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THREE YEARS OF OPERATIONAL EXPERIENCE WITH THE SOLARIS VACUUM SYSTEM

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Abstract

Solaris, a 1.5 GeV third generation synchrotron light source, was commissioned in 2016 April and is currently operated in decay mode. Two beamlines PEEM/XAS and UARPES were installed and now are being commissioned. Three more PHELIX, XMCD and diagnostic beamlines have received funding and will be installed and commissioned in next few years. With total accumulated beam dose near to 690 A.h and three orders of magnitude reduction of outgassing the design goal of 500 mA beam current and electron energy of 1.5 GeV has been achieved. As the beam current was increased, a few vacuum problems were encountered, including vacuum leaks in RF and arc sectors and unexpected pressure bursts near photon absorbers. Lessons learned and operational experience will be presented and discussed in this paper.

ACCELERATORS 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 transfer line and a 1.5 GeV storage ring with 96 m circumference. The pre-injector contains six Sputter Ion Pumps (SIP) with total nominal pumping speed of 165 l/s for N_2. Two SIP's (15 l/s each) are installed near to the energy filter and one SIP (60 l/s) on the waveguide close to the RF unit. A linear accelerator consists of six S-band 5.2 m long accelerating structures, combined in three accelerating units. Each accelerating unit contains SLED cavity system, 3dB power divider and 2 linac structures. Nine SIP's with total nominal pumping speed of 540 l/s for N_2 were installed for each accelerating unit. A short beam dump section is present at the end of the linac. A transfer line (TL) based on 10 degree Lambertson DC septa at the beginning and the end of transport system and two 17 degree vertical bends provides the beam to the storage ring. The TL is equipped with eight SIP's with total nominal pumping speed of 635 l/s for N_2. The Solaris storage ring is composed of twelve Double Bend Achromat (DBA) cells and twelve straights [1]. The 1st straight section is for the injection and the diagnostics, the 3rd straight contains a dipole kicker [2] and in the 12th straight RF system is installed [3]. The DBA vacuum chamber has inner dimensions of 40x20 mm (horizontal/vertical). However, in the DBA centre the aperture is increased up to 56x28 mm. This chamber contains two Non Evaporable Getter (NEG) strips ST707 (Zr-V-Fe), Sputter Ion Pumps (SIPs) and one Titanium Sublimation Pump (TSP). To absorb a synchrotron radiation power each arc vacuum chamber contains three photon absorbers, one end absorber (HAA) and two distributed absorbers. A standard straight section vacuum chamber includes two SIPs and one photon absorber. One vacuum chamber arc and one straight with three valves define one vacuum sector in the Solaris storage ring. The nominal pumping speed of all SIPs in the storage ring for N_2 is around 6660 l/s whereas the nominal pumping speed of NEGs combined with TSPs for H_2 is around 29498 l/s [4]. All SIP's installed in the linac, the transfer line and the storage ring were differential diode type. Two Cold Cathode Vacuum Gauge (CCVG) (one - in the transfer line and the second - in the storage ring in the 1st straight section together with the Residual Gas Analyser (RGA) from MKS) were installed in the machine. One NEG coated undulator vacuum chamber was installed for UARPES beamline. To evaluate a residual gas composition in the storage ring Microvision 2 mass spectrometer with 3 meters extender from MKS was chosen. Four additional RGA's from Hiden Analytical HAL 101 RC, have been recently installed in the storage ring. All of those devices were foreseen to measure a gas composition at the connection of the beamline with the storage ring in a front-end area. So far two of them for beamlines PEEM and UARPES were installed in a target location. Static (without) and dynamic (with the electron beam) pressure in linear and circular accelerators for 690 A.h of the integrated current has been presented in Fig 1.

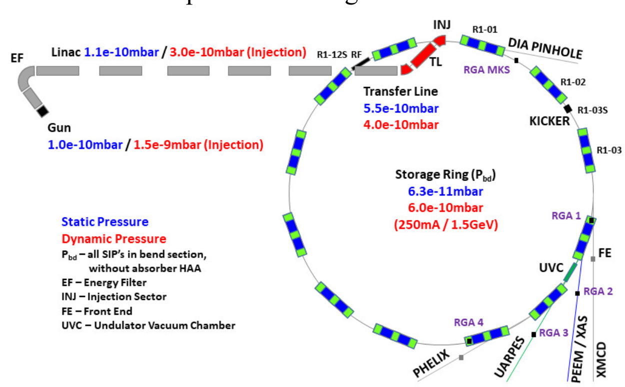

Figure 1: Static and dynamic pressure in accelerators vacuum system.

PROBLEMS WITH VACUUM SYSTEM

For the last 3 years more than few problems related to vacuum system has occurred. In case of the linear accelerator malfunction of the YAG screen device was detected.

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During insertion and extraction of the device high increase of pressure, up to interlock level set at $1\cdot10^{-7}$ mbar, was detected. After this incident pressure in the linac was recovering to the value of $5\cdot10^{-10}$ mbar for almost 20 hours. Because of good reliability of linear accelerator itself, it was decided to switch off diagnostic device from the operation instead of venting two S-band structures.

