ISBN: 978-3-95450-231-8 ISSN: 2673-5490 doi: 10.18429/JACoW-IPAC2023-THPA147

SLS 2.0 VACUUM COMPONENTS DESIGN

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Abstract

The installation of the SLS2.0 storage ring will start in October 2023. Most of the vacuum chambers comprising the 288 m long storage ring will be made out of copper to dissipate the synchrotron radiation heat and to decrease resistive wall impedance. The nominal inner diameter of the vacuum chambers is 18 mm, with a wall thickness minimum of one millimeter, and their clearance to neighboring magnet poles, in some cases, 0.3mm. In the bending magnet locations, the chambers will have an antechambers, with a Glidcop crotch absorber at each end. The whole ring will be NEG-coated to speed up the vacuum conditioning. Each arc is approximately 18 m long built up without any bellows, thus requiring the NEG activation performed in an oven outside the tunnel. The installation of this completed arc into the magnet apertures will be a delicate crane transport. This paper describes the design and production of the different vacuum components, as well as the first test of components.

SLS 2.0 VACUUM CONCEPT

The SLS 2.0 storage ring [1] is based on a seven bend achromat design which combines longitudinal gradient bends with reverse bends. Permanent magnets are used to achieve this high magnet density per unit cell with the consequence that magnet aperture minimum must be 22 mm to get enough field strength. The nominal inner cross section of the SLS2.0 arc vacuum chamber is 18 mm, which means poor pumping conductance and high photon flux impinging on the inner chamber surfaces. These surfaces are coated with Non-Evaporable-Getter (NEG) to limit photon stimulated desorption (PSD) [2-4].

Storage Ring Layout and Simulations

The storage ring consists of twelve identical arcs, each approximately18 m in length (Fig. 1). Due to the high packing of magnets, no bellows can be installed, thus preventing any bake-out and NEG activation after installation in the tunnel. The arc includes seven bending magnet vacuum chambers each ending with a stainless steel cube with a 55 l/s ion pump (#Vaclon Plus 55), a getter pump (#CapaciTorr Z400) and a Glidcop crotch absorber [5]. The arc design of Fig.1 was simulated in MOLFLOW [6] to predict the pressure profile along the beam orbit (Fig. 2). The outgassing rate of the inner surfaces was preliminary simulated with the code SYNRAD[6], taking into account the magnetic field maps, the presence or not of NEG, and the different cumulated photon dose illumination, which is proportional to the beam dose in A.h. NEG coating of the inner surface helps speed up the vacuum conditioning time allowing the required pressure for nominal beam lifetime of 1.0×10^{-9} mbar equivalent CO to be reached after 100 A.h of beam time. Without NEG coating at least an order of magnitude more conditioning time (1000 A.h) would be required.

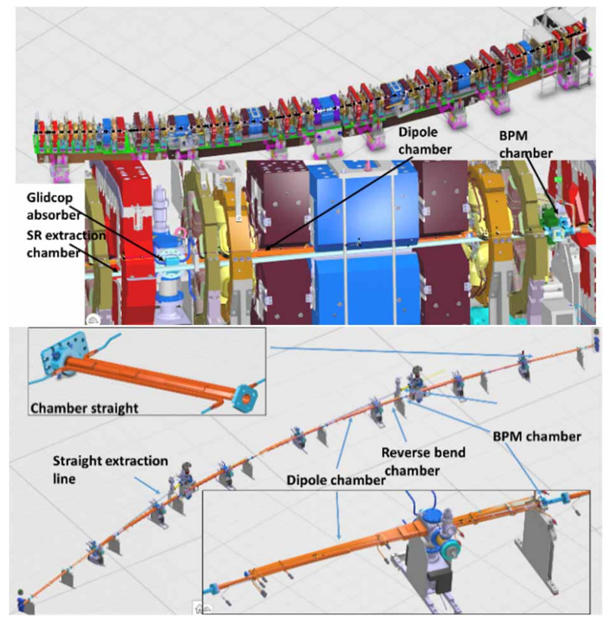

Figure 1: 3D plots of an SLS2 arc including all magnets (top) and of the vacuum chambers arc assembly (bottom).

