VACUUM PERFORMANCE CHARACTERISTIC OF 5m-LONG PUMP FREE INSERTION DEVICE VACUUM CHAMBER FOR ELETTRA

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Abstract

An insertion device (ID) vacuum chamber pumped only on both ends by two 120 l/s sputter-ions pumps has been installed in the ELETTRA storage ring (SR). The vacuum chamber 5 m in length has an elliptical cross section and is made of stainless steel ESR AISI 316 LN. The specific outgassing rate of the ID vacuum chamber was measured before mounting into the storage ring as well as during commissioning. Mass spectra were scanned at different beam currents and energy. The rapid dynamic pressure decrease allowed to store high beam currents (over 200 mA@2 GeV) immediately. Requested lifetimes were achieved after about 35 Ahrs of conditioning. Results of residual gas analysis, desorption yield and wall pumping measurements will also be discussed.

1 VACUUM CHAMBER DESIGN AND MANUFACTURE

Six insertion devices vacuum chambers are now installed in the ELETTRA storage ring (4 for undulators and 2 for wigglers). Five of them have a standard rectangular cross section 18x80 mm^2 or 15x80 mm^2 of dimensions. The first five ID chambers are pumped by two central 120 l/s sputter-ion pumps (SIPs) through the slots connecting the rectangular part with the cylindrical antechamber. Static as well as dynamic pressures in these chambers can be checked by 2 or 3 inverted magnetron gauges (PEG) symmetrically attached to the antechamber. More details ca be found in ref. [1].

Following the pumping system efficiency experiment at Elettra, where after switching off more than 60% of storage ring SIPs, the pressure in the ring increased negligibly [2], a series of tests were carried out to verify the necessity of the central pumps installation for the ID chamber pumping. The standard procedure repeated in all vacuum sectors containing ID chamber was the following: at first the two SIPs in the one ID chamber were switched off and the pressure and lifetime changes were monitored. Then the central pumps were switched off in the second, third, etc. ID chambers. All measurements were done at various currents stored in the ring and after different dose of conditioning.

In all these cases the pressure increase was negligible after switching off the central SIPs. Lifetime only slightly decreased (10 min at 235 mA@2 GeV) when the central SIPs stopped pumping, but its recovery started after about 15 min. This is consistent with the fact that any pumping is a dynamic process. The closest pumps installed on both ends of the ID chamber are efficient to substitute the ones switched off.

Theoretical simulation of the pressure profile after 25 Ahs of conditioning in the ID chamber pumped only on both ends is shown in Fig. 1. The experimental results obtained during previously described experiments are also included.

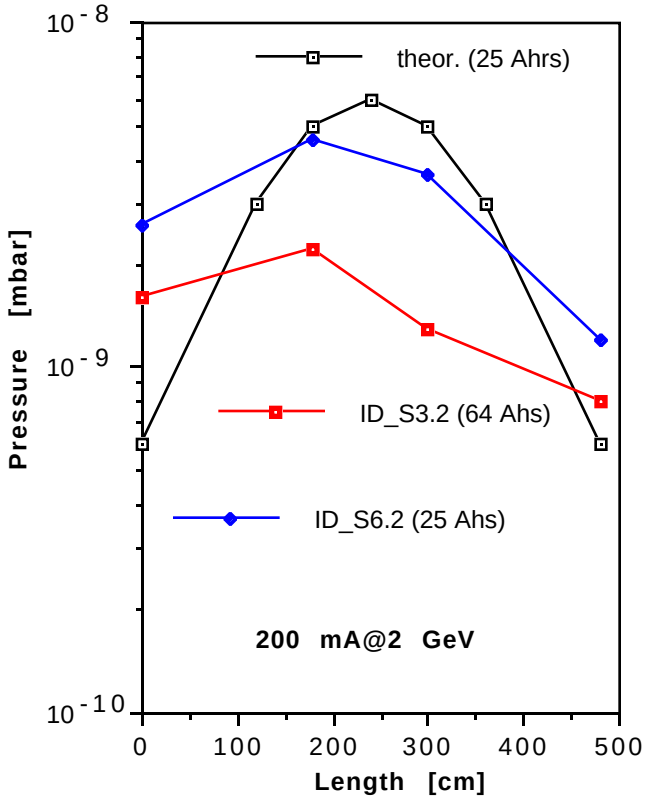

Figure 1: Theoretical and experimental pressure profiles with zero pumps in ID chambers

Taking into account the equation [2]

$$S_{ef} = (17.8\eta + q_D A) / P \qquad 1.1$$

where S_{ef} [l/s] is the effective pumping speed, η [molec/phot] is the desorption yield coefficient, q_D [mbar.l/s.cm^2] is the specific outgassing rate, A [cm^2] is the inner surface of the pumped volume, P [mbar] is the total pressure, it is clear, the lower is the inner surface the lower pumping speed in needed. Moreover, the specific outgassing rate in the 10^{-12} mbar.l/s.cm^2 range as well as the desorption yield coefficient lower than 10^{-6} mol/phot can be routinely achieved, after about 10 Ahrs of conditioning which leads to the smooth pressure profile between the pumps.

