DEVELOPMENT OF THE NEW C-BAND 50-MW CLASS SiC RF LOAD

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Abstract

A high power rf-load is being developed as a part of the R&D for the e^+e^- linear collider (GLC). In this rf load the microwave power is absorbed using sintered ceramic Silicon Carbide (SiC). The main body of this rf-load is composed of a cylindrical cavity chain of 10 TM_{011} cavities each having 4 SiC disks brazed on the loading disk to absorb enough microwave power to meet the requirements in a system at C-band frequency with 50-MW of peak rf power at a pulse width of 2.5-μs and pulse repetition rate of 50-pps. In this paper we present the design and progress of the development of the C-band 50-MW class SiC rf load.

INTRODUCTION

The Linear Collider project (GLC-I, Japan) is aimed for a high energy e^+e^- linear collider at 300-500 GeV. The high power klystrons for the GLC-I will be of 50-100 MW class. The accelerator will need more than 8,000 of them [1] and more than 16,000 high power rf-loads. This huge-scale machine requires an almost astronomical total component count and certainly no laboratory has any experience in fabricating, or operating such so many accelerator devices. Therefore, manufacturability, reliability and maintainability are all critical considerations in the developing the rf-loads.

We are developing a new type rf-load using SiC absorbers. The advantages of this rf-load over the existing ones, the SiC rf-load of bullet shape [2] which uses direct water-cooling system and the SiC rods of different height brazed on the narrow wall of the rectangular wave-guide [3], are as follows: i) its main body is TM_{011} mode cavity-chain which is axially symmetric and can be manufactured by a conventional turning lathe, ii) the SiC disks brazed on the loading disk are of same size and axially symmetric, and iii) a simple and indirect water cooling is used. Since it allows us to eliminate the use E-bends the system will become simpler and the cost of 8,000 of the E-bend high power wave-guide components will be reduced.

In this paper, we discuss the detailed design of the cavity type SiC rf-load. The front, end and side cut-away view of the rf-load is shown in Figure 1 and its specifications are listed in Table 1.

Table.1 Specification of the SiC rf load

Frequency	5712 ± 10-MHz
Handling power	
P_{peak}	50-MW, 2.5-ms pulse, 50-pps
$P_{average}$	6.25-kW
Input VSWR	1.05
Materials	
Main body	OFHC
Waveguide flange	SUS316L
Water jacket	SUS304
Q	~ 30
Cooling water rate	10 ~ 20-l/min

DESIGN STUDY

The rf load consists of four major components [4]; an impedance matching section, a mode filter, a cavity-chain of 10 TM_{011} mode cavities, and a cooling water jacket.

