# CONCEPTUAL DESIGN OF VACUUM SYSTEM FOR SUPER KEKB

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*Abstract*

Conceptual design of the vacuum system for the upgrade of KEKB (Super KEKB) is presented. For its large storage current, the synchrotron radiation (SR) power is much higher than ever before. The beam chamber will have an ante-chamber structure to reduce the irradiated SR power density. To accommodate the intense higher order mode (HOM) arising from the short bunch length, the careful R&Ds are required for bellows, movable masks (collimators), HOM absorbers and so on. The first step of R&D has just begun using the KEKB.

## INTRODUCTION

The luminosity goal of the Super KEKB is 100 nb$^{-1}$ s$^{-1}$, ten times higher than that of KEKB. Main parameters related to the vacuum system of the Super KEKB are listed in Table 1 [1]. The most important feature is the high storage currents, 9.4 A and 4.1 A for the Low Energy Ring (LER) and the High Energy Ring (HER), respectively. The synchrotron radiation (SR) intensity, therefore, becomes much stronger than ever before. The major issues of the vacuum system consequently come from the intense SR. Another notable feature is the short bunch length, 3 mm, to relieve the hourglass effect at the collision point. That leads to severe impedance and heating problems for various vacuum components.

## BASIC DESIGN

### *Structure of Beam Chamber*

An ante-chamber scheme will be adopted for the beam chamber. A conceptual structure of the ante-chamber for the HER is shown in Fig.1 [2]. The ante-chamber consists of two channels, one is for the beam and another is for the SR. The SR hit the sidewall at far side of the ante-chamber. Since the irradiated point of SR at the side

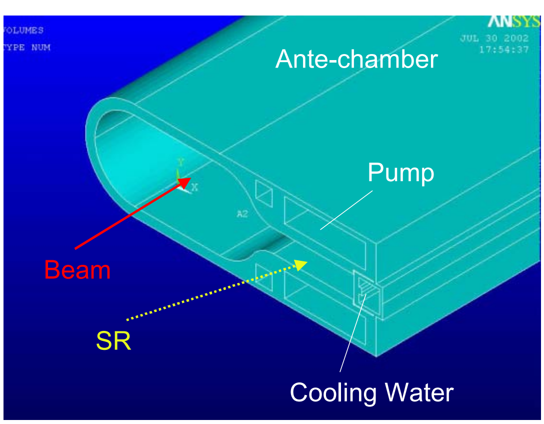


Figure 1: Typical structure of ante-chamber (HER).

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Table 1: Vacuum related main parameters of Super KEKB. The parentheses are those for the KEKB.

| | LER ($e^-$) | HER ($e^+$) |
|---|---|---|
| Goal Luminosity [nb$^{-1}$ s$^{-1}$] | 100 | |
| Energy [GeV] | 3.5 | 8.0 |
| Beam Current [A] | 9.4 | 4.1 |
| Bunch Length [mm] | 3 | 3 |
| Bunch Number | 5018 | 5018 |
| Bending Radius [m] | 16.31 | 104.46 |
| Aperture [mm] | $\phi$94 | 104×50 |
| Total SR Power without Wigglers [MW] | 7.64 (2.11) | 14.21 (3.81) |
| Max. Line Power Density of SR* [kW m$^{-1}$]{present chamber} | 53.50 (14.8) | 21.64 (5.8) |
| Critical Energy of SR [keV] | 5.84 | 10.88 |
| Ave. Photon Density [photons m$^{-1}$s$^{-1}$] {C = 2200 m} | 1.21E19 | 1.20E19 |
| Ave. Gas Load [Pa m$^3$s$^{-1}$m$^{-1}$] {$\eta$=1E-6 molecules photon$^{-1}$} | 4.56E-8 (1.35E-8) | 4.52E-8 (1.31E-8) |

* Using present single beam chamber.

wall goes far from the emitting point, the input SR power can be diluted. In the present ante-chamber design, the maximum power density at the side wall is 40 W mm$^{-2}$ (LER), which is about 30 % of that expected for the existing chamber and almost same as that of the present one [3,4]. The photon stop scheme will not be realized due to the high concentrated power.

For the HER ($e^+$), the electron cloud instability [5] is aother major problem. The electrons, at least the seeds of the electron cloud, are mainly provided by the photoelectrons emitted from the inner surface irradiated by the SR. To avoid the problem, therefore, the ante-chamber scheme is also suitable for HER. Some additional measures will be prepared to suppress the photoelectron yield, such as the saw-tooth structure on the surface of sidewall [6]. Appling the external magnetic field by solenoids or permanent magnets are also considered, which has been working successfully in the KEKB [7].