Much more problems appeared in case of the storage ring. One of the most frequently vented by Nitrogen vacuum sector was the RF sector containing two 100 Hz main cavities and two 300 MHz Landau cavities. Four pick-up ceramic probes were exchanged to new type. 600XL SIP's from both main cavities were dismounted in case to replace not leak tight ceramic feedthrough from the high voltage connection. Two plungers for fast detuning of Landau cavities during injection and ramping were installed. Recently two TSP's were integrated with main cavities and two SIP's were exchanged to SIP's with integrated NEG cartridge. Unusual vacuum performance of RF sector during injection, ramping and decay compared to other vacuum sectors has been presented in Fig. 2.

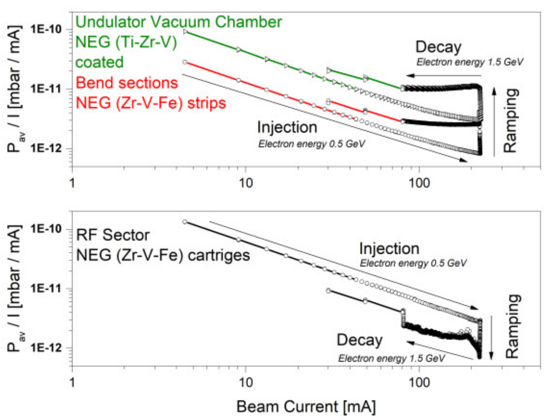

Figure 2: The evolution of P_{av}/I product for different vacuum sectors.

Second the most frequently vented vacuum sector was R1-02 sector placed near to the kicker magnet. So far the vacuum chamber in the DBA 02 was dismounted from vacuum system two times.

First time when a short-circuit of a sextupole magnet coil in the bottom half of the magnet block was detected. Replacing of the coil and improving of electrical insulation of pole-face strips in bending magnets caused breaking the vacuum system in sector R1-01. Restoring of vacuum level in sector R1-01 contributed to detection of a leak at connection between two vacuum chambers (VK1 and VK2) placed in this bend section. Even if the average pressure in this vacuum sector was around $3.5\cdot10^{-10}$ mbar, it was still possible to detect leak at the level of $1.3\cdot10^{-7}$ mbar·l/s. Radiation level at 0.6 µSv/h was the highest around the flange connections, where leak was present, compare to the background value measured at level of 0.1 µSv/h.

Second time sector R1-02 was vented, when an abnormal value of heat was detected at the exit of the vacuum chamber by thermocouple connected in the vicinity of crotch absorber (CROD) and RF shielding. During visual inspection the shape of the RF shield was found out of the specification due to, as we think, a huge thermal load caused by synchrotron radiation (see Fig. 3). Before mechanical adjustment thermocouple connected to vacuum chamber near to RF shielding was indicated about 55 °C for 100 mA of beam current at 1.5 GeV and after mechanical adjustment 40 °C in measurement time range of 1 hour.

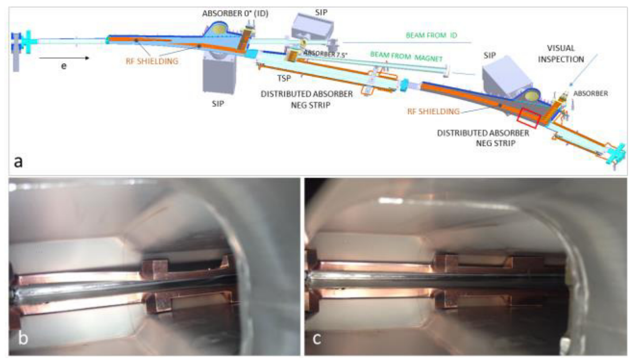

Figure 3: The vacuum chamber in DBA 02 (a) and the view of RF shielding before (b) and after (c) mechanical adjustment.

Significant increase of pressure, about one decade compere to other sectors, was detected during operation. At the same time an increased radiation level near this sector was measured. Since the vacuum performance of this chamber stood out clearly from the others vacuum chambers mounted in DBA's it was decided to replace this chamber with the spare one.

Problem with photoelectrons disturbing signal from SIP's was temporary solved. The magnetic tape was installed close to SIPs in each place, where significant influence of photoelectron current was detected. This approach allowed for better interpretation of events in the circular accelerator based on the pressure measurement. Too frequent activation of TSP caused by wrong pressure reading now has been reduced to one activation per week.