The pump free ID chamber was fabricated from the SS AISI 316L tube of circular cross section 57 mm in diameter and 1.5 mm of thickness. The elliptical cross section was obtained by pressing this tube to reach the requested internal dimensions 15x77mm^2 of the oval shape. Then the shaped tube was cleaned using the standard cleaning procedure described in ref. [3]. The two transition parts of the chamber between the elliptical and rhomboidal cross section was fabricated by electrophoresis and are equipped with CF flanges for pump installation. These transitions were welded on both ends of the chamber. The complete vacuum chamber (without SIPs) was pre-baked in the vacuum oven at 300 ˚C and then saturated by dry nitrogen, as usual.

2 LABORATORY VACUUM TESTS

The ID vacuum chamber was equipped with the fore-vacuum system (composed of the membrane and turbo pump) and 120 l/s SIP on the one end, on the second end the RGA analyser and the inverted magnetron gauge were installed. The first mass spectra were scanned without in situ baking of the chamber at the equilibrium pressure of 1.2x10^{-8} mbar, measured by the gauge. At the same time the pressure measured by the SIP was 8.6x10^{-9} mbar. It means that despite of the large distance between the pump and gauge (5.3 m) and the small conductance of the tube (2.6 l/s for air), the pressure profile was very smooth. The water peak (mass 18) was dominant as it is typical for unbaked vacuum systems. Traces of hydrocarbons were detected as the groups of masses 24-30, 36-45 and 49-54 but did not exceed the 10^{-9} mbar range.

Then the whole vacuum chamber was baked at 150 ˚C for 24 hours, while the SIP was baked by the own heating system at 200 ˚C. After cooling the system the pressure profile varied from 6.2x10^{-10} mbar (measured by the SIP) to 1.1x10^{-9} mbar (measured by the gauge). The mass spectra scanned after switching on the SIP corresponded to the very clean UHV conditions. The hydrogen peak was dominant at 1.1x10^{-9} a.u. level and the peaks 12 (C^+), 16 (CH_4^+), 28 (CO^+) and 44 (CO_2^+) were lower than 10^{-10} a.u. level.

Specific outgassing rates q_D were measured by the pressure rise method in both cases for the unbaked as well as for the baked chamber following the equation:

$$P_L - P_0 = q_D \, B \, L / 2C \qquad 2.1$$

P_L, P_0, B, L, C are the pressure at the closed end of the pipe, the pressure at the inlet of the pump, the perimeter of the pipe cross section, the pipe length, the pipe conductance, respectively. Corresponding values of specific outgassing rates are 2.2x10^{-12} mbar.l/s.cm^2 and 2.7x10^{-13} mbar.l/s.cm^2 for the unbaked and baked chamber, respectively.

3 EXPERIENCE DURING COMMISSIONING

The ID chamber, at the end of laboratory tests saturated with dry nitrogen, was then equipped with two 120 l/s SIPs and installed in the storage ring. After opening the ID valves the pressure profile in the second vacuum sector, where the chamber has been installed, varied from the low 10^{-9} mbar range up the to the high 10^{-11} mbar range. Commissioning started with the stored current of 10 mA@1 GeV, 80% of filling in the multibunch operation mode. The pressure increase in the chamber was significant, however, after orbit correction the current of 400 mA@1 GeV was stored without any difficulties. Understandably, lifetime was very poor due to the significant pressure increase in the second vacuum sector as is shown in Fig. 1.

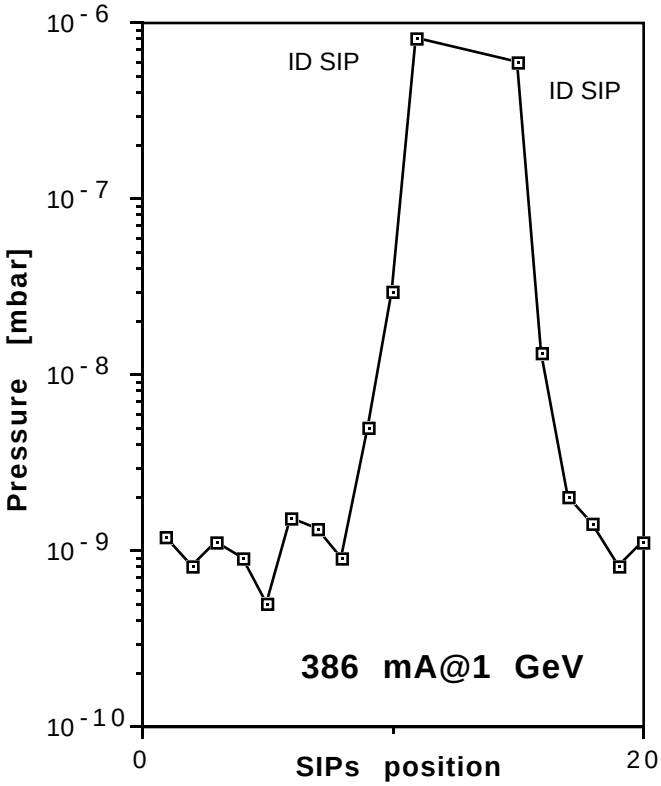

Figure 2:Pressure profile in the ID part of the II. vacuum sector

This fact is in accordance with the experience of beam cleaning efficiency [4].

