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# VACUUM DESIGN FOR KEKB

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Abstract

In designing a vacuum system of a new asymmetrical collider for KEKB, the vacuum ducts deal with intense heat from synchrotron radiation because of high stored current. Due to the short bunch length, the requirement for the smoothness of the inner surface is tight. OFC is adopted for vacuum chambers. Acid etch or chemical polishing is applied to clean extruded surface. Using NEG strips as the main pump, pumping speed is designed as 100 l $s^{-1}$ $m^{-1}$. When the photo-desorption coefficient is $10^{-6}$ a pressure of $10^{-9}$ Torr will be realized. All chambers are baked before installation. By adopting "dry-hood" technique, in situ bake out will be omitted. Pumping slots are backed up by grid to prevent the penetration of beam induced field which causes heat up of pump elements. A gap between flanges are filled using Helicoflex as a vacuum seal. Contact force of an RF finger in a bellows is assured by a spring finger.

## 1. Introduction

KEKB is a project to study B meson physics as a second stage of TRISTAN. The accelerator consists of two rings with one intersection where electrons and positrons collide with different energies[1]. The vacuum system deal with high beam current to obtain high luminosity. Described in the following are general aspects applied for the most part of rings which includes the regular arc, the wiggler straight and the RF cavity sections. The design outline of KEKB vacuum system are summarized in Table 1.

Table 1

| | LER | HER | |
|---|---|---|---|
| Beam energy | 3.5 | 8.0 | GeV |
| Beam current | 2.6 | 1.1 | A |
| Circumference | 3016 | ← | m |
| Bunch length | 4 | ← | mm |
| Bending radius | 16.31 | 104.46 | m |
| Total Power of SR | 2117 (arc) | 3817 | kW |
| Critical Energy of SR | 5.84 | 10.9 | keV |
| Total photon flux of SR | $7.35\times10^{21}$ | $7.11\times10^{21}$ | photons $s^{-1}$ |
| Local maximum of the linear power density | 14.8 (bend)<br>~13 (wiggler front)<br>~10 (wiggler) | 5.8 (bend) | kW $m^{-1}$ |
| Duct material (thickness) | OFC (6) | ← | (mm) |
| Radiation dose on duct surface | $<10^5$ | $<10^7$ | rad $year^{-1}$ |
| Maximum temperature | 120 (bend) | not estimated | °C |
| Maximum strain | -0.15 (bend) | not estimated | % |
| Surface exposed to SR | wall of beam duct | ← | |
| Average linear photon density | $3.3\times10^{18}$ | $3.2\times10^{18}$ | photons $s^{-1}$ $m^{-1}$ |
| Average pressure with beam | $\sim10^{-9}$ | ← | Torr |
| Average base pressure | $\sim10^{-10}$ | ← | Torr |
| Photo desorption coefficient | $10^{-6}$ | ← | molec. $photon^{-1}$ |
| Static outgassing rate | $\sim10^{-12}$ | ← | Torr l $s^{-1}$ $cm^{-2}$ |
| Linear pumping speed | 100(target) | ← | l $s^{-1}$ $m^{-1}$ |
| Cross section of duct | circle | racetrack | |
| Conductance of beam duct (1m) | 102 | 52.3 | l $s^{-1}$ |
| Arrange of pump | array of port | integrated | |
| Main pump | NEG cartridge | NEG strip | |

LER=Low Energy Ring, HER=High Energy Ring, SR=Synchrotron Radiation.

## 2. Effect of Synchrotron radiation

In designing pumping system, we assume the desorption coefficient reaches $10^{-6}$ after about a1000 Ah operation for the LER. In recent high current rings this is an attainable value [2]. It is considered important to set a static base pressure to be one order lower than the operating pressure.

Because of the high local linear power density, OFC is adopted as a material for vacuum chambers of the LER. It is known copper works as a good self-shield against γ-ray[3]. So it is used also for the HER

In the LER, rather large strain of -0.15% is induced locally by synchrotron radiation from a dipole magnet. Applying a 0.15% strain over $10^8$ cycles does not cause cracks on a half or quarter tempered OFC[4]. However, localized heating will lead to annealing of the material which can reduce the local mechanical strength[5]. Annealed OFC can still withstand $10^4$ cycles of 0.5% deformation at 150°C[6]. But it is considered preferable to keep the local temperature below 140°C at KEKB.

## 2. Fabrication of copper chamber

The grade of OFC is ASM C10100 (oxygen-free electronic copper) for vacuum surface, and C10200 (oxygen-free copper) elsewhere. An oxide layer on the inner surface of an extruded pipe contains a large amount of carbon compositions, which are released as CO and $CO_2$ in photo-desorption. To avoid frequent conditioning of NEG during commissioning, it is necessary to remove this first oxide layer and to produce a new oxide layer with much less carbon. This treatment will be done by using a commercially available chemical polisher which contains $H_2O_2$ and $H_2SO_4$[7]or by applying standard acid etch with $H_2SO_4$, $HNO_3$, HCl, and water. Both treatment can reduce the total amount of the desorbed gas to a one order value compared to an untreated case.

Joining together Cu pieces is possible by TIG welding, EBW and Brazing. TIG welding in uncontrolled atmosphere will give a damage on vacuum surface. The use of TIG welding must be limited. The joint between Cu and stainless steel which is necessary to use stainless steel flanges is possible by various ways, direct welding along a lip structure[8], welding using third material, explosive bonding , HIP, and brazing.

