BEHAVIOR OF VACUUM PRESSURE IN TPS VACUUM SYSTEM

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Abstract

Taiwan Photon source (TPS) is in its first stage commissioning in 2014-2015. The vacuum systems of TPS were installed for commissioning since August 2014. After four months performance testing and subsystem integration, the commissioning of booster ring began on 12 December and then the first 3 GeV beam was stored on 31 December. 100mA beam current, 35Ah accumulated beam dose was archived in March 2015 before machine shut down.

The average pressure in storage ring is 2.8×10^{-8} Pa before commissioning, rising to 1.33×10^{-7} Pa with 100mA beam current. In 35Ah accumulated beam dose, the target of beam cleaning effect has reached to 8.92×10^{-10} Pa/mA. The vacuum performance, experience and events during commissioning will be presented in this paper.

INTRODUCTION

TPS is a low-emittance 3-GeV synchrotron ring with the concentric storage and booster rings in the same tunnel. The storage ring, with 518.4m circumference, is divided into 48 sections by RF gate valves, including 24 arc cells and 24 straight sections [1]. The 14m arc cells, which were prebaked to ultra-high vacuum in NSRRC's facility during 2012 November to 2013 August, and installed into TPS tunnel under vacuum in 2013 October to 2014 March. The straight sections, six of length 12 m and 18 of length 7 m are assembled continually, including one injection section, one diagnostic section, two PETRA cavities and other dummy sections until 2014 August. During the installation of straight sections of storage ring, booster ring, the transfer line from the LINAC to the booster ring (LTB, LINAC to booster ring) and the transfer line from the booster ring to the storage ring (BTS, booster to storage ring) were also assembled at the same time.

Aluminium alloy was chosen as the material of vacuum chamber because of its lower thermal outgassing rate and good experience in Taiwan Light Source at NSRRC in the past 20 years. For the arc sections, the triangularly shaped vacuum chambers were designed and Cu crotch absorbers located downstream intercepts more than 70 % of the synchrotron radiation from the bending magnet. Pumping unit combined sputtering ion pump (SIP) with non-evaporable getter pump (NEG) was design and located at the antechamber so as to decrease the pumping ports and produce a smooth vacuum surface with small impedance. Besides, near the crotch absorbers and photon stoppers, NEG pumps were also installed to enhance pumping speed. In addition, exhaust pumping systems with turbo-molecular pumps were used to remove large amount of the photon stimulated desorption during machine commissioning. The geometric layout of bending chamber in arc section is shown in Figure1.

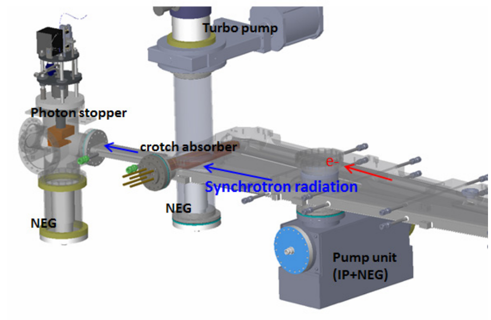

Figure 1: The geometric layout of bending chamber in arc section.

Extractor ion gauge (EIG) was used as pressure reading and safety interlock system in TPS storage ring while cold cathode gauges (CCG) were used in booster ring. Total 144 gauges installed averagely into 48 vacuum sections were planned; it means all 3 gauges were installed between two section gate valves (SGV). 1×10^{-4} Pa pressure trip was set as high limit for vacuum interlock. If any two gauges reach high limit or malfunction, the logic trigger signal would then be sent out to close the SGVs at this section. In order to extend the operation lifetime, self-protection mode of EIGs was set. In such mode, EIGs will be switched off automatically when the vacuum pressure raises higher than 1×10^{-3} Pa [2].

Due to impedance issue and reducing the interference from scatter electron, EIG was installed into pumping unit shown as EIG3 in Figure 2. In straight section, another one was installed near the orbit of electron beam, especially in out-of-vacuum insertion device which has no space to install. The reading of EIGs in different location was summarized in table1. In static pressure, the readings were similar; a 1.5x difference was found in dynamic condition with 100mA beam current.

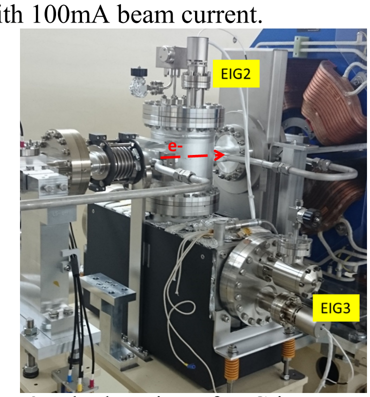

Figure 2: The location of EIG in storage ring.