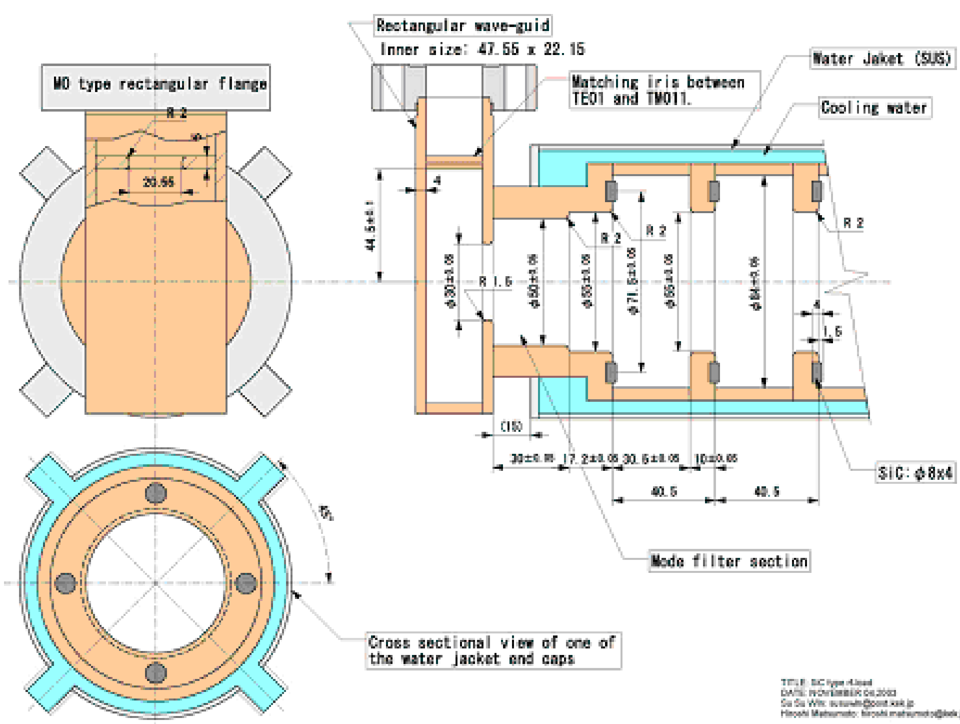

Figure 1: A conceptual drawing of 50-MW Class SiC rf-load

Using HFSS, used the ANSOFT FEM code, we carried out the simulation of design study. For the impedance matching section inductive iris type coupler is used to match the impedance between the rectangular wave-guide, TE_{01}, and TM_{011} mode cavity-chain due to its simple structure and reduction of surface electric field at the coupling iris. The design drawing of the coupler for the simulation is shown in Figure 2. The mode converter not only provides the impedance matching but also purify the TM_{01} mode. By adjusting the inductive coupling hole on the rectangular wave-guide the mode filter can match the impedance while by adjusting position of the short plane it can provide the separation of cylindrical TM_{01} mode from cylindrical TE_{11} mode.

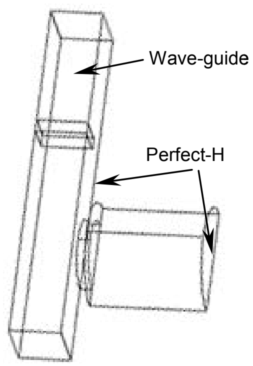

Figure 2: Half-sectioned impedance matching for simulation

The mode filter is 50-mm in diameter, which was chosen to be excited only the TM_{011} mode into the chained cavities, and it can suppress unwanted modes. We used quarter-wave impedance matching method to minimize the reflection coefficient, S_{11}, between the mode filter and the TM_{011} cavity-chain. From analytical calculation we decided the simulation for mode filter section to begin with the combination of 50-mm in diameter for the mode-filter and 55-mm in diameter for the quarter-wave section.

The cavity-chain includes 10 TM_{011} mode cylindrical cavities. As it is important to control the transmitted rf-power the optimum diameter of coupling iris was determined so that the absorbing power density in each SiC disk is below 300-W/cc. Figure 3 shows the loaded quality factor and group velocity with various diameter of coupling iris. The iris was chosen to be 55-mm with which the loaded quality factor of the cavity is about 30.

For absorbing microwave power the disks of β-crystallized SiC with good uniformity of powder size are brazed on one side of each loading disk (Figure 4). The effect of dielectric constant of SiC on loaded quality factor and S_{21} parameter are determined with single TM_{011} mode cavity and 4 SiC-disks. The power loss per cavity was calculated by varying the dimensions of SiC. We have chosen the SiC size of 8-mm in diameter and 4-mm in height, which can provide 10% power loss per cavity. Each SiC is mounted into 8.25-mm in diametr and 2.5-mm deep hole on the surface of loading-disk to mesk the

