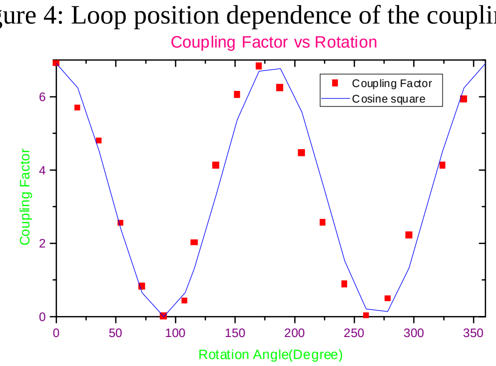

Figure 5: Coupling factor vs. Rotation angle

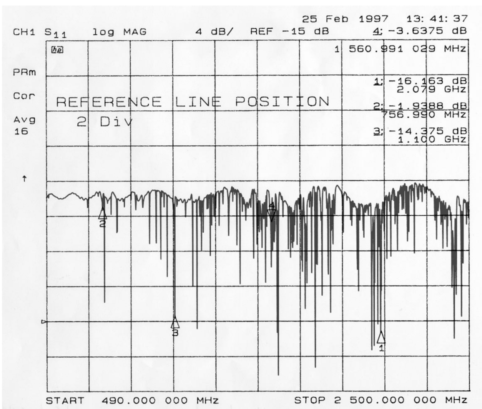

Figure 6: HOM characteristic of old input coupler

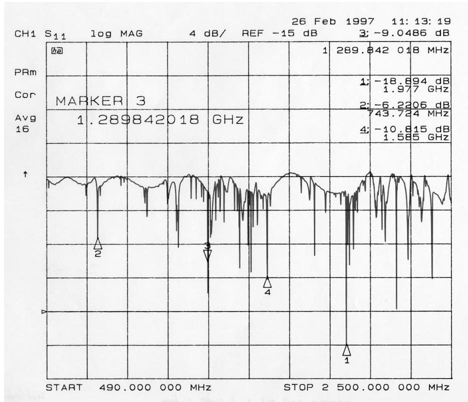

Figure 7: HOM characteristic of prototype input coupler

4 SUMMARY

A loop coupler with a disk-type window has been developed and tested for evaluating mechanical and electrical performances. It will be placed in a high power test stand for testing under high RF power. A HOM absorber outside the window is also being developed.

5 REFERENCES

[1] I. S. Park, et al., ‘Development of Input Coupler for PLS RF Cavity’, Annual Report of the 1996 PAL, (1997).

[2] J. S. Yang, et al., ‘Low Power Test of Input Coupler for PLS RF Cavity’ PAL Tech. Report, PAL-PUB-97-014, (1997).