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VACUUM SYSTEM DESIGN FOR THE SIRIUS STORAGE RING

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Abstract

Sirius is a 3 GeV 4th generation light source under construction by the Brazilian Synchrotron Light Laboratory (LNLS). Sirius will have a low emittance storage ring, 0.28 nm.rad, based on 20 cells of a highly compact lattice – 5 bend achromat (5BA). This lattice concept leaves very little space for components and therefore requires narrow vacuum chambers with tight mechanical tolerances. Most of the storage ring vacuum chambers will be made of oxygen-free silver bearing (OFS) copper and have a circular cross section with inner diameter of 24 mm and a wall thickness of 1 mm. Unused synchrotron radiation will be distributed along the water cooled walls of the chambers. Due to the small conductance of the chambers, vacuum pumping will be based on distributed concept and then non-evaporable getter (NEG) coating will be extensively used, with more than 95% of the chambers being coated. In this paper, we present an overview of the storage ring vacuum system and the fabrication approach for some components.

INTRODUCTION

In order to reduce the horizontal emittance to sub-nm.rad value, the Sirius storage ring will be based on a 5-bend achromat (5BA) lattice [1], with a circumference of 518 m comprising 20 achromat cells, 10 straight sections of 7 m and 10 straight sections of 6 m.

The compact lattice of the storage ring leaves very little space for components and therefore requires narrow vacuum chambers. For this reason, the storage ring will base vacuum pumping mainly on NEG coatings.

The vacuum chambers will be made of OFS copper. The high electrical conductivity of this material minimizes the impact on the machine's impedance, while its thermal conductivity makes it a suitable choice to absorb unused synchrotron radiation. Also, OFS copper has good resistance to softening at the NEG activation temperature of 200°C.

LNLS NEG COATING FACILITY

Since all the vacuum chambers will have small vacuum conductance, on account of their narrow cross section, NEG coatings will be extensively used. The host lab of Sirius, LNLS, has signed a license agreement with CERN to develop the coating technology in Brazil. Moreover, LNLS has designed and built its own NEG coating facility to produce the vacuum chambers (Fig. 1). The current facility allows LNLS to produce coatings according to standards determined by CERN – offering the ability to coat vacuum chambers up to 3.2 m long and 450 mm in diameter.

Figure 1: NEG coating facility at LNLS.

THE STORAGE RING VACUUM SYSTEM

One achromat cell of the storage ring vacuum system is illustrated in Fig. 2. Each cell comprises 18 chambers, 2 crotch absorbers with radiation extraction ports and 1 pumping chamber to install an additional ion pump.

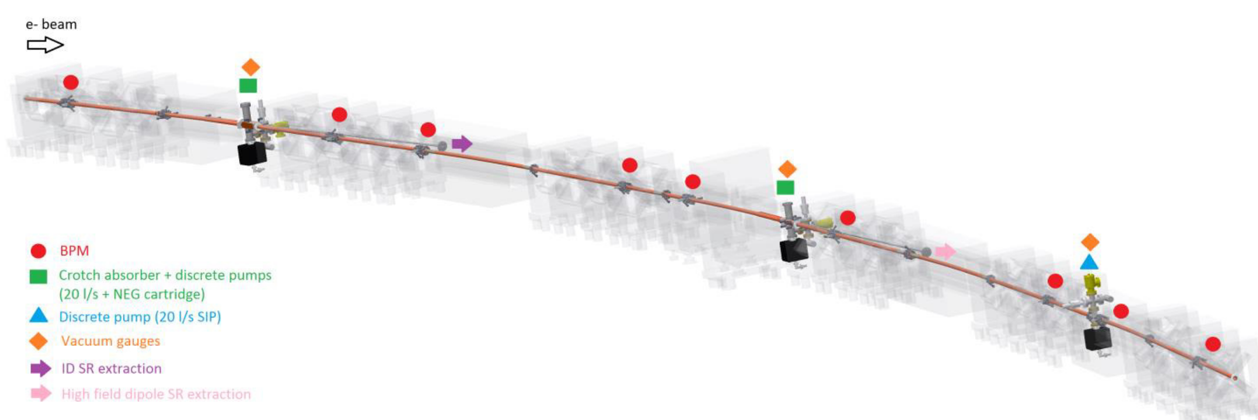

Figure 2: Vacuum system layout for one achromat cell.

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Flanges

A design based on a modified KEK MO-type flange [2] will be used for the circular (Fig. 3) and non-circular vacuum chambers of the storage ring. This flange presents no material transition (the electron beam only sees copper) and makes the seal at the inner surface, which maintains a smooth RF continuity and provides a small contribution to the machine's impedance.