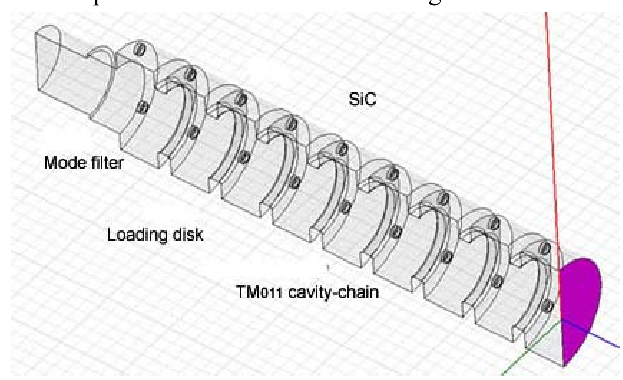

Figure 6: TM_{011} mode half-cavity chain for the simulation

brazing material from the electrical field. As shown in Figure 5 the S_{21} parameter, the transmission power, increases about 20% when the dielectric constant is reduced from 23 to 10.8. Therefore, the S_{21} is sensitive to the dielectric constant while there is no change in loaded quality factor with changing the dielectric constant of SiC. Figure 6 shows the half-cavity chain for the simulation. The physical tolarance of the dimensions of the cavity and SiC is necessary for manufacturing and fibricating. Therefore, we determined frequency

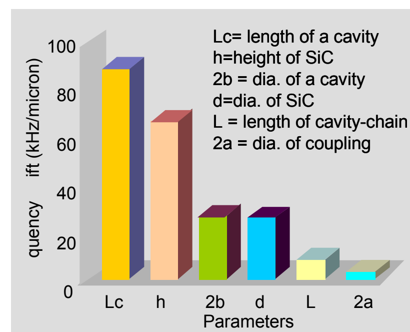

Figure 7: Frequency shift due to the dimension of TM_{011} mode cavity and SiC disk

