

DESIGN OF A MOVABLE SYNCHROTRON RADIATION MASK WITH SiC ABSORBER FOR THE PHOTON FACTORY ADVANCED RING (PF-AR)

T. Takahashi[#], M. Izawa, S. Sakanaka, and K. Umemori, High Energy Accelerator Research Organization (KEK), 1-1 Oho, Tsukuba, Ibaraki 305-0801, Japan
 H. Suzuki, J. Watanabe, Toshiba Corporation, Yokohama 235-8523, Japan

Abstract

We have six rf cavities in the Photon Factory Advanced ring (PF-AR) at KEK. One of them was seriously damaged by the synchrotron radiation (SR) from the upstream of the cavity in 2003. In order to protect the cavities from the SR, we developed movable SR masks that have SiC absorber to protect an RF contactor from HOM of the cavity. The mask head is made of Alumina dispersion-strengthened copper to block high power from the SR. It will be installed nearby the cavities in this summer. We report the design of the movable SR masks and the results of high power test.

INTRODUCTION

The PF-AR [1] is a 6.5-GeV synchrotron-light source at the High Energy Accelerator Research Organization (KEK). The accelerating system [2] for the PF-AR comprises six 11-cell cavities, two 1-MW klystrons and rf distribution networks. Two cavities were located in the east straight section and four cavities in the west section until 2004. One of four cavities was seriously damaged by the synchrotron radiation in April, 2003 [3], and it was replaced with a spare cavity. Though some fixed SR masks were installed at the cavity sections after the trouble, they were not enough to block the SR completely. Because the cavity is made of iron and its inner surface is plated with copper, the inner surface of the cavity does not fit for high local heat load due to the SR. Therefore we decided to install the new movable SR masks before remaining cavities will be damaged. The new mask will be installed in the upstream of each cavity section in summer, 2007.

DESIGN OF THE MOVABLE SR MASK

The synchrotron-radiation mask will be installed next to the cavity as shown in Fig. 1. Because each 11-cell cavity for the PF-AR is very long (3.4 m), the SR mask, which can protect the cavity from impinging the SR, should be located very close to the beams. For the most upstream cavities (two cavities in both east and west sections), the head of the mask should be located 19 mm apart from the beams. Because this aperture is not acceptable for beam injection, the SR masks should be movable. Another concern is high wakefield power from the cavity. The PF-AR is routinely operated with single-bunch beams of up to 60 mA, the beams can induce high parasitic losses in the cavities. We actually experienced heating problems in

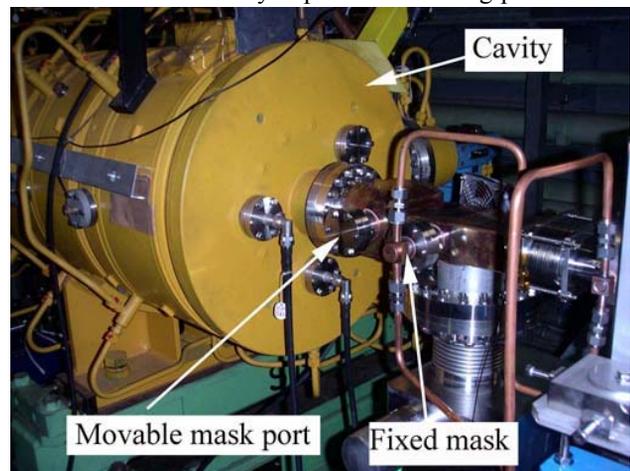


Figure 1: Photograph of the upstream side of the cavity.

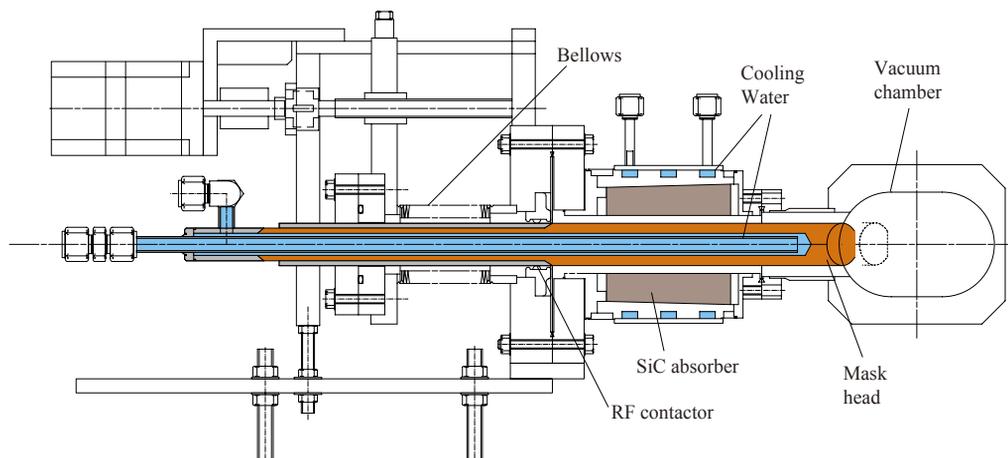


Figure 2: Schematic view of the movable SR mask.

