PERFORMANCE OF THE VACUUM SYSTEM FOR THE SOLARIS 1.5GeV ELECTRON STORAGE RING

A. Marendziak†, P. Borowiec, P. Bulira, Ł. Dudek, P.P. Goryl, K. Karaś, A. Kisiel, W. Kitka, M. Kopeć, M. Nowak, M. Madura, M.J. Stankiewicz, A.I. Wawrzyniak, K. Wawrzyniak, J. Wikłacz, J. Wiechecki, M. Zając, T. Zbylut, Solaris NSRC, Krakow, Poland
C.J. Bocchetta, ESS, Lund, Sweden
R. Nietubyć, NCNR, Otwock, Poland
Ł. Żytniak MAXIV Laboratory, Lund, Sweden

Abstract

Solaris is a third generation light source recently constructed at the Jagiellonian University in Krakow, Poland. The machine was designed by the team at the MAX IV Laboratory. A replica of the 1.5 GeV MAX IV storage ring with a 96 m circumference was successfully built at Solaris and now the facility is in its 3rd phase of commissioning. The average pressure in the storage ring was $1.2 \cdot 10^{-10}$ mbar before beam commissioning and increases to $1.2 \cdot 10^{-8}$ mbar with 511 mA of stored beam current for electron energy of 524 MeV. With 10 A·h accumulated beam dose, beam cleaning has permitted an average pressure of $3 \cdot 10^{-10}$ mbar/mA. In this paper the result of vacuum performance from beam cleaning and the beam lifetime will be presented. Moreover vacuum maintenance procedures will be reported.

VACUUM SYSTEM

The Solaris light source is based on a 0.6 GeV S-band linac with a thermionic RF gun, a vertical dog-leg beam transfer line and a 1.5 GeV storage ring with 96 m circumference [1]. The storage ring is composed of twelve double bend achromat (DBA) cells and twelve straight sections. Three straight sections are used for injection and RF: injection (1st straight), kicker (3rd straight) [2] and RF system (12th straight) [3]. The DBA vacuum chamber has inner dimensions of 40/20 mm (horizontal/vertical). However, in the DBA centre the aperture is increased up to 56/28 mm. This chamber contains two Non Evaporable Getter (NEG) strips ST707 (Zr-V-Fe) from SAES, three differential diode Ion Sputter Pumps (ISP) and one Titanium Sublimation Pump (TSP) from Gamma Vacuum. To absorb synchrotron radiation power each chamber contains three crotch absorbers, one movable and two distributed absorbers that are located near the NEG strips. A standard straight section vacuum chamber includes two SIPs and one crotch absorber. The storage ring has twelve DBA vacuum chambers, nine standard straight sections, the RF and injection straight sections and an Undulator Vacuum Chamber (UVC) section 65 ISPs, 24 NEG strips and 12 TSPs installed. The nominal pumping speed of SIPs for N_2 is around 6660 l/s whereas the nominal pumping speed of NEGs combined with TSPs for H_2 is around 27850 l/s. At this moment only one cold cathode vacuum gauge has been installed in the transfer line. For this reason, the average pressure in the storage ring is estimated from the ion current of SIPs. An overview of the storage ring and local pressure is shown in Fig. 1.

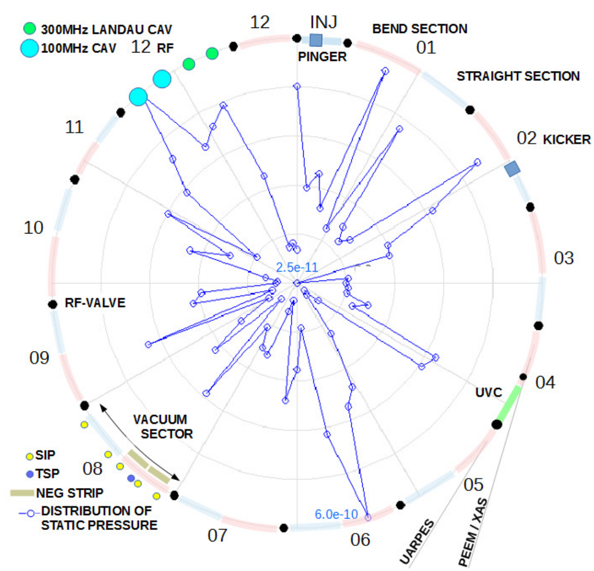

Figure 1: Solaris storage ring.

