

THE VACUUM SYSTEM OF MAX IV STORAGE RINGS: INSTALLATION AND CONDITIONING

E. Al-Dmour[#], M. Grabski, MAX IV Laboratory, Lund University, 22100 Lund, Sweden.

Abstract

The installation of the vacuum system of the 3 GeV storage ring was started in November 2014 and finished in May 2015. In August 2015 the commissioning of the storage ring started, the first stored beam has been achieved on the 15th of September 2015.

The installation of the vacuum system of the 1.5 GeV storage ring was done from September 2015 and the main part finished in December 2015, the connection to the Linac with the transfer line has been done in August 2016. In September 2016 the commissioning of the 1.5 GeV storage ring started with the first stored beam achieved on the 30th of September 2016.

The vacuum system conditioning for the two rings was successful; the average dynamic pressure reduction and the increase in the lifetime with the accumulated beam dose is a demonstration of the good performance of the vacuum system.

The installation procedure and the results of the conditioning together with the latest developments are introduced here.

INTRODUCTION

The MAX IV facility is composed of two storage rings, with energies of 1.5 GeV and 3 GeV, a 3 GeV LINAC serves as a full-energy injector into the two rings as well as a driver for a short-pulse facility.

The vacuum chambers of the 3 GeV ring are made of copper and the whole ring is NEG (Non-evaporable getter) coated. The 1.5 GeV storage ring vacuum chambers are made of stainless steel and pumped down by ion pumps, TSP (Titanium Sublimation Pump) and NEG strips.

The MAX IV started delivering light to the users in April 2017.

3 GeV STORAGE RING VACUUM SYSTEM

3 GeV Storage Ring Vacuum System Installation

The vacuum system design of the 3 GeV storage ring is described in [1]. The assembly and installation of the storage ring vacuum system was performed inside the tunnel. The vacuum chambers were assembled independently for each of the 20 achromats, directly above lower magnet blocks on assembly tables. Each vacuum section was sealed with all-metal RF gate valves at the ends. After the assembly, the chambers were pumped down with turbo-molecular pumps and vacuum tests were performed to ensure its integrity and cleanliness. Then, the vacuum section was lifted ~0.5 m

with a strongback as shown on Figure 1, baking oven was mounted around the vacuum chambers and the strongback as presented on Figure 2.

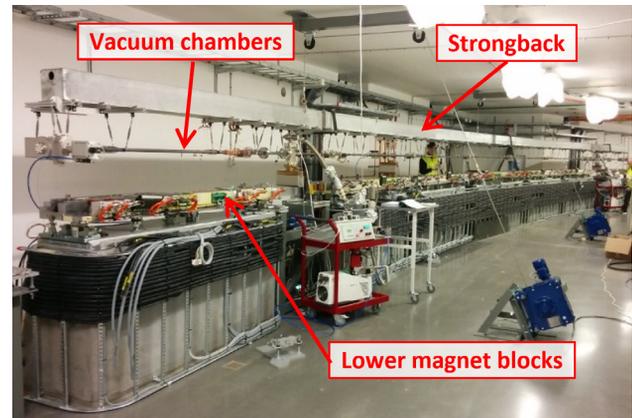


Figure 1: 3 GeV storage ring vacuum system assembly inside the ring tunnel.



Figure 2: 3 GeV storage ring vacuum system baking oven.

The bakeout and NEG coating activation of each achromat was performed at 160 and 190 °C respectively over period of 2-3 days. After the chambers were cooled down to room temperature leak test was performed and the system was lowered down back to the assembly tables so that the unbakable elements could be added (BPM cables, fast corrector magnets, thermocouples, supports etc.). Afterwards the chambers were lowered and placed in the final position inside the lower magnet blocks. As the last step the top magnet blocks were mounted. Consecutive achromats were connected with each other by straight vacuum chambers that were installed and activated in-situ. The normal conducting 100 and 300 MHz RF (Radio Frequency) cavities were installed and baked in-situ in reserved short straight sections flanked with gate valves.

3 GeV Storage Ring Vacuum System Conditioning

The 3 GeV storage ring commissioning started in August 2015, the average base pressure from the extractor gauges was $2 \cdot 10^{-10}$ mbar, and that of the ion pumps was $8 \cdot 10^{-11}$ mbar. With the first stored beam (0.1 mA) the pressure increased into high 10^{-9} mbar range. As per May 2017 the total accumulated beam dose is 175 Ah, and the maximum stored beam current is 198 mA.

The vacuum conditioning has been observed both, by the average pressure reduction with the beam dose and by the increase of the total beam lifetime.

Figure 3 presents the average pressure (N_2 equivalent) from the extractor gauges vs. the beam current at different accumulated beam doses, the plot illustrate how higher pressure was measured at early stages of commissioning (16 Ah) compared to later stage when the vacuum chambers are more conditioned (at 95 Ah).

