Advanced Low Emittance Rings Technology (ALERT) 2016 Workshop

MAX IV 3 GeV ring vacuum system

On behalf of the vacuum team

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Trieste, Italy
Contents

• Machine and vacuum system layout,
• NEG-coating R&D at CERN,
• Installation procedure,
• Vacuum commissioning status.
Max IV - Synchrotron light source facility in Lund, Sweden.

**Linac (300 m)**

**1.5 GeV ring (96 m)**
Conventional design

**3 GeV ring (528 m)**
Small aperture, all NEG-coated

Commissioning started:
- September 2016
- August 2015

Short pulse facility

MAX IV layout

Alert workshop, 16th September 2016, Trieste, Italy
Marek Grabski
3 GeV ring layout

Circumference 528 m, 20 achromats, 19 straight sections for IDs

Legend:
- **Dk**: Dipole kicker (S1)
- **Mk**: Multipole kicker (L)
- **LK**: Longitudinal kicker (S2)
- **VP**: Vertical pinger (S2)

L=long straight, S=short straight,

Installed Insertion Devices:
- 2 In vacuum undulators (2 m long)
  - NanoMAX IVU18
  - BioMAX IVU18
- 2 EPU (4 m long, min gap 11 mm)
  - VERITAS EPU48
  - HIPPIE EPU53
- 1 In vac. Wiggler (2.4 m long)
  - BALDER IVW50

Emittance measurement

Injection

100 MHz RF cavities

Landau cavities
3 GeV magnet layout

- Total length ~26 m,
- 4.5 m straight section (L)

Beam direction

Sextupole
Magnet apertures Ø25mm

Corrector
Chamber ID 22mm

Min. clearance with the iron 0.5 mm, min. clearance with the coils 2 mm.

Dipole
Ø22 (ID)
Standard vacuum chamber geometry

Material: OFS copper

Inside diameter: 22 mm,
Total length: 2.5 m,

Bent part
Arc length: 1 m,
Bending angle: 30,
Bending radius: 19 m.

NEG-coated.
In each achromat:
- 10 BPMs,
- 3 pumping ports (with ion pumps) and 1 pump in FE,
- 1 crotch absorber,
- 3 gate valves.
NEG coating development

- NEG-coating of vacuum chambers by magnetron sputtering was developed at CERN for warm LHC sections, 6 km of vacuum pipe was coated.
- NEG-coating is used widely in many light sources - mainly for ID chambers.
- At SOLEIL 56% of storage ring is NEG coated.
- In MAX II since 2007 three dipole chambers were replaced by NEG-coated vacuum chambers.

‘NEG thin film coatings: from the origin to the next-generation synchrotron-light sources’, Paolo Chiggiato, CERN (presented at OLAV’14)
To validate the coating feasibility 3 main stages of NEG (Ti, Zr, V) coating validation by magnetron sputtering in collaboration with CERN were undertaken. (R&D duration ~2 years).

1. Define and perform initial **surface treatment** of OFS copper substrate.

2. Validate compatibility of NEG-coating (adhesion, thickness, activation behavior):
   a). on etched **OFS copper**.
   b). on **wire-eroded** surfaces and used **brazing alloys**.

3. NEG-coating validation of compact vacuum chamber **geometries**: 
   a). Coating and testing of **small diameter, bent** tubes.
   b). Establish coating procedure/technology and coat chambers of **complex geometry**.
Main vacuum chamber types:

1. Standard bent vacuum chambers (VC4) - 1.5° and 3° bends,
   Industry (70% length wise)
   Beam direction
   2.8 m (VC4)
   3°
   BPM
   17.2 mm

2. Straight vacuum (VC10) chambers,
   Collaboration with ESRF (15%)
   2 m (VC10B)

3. Special vacuum chambers.
   Collaboration with CERN (15%)
   Electron beam
   Photon beam
Installation of NEG-coated ring

Ring installation was tested and rehearsed by installing and activating 1 mockup achromat in summer 2014.