INSTALLATION

The installation process took seven months between September 2014 and March, 2015. After pre-assembly all dipole vacuum chambers and straight sections were baked out at 220 °C for 48 hours. All vacuum chambers at the end of the bakeout process had a pressure lower than $5.0 \cdot 10^{-10}$ mbar and leak test results below $2.0 \cdot 10^{-10}$ mbar·l/s. During the bakeout process NEG strips were heated up to 130 ºC. During the first stage of installation all dipole vacuum chambers were transported to the storage ring and mounted inside the DBA magnet blocks. After preliminary alignment and sag elimination of all DBAs, straight sections were installed. Connections between dipole vacuum chambers and straight sections were made under a constant flow of Nitrogen. The storage ring was under the vacuum by March, 20 2015. The next step was to activate NEG strips. Three pump station units, two

*Work supported by the European Regional Development Fund within the frame of the Innovative Economy Operational Program: POIG.02.01.00-12-213/09
† andrzej.marendziak@uj.edu.pl

DC power supplies and one RGA were used to perform this process for one vacuum sector. According to SAES specification to activate the NEG strips it was necessary to apply a 28 A DC current for over one hour. The pressure distribution in the storage ring just after activation of NEG strips is presented in Fig. 2.

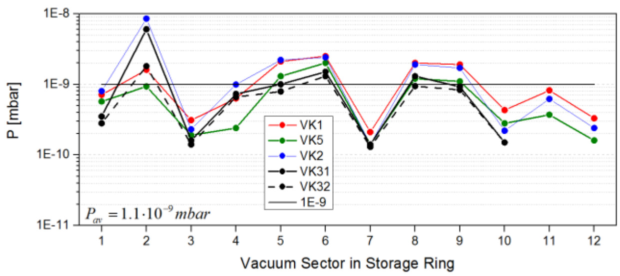

Figure 2: The pressure in storage ring after NEG strips activation.

Before activation of the NEG strips all filaments of TSP were degased. The TSP activation took place after NEG strips activation. The pressure distribution in the storage ring after the first activation of TSPs is shown in Fig. 3.

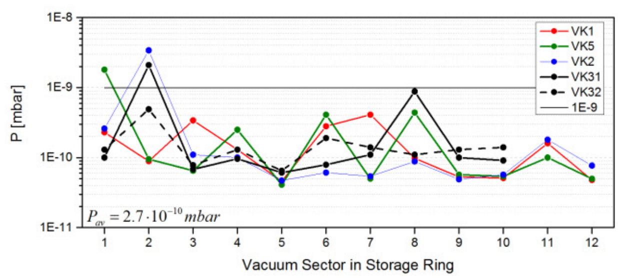

Figure 3: The pressure in the storage ring after TSPs activation.

CONDITIONING

The first and the second stage of storage ring conditioning process took place between May and November, 2015 [2]. At the end of November it was possible to store almost 200 mA beam current at an electron energy of 517 MeV. The third stage of vacuum conditioning began in February, after the winter shutdown, and will end in July of 2016. During the first and second stage of the conditioning the static pressure in the storage ring was around $3.6 \cdot 10^{-10}$ mbar with a small tendency of rising up to $5.0 \cdot 10^{-10}$ mbar over next three months. During the installation of the Landau cavities leaks were detected on both pick-up loops from the main cavities. The level of the leaks in both cases was around $2.1 \cdot 10^{-7}$ mbar·l/s. A second leak in the storage ring was also found in the first DBA vacuum sector, just after the injection section on the connection between two vacuum chambers. Even if the average pressure in this vacuum sector was around $3.5 \cdot 10^{-10}$ mbar, it was still possible to detect leak at the level of $1.3 \cdot 10^{-7}$ mbar·l/s. At this moment static average pressure (P_{av}) in the storage ring is around $1.2 \cdot 10^{-10}$ mbar before injection. With a stored beam current of 140 mA the average pressure usually rises to $4.0 \cdot 10^{-9}$ mbar. During the ramping of the electron energy to 1.5GeV for a stored beam current of 90 mA, the dynamic average pressure usually is around $1.6 \cdot 10^{-8}$ mbar for a 2/3 filling mode (Fig. 4).

