UPGRADE AND CURRENT STATUS OF THE PF RING VACUUM SYSTEM

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Abstract

The vacuum system for the KEK Photon Factory (PF) storage ring was extensively modified in 2005 as part of the PF ring straight sections upgrade project [1]. More than half of the vacuum ducts were replaced for the reinforcement of the free spaces for insertion devices. Since the recommissioning of the accelerator started in September 2005, recovery of the beam lifetime due to the process of the beam scrubbing has been progressing favorably. Details of these modifications, as well as the current status of the new vacuum system, are presented.

UPGRADE OF THE VACUUM SYSTEM

As part of the PF ring straight sections upgrade project, more than half of the 187m-circumference ring was reconstructed in 2005 (see Fig.1). Main purposes of this reconstruction were to create four new straight sections and to expand existing straight sections by replacing Q-magnets, vacuum ducts, and their related beamline front-ends. As a result, the number of the spaces available for insertion devices increased by 6 to 13.

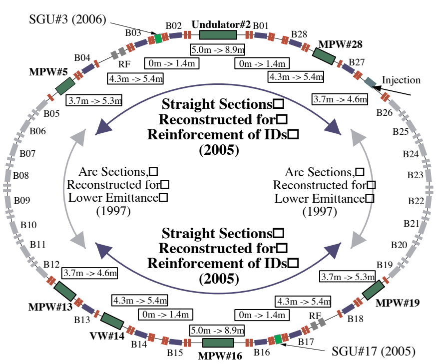

Figure 1: Reconstructed regions in the PF ring straight sections upgrade project.

Vacuum Ducts

New vacuum ducts were designed to be adaptable to new Q-magnets, new and existing insertion devices, and new beamline front-ends. Typical composition of the vacuum ducts after the reconstruction is shown in Fig. 2.

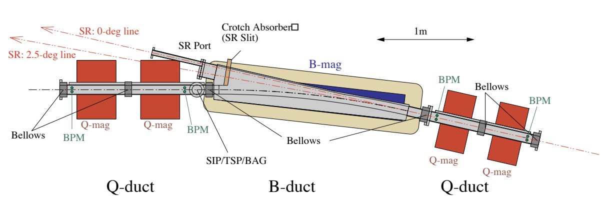

Figure 2: Typical composition of the new vacuum ducts.

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Twelve of twenty-eight B-ducts were replaced, and the synchrotron radiation (SR) ports of the B-ducts became compatible with new or future insertion device beamlines.

The cross-section of the Q-duct became smaller as the bore diameter of the Q-magnet changed to 70mm from 110mm (see Fig. 3). And rearrangement of Q-magnets restricted the positions of pumping ports. Therefore, the effective pumping speed in the Q-ducts was reduced.

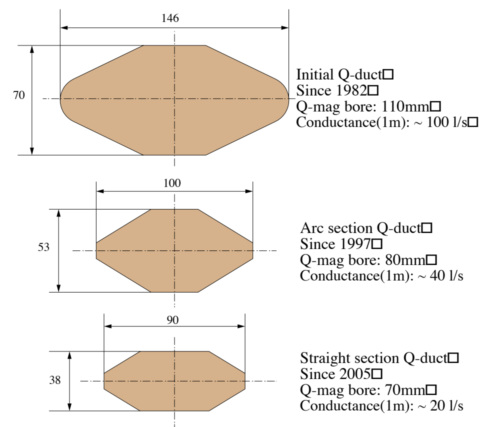

Figure 3: Transition of the Q-duct cross-sections.

Beam position monitors (BPMs) were welded to the Q-ducts, and all of them were calibrated before the installation. In order to decrease the impedance of the vacuum ducts, RF-contact chips were attached to all Q-duct flanges to bridge the flange gaps.

Main material of the vacuum ducts is aluminum-alloy, which is the same material as before. However, the material of new crotch absorbers, which are inserted at the end of each B-duct and function as slits for SR, was changed to GlidCop® (AL-15). Because the results of thermal analysis indicated that GlidCop® was more tolerant against high thermal load (SR power from a 2.5GeV-800mA beam was assumed as the heat input).

Reconstruction work was carried out during the shut down period from March through September in 2005. Fig. 4 is a photograph of one of the new ducts, taken just after put on the magnets.

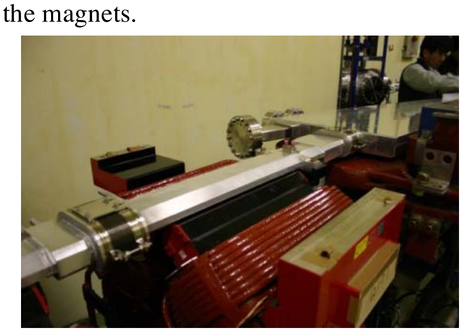

Figure 4: Photograph of one of the new ducts.

