RESIDUAL GAS IN THE VACUUM SYSTEM OF THE SOLARIS 1.5 GeV ELECTRON STORAGE RING

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Abstract

Solaris is a third generation light source constructed at the Jagiellonian University in Krakow, Poland. The machine was designed by the MAX IV Laboratory team. The replica of the 1.5 GeV storage ring with 96 m circumference of a vacuum system was successfully built and now the synchrotron facility is after the 3rd phase of commissioning. Recent installation of the Residual Gas Analyzer (RGA) in the storage ring allows now for evaluation of the residual gas composition. Within this paper the result of residual gas analysis in the vacuum system of storage ring during different states of the machine will be presented. Result of vacuum performance regarding beam cleaning and beam lifetime will be presented. Moreover, the NEG strips performance will be evaluated and reported.

VACUUM SYSTEM OF THE STORAGE RING

The Solaris storage ring is composed of twelve double bend achromat (DBA) cells and twelve straight sections with circumference of 96 m [1]. The 1st straight section is for injection and diagnostic, 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).

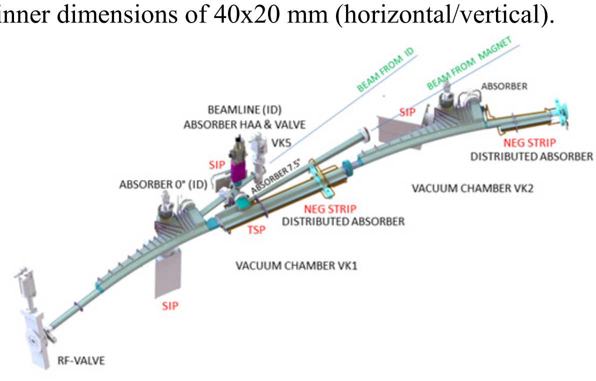

Figure 1: Vacuum chamber of the arc section.

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), three differential diode Sputter Ion Pumps (SIPs) and one Titanium Sublimation Pump (TSP). To absorb synchrotron radiation power each arc vacuum chamber contains three crotch absorbers, one end absorber (HAA) and two distributed absorbers. A standard straight section vacuum chamber includes two SIPs and one crotch absorber (see Fig. 2). One arc vacuum chamber and one straight with three valves define one vacuum sector in the Solaris storage ring.

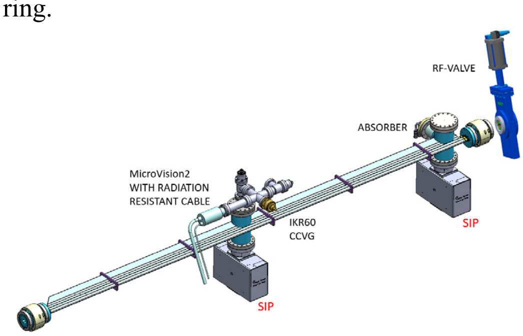

Figure 2: Vacuum chamber of the straight section.

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 [4]. Two Cold Cathode Vacuum Gauge (CCVG) have been recently installed in the machine. First in the transfer line and second in the storage ring in the 1st straight section together with the residual gas analyser. To evaluate progress of the conditioning process the average pressure in the storage ring was estimated based on ion currents from SIPs.

RGA CRITERIA

Depending on the pressure regions in the vacuum system (Low/Medium/High/Very High/UHV/XHV) standard limits of acceptability of species: hydrocarbon residue, chlorine residue and general contaminants may vary [5, 6]. The most common general rule says, that for a leak tight system, where sum of all leaks is lower than $1\cdot10^{-10}$ mbarl/sec, vacuum components are considered to be free of hydrocarbons if for a total pressure below $1\cdot10^{-7}$ mbar in the system the sum of the partial pressures of masses above mass/q 45 is less than 10^{-3} of the total pressure [7]. Sometimes, this criteria can be relaxed [8] and depending from application can be modified [9] or extended [10, 11]. The residual gas composition in the R1-01 vacuum sector of Solaris storage ring without the electron beam are presented in Fig. 3 and Fig 4. If we apply the most common general rule for those mass spectra the criterion for hydrocarbon free vacuum system is fulfilled for different states of the machine. For storage ring without the beam current and SIPs switched on (see 1st state in Fig. 3 and Fig. 4), when SIPs are switched off in the range of one vacuum sector for pressure build-up measurements [12] (see 2nd state in Fig. 3) and for the storage ring with

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the beam current of 408 mA and electron energy of 1.5 GeV (see 3rd state in Fig. 4).

