ALBA STORAGE RING VACUUM SYSTEM COMMISSIONING

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Abstract

The ALBA booster and storage ring vacuum system installation has been done in 2009, followed by the installation of the RF cavities and the booster to storage transfer line in 2010. Early 2011, the first phase of insertion devices (ID) installation took place, with three narrow gap NEG coated vacuum chambers have been installed, for the use of two Apple-II undulators and one conventional wiggler.

On 8th of March 2011, the storage ring commissioning started and it was marked with the achievement of the first turn in the storage ring on the 9th of March and on the 1st of April 2011, 100 mA of beam current has been accumulated. During this period the vacuum system conditioning took place with very good performance. The base pressure without beam was $4{\cdot}10^{-10}$ mbar and the average pressure with 100 mA was $7.7{\cdot}10^{-9}$ mbar. The results of the conditioning together with the latest developments are introduced.

THE STORAGE RING VACUUM SYSTEM OVERVIEW AND CURRENT STATUS

Storage ring vacuum system overview

The storage ring has a circumference of 268.8 m, and it is divided into 16 sectors of two types: the matching cell which is 11 m long and the unit cell which is 13 m long. Between the sectors the long straight sections of 8 m and the medium straight sections of 4.2 m long are located. The vacuum system is mainly made of 316LN stainless steel, and has a keyhole profile where the electron beam is circulating in the chamber, and the photon beam is passing through a slit to the antechamber. Copper crotch absorbers are placed in the antechamber which serves in handling the unused synchrotron radiation and passing the beam to the front ends. In addition the absorber provides a shadow to the vacuum chamber and allows the outgassing to be only at the location of the absorbers, this allows fast conditioning for the vacuum system.

The main pumping system of the storage ring is based on ion pumps, placed close to the areas of outgassing, mainly near the absorbers, the nominal pumping speed of the ion pumps installed is around 57,000 l/s. In addition NEG pumps are fitted in the areas where it is not possible to place ion pumps due to limited space or whenever more pumping speed is needed (near absorbers). NEG coating is done for the aluminum narrow gap vacuum chambers, where the conductance is very small and distributed pumping is more favorable.

Storage ring vacuum system installation

The main installation stage took place over a period of 4 months in 2009, during this; each sector was assembled in the clean room and then tested: leak tests, dimensional tests…etc. Following this the whole sector was connected to a supporting structure, and moved under vacuum to the 14 m long bakeout oven. Inside the oven the sector was leak tested again, then baked up to 200°C for min. 48 hours, then the sector was allowed to cool down to room temperature and transported under vacuum to the girders where it was connected to the supports (which have been aligned prior to the movement of the sector), following this the ion pumps were turned on and RGA scan was performed to assure the good vacuum of the sector [1].

The installation of the insertion devices

During the first phase of the installation, all the straight sections have been fitted with “dummy” straights; the dummy chamber is replaced in later stages for installing the insertion devices.

Due to some delays in the start up of the commissioning stage of the storage ring, it has been decided to place three aluminum narrow gap vacuum chambers in early 2011; these chambers were for the two APPLE II undulators and for the conventional wiggler. These chambers have been baked and the NEG coating has been activated in-situ.

During the summer shutdown of 2011, two in-vacuum undulators IVU and one superconducting wiggler (SCW) have been installed. In-situ bakeout was performed for the two IVUs the pressure after the bakeout is in the low 10^{-10} mbar range.

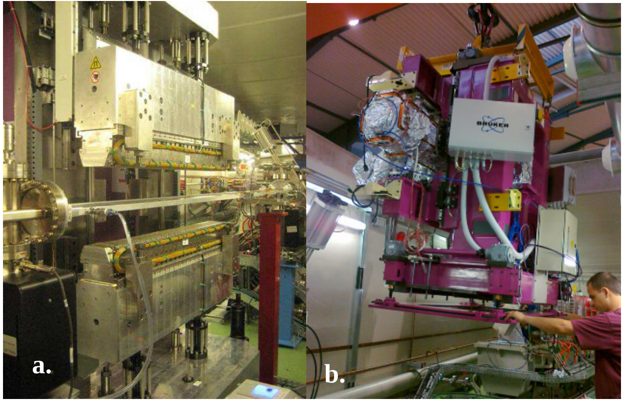

Figure 1: a. the narrow gap vacuum chamber installed in the storage ring, b. IVU movement to the tunnel.

STROAGE RING COMMISSIONING

The average pressure

The average pressure results were obtained from the readings of the cold cathode gauges (CCG) which are distributed around the machine (62 gauges in total).

The average pressure in the storage ring before the first beam injection was $4{\cdot}10^{-10}$ mbar; the pressure was uniform except in the RF cavities and the injection straights which was slightly higher. With this static pressure it has been estimated that the thermal outgassing of the vacuum chambers is around $1{\cdot}10^{-11}$ mbar.l/sec.cm^2.

