Development of the Movable Mask System for KEKB

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Abstract

The movable mask is a device that cuts off spent electrons/positrons just near the beam orbit and reduces background of a detector. Sixteen movable masks were installed for each ring of KEK B-factory (KEKB). The originally designed masks, however, had troubles of heating and arcing, which sometimes caused vacuum leaks. The mask problem has been limiting the stored beam current. Since the problems were revealed, new movable masks have been designed partly employing RF technologies for HOM damping and some of them were installed experimentally in May 2000. The new masks are working almost as expected and all of old masks will be replaced by new ones in this summer shutdown.

1 INTRODUCTION

Initially sixteen movable masks had been installed for each ring of KEK B-factory (KEKB), i.e., Low Energy Ring (LER) and High Energy Ring (HER). The movable mask is a device that cuts off spent electrons/positrons just near the beam orbit and reduces background of BELLE detector. The masks were located at the straight and arc sections upstream side of the interaction region (IR) as shown in Fig.1. The masks are working for the time being. The originally designed masks, however, had troubles of heating and arcing due to the transient wall current or the intense RF fields of a trapped mode. The heating and arcing sometimes caused vacuum leaks. The trapped mode also excited a strong longitudinal coupled bunch instability and limited the stored beam current. The mask problem, therefore, was one of the most serious hardware issues of KEKB. Since the problems were revealed, a new joint team including some members from the KEKB RF group has been established for the R&D of new mask. Some of newly designed masks were experimentally installed in May 2000. The installed masks are working almost as expected up to now. Here we report the structure of the original mask and its problems and then the design of new ones.

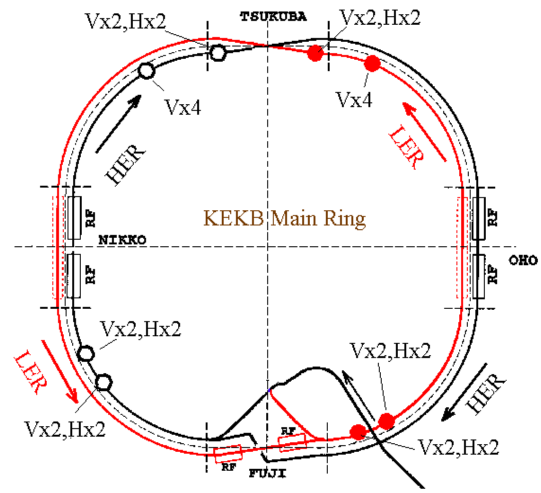

Figure 1: Location of movable masks for KEKB, where V and H are the vertical and horizontal mask, respectively.

2 ORIGINAL MASK

The outlook and the structure of the originally designed movable mask are shown in Fig.2 and 3, respectively. The mask head is a block made of Cu-W and inserted from a vacuum flange into the beam chamber. The mask head position can be controlled remotely. The stroke of the mask head is about 20 mm and a vacuum bellows absorbs the movement. The inside of the mask head is

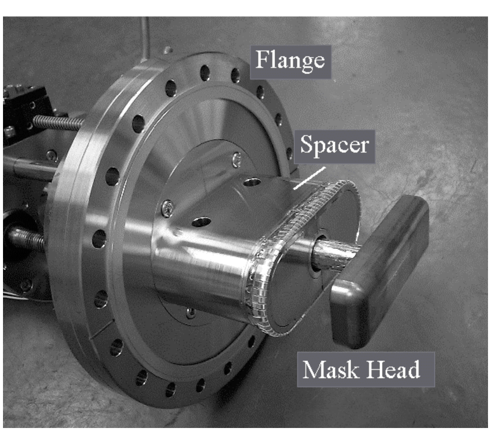

Figure 2: Original mask (vacuum side).

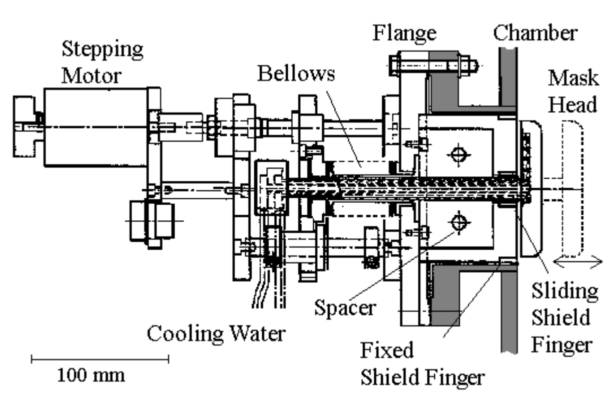

Figure 3: Structure of original mask.

cooled by water flowing though the stem. The spacer fills the space of flange port and makes the chamber inner surface smooth. The stem, the spacer and the bellows are made of stainless steel. The fixed and sliding shield fingers are at the gap between spacer and the chamber and between the stem and the spacer, respectively. The shield finger is made of silver-coated Inconel or Be-Cu. The shield finger should prevent the RF fields of the trapped mode from intruding inside the structure.