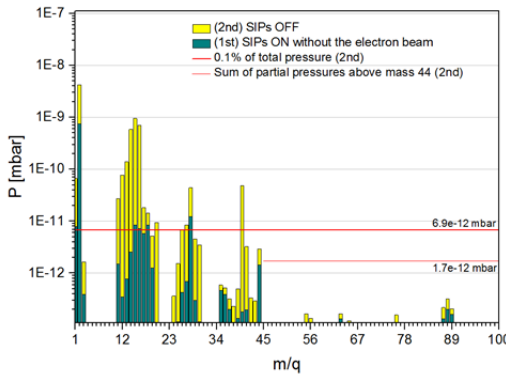

Figure 3: RGA of one vacuum sector without electron beam and with SIPs switched on and off.

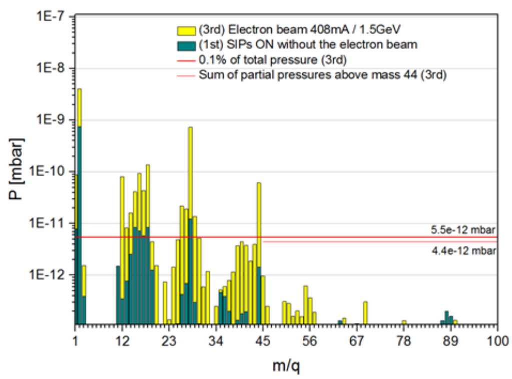

Figure 4: RGA with and without electron beam.

The question may arise, whether the RGA criteria should be fulfilled only during installation process or maybe they should be also fulfilled during commissioning and operation of prototype machines?

RGA OF THE STORAGE RING

To evaluate residual gas composition in the storage ring Microvision 2 mass spectrometer with 3 meters extender from MKS was chosen [13]. Device with factory calibration settings, accuracy level equal to 7, electronic gain and multiplier switched on allowed for qualitative measurement of partial pressure in dynamic range of 6 decades between $1\cdot10^{-7}$ and $1\cdot10^{-13}$ mbar [14]. During pressure build-up measurements it was possible to establish, that after switching off the SIPs, ion pumps itself were capable of reemitting any pumped gases [12]. When the ion pumps were turned off the gases were released from the cathodes and including thermal outgassing of the chamber the major percentage of build-up gases in our case were as presented in Tab. 1. Differential diode SIPs are able to pump down noble gasses, but since argon instead of nitrogen has been chosen for a venting gas during maintenance procedures, to save lifetime of NEG strips [15], increasing of it was not a surprise.

For the storage ring without the beam the composition of the residual gas was dominated in 92% by hydrogen. When the e-beam was stored, the hydrogen dropped down to 74% at the expense of increased other compounds like: carbon monoxide (13%) and carbon dioxide (1%) (see Tab.1).