### *Material of Beam Chamber*

Copper should be the most suitable material for the beam chamber for its high thermal strength, the high electrical conductivity and the relatively low photoelectron yield [3]. Lots of experiences on the copper chamber have been accumulated in the KEKB, such as the welding method and the cleaning procedure. Aluminium may be another candidate. The manufacturing and welding is easier than copper, but the thermal properties is inferior to copper. Aluminium will be used only for special and complex chambers.

### Pumping Scheme

The aimed pressure during the operation is on the order of $10^{-7}$ Pa. The low pressure is necessary to reduce the background noise in the particle detector rather than to ensure the sufficient beam life time. The linear pumping speed of about 0.1 $m^3$ $s^{-1}$ $m^{-1}$ is required assuming the photo-desorption rate, $\eta$, of $1\times10^{-6}$ molecules $photon^{-1}$ (Table 1). A distributed pumping scheme should be adopted and the pumps will be a combination of the strip type NEG pumps and the ion pumps as the present KEKB [3]. The pump ports are top or bottom of SR channel as shown in Fig.1 to reduce the impedance of beam channel and to evacuate effectively the desorbed gas.

### Connection of Beam Chambers

The Helico-flex gasket has been working well in the KEKB as an RF-bridge between flanges [4]. For the Super KEKB, however, the impedance of that (~1 V $nC^{-1}$) will be a problem due to the short bunch length and its large quantity. The number of flange connections will be limited as much as possible. Instead, the welding in situ will be used to a large extent.

The heating of bellows chambers [8], usually installed between adjacent beam chambers, due to HOM will be a serious trouble. The heating has been actually observed already at the present KEKB [4]. The impedance of steps at the RF shield structure (~10 V $nC^{-1}$) will be also a problem for its large amount. Removing the bellows and connecting the adjacent chambers directly by welding in situ may be one countermeasure [2,9]. If the temperature of beam chamber is well controlled, the thermal stress would be tolerable. Remaining crucial problems, however, are how to absorb the errors of alignment or manufacturing, and how to fit the welding plane. For the Super KEKB, therefore, the bellows chamber with a new RF-shield structure, which will have higher thermal strength and lower impedance than before, is studied now as described below.

### HOM Damper

In the Super KEKB, the current is so high and the bunch length is so short that intense HOM can be generated at various kinds of vacuum components. The intense HOM leads to excess heating or abnormal discharge of those. To avoid these troubles, the HOM absorbers will be indispensable in the Super KEKB. The R&D has started using KEKB as presented below. Reduced HOM design should be widely adopted for vacuum components at the same time.

### Movable Masks

To protect the detector from damages by spent particles and to reduce the background noise, the movable mask (collimator) system will be equipped in the ring. The chamber-type movable masks, which has a trapped-mode free structure, have been installed to the KEKB and working almost well [10]. The major problems expected in the Super KEKB are grooves generated on the mask head and the excess heating of bellows just near the mask, which have been already experienced in the KEKB [4,7,10].

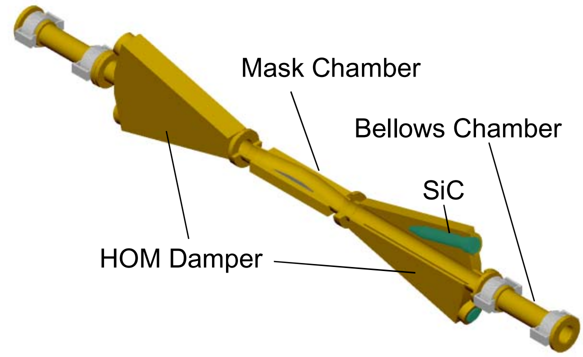


Figure 2: A set of movable masks combined with HOM dampers.

The grooves at the mask head are now understood as a result from the attack of abnormally steered beam. An effective way to avoid the generation of grooves is to use the light material as a mask head such as carbon or beryllium with a minimal length. The safe and rapid beam abort system using the beam orbit or the beam loss monitor will also help the damage of mask head.

Heating due to the HOM will be relieved combined with HOM damper described above. A schematic picture of a future movable mask is presented in Fig.2.

## R&D PLANS

### Ante-Chamber

A proto-type ante-chamber made of copper had been installed in the KEKB LER in 2001. Any severe problems have not been observed during the operation up to the stored current of 1.4 A. The number of electrons in the beam channel was found to decrease to about 1/7 of the case for usual single beam chamber without special coating inside [2]. The reduction of the electrons in the beam channel by the ante-chamber structure was verified. The external magnetic field was also found to be effective to reduce the electrons in the beam channel, that is, the electrons further decreased to 1/2 by applying the solenoid field of about 50 G.

