PRESENT STATUS OF KEKB VACUUM SYSTEM

H. Hisamatsu, K. Kanazawa, M. Sato, M. Shimamoto, M. Shirai, S. Kato, Y. Suetsugu,
KEK, Tsukuba, Ibaraki 305-0801, Japan

Abstract

The commissioning of KEKB (KEK B-factory) started in December 1998. The vacuum system has been working almost satisfactorily. The photon stimulated gas desorption coefficient of copper beam chamber is decreasing steadily and reached to about 2 - 4×10^{-6} molecules $photon^{-1}$ at the end of May 2000, where the integrated linear photon flux was about 9 - 5×10^{24} photons m^{-1}. The most serious problem in these days is the excess heating and vacuum leaks of movable masks. All original masks will be replaced by new ones in this summer shutdown.

1 INTRODUCTION

The KEK B-factory (KEKB) is an electron-positron collider with asymmetric energies to detect the CP violation in bottom quark decay[1]. The KEKB consists of two rings, that is the High Energy Ring (HER) for 8.0 GeV electrons and the Low Energy Ring (LER) for 3.5 GeV positrons. Main parameters of KEKB are listed in Table 1. The design beam currents are 1.1 A and 2.6 A for HER and LER, respectively. Withstanding high gas and heat load due to the intense synchrotron radiation was the most important issue in designing the vacuum system.

The commissioning of the KEK B-factory (KEKB) started in December 1998. The commissioning progressed almost satisfactorily and the physics experiment started from June 1999. At the end of May 2000, the beam dose (integrated beam current) reached to 790 and 1010 A·Hours and corresponding photon dose (integrated linear photon flux) were 8.6×10^{24} and 4.9×10^{24} photons m^{-1} for HER and LER, respectively. The maximum stored beam currents were about 500 and 750 mA for HER and LER, respectively. The vacuum system has been working almost smoothly although several troubles occurred near the collision point and, recently, at the movable mask system. The photon stimulated gas desorption (PSD) coefficient, η [molecules $photon^{-1}$], at arc section is decreasing steadily with beam dose. Here we overview the vacuum system of the KEKB at first and then report the present status of it.

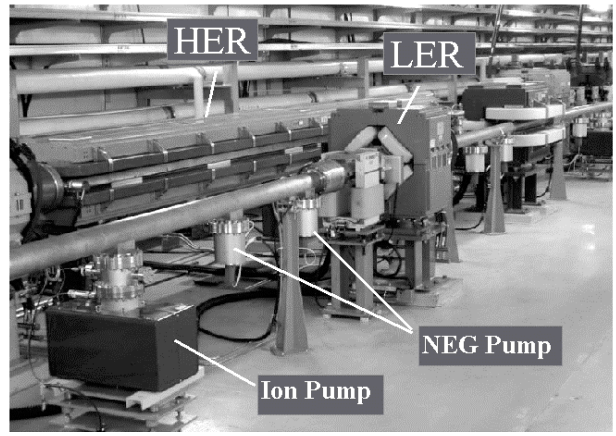

Figure 1: Typical layout of vacuum chamber and pumps in KEKB tunnel.

Table 1 Main parameters of KEKB.

	LER (Low Energy Ring)	HER (High Energy Ring)
Beam Energy [GeV]	3.5	8.0
Design Beam Current [mA]	2600	1100
Design Bunch Number (Harmonic Number)	5120	
Circumference [m]	3016	
Bunch Length [mm]	4	
Bending Radius [m]	16.31	104.46
Critical Energy of SR [keV]	5.84	10.9
Max. Liner Power Density of SR [kW m^{-1}]	14.8	5.8
Average Liner Photon Density [photons m^{-1}]	3.3×10^{18}	3.2×10^{18}
Chamber material (arc)	OFC (Oxygen Free Copper)	
Main pump	NEG Cartridge	NEG Cartridge + NEG Strip
Auxiliary pump	Sputter Ion Pump (200 l s^{-1})	
Average Linear Pumping speed [l s^{-1} m^{-1}]	70	65
Goal pressure with beam [Pa] (η = 1×10^{-6} molecules $photon^{-1}$)	in the order of 10^{-7}	
Vacuum monitor	CCG (Cold Cathode Gauge)	

SR : Synchrotron Radiation, NEG : Non Evaporable Getter pump

2 OUTLINE OF VACUUM SYSTEM

Some features of KEKB vacuum system are also summarized in Table 1[2]. Most of beam chambers including arc sections are made of OFC (Oxygen Free Copper, ASM10100) for its ability to withstand intense heat load and to shield effectively the radiation from beam. Other chambers at straight sections are made of stainless steel or aluminum. The inner surface of beam chamber was chemically polished, which is specially developed for KEKB[3].

A Helicoflex gasket (Le Carbone K.K.) that just fits each aperture of chamber is used for vacuum seal, which has also a role of RF contact between flanges. The Helicoflex sealing is very stable up to now. All bellows (about 2000 in total) have RF-shield structure inside[4].