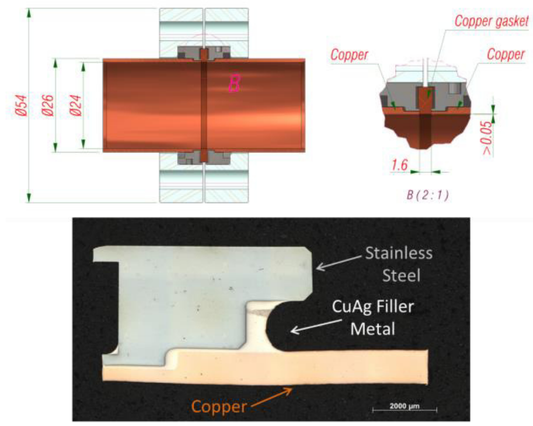

Figure 3: Section view of a circular vacuum flange assembly (top) and section cut of an as-brazed flange (bottom).

Multipole Vacuum Chambers

All the multipole vacuum chambers will have a circular cross section with an inner diameter of 24 mm and a wall thickness of 1 mm. Since these chambers also have to absorb unused synchrotron radiation, narrow copper cooling tubes will be attached to their outer side. These cooling tubes are special shaped (Fig. 4) to fit in the available gap of sextupole poles.

Three joining processes will be needed to fabricate every single chamber to ensure that the copper does not become annealed and distorted. Vacuum brazing will be used to join short copper adapters to the stainless steel vacuum flanges (Fig. 3), while tungsten inert gas (TIG) welding will be used to weld these components to the copper vacuum chamber. A robotized TIG welding station is being used due to its precise control and suitability for complex geometries. Vacuum soldering at a temperature of about 260 °C is being developed to join the cooling tubes to the chambers.

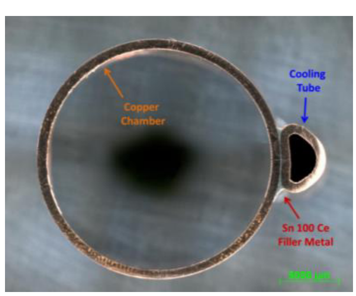

Figure 4: Multipole vacuum chamber cross section with the vacuum soldered special shaped cooling tube.

Absorbers

The total calculated synchrotron radiation power from dipoles is 228.4 kW. Most of this radiation will be distributed along the water cooled small thickness vacuum chambers. In addition, a great amount of power from insertion devices (IDs) must also be absorbed. This power will come mainly from a 4T Superconducting Wiggler (4T SCW), which has a fan-out bigger than the acceptance of the downstream vacuum chambers.

Because of the high power density radiation from IDs, Glidcop® AL-15 will be used to fabricate the crotch absorbers (based on PETRA III design [3]) downstream of dipole chambers. These absorbers will have angular apertures of ± 1.2 mrad (hor) and ± 0.5 mrad (ver) to extract ID radiation (Fig. 5). In the case of the 4T SCW, the absorber will have to handle about 8 kW of beam power.

The absorbers will be full NEG coated and will be assembled together with a 20 l/s sputter ion pump and a 200 l/s SAES Getter NEG cartridge. As IDs radiation will hit just NEG coated surfaces, a fast vacuum conditioning is expected in consequence of the low photon stimulated desorption yield of the NEG film [4].

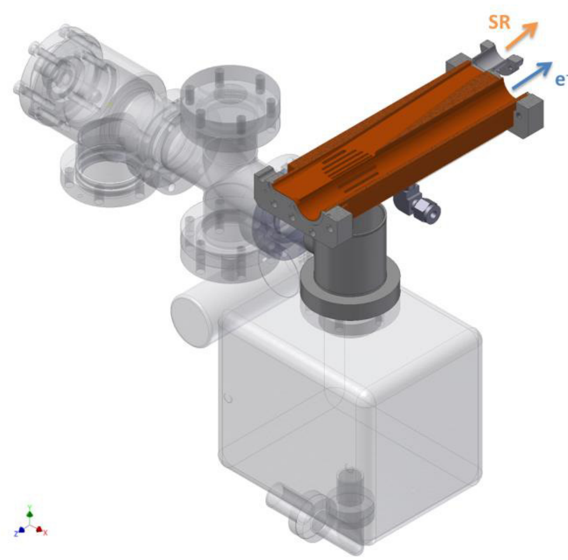

Figure 5: Crotch absorber with a radiation extraction port.