Figure 4 shows the normalized average pressure rise (mbar/mA) with the accumulated beam dose (Ah), the conditioning slope is ~ 0.85 , this value is somewhat higher than that reported in other facilities [2, 3].

Figure 5 presents the progress in the normalized beam lifetime vs. accumulated beam dose, the increase in the $I \cdot \tau$ product is an indication of beam cleaning effect and vacuum conditioning.

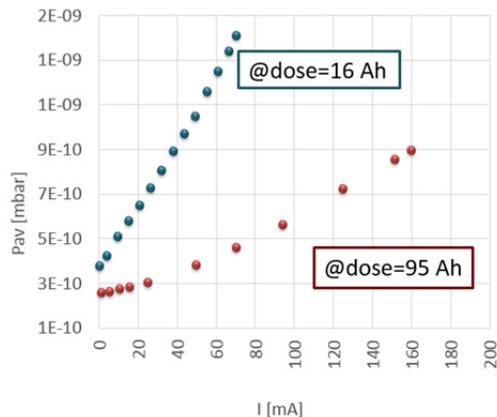


Figure 3: the average pressure (N_2 equivalent) of the extractor gauges vs. current for two different beam doses.

The residual gas composition in the 3 GeV storage ring is measured in few locations around the ring by Quadrupole Mass Analyzers (QMA). The approximate average gas composition (taking into account gas sensitivity for most common gas species) from 4 sensors around the ring at beam current of 40 mA and accumulated beam dose 132 Ah, is: H_2 (mass 2) – 96.8%, mass 12 – 0.15%, methane (mass 15 and 16) – 0.7%, CO (mass 28) - 2%, CO_2 (mass 44) - 0.07%, others - 0.28%.

Those gases are emitted due to photo-stimulated desorption process. However, there is a clear presence of methane inside MAX IV chambers (than it is in conventional vacuum systems), this is due to the fact that it is not pumped down by NEG coating.

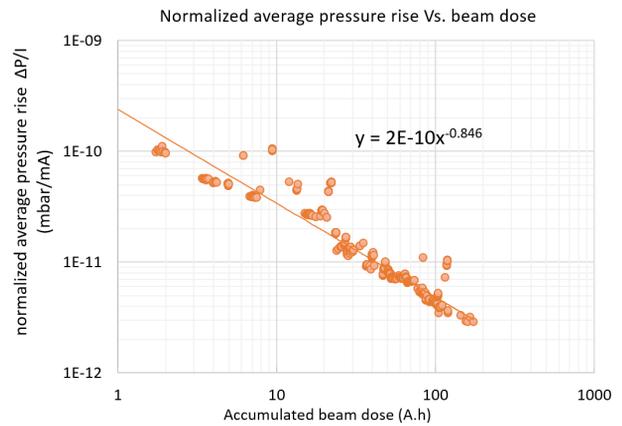


Figure 4: the vacuum conditioning of the 3 GeV storage ring vacuum chambers.

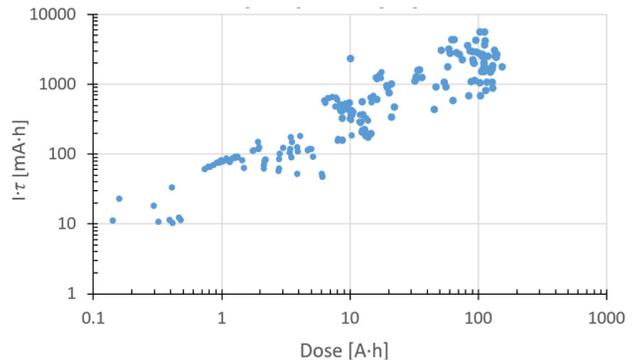


Figure 5: the progress of the beam lifetime with the accumulated dose for the 3 GeV storage ring.

Currently five insertion devices are installed in the 3 GeV storage ring: two in-vacuum undulators, one in-vacuum wiggler and two elliptically polarizing undulators, where narrow gap aluminium NEG coated vacuum chambers of 8 mm vertical opening are used.

During the commissioning it has been observed that some thermocouples installed on the chambers are showing higher temperatures than the simulations indicated, mainly due to the radiation hitting the wall in uncooled areas. Further investigation shows that the cause is mis-positioning of the chambers, and in other cases the issue is related to chambers non-conformities. Replacement for the chambers are planned during the incoming shutdown.

1.5 GeV Storage Ring Vacuum System Installation

The 1.5 GeV storage ring is divided into twelve achromats, and it is equipped with twelve gate valves that establish twelve vacuum achromats. There are two additional gate valves for the injection and RF straight sections. The assembly of the 1.5 GeV storage ring was done on assembly tables, inside a clean tent. Six achromats were equipped with gate valves at both ends therefore, after assembly, pumping down and vacuum tests, were baked and conditioned in a baking oven and installed inside the tunnel without venting. The other six

vacuum achromats were assembled without gate valves, therefore had to be vented after baking with dry nitrogen, then transported to the tunnel, connected to flanking achromats, and pumped down again and the NEG strips and TSP were activated for the second time. On the Figure 6 one complete achromat inside lower magnet block is presented.