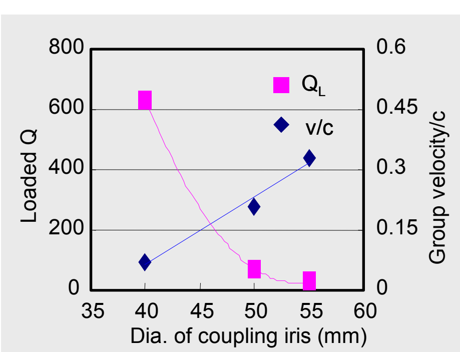

Figure 3: Loaded Q and group velocity with diameter of coupling iris

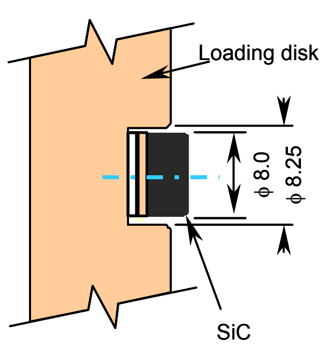

Figure 4: SiC disk brazed on loading disk

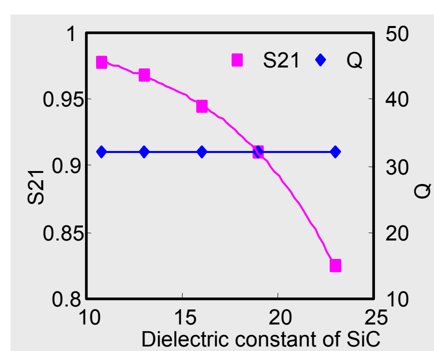

Figure 5: Changes in S_{21} and loaded Q with dielectric constant of SiC

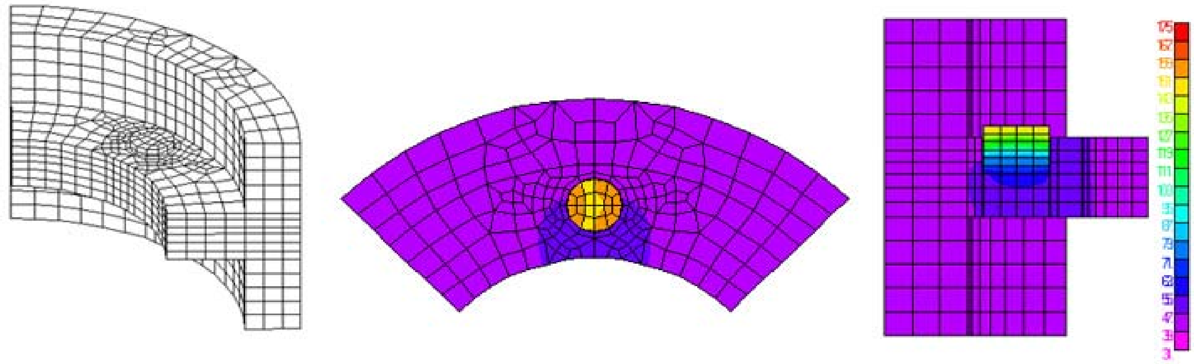

Figure 8: Thermal analysis of the TM_{011} main body using NASTRAN V70; FEM model and temperature distribution of TM_{011} cavity and SiC disk

sensitivity on the dimensions of the TM_{011} and SiC disks and the results are shown in Figure 7. Among the parameters of the cavity the maximum frequency shift is due to the length of the cavity and is 86-kHz/μm while the frequency shift due to the height of SiC disk is 65-kHz/μm. As the maximum frequency shift is of TM_{011} cavity is very low so that the standard mechanical machining is applicable.

For cooling, the jacket type water cooling system is used. The water jacket includes 4 inlets and 4 outlets to maintain uniform water flow. The thermal analysis of the TM_{011} cavity-chain with SiC was done by using the FEM program, NASTRAN V70. The typical data are shown in Figure 8 for FEM model and the temperature distribution at the cooling water flow speed of 0.5-m/s whose equivalent volume flow rate is 17-l/min. Using cooling water flow rate at 17-l/min, the periphery of the SiC on the top surface which has the highest temperature is about 151°C. The temperature difference between the periphery and the centre on the top surface of the SiC is about 10°C. The highest temperature of the cavity is just below the mounted SiC and is about 70°C.

SUMMARY

The design study and the test model of the 50-MW rf-load using β-crystallized SiC absorbers have been completed (Figure 9). The HFSS was used for the design study and the NASTRAN was used for the thermal analysis. The rf-load consists of 4 major components; impedance matching section between the rectangular waveguide and cylindrical cavity, the mode filter section, the TM_{011} mode cylindrical cavity chain, and the cooling water jacket.

The transmitted rf power is controlled below a 300-W per cc for the safety of absorbing power density in each SiC disk. As 4 SiC disks are brazed on one side of each loading-disk there are 40 SiC disks in total which will absorb the rf power. We will use the same brazing method as was used for the KEKB injector linac rf-loads.

At the rf input power 50 MW, 2.5-μsec and 50-pps which means 6.25-kW power in average with the cooling water (30°C) flow rate of 20-l/min when running the highest temperature of SiC will be about 150°C. Therefore, we will use a very simple water jaket which has one way flow of water.

Figure 9: Test model of 50 MW class SiC rf-load

The goal is to develop an integral rf-load for the accelerating structure . By using such rf-load we will be able to eliminate all 8,000 output couplers. Therefore, the cost will be enormously reduced as a result. Moreover, it will also increase the reliability especially in high gradient operation.

REFERENCES

[1] H. Matsumoto et al., “KEK C-band RF System R&D Status for Linear Collider”, Proc. of 28th LINAC Meeting, July 30-August 1, 2003, Tokai, J-PARK.

[2] H. Matsumoto, “Application of the SiC-ceramics for Microwave absorber” (in Japanese), Proc. of the Linac Meeting in Japan, 1983.

[3] H. Matsumoto et al., “Experience on the High-Power SiC Microwave Dummy load using SiC Absorber”, PAC99, March 29-April 2, 1999, New York City, U.S.A.

[4] S. S. Win et al., “A new C-Band 50 MW Class SiC RF load”, Proc. of 28th LINAC Meeting, July 30-August 1, 2003, Tokai, J-PARK.