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Table 1: The Reading of EIGs in Different Location and Status

	Static (nPa)	Dynamic(nPa)
EIG2	11.7	115
EIG3	11	80

VACUUM PERFORMANCE

Figure 3 shows the graphical user interface (GUI) of the TPS storage ring. The bar chart of pressure reading and status of SGVs are displayed mainly. All EIGs and SGVs are listed and arranged from R01 to R24 sequentially. Other information including time, beam current, and average pressure of all EIGs also shows in GUI page for easy recording, investigation and problem solving.

During the storage ring assembly period, few problems were occurred. One of main is the shortage of NEG pump. It is planned to install 293 NEG pumps around the storage ring: 240 in arc sections, 46 in straight section, and 7 in injection section. There is shortage of 15 NEG pumps which will be installed in some straight sections finally. The shortage of NEG affects the performance of static pressure in steady state. Another one is the operation of EIG. This actual problem source was divided into gauge head and controller. In the stage of arc section assembly, leakage in ceramic pin of gauge head was found after bake. This problem still occurred during the assembly of straight sections. In the controller part, the type of the purchased controller is IM540 and 15% of IM540 were malfunction after installed inside racks and connected to gauge head with 20~25m cable. After several verification and test, the problem was resulted from IM540. The actual reason was not clear so far and still kept to work with supplier.

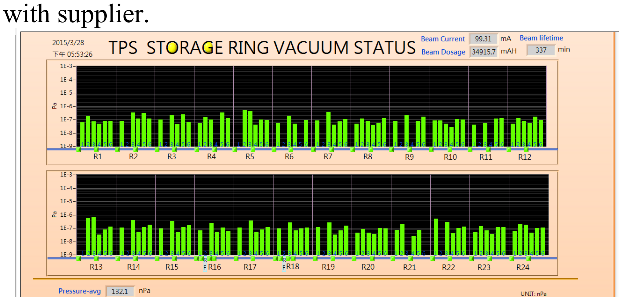

Figure 3: The graphical user interface of the TPS storage ring.

The average pressure of storage ring before commissioning is 2.8×10^{-8} Pa. The highest pressure is 5.4×10^{-7} Pa in straight section of R22 attributed by high outgassing rate. The reason was not clear and will be improved in next machine shut down. Furthermore, the average pressure is 1.2×10^{-8} Pa in injection section (R1), 3.7×10^{-8} Pa in cavity sections (R16&R18), 5.75×10^{-9} Pa in all arc sections and 4.1×10^{-8} Pa in all straight sections. The pressure in straight sections is higher due to the shortage of NEG pumps. The pressure reading of vacuum sections in different condition and beam current is shown in Figure 4.

	static	1mA	5mA	1Ah	100mA	35Ah
Average	28	1780	3850	163	133	117
Arc sections	5.7	986	2336	142	116	102
Straight sections	41	2252	4744	175	138	127
Injection section	37	262	637	253	110	93
Cavity sections	38	422	896	152	189	232

Figure 4: The pressure reading of vacuum sections in different condition and beam current (unit: nPa).

The commissioning of booster ring was started on 12 December 2014. The electron beam was successfully accelerated to 3GeV on 16 December. During booster commissioning, the behaviour of CCGs at booster ring was shown as Figure 5. The average pressure was 6×10^{-7} Pa before commissioning and raised to 1.26×10^{-6} Pa, 4×10^{-6} Pa as the highest, during ramping.

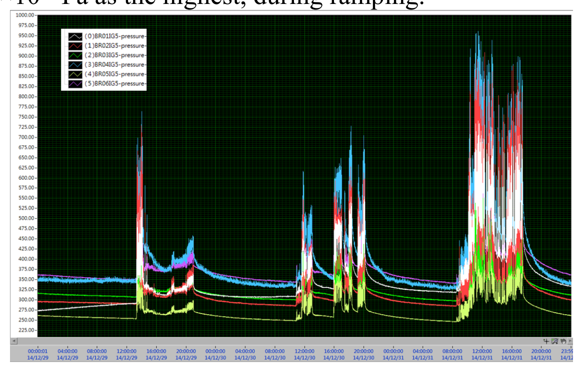

Figure 5: The behaviour of vacuum gauges at booster ring during commissioning.

The storage ring commissioning began on 29 December. The 3GeV electron beam of storage ring was stored and the first synchrotron light was observed on 31 December [3]. The average pressure raised to 1.8×10^{-6} Pa while 1 mA beam current was archived. The beam current was continuously injected to 5mA until vacuum interlock was tripped due to pressure high than 1×10^{-4} Pa. Three times of vacuum interlock trip were occurred: two is in straight section of R7 and the other in straight section of R10. When 5 mA beam current was archived, the average pressure was raised to 3.85×10^{-6} Pa and the highest pressure was 1×10^{-4} Pa in the straight section of R10.