The second trial model of the ante-chamber with almost the same design for the Super KEKB is now under manufacturing and will be installed in the KEKB LER in 2003. The SR hit the sidewall of the SR channel instead of photon stops. The saw-tooth structure is formed on the surface of sidewall. The thermal properties and the reduction of the electrons in the beam channel will be studied again.

### HOM Damper

A winged HOM absorber chamber (HOM damper) was newly designed and the trial model was installed near the movable masks of the KEKB LER, where the heating of pump elements due to the HOM generated at mask heads has been observed [11]. The design is based on the HOM

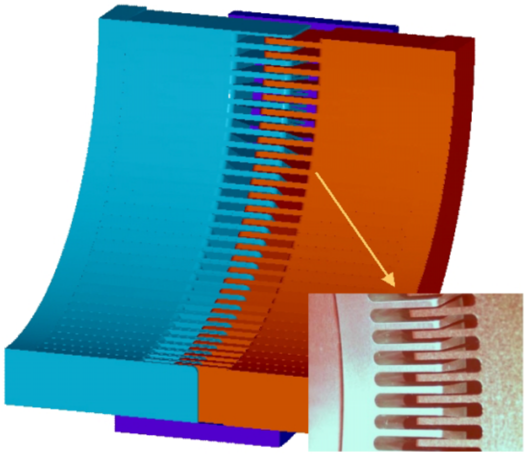

Figure 3: Comb-type RF-shield structure.

absorber successfully applied for the KEKB ARES cavity system [12]. The long narrow slots in the beam direction (20 mm × 707 mm) connects the beam chamber and the HOM absorber. The damper can absorb effectively the TE modes. The loss factor is less than 0.01 V $pC^{-1}$ (10 mm bunch length) and the impedance due to the HOM damper is sufficiently small. The chamber has two SiC rods and can absorb the HOM power up to 10 kW. In the autumn run 2002, two pairs of HOM damper is installed putting four movable masks inside of each pair. The absorbed power per one damper was about 3 kW. The pressure rise due to the heating of pump elements was disappeared and the heating of bellows near masks are also suppressed effectively. The study will be continued.

### *Bellows Chamber*

Recently a new RF-shield structure for bellows chambers is proposed as shown in Fig.3 [13]. The RF-shield is not a finger-type as usual but the comb-type. At the initial design, a tooth has a width of 1 mm and a radial thickness of 10 mm. About 100 teeth surround the inner surface of LER beam chamber. Gap between each nested tooth is 0.5 mm. The thermal strength of the shield is much higher than before. The new RF-shield structure has a lower loss factor compared to the conventional one (1 mm step at inner wall) as indicated in Fig.4. The R&D of the RF-shied has just started and test bellows chambers will be installed in KEKB LER this summer. The RF-shield structure can be applied for that of gate valves.

## REMAINING ISSUES

The following are the issues to be considered or studied in the future; (1) Design of the beam chambers at the interaction region. The design should take into account the aperture, the impedance, the SR mask and the effective pumping scheme. (2) Impedance estimation of various vacuum components, such as the tapers, the pumping slots and so on. (3) Radiation shielding. Lead

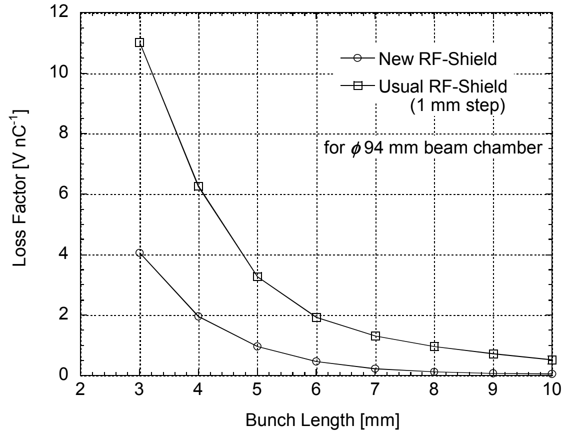


Figure 4: Loss factors for new and conventional RF-shield (1 mm step) as a function of bunch length.

shielding around the beam chamber may be necessary. (4) Alignment and supports of beam chambers. (5) Abort system. A rapid and safe beam abort system is required. (6) Alarm system. The flow rate of cooling waters and the temperatures of these components should be kept watching any time.

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