The main pump is NEG (Non Evaporable Getter ST-707, SAES GETTERS CO. Ltd.) pump (200 l s^{-1} for a typical cartridge). Auxiliary pump is a 200 l s^{-1} sputter ion pump located at about every 10 m. The estimated average liner pumping speeds are 65 and 70 l s^{-1} m^{-1} for HER and LER, respectively, for CO just after activation. Goal pressure is in the range of 10^{-7} Pa during operation with a maximum current assuming the η of 1×10^{-6} molecules $photon^{-1}$. Typical layout of vacuum chambers and pumps in the tunnel is shown in Fig.1.

Cold cathode gauges (CCG, about 580 in total) monitor the total pressure of whole rings. Residual gas analysers give the residual gas species during operation. All components, such as ion pumps, CCGs, are remotely controlled and monitored on the EPICS (Experimental Physics and Industrial Control System) scheme. The control system is working almost perfectly.

3 STATUS OF VACUUM SYSTEM

3.1 history

Figure 2 presents histories of HER vacuum pressure and stored beam current from the beginning. The similar history is obtained for LER. The pressure during operation is in the order of 10^{-7} Pa. The base pressure is about 3×10^{-8} Pa. The reasons for long shutdown times are written in the figure. We had two vacuum leak troubles at near the interaction region (IR) and four at LER movable masks.

3.2 Decrease of ΔP/ΔI

Figure 3 shows a typical variation of pressure rise per beam current ($\Delta P/\Delta I$ [Pa mA^{-1}]) at HER arc section (copper chamber) against the beam dose. For reference, the η is given at the right axis of the figure assuming a constant liner pumping speed of 30 l $s^{-1}m^{-1}$. In the beginning η was about 1×10^{-1} molecules $photon^{-1}$ and relatively high compared to a copper chamber received a chemical polish. The η is decreasing steadily with beam dose and now below 2×10^{-6} molecules $photon^{-1}$. The η for LER gives the same tendency and reached near 4×10^{-6} molecules $photon^{-1}$. The decrease of η for HER and LER are almost same with respect to the photon dose. The

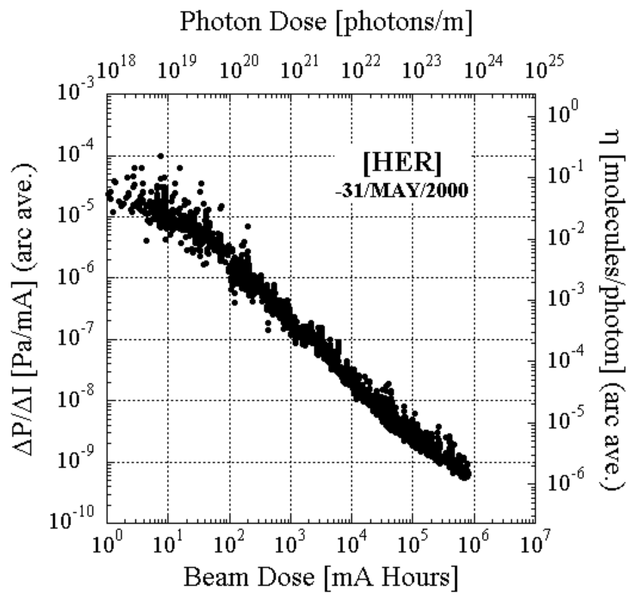

Figure 3: Decrease of *ΔP/ΔI* for HER.

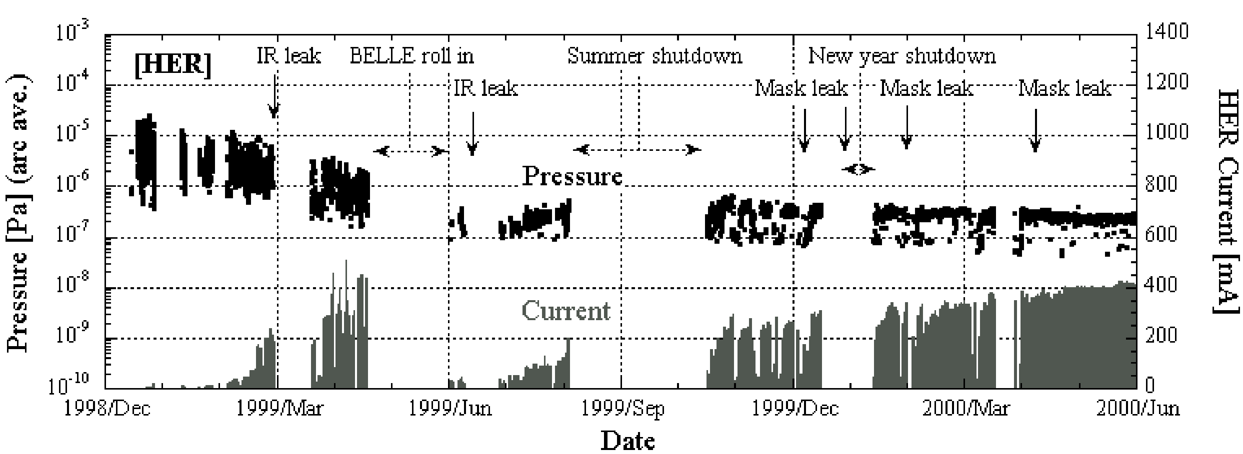

Figure 2: History of average pressure and beam current for HER.