Table 1: Percentage Change of the Residual Gas Composition in Storage Ring for Different States of Storage Ring

Mass [16] [m/q]	SIPs ON [%] without beam	SIPs OFF [%] without beam	408mA/1.5GeV [%] with the beam
(2) H_2^+	**92.36**	**60.78**	**74.25**
(14) CH_2^+, N^+	0.32	**8.42**	0.30
(15) CH_3^+	1.03	**13.66**	0.75
(16) CH_4^+	0.90	**10.10**	1.72
(19) F^+, H_3O^+	0.16	0.07	0.08
(28) CO^+, N_2^+	1.50	0.63	**13.46**
(40) Ar^+	0.02	**0.70**	0.08
(44) CO_2^+	0.18	0.04	**1.13**
(55) $C_4H_7^+$	0.00	0.00	0.01

Those results are similar to the ones reported elsewhere [17]. At very low level presents of chlorine (35, 37) 0.02% and fluorine (19) 0.08% were detected. The presence of these halides is undesirable because they degrade pumping speed of NEG strips and coatings. From the other hand fluorine F^+ is so electronegative that it is more likely that hydronium H_3O^+ has been measured. According to Jiang-Tao Li hydronium is generated by the electrons from the RGA filament through electron stimulated desorption from the local surface near the RGA ionizer [18]. Organic material like cyclobutane $C_4H_7^+$ (55) and butyl $C_4H_9^+$ (57) al level of 0.01% have been also detected. This type of organic contamination could be introduced to vacuum system by equipment used during installation process [19].

CONDITIONING

From the beginning of the storage ring conditioning process up to now it was possible to accumulate about 371 A.h. To establish the progress of conditioning process evolution of the product P_{av}/I [mbar/mA] over integrated current has been chosen. All calculations were performed in decay mode for beam current of 20 mA and an electron energy of 1.5 GeV.

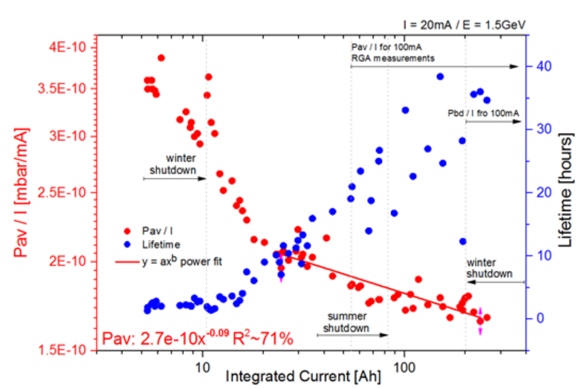

Figure 5: The evolution of P_{av}/I and lifetime versus integrated current.

The negative slope of the conditioning (vacuum clean-up rate) has decreased recently to 0.09 and now is lower than reported previously 0.51 [20] (see Fig. 5). To establish why the progress of the storage ring conditioning process was slower than expected it has been decided to define and measure evolution of additional products over integrated current. Calculation of normalized average pressure was performed not only for the whole ring P_{av}/I based on all SIPs, but separately for different sectors and components (see Fig. 6).

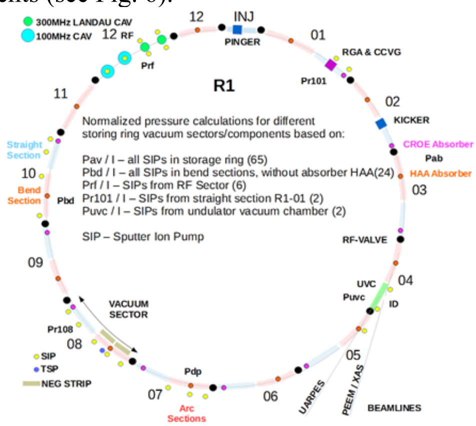

Figure 6: Definition of additional products for evaluation of storage ring conditioning process.

Result of normalised average pressure calculation for additional products over integrated current for higher beam current 100 mA and an electron energy of 1.5 GeV in decay mode is presented in Fig. 7.