After three months commissioning, 100mA beam current was archived and the average pressure reduced to 1.33×10^{-7} Pa while 26 Ah beam dose was accumulated. Just before the machine shut down for the installation of superconductivity cavities and insertion devices, beam dose was accumulated to 35 Ah with 1.17×10^{-7} Pa dynamic pressure. Figure 6 shows the pressure rise per beam current (Pa/mA) vs. accumulated beam dose (mAh). The beam cleaning effect is clear. The beam lifetime also shows in Figure 6. As expectation, beam lifetime increases with decreased pressure. 6 hour beam lifetime at 100mA beam current was archived before machine shut down.

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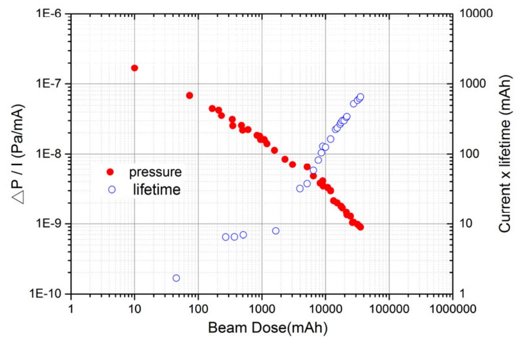

Figure 6: Average pressure rise per beam current and beam life time vs. accumulated beam dose.

During the first stage of TPS commissioning, machine was shut down several times to optimize the vacuum performance. First is to replace two short circuit SIPs and to install NEG pumps. During the first day of commissioning, vacuum interlock was tripped due to the short circuit of SIP in the straight section of R10; it limited the highest beam current as 5mA. After replacing, although the average pressure didn`t improve obviously in static state, 5mA was not the bottleneck during commissioning.

Second is exhaust pumping systems which were used to enhance the pumping speed and extend the lifetime of NEG pumps near the crotch absorbers. The interlock of pumping system was checked carefully to reduce the risk of air back-stream from atmosphere. The exhaust system including turbo pump, fore-line dry pump, UPS and isolated valve is shown in Figure 7.

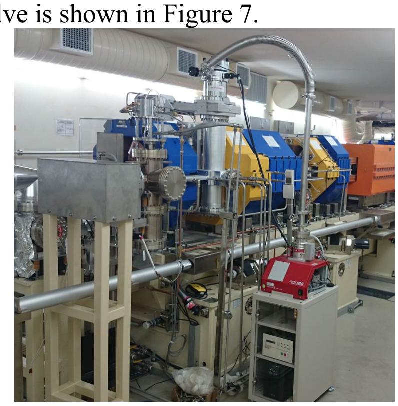

Figure 7: The exhaust pumping system in TPS storage ring.

At first, the effect of exhaust pumping system was not clear due to unstable machine condition. One study was implemented by isolating all exhausting systems under stable beam current condition to inspect the performance for beam cleaning. When exhaust systems were isolated, max 20% of dynamic pressure increasing in arc sections and 12% in all average pressure were observed. The readings of vacuum pressure during isolating the exhaust systems were shown in Figure 8.

In the late of commissioning, exhaust pumping systems were isolated from vacuum system and powered off due to the vibration issue [4]. Although extra pumping capacity was added by the exhaust systems, beam cleaning curves kept to decrease even when exhaust systems were isolated. The contribution of exhaust pumping system for beam cleaning was not clear and will continue to study in the future.

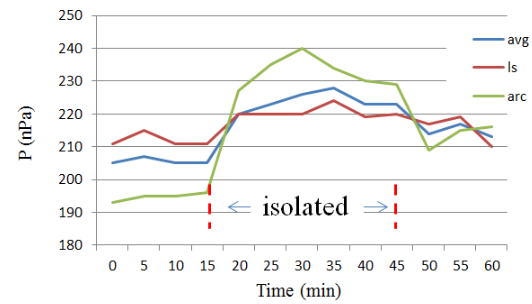

Figure 8: The reading of vacuum pressure when isolating the exhaust systems from vacuum system.

CONCLUSIONS

The vacuum behaviour of TPS storage ring during the first stage commissioning is described. During commissioning, few problems were found and solved immediately. The beam cleaning effect is similar to other machines [5] and meets the estimation [6]. TPS machine now is shut down for the installation of superconducting RF cavities and insertion devices. The vacuum relating items including pressure optimization and upgrade of safety interlock are also in progress. The behaviour of vacuum pressure will be continuously studied in the future.

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