A summary of the changes in the average pressure during the commissioning stage is as follow:

- On the 13th of March 2011, the first stored beam has been achieved, during this, the pressure increased, and the max. pressure was $6{\cdot}10^{-7}$ mbar and the max. average pressure was $6{\cdot}10^{-8}$ mbar.
- Three days later, the first accumulated beam in the machine has been achieved. The average pressure increased to $2{\cdot}10^{-8}$ mbar with accumulated current of 0.1 mA.
- With the first 100 mA stored beam in the machine, the storage ring average pressure increased up to $8{\cdot}10^{-9}$ mbar.
- By the end of the first commissioning stage and after accumulating a beam dose of 4.5 A.h., the average pressure was $3.2{\cdot}10^{-9}$ mbar with 80 mA of beam current and multi-bunch filling mode.

Figure 2 shows the pressure profile for the whole storage ring during one machine shift. The pressure in the RF cavities was in general higher with and without beam, the highest increase in the pressure was in the RF cavities; during 100 mA of beam current is accumulated.

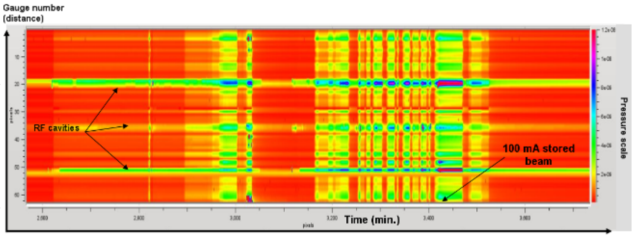

Figure 2: pressure readings during one machine shift.

Figure 3 shows the normalised average pressure to the beam current (mbar/mA) vs. accumulated beam dose (A.h.), it is clear the reduction in the average pressure with more beam cleaning effect to the vacuum chamber (mainly in the absorbers). These results are comparable to the vacuum conditioning curves achieved in other synchrotron facilities [3], [4].

Figure 4 shows similar behaviour of proof of beam cleaning effect, this figure presents the average pressure normalised to the beam current (mbar/mA) vs. the beam current (mA) for each week of the machine operation. Each week, the pressure is less than the previous one when the machine operating at the same current.

The residual gas analysis (RGA) before the beam injection was dominated by hydrogen with 90% of the total pressure. With the first beam the scans show increase in CO and CO_2 and the percentage of the gases was as follow: hydrogen: 71%, CO: 16%, CO_2: 6%. With more vacuum conditioning, the percentage of CO and CO_2 gases was slightly higher than that with the first stored beam.

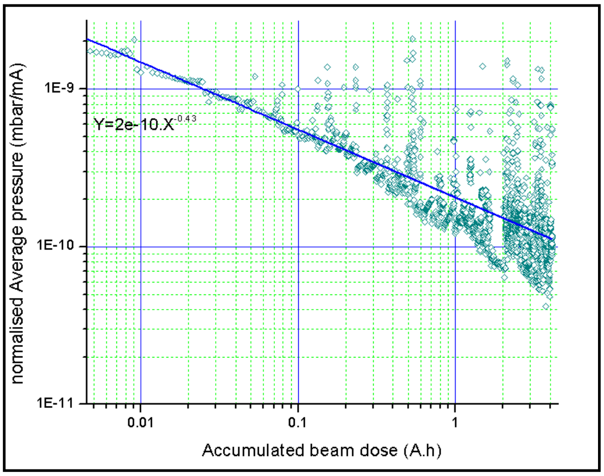

Figure 3: average pressure normalised to the beam current (mbar/mA) vs. accumulated beam dose (A.h).

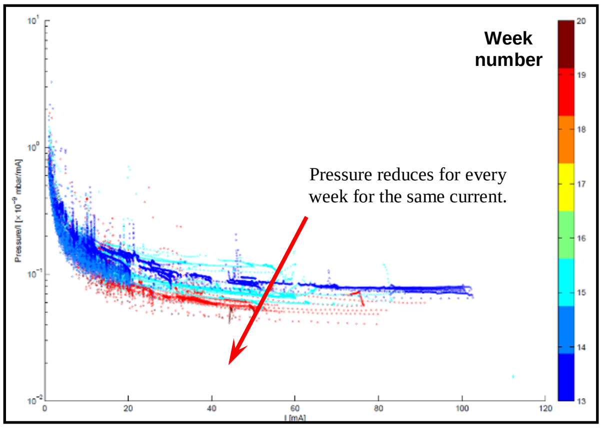

Figure 4: the average pressure normalised to the beam current (mbar/mA) vs. beam current (mA) during each week of the first commissioning stage.

Photon stimulated desorption yield.

Figure 5 presents the change of the photon stimulated desorption yield PSD (molec/ph) vs. the integrated photon dose per unit length (ph/m), together with the best fit curve of these data.