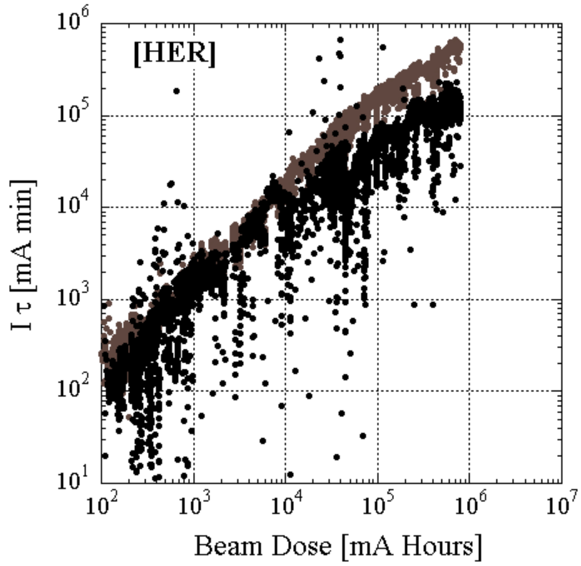

Figure 4: Variation of $I\tau$ against beam dose for HER.

decrease of η is in the range of expected one from our R&D[5].

The activation of NEG was carried out for 7 and 8 times for HER and LER, respectively, except for the regions where we had vacuum troubles. The timing of conditioning was determined by the absorbing gas load of 3 Pa m^3 m^{-1} and by checking the change of decrease rate of $\Delta P/\Delta I$. The number of conditioning is almost same as expected one.

For LER, it is observed that the pressure rise has a non-linear dependence on the beam current for some locations. Further investigation is undergoing on the phenomenon.

3.2 Beam Lifetime

As the η decreased, the beam lifetime increased. Figure 3 presents the variation of beam current I [mA] × lifetime τ [min] against the beam dose for HER. The increase is not so smooth as η since the lifetime depends on not only the vacuum pressure but also operation conditions and beam parameters.

The grey points in the figure are the $I\tau$ estimated from the $\Delta P/\Delta I$ in Fig.3 assuming that the residual gas is CO and the lifetime is determined by the bremsstrahlung. Actually CO accounts for more than 50 % of the residual gases during operation. The lifetime until the beam dose of about 1×10^4 mA·Hours was almost determined by the average pressure. Now, however, $I\tau$ is about 1.5×10^5 mA·min for HER and is about one fourth of the expected one. The following reasons will explain the difference: (1) Small physical aperture at movable masks (Rutherford scattering). (2) Small dynamic apertures that decrease the lifetime by the Touschek effect. (3) Beam-beam effect. (4) Beam parameters such as a tune, orbit are not optimised. The similar discussions can be applicable for LER. The $I\tau$ is about 7×10^4 mA·min for LER now. The lifetime of LER is very sensitive to the beam size and the Touschek effect seems to be more evident than in HER.

3.5 Problems of today

The most serious problem is the movable mask system. The movable mask is a device that protects the BELLE detector from spent electrons/positrons and reduces the background. Sixteen masks were installed for each ring. The original designed masks, however, had troubles of heating and arcing due to the transient wall current or the intense RF field of a trapped mode. The heating and arcing sometimes caused vacuum leaks. The trapped mode also excites a coupled bunch instability. The movable mask problem has been limiting the stored beam current, that is, the luminosity. We are designing new movable masks and will be installed in this summer shutdown6.

Other problem that is limiting the stored beam current is the heating of a bellows due to the higher order mode and a copper chamber due to the synchrotron radiation. Both components are at the interaction region. The change of chamber structure and the increase of cooling power is planned in this summer shutdown.

4 SUMMARY

The KEKB vacuum system is working almost satisfactorily. The η is decreasing smoothly from the beginning. The η at arc section reached near the 2 - 4×10^{-6} molecules $photon^{-1}$ for both rings now. Now the beam lifetime is not determined by not only the average pressure but also the other beam conditions. The movable mask has been the most serious problem but will be fixed in this summer shutdown.

ACKNOWLEDGEMENTS

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

REFERENCES

[1] A.Kurokawa, "Present Status of KEKB Project", 6th EPAC, Stockholm, June 1998.

[2] H.Hisamatsu et al., "Design of the vacuum system for KEKB", Vacuum, 47, 601,1996.

[3] S.Kato et al., "Measurement of Secondary Electron Yields of Copper Materials and the Surface Analysis", 45th AVS Int. Symp., Baltimore, 2-6 November 1998.

[4] Y.Suetsugu et al., "Design studies on a vacuum bellows assembly with radio frequency shield for the KEK B factory", Rev. Sci. Instrum., 67, 2796, 1996.

[5] Y.Suetsugu et al., "Measurements of Gas Desorption Rates from a Copper Beam Duct", Proc. 9th Symp. Acc. Sci. Technol., Tsukuba, August, 1993.

[6] K.Kanazawa et al., in this proceedings.