The first essential defect of the original mask is the sliding shield finger. It was so weak to ensure the intense RF fields of the trapped mode that it was easily heated and melted. The insufficient cooling structure worsens the heating problem. Once the sliding shield finger is broken, the trapped mode can easily enter inside the spacer because of its coaxial line structure. Since the inside of the spacer is also a coaxial cavity structure, an extensive power of the entered trapped mode was dissipated at the bellows in a resonance condition. Furthermore, the broken fingers can be a seed of arcing between the spacer and the stem. We had experienced vacuum leaks four times with this original masks. Two cases are at the gap between stem and spacer, and other two cases are at the bellows.

The second serious defect is that there is no effective absorber for the trapped mode of the mask. The Q-value of the major trapped mode is several thousands. Even if the sliding fingers are not broken, the intense trapped RF field remains around the mask. Actually, we had sometimes observed a longitudinal coupled bunch instability when the mask head approached the beam.

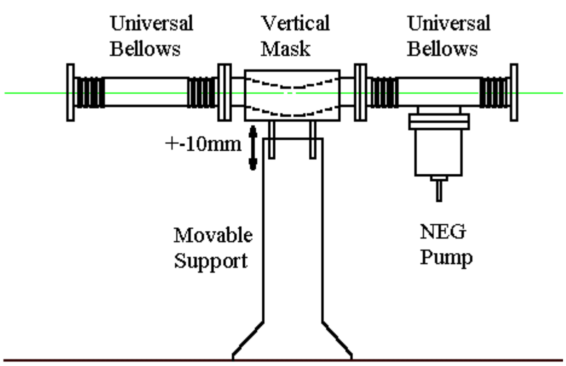

Figure 4: One set of Type-1 mask (vertical).

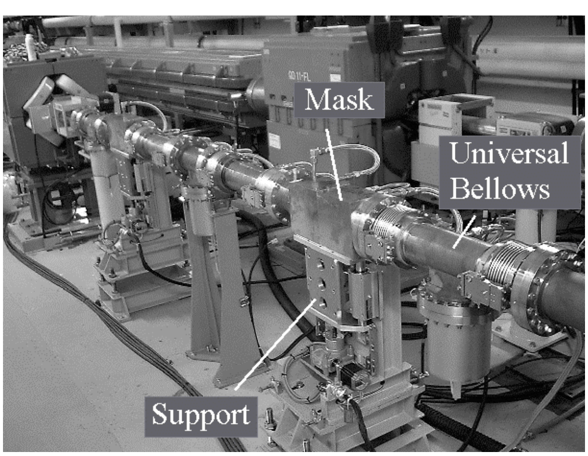

Figure 5: Type-1 mask in KEKB tunnel (two sets).

The heating and the longitudinal coupled bunch instability had been limiting the stored beam current, i.e., the luminosity. The heating of masks, furthermore, had been limiting the flexibility of filling pattern since the beam spectrum changes with the filling pattern and sometimes coincides with the resonance frequency of the major trapped mode.

3 NEW MASKS

Since the problems of the movable mask had been recognized, we have started designing new movable masks employing RF technologies for HOM damping. Since the time was limited, the several tentative masks were designed and installed using a short shutdown. But in each time unexpected problems were revealed. We had fixed the problems step by step and three types of mask were developed as almost final design at present.

3.1 Type-1

Type-1 movable mask was designed for LER arc section. The structure is quite different from the original one. The schematic structure of a vertical mask and the installed masks in the tunnel are shown in Fig.4 and Fig.5, respectively. The mask is not a small block as before but a bent chamber. The movable support moves the chamber and the chamber in itself works as a mask. The chamber is made of pure copper. The stroke is about 20 mm. The movement of the mask chamber is absorbed by two universal bellows connected at the both side of it. The universal bellows has the RF shield structure as other bellows for KEKB[1]. The most important feature of Type-1 is that there is no trapped mode. Therefore, there is no heating problem.

3.2 Type-2

Type-2 movable mask is a temporal one for LER and

Figure 6: Type-2 mask (vacuum side).