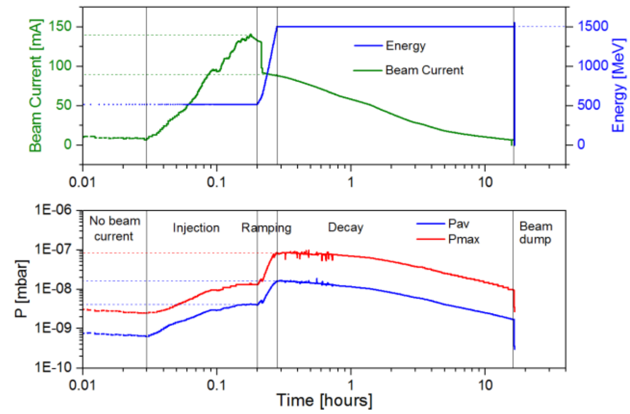

Figure 4: Pressure behaviour during injection and ramping in loglog scale.

The maximum dynamic pressure (see red line in Fig. 4.) during the ramping process was close to $1.0 \cdot 10^{-7}$ mbar. The pressure level in the storage ring depends on the following states of the machine: no beam current, injection, ramping decay and beam dump. To establish the evolution of P_{av}/I [mbar/mA], $I \cdot \tau$ [mA.h] and lifetime (τ) [min] as a function of integrated current [A.h], it was decided to monitor the behaviour of these parameters in a decay mode. All necessary calculations were performed for a beam current of 20 mA and an electron energy of 1.5GeV.

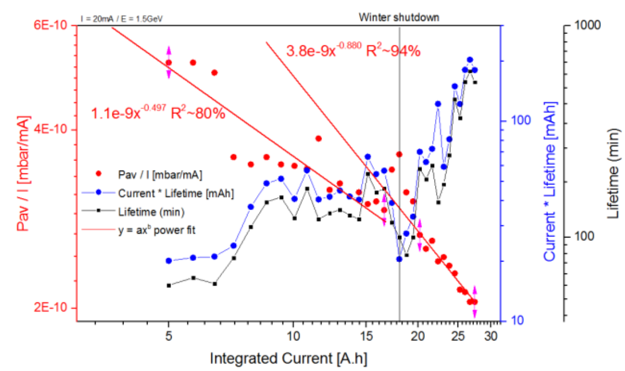

Figure 5: The evolution of P_{av}/I, $I \cdot \tau$ and τ vs integrated current.

The results of P_{av}/I, $I \cdot \tau$ and the lifetime in the integrated current domain are shown in Fig. 5. More than 27 A.hr has been accumulated since the start of the storage ring conditioning. The progress of the conditioning process in comparison to the other storage rings for the same dose level is presented in Table 1. One can see that the process of cleaning the Solaris storage ring does not depart a lot from the other light sources. It is possible to notice (see Fig. 5), that an exposure of the vacuum system (1st, 2nd, 3rd and 12th RF sector) for the Nitrogen (installation of Lanadu cavities) and Argon (fixing the leaks in the first DBA vacuum sector) during winter shutdown, had reduced the value of both products.

ISBN 978-3-95450-147-2

Table 1: The cleaning process of different storage rings for 10 A·h

Storage ring	Ref.	Energy [GeV]	P_{av} / I [mbar/mA]
Solaris		1.5	$3.0 \cdot 10^{-10}$
Diamond	[4]	3	$5.0 \cdot 10^{-11}$
Soleil	[5]	2.75	$6.0 \cdot 10^{-11}$
Sortec	[6]	1	$1.1 \cdot 10^{-10}$
PLS	[7]	2	$1.3 \cdot 10^{-10}$
HLS II	[8]	0.8	$1.0 \cdot 10^{-10}$
ASP	[9]	2	$6.0 \cdot 10^{-11}$
Alba	[10]	3	$5.0 \cdot 10^{-11}$
SLS	[11]	2.4	$8.0 \cdot 10^{-11}$
TPS	[12]	3	$1.8 \cdot 10^{-9}$
NSLS II	[13]	3	$3.3 \cdot 10^{-11}$
ELETTRA	[14]	2	$1.8 \cdot 10^{-10}$
LNLS	[15]	1.37	$4.1 \cdot 10^{-11}$

Fixing the leaks and installation of Landau cavities have significantly reduced the time necessary to get back on track with the cleaning process, which in a short time contributed to improving the total lifetime. The negative slope of the conditioning (vacuum clean-up rate) has increased significantly after the winter shutdown to 0.88 and now is higher than the reported elsewhere 0.63 [5] and 0.69 [6] (see Fig. 5).