After some small dose of conditioning (Amin) the rest of the stored current (~200 mA) was ramped to 2 GeV, but the pressure increase in the ID chamber was not so significant. The conditioning of the chamber proceeded well and the dynamic pressure decrease vs integrated current is shown in Fig. 2.

The ID chamber was fully conditioned after 35 Ahours of integrated current and lifetime of 9 hours at 250mA@2 GeV (in high brilliance mode) could be obtained.

The mass spectra were scanned at different stages of conditioning. The water peak decreased very fast and after 3 Ahours of conditioning was stabilised at the high 10^{-11} a.u. level. The mass peaks of hydrocarbon fragments, nitrogen and carbon dioxide exceeded the 10^{-8} a.u. level at the beginning of conditioning but their heights

proportionally decreased and the standard residual gas mixture composed of 95% of H_2, 3% of CO, 1% of CH_4 and 1% of CO_2 and C has been established.

At various stages of the ID chamber conditioning the wall pumping speed has been measured using the following procedure. Before the beam is dump the two SIPs installed on both ends of the chamber were switched off. When they stop pumping we can proceed and dump the beam. The two valves which separate the chamber from the rest of the ring are then closed.

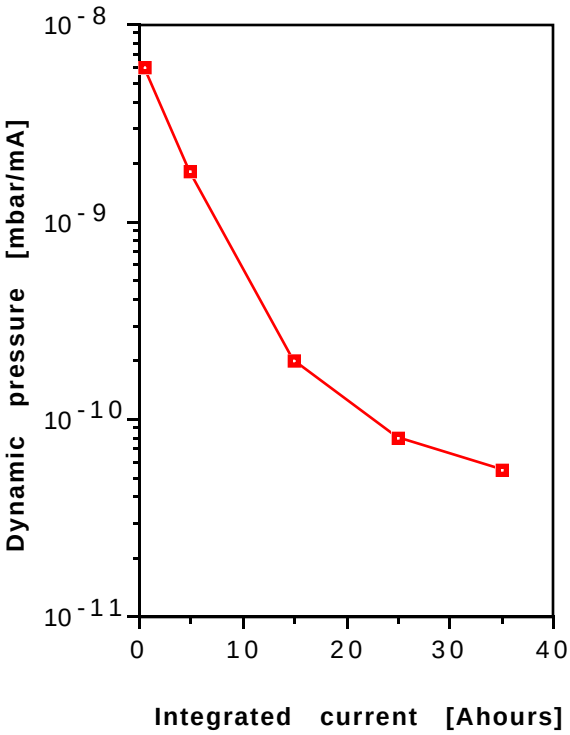

Figure 3: Dynamic pressure decrease (100 mA@2 GeV) in the pump free ID chamber during conditioning

The wall pumping speed, i.e. the rate of adsorption of gas molecules on the inner chamber surface, was then evaluated by constant volume method. This method is based on the following equation

$$S = 2.3\ (V / t)\ \log\ (P_1 / P_2) \qquad 3.1$$

in which the pumping speed S is determined by measuring the change in pressure (from P_1 to P_2) during the time interval **t** in the constant volume V. This method is usually less accurate than the constant pressure one, because all pump speeds vary in fact with pressure, but in the ELETTRA SR does not exist any other possibility to estimate this parameter.

From the pumping speed calculated according to the equation 3.1 the pumping speed of inverted magnetron gauge installed in the transition part of the chamber had to be subtracted.

The highest wall pumping speed of approximately 1.2 l/s has been reached after 50 Ahours of dose. This value seems to be very small. However, the SIPs have also very low pumping speed at such UHV conditions achieved in Elettra despite of the high nominal pumping speed which is only maintained at the $10^{-6} \div 10^{-7}$ mbar ranges.

The desorption yield coefficient η might not be measured directly. This one can only be estimated from the equation 1.1. The desorption yield coefficient decreased approximately from the 10^{-5} mol/phot range to the 10^{-7} mol/phot range during 35 Ahours of conditioning.

4 CONCLUSIONS

Based on 8 months experience with the pump free ID chamber it can be concluded that UHV conditions can be mainted by a lower number of pumps. The lower number of pumps allows also to achieve a low ultimate and operating pressure subsequently leading to the good lifetime in the storage ring. This pump free ID chamber is much more simple from the fabrication point of view and the cost reduction is not negligible. Based on the positive experience with the present chamber, future ID vacuum chambers will also be pump free, but will be based on an Aluminum extrusion rather than stainless steel.

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