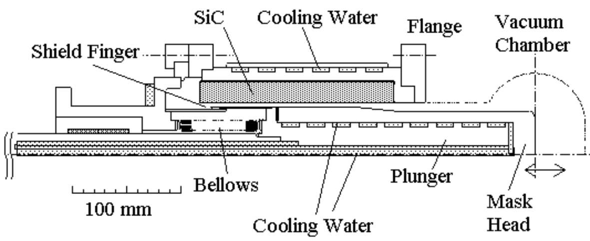

Figure 7: Type-3 mask design.

will be used for HER where the beam current is less than in LER. As shown in Fig.6, the basic structure is the same as the original one but the stem and spacer is made of one body pure copper. A quite different feature from the original one is RF field absorbers made of SiC ceramics. The four cylinders between the spacer and the mask head in Fig.6 is SiC blocks blazed on the spacer. The cooling water is flowing inside the stem as the original one but also inside the spacer. The sliding shield finger is around the spacer in double to reduce the current density. The Q-factor of Type-2 is estimated as about 40 due to SiC, that is, less than 1/50 of the original type.

3.2 Type-3

The R&D of the Type-3 mask is now undergoing to be installed it at the interaction region. Two masks will be installed for LER experimentally in this summer shutdown. Due to the spatial limitation of the interaction region we cannot use Type-1 mask. The design of Type-3 is shown in Fig.7. The basic structure is a plunger. The mask damps the RF field heavily through its coaxial waveguide structure loaded with a cylindrical SiC absorber. The Q-factor of Type-3 for the major trapped mode is estimated to be about 10 and the design power capability of the SiC absorber is up to 10 kW.

4 BEAM TEST

Four Type-1 and four Type-2 masks were installed experimentally at the end of May 2000 to LER and the temperature rise due to the beam and also the influence to the beam was studied.

We observed no abnormal temperature rise at the region of Type-1 mask that includes two masks and eight bellows. Any affect on the beam was not detected.

For Type-2, we had also observed no longitudinal coupled bunch instability of the stored beam. We found, however, a clear temperature rise between the inlet and outlet of the cooling water. Figure 8 shows an example of the temperature rise against the beam current. Considering the cooling water flow rate of 3.6 *l* min^{-1}, the estimated power dissipation is about 1.8 kW at the beam current of 600 mA. This input power corresponds to that expected when the peak of the beam spectrum hits the major trapped mode. The temperature, however, seems to be independent of the position of the mask head. That

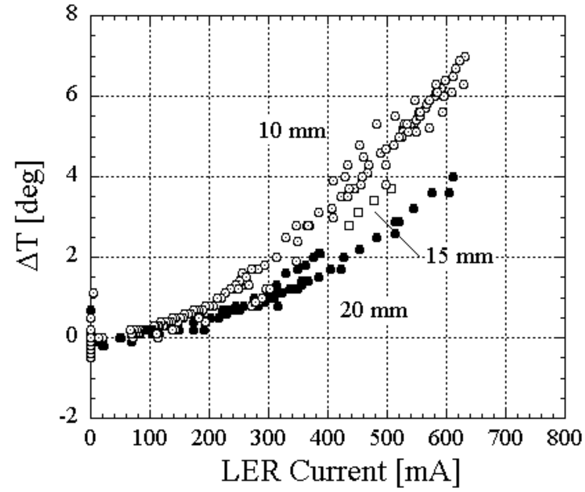

Figure 8: Temperature rise between outlet and inlet of the cooling water of Type-2 mask, where the numbers are the distance between mask head and beam.

means that the heating is not due to the resonance. The RF field (wake field) around the mask or generated by itself may be absorbed by the SiC blocks of the mask. We have to examine the power dissipation in detail and optimise the height and number of the SiC absorber before applying it to HER.

5 SUMMARY

The original movable mask for KEKB has some serious problems in high current operation. The heating trouble and the excitation of the longitudinal coupled bunch instability had limited the stored beam current, that is, the luminosity. The three type of new movable masks have been developed to overcome the situation. Type-1 and Type-2 were installed experimentally to LER and shows no essential problem except for some excess power dissipation for Type-2. Type-3 will be installed in this summer shutdown and the R&D is undergoing now. All of movable masks for both rings will be replaced by new ones in this summer shutdown.

ACKNOWLEDGEMENTS

The authors would like to thank Prof. S.Kurokawa, Prof. M.Yoshioka, Prof. Oide and many other staff of the Accelerator Laboratory in KEK for their continuous encouragement and cooperation.

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