Ohno et al [6] were able to distinguish, during conditioning of the Sortec storage ring, faster beam cleaning for the bending section (P_{dp}/I) than for straight section (P_{id}/I), due to higher photon flux for increased beam dose. Similar calculations have been performed for Solaris, but at this moment it is not possible to observe significant differences. The average normalized pressure for the bending section (P_{dp}/I) is lower than the normalized pressure of the straight section by about $2.3 \cdot 10^{-10}$ mbar/mA.

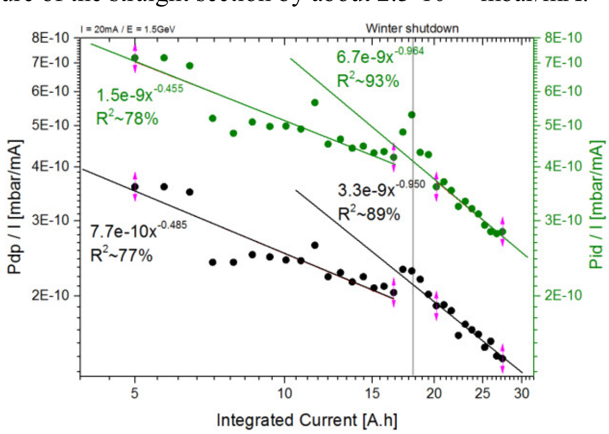

Figure 6: The evolution of P_{dp}/I and P_{id}/I vs integrated current.

This comes from the fact that for the DBA section there is higher pumping speed than for the straight section. Both fittings have similar negative slope of about 0.95 which have increased significantly after the winter shutdown (Fig. 6).

Unfortunately, so far it was not possible to assemble the Residual Gas Analyzer (RGA) in the storage ring, due to a malfunction of the device itself. At this moment it is hard to predict what is the current level of typical residual gases present in the storage ring like: hydrogen, CO or CO_2 and how this level is changing during the conditioning process [10]. Moreover it is not possible to detect contamination caused by heavy hydrocarbons, which can reduce beam lifetime.

MAINTENANCE

One of the main activities during each shutdown is to re-activate all TSPs. All filaments from each TSP have been degassed during the activation of the NEG strips and now maximum pressure during reactivation of TSPs is around $3.5 \cdot 10^{-8}$ mbar. The TSP is situated in a small chamber near the crotch absorber of the 7.5 deg photon beam port. So far one short cut of the filament to the vacuum chamber has been detected.

Another activity is to check the performance of the ISPs. From time to time unstable readouts have been observed from random controllers, mainly due to the leakage currents. Small Pump Controllers (SPCe) from Gamma Vacuum allow to perform Fowler-Nordheim Field Emission Analysis (FEA) and as a result hi-potting procedure may be recommended [16]. This procedure has been performed a few times and recently a significant improvement of current signal stability has been observed.

CONCLUSION

The conditioning process of the Solaris storage ring is going well and for an accumulated beam current around 10 A.h the cleaning process does not differ significantly from the level observed in other storage rings. Leaks which were detected during winter shutdown have been fixed. Moreover, the frequent TSP activations after the winter shutdown has contributed to a significant improvement of the cleaning process. The specificity of the storage ring vacuum system suggests to conduct regular leak tests. Even if good average vacuum level around $3.5 \cdot 10^{-10}$ mbar in the range of one vacuum sector can be achieved, leak as high as at the level of $1.3 \cdot 10^{-7}$ mbar·l/s may be present.

ACKNOWLEDGEMENTS

Authors would like to express thanks to all the MAX IV team for sharing their technology and know-how. Special acknowledgements to E. Al-Dmour and J. Ahlbäck for sharing their knowledge and discussions on vacuum technology. Gratitude to whole team for bringing Solaris into the light.

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