Actual installation started in November 2014, ended June 2015.
Installation procedure

• Assembly insitu (above magnets),
• Pumpdown and testing,
• Lifting,

• Baking/activation for 20 h,
Installation procedure

- Lowering to the bottom magnet half,
- Installation of final equipment (supports, BPM cables),
- closing magnet blocks.
Coating non-conformities

All the chambers were inspected at site before installation.

Observed peeling-off:
At RF fingers Cu-Be insert and Cu end piece. RF fingers and Cu end were not shielded properly during coating.
Solution: new pieces ordered and replaced (without coating).

Peeling-off at RF fingers and Cu endpiece

Peeling-off at the edge of stainless VC. Chamber not approved for installation.

Severe peeling-off

Uncoated areas:
Few cm^2 uncoated, in complex chambers.

Uncoated areas
Commissioning progress

Commissioning started in August 2015

Average base pressure:
Gauges 2e-10 mbar,
Ion pumps in 8e-11 mbar range.

Accumulated beam dose reached: 112 Ah.

March 2016 shutdown:
- 2 in-vacuum undulators,

August 2016 shutdown:
- 2 EPU chambers (8x36mm),
- In-vacuum wiggler.
Pressure vs beam current, dose

Pressures at dose 16 Ah and 95 Ah, during beam ramp up.
(pressure recorded by extractor gauge at not NEG coated crotch absorber in S1)
Pressure in one achromat vs beam current

Pressures at dose 95 Ah, during beam ramp up, recorded at different positions along achromat (L, S1, S2)

- Pressure at S1 (ion pump)
- Pressure at S1 (extractor gauge)
- Pressure at S2 (penning gauge)
- Pressure at S2 (ion pump)
- Pressure at L (ion pump)

Legend:

* Pressure at L (Ion pump) probably due to electric effect
Normalized average pressure vs beam dose, recorded in S1 uncoated crotch absorber, and S2 NEG-coated

Legend:
- Pressure at S1 (extractor gauge)
- Pressure at S2 (penning gauge)

\[ Y = (3.08 \times 10^{-10}) \times x^{-0.68} \]

\[ Y = (1.64 \times 10^{-10}) \times x^{-0.75} \]
Lifetime evolution

Normalized lifetime vs accumulated dose

$I \cdot \tau [\text{mA} \cdot \text{h}]$ vs Dose [Ah]

Beam lifetime up to 6 Ah,

Maximum stored beam current 180 mA
Residual gas spectrum

Residual gas spectrum at 140 mA beam current

Main residual gasses:
- Hydrogen 85.33 %
- Carbon monoxide 9.39%
- Carbon dioxide 0.42 %
- Methane 1.17%

* Mass 16 and 19 is most likely due to intrinsic degassing of the gas spectrometer.
Scraper measurements

Mean lifetime vs vertical scraper distance from the beam center (Done at beam dose 40 Ah)

At 50 mA:
- \( P_{\text{Torr}} = 3.3 \times 10^{-9} \) torr
- \( T_{\text{elastic}} = 104.69 \) h
- \( T_{\text{inelastic}} = 88.47 \) h
- \( T_{\text{Touschek}} = 16.62 \) h

Total average pressure along the beam path (contribution from all gases based on the RGA spectra)

\[ y = 0.0363x + 1.5052 \]
\[ R^2 = 0.9849 \]

*Scraper measurements and calculations done by Jens Sundberg, Thanks!
Problems

- RF cavity (S2) venting due to broken high power feedthrough during conditioning (with closed valves). Now cavity is removed from the ring and dummy chamber placed as could not be run with high power anymore. Now awaits conditioning outside the ring.

- Hot spots in proximity of crotch absorber (S1), mis-positioning of the crotch chamber,
Future plans and development

Vacuum system constraints:
- Vacuum chamber outer diameter 10 mm,
- Compact vacuum system design,
- Very low impedance flange/bellow assemblies,
- Distributed pumping.

Development needed:
- Coating of 8 mm aperture, long, bend chambers,
- Effective thin layer in-situ baking system without the need of removing the vacuum chamber from the final location for re-activation,
- Handling of flexible delicate small vacuum pipes,
- Study new materials possible for chamber manufacturing,
- New methods of manufacturing (electroforming).
Thank you for your attention

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