[#]takeshi.takahashi@kek.jp



Figure 3: Photograph of the movable SR mask.

some taper ducts and slits beside the cavities. Since the SR masks have some trapped resonance modes, the beam-induced microwaves from the cavities can be built up at the movable masks, and can damage RF contacts in the masks. To avoid such problems, we decided to equip a microwave absorber in its coaxial-line part. The schematic view of the SR mask, and its photograph, are shown in Fig. 2 and 3, respectively. To manage high heat density due to the SR (input power: 450 W at 60 mA) from 6.5-GeV beams, we used an Alumina dispersion-strengthened copper (GlidCop™) for the mask body. The inside of the mask is cooled by water. The mask can move with a stroke of 40 mm using a stepping motor. The microwave absorber, made of silicon-carbide (SiC) is located in the coaxial-line part between the mask head and the RF contactor at the end of the line. The SiC absorber can dissipate microwave power which is induced in the neighboring cavity.

ESTIMATION OF DISSIPATION POWER

The estimation of dissipation power was done by using HFSS. Figure 4 shows the model structure used in HFSS calculation. The condition of the estimation is as follows; 1) the beam duct is simplified to a round duct ($\phi 100\text{mm}$).

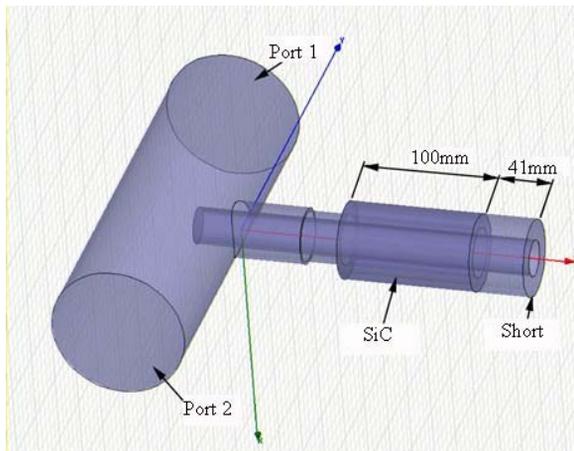


Figure 4: Model structure of the SR mask.

2) the wakefield comes from the cavity in the propagation mode of TM₀₁ of which frequency is above the cutoff frequency of the round duct (2.297GHz). 3) the power spectrum of the wakefield is roughly approximated;

$$P(\omega) \propto \exp(-\omega^2 \sigma_t^2) \quad (1)$$

,where ω is the frequency and σ_t the bunch length.

Under these conditions, S-parameters for port 1 and port 2 shown in Fig. 4 were calculated. Then the ratio of power R_p , which is dissipated in SiC, is expressed as,

$$R_p = 1 - (S_{11})^2 - (S_{21})^2 \quad (2)$$

Using Eq.(1), the total power P_{total} is expressed as,

$$P_{total} = a \int \exp(-\omega^2 \sigma_t^2) d\omega \quad (3),$$

where a is the normalize factor.

The total power of the wakefield come from the cavity is estimated as follows, the total power induced in the cavity by a bunch is easily obtained from the loss parameter of the cavity. A part of power is dissipated on the cavity surface. Assuming the remaining power propagates out of the cavity through beam duct, the contribution of propagating power to the loss parameter is obtained by substituting the contribution of eigen modes from the loss parameters of the cavity. Using MAFIA, the loss parameter of the cavity was calculated and the value was 5.05 V/pC. The contribution of eigen modes was also calculated by using MAFIA. The value was 4.345 V/pC. Therefore the loss parameter corresponding to the propagating power is 0.705 V/pC. Total power is then estimated to be 3.2 kW with σ_t of 1.7 cm and the beam current of 60 mA. Now we can estimate the rough power distribution of the wakefield above the cutoff frequency as shown in Fig. 5. The power loss distribution on