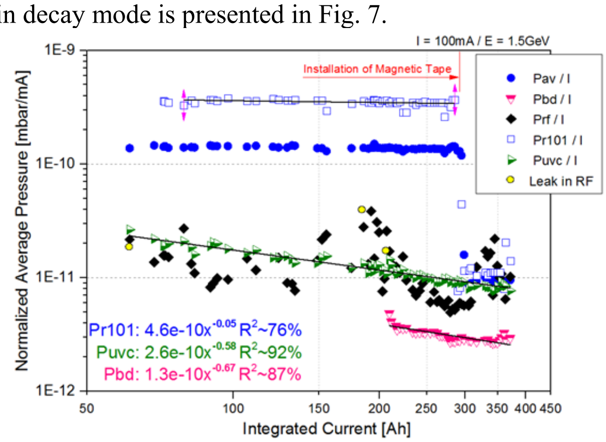

Figure 7: Evolution of the products for different vacuum sectors/components.

One can notice that products: P_{bd}/I where NEG strips were installed and P_{uvc}/I, where NEG coated undulator vacuum chamber was installed are 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 as the value of P_{av}/I product. Analysis of normalised average partial pressures over integrated current for this section was presented in Fig. 8. One can notice that vacuum clean-up rate (slope) for R1-01 sector (0.05) defined by P_{r101}/I product evaluated based on SIPs (see Fig. 7) is much slower, than this one evaluated as a sum of scanned masses (SSM) (0.83) measured by RGA This type of behaviour has contributed to the conclusion that pressure readouts from SIPs is adulterated by additional current inside SIP caused by photoelectrons.

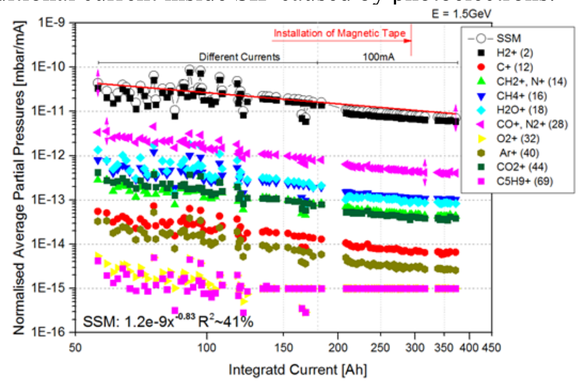

Figure 8: Normalised average pressure for different partial pressures in section R1-01.

This current comes mostly from electrons entering to the pump from the beam chamber and being collected at the pump anode [21]. Similar investigation to experiment performed by A. Kulikov regarding removing of the permanent magnets from the SIP was executed and result is presented in Fig. 9.

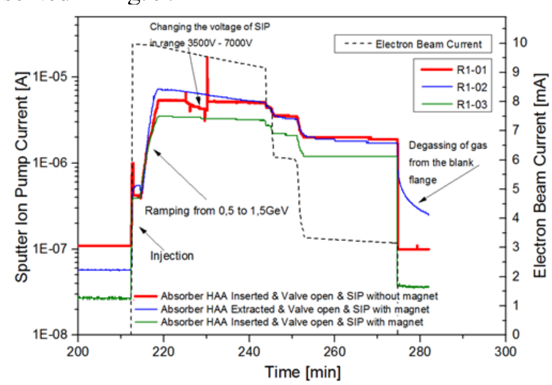

Figure 9: SIP without permanent magnet as a "dedicated electron cloud instrument".

One can notice that unusual behaviour of SIP without the magnet (red line in Fig. 9) is similar to behaviour of SIPs with the magnet [22]. Additional installation of magnetic tape around vacuum chamber near to SIP has significantly reduced additional current inside SIP caused by photoelectrons (see Fig. 7).

CONCLUSION

Evaluation of the progress of storage ring conditioning process by currents readout only via SIPs can be tricky and misleading. After installation of magnetic tapes values of the products for the amount of integrated current of 371 A.h measured for R1-01 straight section by SIPs (P_{r101}/I) and by RGA as a SSM (P_{SSM}/I), were at the same level of $1\cdot10^{-11}$ mbar/mA (see Fig. 7 and Fig 8). Progress regarding conditioning of sectors with NEG technology like: strips P_{bd}/I and coating P_{uvc}/I (see Fig. 7) evaluated based on SIPs can still be measured, but further installation of vacuum gauges is now considered.

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