## 3. Pumping elements

Since the space of dipole magnets fills only 5% and 31% of the standard cell in the LER and the HER, respectively, a build in sputter ion pump is not effective as a distributed pump. We adopt, instead, NEG [9] strip (St707) for distributed pumping. All pumps of LER are attached to pumping ports (see next section). A distributed pumping speed of 100 l $s^{-1}$ $m^{-1}$ is possible by installing a 200 l $s^{-1}$ pump to a port with a 200 l $s^{-1}$ conductance at every 1 m. A special cartridge arranged with short NEG strips is designed for the LER. At the HER, a beam duct is pumped through side slots by long NEG strips.

In addition to NEG, 200 l $s^{-1}$ ion pumps are installed at every 10m in the arc. These ion pumps are of recently developed type which can keep their nominal pumping speed down to $10^{-10}$Torr[10]. Roughing pumps are attached at every 40m. Roughing unit consists of a magnetic bearing turbo-molecular pump and a scroll pump. It is essentially oil free. The pressure of the ring must be monitored at intervals less than 20 m to find a vacuum leak which affect an average pressure over the ring. Cold cathode gauges will be equipped at the same pumping port as an ion pump.

All chambers are baked 24 hour at 150°C before installation fully equipped with vacuum components to check an outgassing rate. After bake out they are filled with dry $N_2$ and closed with flanges for storage. In the tunnel chambers are connected using "dry-hood" technique like ALS[11] and will not be baked *in situ*.

## 4. Impedance-related structures

Pumping slots must be backed up by a grid so that penetration of wake fields which causes a heat-up of pumping elements may be reduced. Unfortunately no reliable estimation is available on the magnitude of the radiation that propagates through pumping slots. Consequently, the vacuum system design must be prepared for an unexpectedly high power penetration especially in the LER which has higher current. This is done by making it possible to add a further grid through a pumping port.

The connection with standard conflat flanges will leave a gap between the gasket and the flange where beam induced field can be trapped. There are 1500 flange connections in the LER arc. The contribution for broad band impedance is not negligible. The use of Helicoflex[12] with the same inner diameter as a beam duct can drastically reduce the loss factor to an acceptable level.

All bellows have an RF-shield inside to connect a duct aperture smoothly. In our design, contact fingers are pressed by spring fingers to ensure a contact force between the contact finger and an inner tube. The detail of this bellows will reported by Ohshima[13].

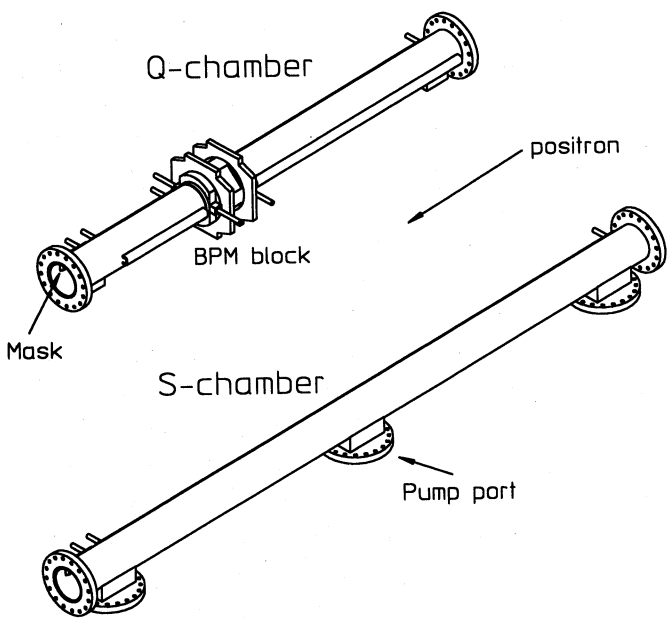


Fig. 1 Typical vacuum chambers of the LER

## 5. Vacuum chambers

In the current design three types of beam ducts will be fabricated. The first is the "B chamber" which is used with dipole bend magnets and supplied with pumps. In B chamber the linear power density is highest.

The second is the "Q chamber" which is used for quadrupole magnets. It includes a beam position monitor and a mask, but no pumping port. Q chamber is fixed to a quadruple magnet through the support of the beam position monitor. It is separated from other chambers with bellows of 16 cm long to avoid strong force from outside. It has a symmetrical cross section which is necessary to causes the eddy current with a good left-right symmetry during an active modulation of the excitation of quadrupole and sextupole magnets for the beam-based alignment.

The third is the straight "S chamber" which has a cooling channel, a mask and pumping element. It is used between Q chambers. Typical Q chamber and S chamber of LER are shown in Figure 1.

## 6. Schedule

LER chambers will be fabricated from 1995 to 1996. The fabrication of HER will start in 1996 and continue to 1997. Installation will start in the beginning of 1997. During 1997-1998 other special chambers used in the injection section and the interaction region will be constructed.

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## Notes and References

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[5] heat cycle test was carried out by Hitachi Zosen using laser beam.
[6] private communication from Hitachi Cable.
[7] the use of chemical polisher was proposed by Toshiba.
[8] collaboration with Sumitomo Heavy Industry reported in I. Taguchi, O Morishita, Y. Suetsugu, and K. Kanazawa, Proc. 9th UHV Techniques for Accelerators and Storage Rings, KEK, March 3-4, 1994, KEK proceedings 94-3, p385. in Japanese.
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[11] CERN Courier, November 1994, p14
[12] Helicoflex delta of Le Carbone-Lorraine Cefilac will be used.
[13] K. Ohshima, Y. Suetsugu, and K. Kanazawa, this proceedings.