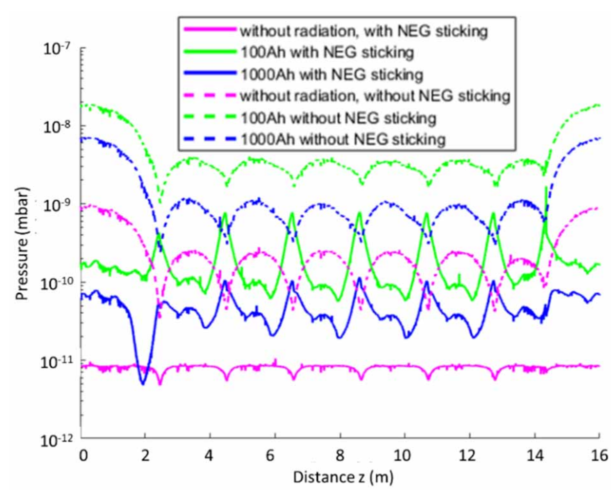

Figure 2: Pressure profile simulated with SYNRAD / MOLFLOW.

VACUUM CHAMBERS DESIGN

About 500 vacuum chambers of length ranging between 150 and 1500 mm are needed for the 12 arcs. The chambers are assembled together with flat silver-plated copper gaskets (VATseal type), having sealing lips protruding by

14th International Particle Accelerator Conference,Venice, Italy JACoW Publishing
ISBN: 978-3-95450-231-8 ISSN: 2673-5490 doi: 10.18429/JACoW-IPAC2023-THPA147

200 μm and which deform to roughly 150 μm after tightening, in between. The main chamber types are described in this section.

Bending Magnet Chambers

The most complicated chambers of the arcs, in terms of fabrication, are the dipole magnet chambers (CB series). Most of these chambers are produced in-house and the rest of the arc chambers are provided by the company FMB GmbH [7]. The inner cross section portion of the vacuum chambers, in which the electron beam travels, has an octagonal shape of 18 mm inner diameter and a minimum of 1 mm wall thickness (Fig. 3). This cross-sectional area is 4 times smaller in comparison to SLS1, significantly increasing the Synchrotron Radiation (SR) power deposition on surfaces. An antechamber leads from the octagonal chamber by a slit with a 3 mm height allowing the dipole-generated SR to escape. A slit with a 10 mm height in the first dipole chamber of every arc allows undulator light originating farther away to be extracted. This slit height corresponds to a maximum vertical opening angle of 1 mrad.

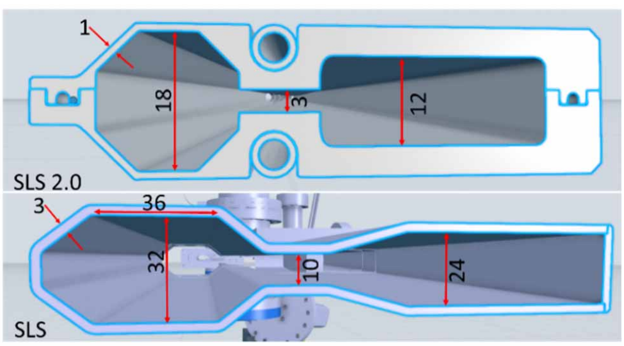

Figure 3: Cross section view at the middle of the dipole chamber in the case of SLS 1 (top) and SLS 2.0 (bottom).

To properly evacuate the SR heat (there is 150 W dissipated in the vacuum chambers walls every two meters of unit cell), copper is used as base material. The chambers were designed using a brazing procedure. PSI has extensive know-how in copper OFHC brazing and a large suitable oven (4 m capability). The central part of the chamber (Fig. 4) consists of two half shells that are milled from plates and brazed together in a horizontal position (step 1). The rest of the copper parts are fabricated by a combination of milling (outer contours) and wire erosion (inner contours). The roughness obtained after wire erosion is better than Ra < 0.8 μm, which is compatible with our impedance specifications. The stainless-steel parts in 316-LN are also pre-brazed with their copper neighbours. Finally, all the parts are stacked vertically including the cooling channels and brazed together (step 2) at a slightly lower temperature than the one used in the first brazing step.