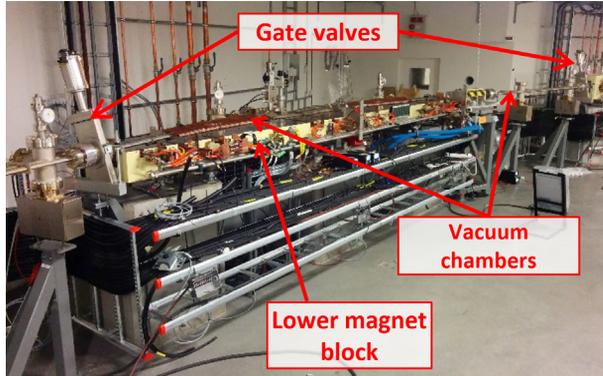


Figure 6: One complete vacuum achromat of the 1.5 GeV storage ring on top of lower magnet block.

1.5 GeV Storage Ring Vacuum System Conditioning

The 1.5 GeV storage ring commissioning started in September 2016, the average base pressure from the ion pumps was 7.10^{-11} mbar. When the first stored beam happened (0.1 mA) the pressure increased by two orders of magnitude.

Since then, the vacuum conditioning was progressing, as per May 2017, the total accumulated beam dose is 164 Ah, with the maximum stored beam of 199 mA.

The vacuum conditioning has been observed both, by the average pressure reduction with the beam dose and by the increase of the total beam lifetime.

Figure 7 shows the vacuum conditioning of the R1 storage ring, the vacuum conditioning appeared to follow different behaviors depending on the location of the ion pumps, a fast conditioning with slope of 0.73 has been observed for the ion pumps located inside the magnet blocks (dipole section), compared to those located on the straight sections (slope is only 0.16), similar behavior was observed in Solaris Synchrotron [4].

Further investigation to the issue, indicated that the reading of the ion pumps was affected by the photoelectrons incoming to the ion pumps and neutralized on the anode. When magnet strips have been placed around the pumping port of few ion pumps, (in order to redirect the electrons before arriving to the pump), the measured pressure was in some pumps almost 32 times lower than before.

Figure 8 presents the progress in the normalized beam lifetime vs. accumulated beam dose, the increase in the $I.\tau$ is an indication of beam cleaning effect and vacuum conditioning.

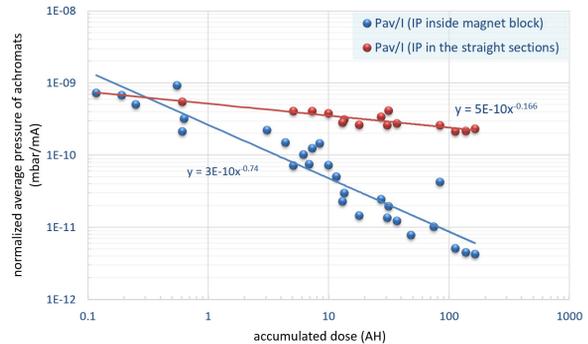


Figure 7: 1.5 GeV vacuum conditioning, normalized average pressure rise vs. beam dose.

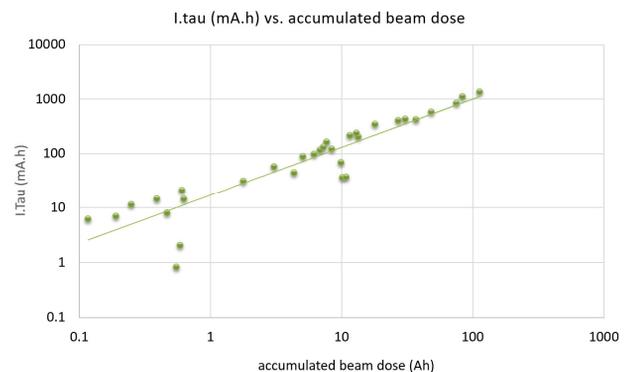


Figure 8: the progress of the beam lifetime with the accumulated dose for the 1.5 GeV ring.

CONCLUSION

The installation of the 1.5 GeV and the 3 GeV storage rings has been presented.

The vacuum conditioning has been observed both, by the reduction of the average pressure and the increase of the beam lifetime. The fast vacuum conditioning and increasing beam lifetime of the 3 GeV storage ring is an indication of the successful performance of the NEG coating.

Few issues have been faced during the vacuum conditioning, solutions will be implemented during future shutdowns.

REFERENCES

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