After the installation of the vacuum ducts, we omitted the thermal in-situ baking, anticipating that beam scrubbing would provide more efficient cleaning, like we experienced in the past reconstructions of the PF [2] and the PF-AR [3]. In addition, in this reconstruction even pre-baking before the installation was not performed for the chambers in the northern half in order to evaluate the effect of the pre-baking during the early period of the recommissioning.

Vacuum Pumps

The PF ring's main vacuum pumping system is composed of three kinds of pumps; distributed ion pump (DIP), sputter ion pump (SIP), and titanium sublimation pump (TSP). There are twenty-eight DIPs in the PF ring, and twelve of them were renewed together with the replacement of twelve B-ducts. By changing the pump cells and applying voltage, the pumping speed for each DIP increased to 180 l/s from 100 l/s. In the straight sections, as well as at heavy gas load positions near crotch absorbers, SIPs and TSPs were installed. The SIPs were reused, and the TSP cartridges were replaced.

Vacuum gauges

Fifty-three Bayard-Alpert gauges (BAGs) are being used as pressure monitors along the ring and also as signal sources for the vacuum interlock system. In order to improve the short lifetime problems of BAG filaments, all of the tungsten filaments were replaced with thoria-coated iridium filaments. Calibrations for all BAGs were carried out in a test chamber.

Vacuum control system

Prior to the main reconstruction in 2005, the vacuum control system was upgraded in the summer of 2004 [4]. The new system is based on PLC (Programmable Logic Controller) and EPICS (Experimental Physics and Industrial Control System). The vacuum interlock system was also upgraded to the PLC-based system. With this upgrade, reliability, operability and maintainability of the vacuum control system were improved.

PERFORMANCE OF THE NEW VACUUM SYSTEM

Calculation of pressure distribution

To verify the new vacuum system configuration, pressure distributions along the beam ducts were calculated at some points of running time (integrated current: 0.1Ah, 1Ah, 10Ah, 100Ah, and 1000Ah).

For the calculations of the outgas rates, photon stimulated gas desorption yields (η) as a function of the photon dose for different characteristics ducts were necessary. In this time, observed data during the previous operations were used for them. In the calculations for the northern (no pre-baked) sections, since it was the first time that we installed new vacuum ducts to the PF ring without any pre-baking, we assumed three conditions for the initial η, like $\eta_n=\eta_s$, $\eta_n=3\eta_s$, and $\eta_n=10\eta_s$, where η_n denotes the η of no pre-baked new duct and η_s denotes the η of pre-baked new duct. In addition, we assumed the difference between η_n and η_s narrowed gradually and disappeared at the integrated current of 200 Ah.

For example, Fig. 5 shows the result of the calculation for the northern straight sections at the integrated current of 10 Ah in case of $\eta_n=3\eta_s$ for the initial η.

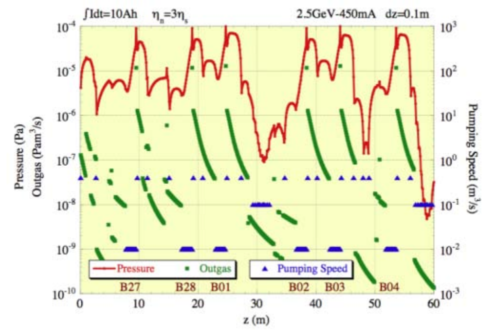

Figure 5: Example of the pressure calculation results.

Estimation of lifetime recovery

Before this reconstruction, ultimate average pressure with a 2.5GeV-450mA beam reached 2×10^{-8} Pa, and the beam lifetime used to be more than 60 hours. Thanks to this long lifetime, sufficient SR flux was being provided even with once-a-day beam refills.

After this reconstruction, the beam lifetime at the restart of the user operation was expected to be longer than 8 hours to make the refill rate less than three times a day. In other words, the product of the stored current and the beam lifetime ($I\tau$) was expected to be more than 200 Amin. This value was achieved after the last large-scale reconstruction in arc sections in 1997, but this time there are several disadvantages compared with the last time.

- Total length of the reconstruction regions is almost double.
- In the long straight sections, progress of the beam scrubbing is slower because the SR density is lower.
- The conductance of the new Q-duct is about half of that of the arc section Q-duct (see Fig. 3).
- No pre-baking was performed on the northern half ducts.
- The KEKB and the PF-AR, which use the same injector linac, are running.