The production of the series has already started, with 5 chambers out of 91 which are leak tight and NEG coated [8]. An average production rate of two chambers per week is expected. For the NEG coating, a magnetron sputtering setup with thin solenoids has been developed in-house. The first three dipole chambers were successfully coated with almost full surface coverage of a 0.5 μm thick layer. Only the area where macor wire spacers were located remained uncoated, yielding a final surface coating of more than 99.8%. (Fig. 5).

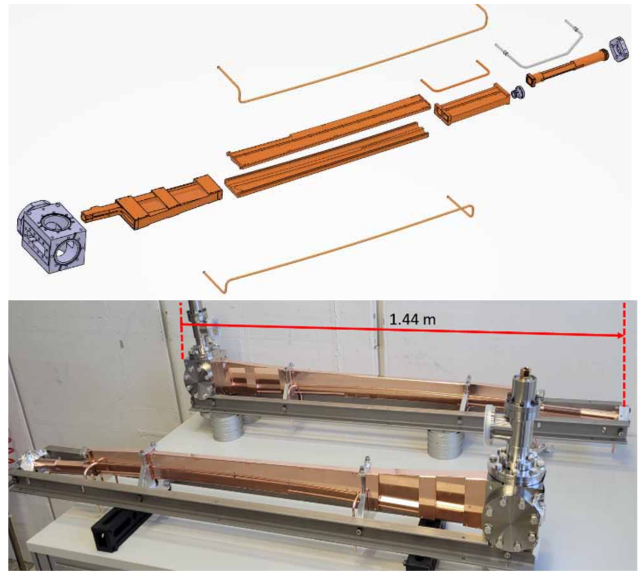

Figure 4: Bending magnet dipole chamber, 3D Exploded view (top) and picture (bottom).

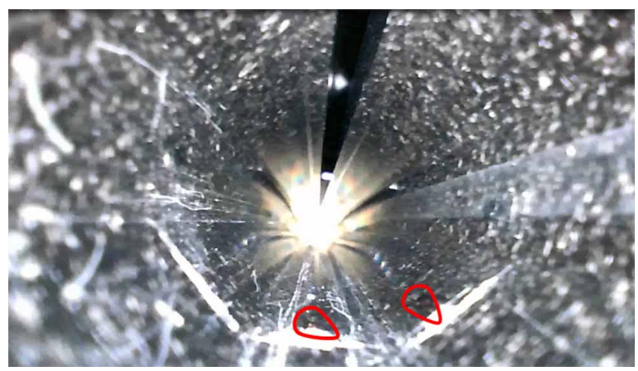

Figure 5: Endoscope picture of the inner octagon after NEG coating, the red marked areas are zones where copper is barely visible, and correspond to the locations of the macor spacers.

Beam Position Monitor (BPM) Chamber

The BPM chambers, made out of stainless steel 316LN (Fig. 6), are both wire-eroded, to form the inside cavities, flat seal (3D view) on its CuCrZr support (picture).and milled, to create the outside surfaces. The inner diameter is chamber and to avoid SR heat-up. The BPM buttons are glass isolated Inconel pins which are TIG welded into the 45 degrees facets of the BPM block. The wall thickness of the pipe following the BPM block is only 0.5 mm to allow a good penetration of the fast-changing magnetic field of the corrector magnets which are positioned there. To limit resistive wakefields, the inner side is coated by electroplating with 5 μm of copper. On top of the copper a NEG layeris deposited. The BPM chamber is mounted on a water cooled Glidcop part to make a thermal barrier

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between the warm BPM block (40 °C) and the main steel support (24 °C). This should limit the thermal drifts. Eleven BPM chambers out of 120 were already produced by FMB.