Dipole Vacuum Chambers

Three of the 5 dipole chamber on the achromat cell will be based on simple bent tubes with the same cross section of the multipole chambers. The remaining 2 chambers, where IDs and high field dipole radiation will be extracted, will have a 6 mm height narrow antechamber to permit radiation extraction (Fig. 6). The chambers with antechamber will be NEG coated in two steps, first the circular profile and them the challenging narrow antechamber.

NEG coatings with good activation have already been achieved at LNLS for the dipole chambers, especially for the narrow antechamber. Further studies are ongoing to optimize the fabrication and NEG coating process.

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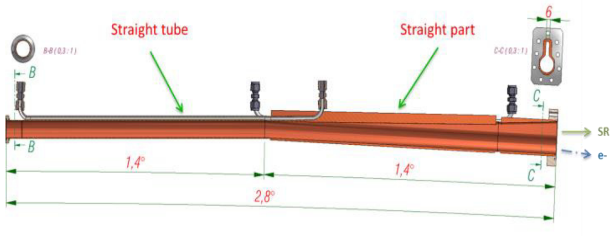

Figure 6: Section view of the dipole vacuum chamber with narrow antechamber for IDs radiation extraction. Fabrication is based on two straight sectors permitting to protect the small thickness tube sector from wigglers high power loads.

RF Shielded Bellows

Bellows must accommodate the thermal expansion of the copper chambers during NEG activation. For a 200°C bake-out, a 3 mm/m expansion of the chambers is expected.

A RF shielded bellows similar to DAΦNE's design [5] is being studied (Fig. 7) and fabricated (Fig. 8). The RF shield comprises 8 quasi-omega shaped Cu-Be alloy strips of 0.15 mm thickness. Because of space constraints, the RF shield assembly is fixed to one of the flanges. Also, the design of the strips was optimized to keep good contact pressure with the beam pipe in the required stroke range. Aiming to reduce friction and consequently particle generation, the strips will be plated. Rhodium is being studied.

The bellows are planned to be welded around both sides of BPMs [6].

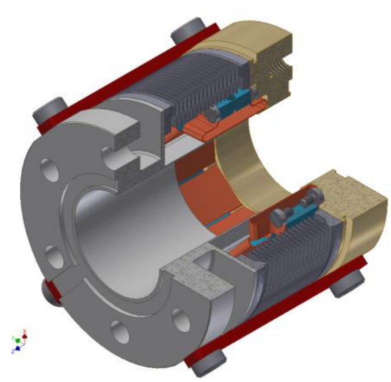

Figure 7: Section view of the bellows. Axial compression/expansion limits are 10/1.5 mm. No lateral movement is allowed. Free length is 50 mm.

Figure 8: View of the main parts of the bellows.

Bake-out for NEG Activation

The less laborious approach for the NEG coating activation is by an *in-situ* bake-out. However, the 1 mm clearance between vacuum chambers and magnets requires a special heater. For this reason, LNLS has developed a customizable thin polyimide heater in conjunction with the Brazilian company *EXA-M*.

The developed heater (Fig. 9) has 0.4 mm thickness and a maximum operating temperature of 210^{0}C. In addition, a top aluminium layer reduces radiation heat loss and diminishes the required input power for the bake-out.

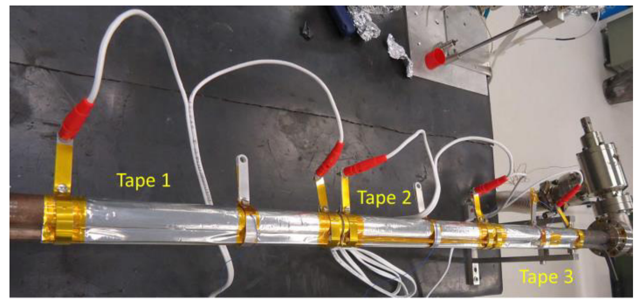

Figure 9: Three heaters assembled on a copper vacuum chamber for NEG activation test.

CONCLUSION

The design for the Sirius storage ring vacuum system has been presented, as well as some fabrication details for the flanges, crotch absorbers, bellows, multipole and dipole vacuum chambers. The compact lattice constrains make the vacuum design and fabrication a challenging task. Considering the high demand of NEG coatings for Sirius, a NEG coating facility was built in LNLS and coatings in accordance with CERN's standards can be produced. Further design and fabrication optimization are being done for the dipole chambers, crotch absorbers and bellows.

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