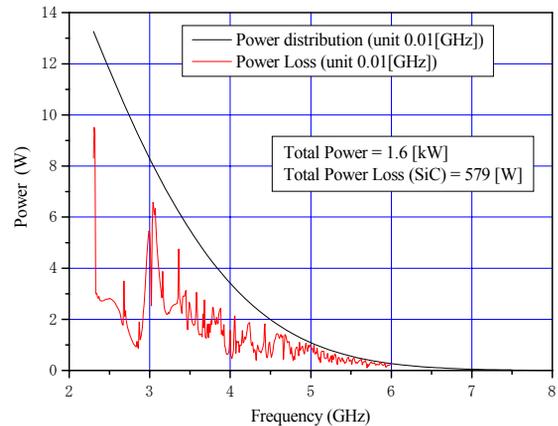


Figure 5: Estimated power distribution of the wakefield absorbed in SiC.

frequency in SiC is estimated to be $P(\omega) * R_p$, which is also shown in Fig. 5. The total power loss in SiC is then obtained by integrating $P(\omega) * R_p$. The result was 579 W. We designed the max power of the SiC absorber upto more than 1kW based on ref.[4].

RESULTS OF HIGH POWER TEST

We made the high power test of the movable SR mask. The max power we tested was about 1kW. Figure 6 shows a block diagram of the high-power test stand. The TEM mode at a frequency of 1.296 GHz is provided by a 5-kW klystron. It propagates in a coaxial line and is then transformed to TE₁₀ mode. TE₁₀ mode propagates in rectangular waveguide. The movable SR mask is attached to the end of the rectangular waveguide as shown in Fig. 7 which shows the movable SR mask under testing. In the middle of rectangular waveguide, a ceramic window is placed in order to evacuate the movable SR mask. The incident power and the reflected power were measured using a directional coupler, which is located just after the circulator. We tested the movable SR mask up to an input power of about 1 kW in the continuous-wave (CW) mode. When the maximum incident power was 1.29 kW, the reflected power was about 215 W, it means that the dissipated power of the SiC absorber was about 1.07 kW. The dissipated power of the SiC absorber estimated from the temperature rises of the cooling water for SiC absorber was about 0.945 kW. The base pressure of the SR mask was 5.9×10^{-5} Pa and it increased only up to 6.8×10^{-5} Pa at incident power of 1.29 kW. We also monitored the SR mask by using movie camera, and found no signs of discharge. We could confirm that the movable SR mask meets the power requirement very well.

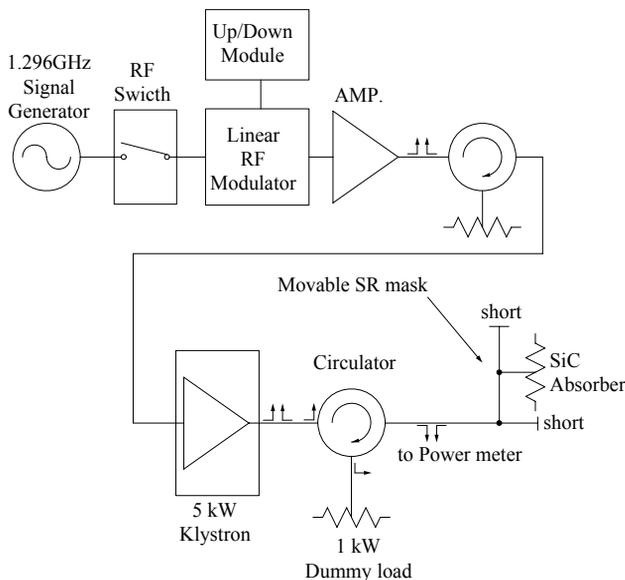


Figure 6: Block diagram of the high power test stand.

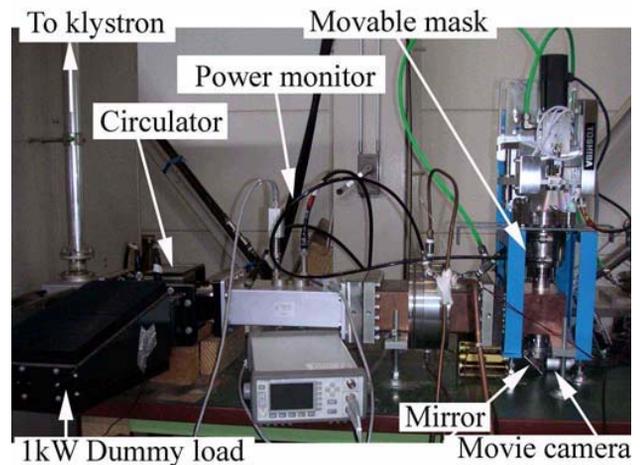


Figure 7: The movable SR mask as installed in the high-power test station.

SUMMARY

A movable SR mask for cavities in PF-AR, which had been a pending request, was designed and manufactured. The estimation of the dissipation power in the mask was done roughly but adequately in detail. High power test was also carried out. The result of high power test was quite successful. We will install them in PF-AR during 2007 summer shutdown.

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