On the other hand, a few advantages for this time are enumerated as follows.

- The pumping speed of DIP is improved.
- Appling RF phase modulation can extend the Touschek lifetime [5].

On account of many disadvantages, the feasibility of required lifetime was uncertain. Therefore, prior to the accelerator recommissioning, progress of the beam lifetime recovery should be estimated.

Using the previously observed data of the relationship between the average pressures and the beam lifetimes (shown in Fig. 6), and also the ring average pressures from the pressure distribution calculations for several points of running time, the progress of the beam lifetime recovery was calculated (shown in Fig. 7).

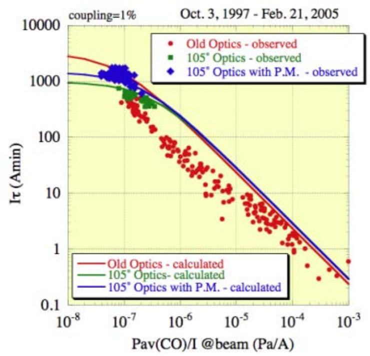

Figure 6: Observed and calculated lifetimes as a function of the CO-equivalent average pressure along the beam.

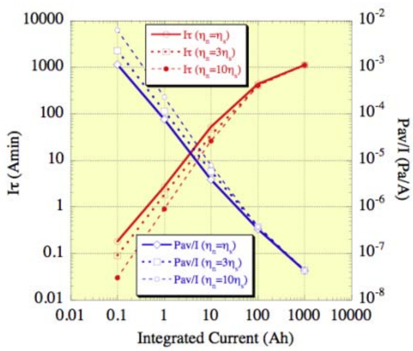

Figure 7: Results of the estimations of the average pressures and the beam lifetimes after the reconstruction.

These estimations indicated that the lifetime at the restart of the user operation (integrated current: 100-200 Ah) could reach satisfactory level.

Recommioning results

Recommissioning of the accelerator started on September 20, 2005, and the user operation resumed on October 18 on schedule. Fig. 8 shows the observed data of the beam lifetime ($I\tau$) and the current-normalized average pressure (*Pav/I*) as a function of the integrated current from the start of the recommissioning.

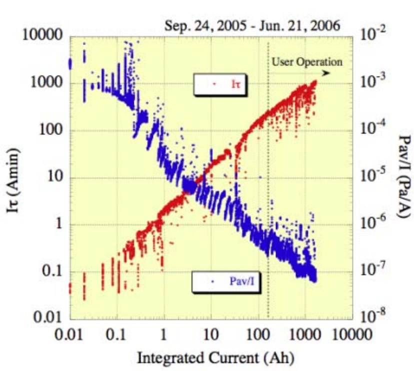

Figure 8: Observed data of the average pressure and the beam lifetime from the start of the recommissioning.

When the one-month recommissioning completed, the lifetime ($I\tau$) was about 200 Amin, and the user operation restarted with the refill rate of three times a day. As of the middle of June 2006, $I\tau$ reached 1100 Amin and the recovery is still progressing. This recovery speed is faster than the speed after the previous reconstruction in 1997.

In comparison with the simulation results, the observed data was similar with the results in the cases of $\eta_n \le 3\eta_s$.

Effect of pre-baking

In comparison of observed average pressures in no pre-baked sections and in pre-baked sections (see Fig. 9), only 2 times or less difference was observed until the integrated current was several 10 Ah (average photon dose: about 1×10^{24} photons/m), and after that, significant difference was no longer observed.

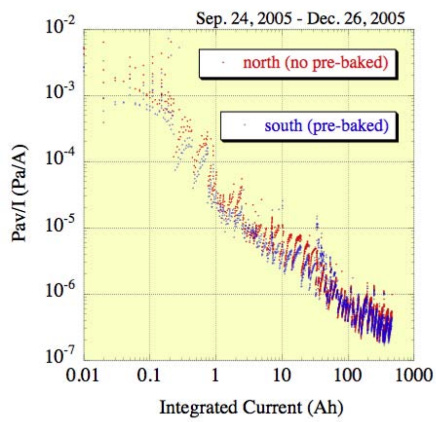

Figure 9: Observed average pressures in the northern (no pre-baked) and in the southern (pre-baked) straight sections.

SUMMARY

The vacuum system for the PF storage ring was extensively modified in 2005 as part of the PF ring straight sections upgrade project. Since the beginning of the recommissioning, the performance of the vacuum system has been satisfactory and the beam lifetime has been recovering favorably. No pre-baking installation was examined, and the observed data showed that there was no significant difference after the average photon dose of 1×10^{24} photons/m.

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