In case of the performance of the PEEM/XAS (Photo Emission Electron Microscope/X-ray Absorption Spectroscopy) beamline it is ready for first users. On the other hand UARPES (Ultra Angle-Resolved Photoemission Spectroscopy) beamline is still going through conditioning process after contamination caused by in-vacuum stepper motors. Residual gases analysis in mirror chambers on the 2nd November 2016 pointed to contamination by perfluoroether grease [5]. At the same time fast degradation of the optics surface was detected. After this event beamline has been cut off from the storage ring. During long discussion it was decided to move on with conditioning process even, if vacuum standard regarding level of hydrocarbons in mirrors chambers was not fulfilled [6]. At that time it was not easy to find the answer to the question whether the RGA criteria should be fulfilled only during installation process or maybe they should be also fulfilled during commissioning of prototype machines? Corrective action has been made by the subcontractor. Mirrors were refurbished. Vacuum chambers were baked-out. Somehow, it was not decided to go on with chemical cleaning. At this moment fast

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degradation of the optics surface is still observed. Vacuum chamber is full of fluorine (ratio $F^+/CO^+ \sim 5$) and with the light still some residual gasses caused by perfluoroether grease contamination are observed. One may wonder now if RGA criteria shall be fulfilled during commissioning process of prototype machines, how this approach would reduce the time associated with the beamline commissioning process.

CONDITIONING OF STORAGE RING

From the beginning of the storage ring conditioning process up to now about 690 A.h of current was accumulated. To establish the progress of conditioning process evolution of the P_{av}/I product [mbar/mA] over integrated current has been chosen. All calculations were performed in a decay mode for a beam current of 100 mA and an electron energy of 1.5 GeV (see Fig. 4).

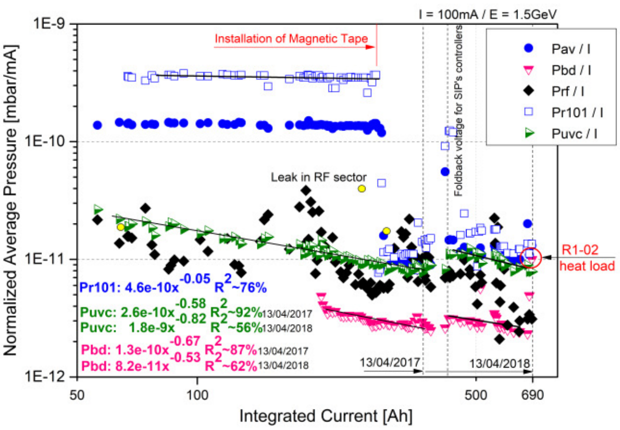

Figure 4: The evolution of the products for different vacuum sectors/components.

One can notice that the P_{rf}/I product calculated for the RF sector has dropped down to the value of $3 \cdot 10^{-12}$ mbar/mA after recent upgrade. Small increase of products was observed for each sector after activation foldback operation mode for each ion pump controller. This operation mode allowed to reduce an applied voltage to the ion pump from 7000 kV to 5000 kV when pressure is better than setpoint value. In our case setpoint value was set to $1 \cdot 10^{-7}$ mbar. According to Agilent it is possible to improve pumping speed performance for about 20 %, when for different value of pressure in the vacuum system a different value of the voltage is applied to SIP. A variable high voltage is applied to maintain optimum ion energy bombardment at the cathode, which resulting in the best possible pumping performance at any pressure [7]. In case of the P_{bd}/I product where NEG strips were installed and P_{uvc}/I, where NEG coated undulator vacuum chamber was installed, those products are still improving in time. For the straight section made from 316L stainless steel, where RGA was installed value of P_{r101}/I product appears to be maintained at a constant level of $1 \cdot 10^{-11}$ mbar/mA as the value of P_{av}/I product. Installation of magnetic tapes were reduced significantly these products value for more than one decade, but the effect of photoelectrons is still observed. Random behavior of products in the range of $1 \cdot 10^{-11}$ mbar/mA was not confirmed by analysis of normalised average partial pressures over integrated current for this sector (see Fig. 5). One can notice that vacuum clean-up rate (slope) for R1-01 sector evaluated as a sum of scanned masses (SSM) (0.87) measured by RGA is still progressing.

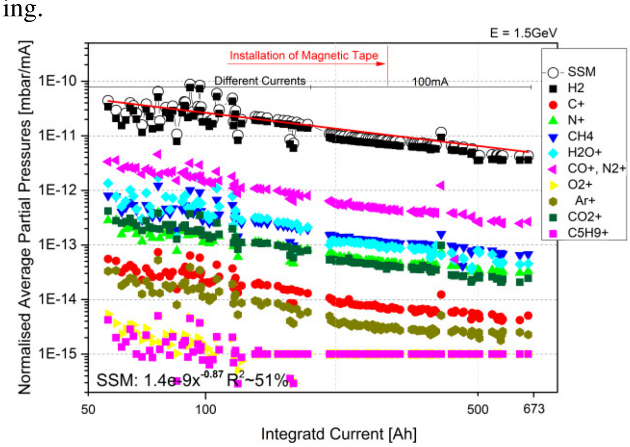

Figure 5: The normalised average pressure for different partial pressures in section R1-01.

CONCLUSION

To maintain short mean time between failures (MTBF) it is important to have experienced team, spare parts and service equipment [8]. Recent event at Solaris proved, that after three years of operation we can in reasonable time deal with problems associated with the light source. Progress regarding conditioning of the storage ring vacuum system is still observed, nevertheless the activation of NEG strips in all dipole vacuum chambers is now considered. Installation of diagnostic beamline has been foreseen, which should improve performance of delivered light.

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