The PSD yield has been calculated based on the pressure reading from the CCG and considering the effective pumping speed of the ion pumps. The photon dose has been estimated over a unit length of the absorbers, where the photon beam is impacting and where the main vacuum conditioning occurs (the beam scattering is ignored over the chambers).

The slope of the conditioning (vacuum clean-up rate) is estimated to be 0.69, which is similar to that reported elsewhere [4].

The beam lifetime depends (among other factors) on the vacuum in the machine, Figure 6 shows the progress in the beam lifetime normalised to the beam current vs. beam current for each week of the first machine commissioning stage. As a trend, it is clear that the beam lifetime is increasing each week for the same current, which could be contributed to improve of the machine vacuum. However, as the lifetime is affected by the coupling and the stability, it is still not clear the effect of the beam-gas scattering on the machine beam lifetime.

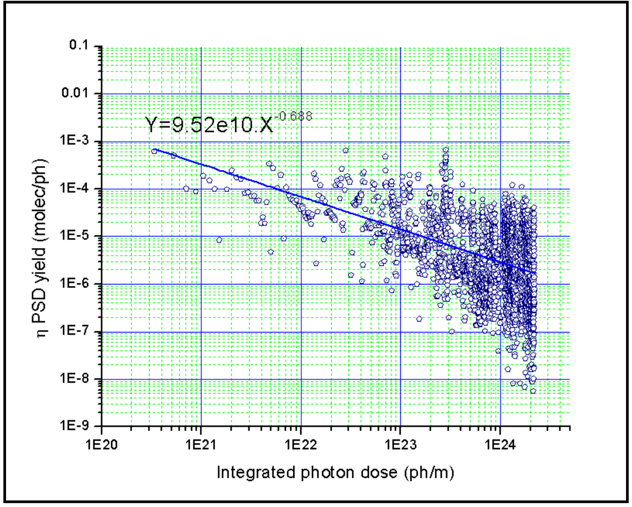

Figure 5: PSD yield (molec/ph) vs. integrated photon beam dose (ph/m).

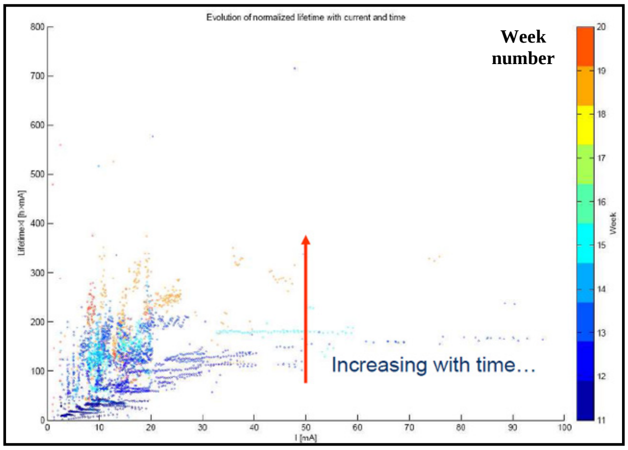

Figure 6: the normalised beam life time with the beam current vs. the beam current during each week of the first stage of the machine commissioning.

Vacuum related problems during the commissioning

Very few problems which are vacuum related have been faced during the first commissioning stage; these problems did not have a high impact on the commissioning. A summary of the main problems is as follow:

- Heating up problems: around 550 thermocouples are placed around the storage ring of ALBA; they are distributed on the vacuum chambers, absorbers and the cooling water return of the absorbers. These thermocouples played a high rule in indicating heating up problems in the vacuum system. During the first days of commissioning, it has been observed that the temperature in the thermocouples located on the water outlets of some absorbers was high, within the investigation, it has been found out that some cooling tubes of the inlets and outlets were swapped and as a result no water was flowing in the absorbers, correction to the tubing was performed, solving this problem. In some other placed the water flow was lower what is supposed to be, and this has been solved by increasing the water flow.
- Photon beam hit the vacuum chamber: during the accumulation of 100 mA beam current in the storage ring, some thermocouples show high temperature on the surface of the vacuum chamber close to one absorber, within the investigation, it has been found out that there was a design error of the absorber and the beam pass through into the vacuum chamber. To solve the problem a copper insert was placed inside the absorber to shadow the chamber, and in a later stage the absorber has been changed.
- Leaks in the pick-up loops of the RF cavities: it has been observed following some machine shifts that the pressure in some RF cavities is increasing and do not recover following the end of the machine shift, RGA scans were performed, and signs of leaks were found (mainly argon peaks), with leak testing of the RF cavities, leaks were found in the pick-up loop, which has been exchanged.

CONCLUSION

The status of the vacuum system of the ALBA machine has been introduced; with the main highlight is the installation of the insertion devices.

The storage ring commissioning took place during a period of 3 months; during this the vacuum conditioning took place. The results of the average pressure reduction with the accumulated photon dose have been presented. Also the PSD yield reduction with the integrated photon beam dose was shown. The results obtained were pleasing and similar to those achieved in other machines [5].

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