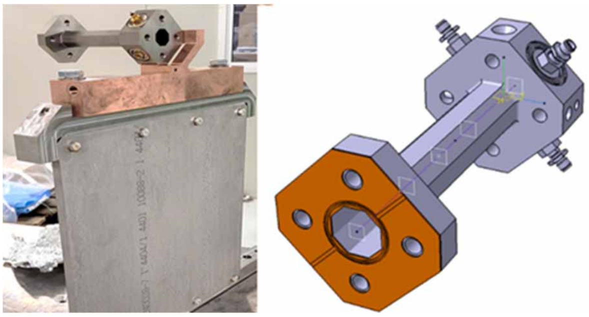

Figure 6: Beam position monitor chamber (CSS) with its 21 mm in order to stay in the shadow of the upstream.

Valves and Bellows

There is a gate valve at each extremity of the arc marking the separation between arc and straight sections. These valves are always connected to bellows which are then the first / last components of the straight sections (Fig. 7). The inner cross sections are round and 21 mm in diameter. The main constraint in the valves and bellows design came from the RF impedance compatibility [9].

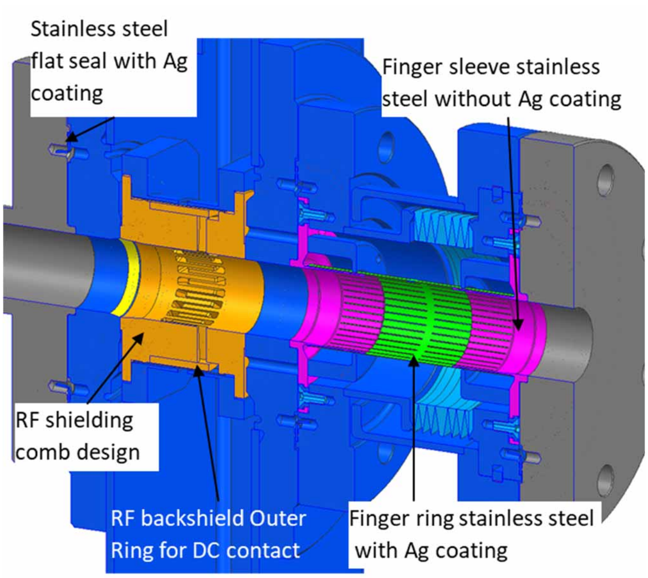

Figure 7: 3D Cross-section view of the inner part of a valve (left) – bellow (right) assembly.

The RF shielding designs for the valve and bellows were co-developed with the company VAT [10]. A combs design in stainless steel [11] was adopted (Fig. 8) for the valve RF shielding as the more standard finger barrel design created some unacceptable beam instabilities. Still, some high order modes (HOM) resonance persists, dissipating 28 W in the combs leading to about 80 °C peak temperature [9]. Due to these temperature cycles a stainless-steel flat gasket is used rather than copper one. The bellows shielding consists of 3 finger barrels in stainless steel. The two extremity finger sleeves (shown in pink in Fig. 7) are spring-loaded outward and have noses protruding at the inner diameter. These features allow the sleeves to mate with the adjacent flanges very accurately centered and without any axial gap. The central barrel has the largest diameter and overlaps the two sleeves.

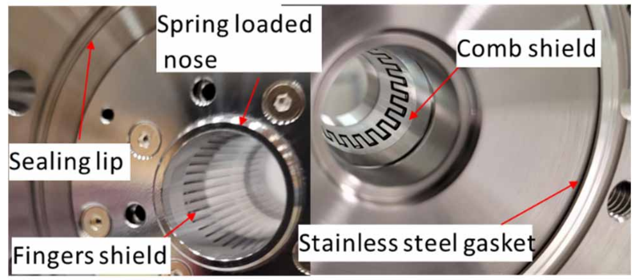

Figure 8: Pictures of the 21mm dimeter RF shielding of the bellow (left) and valve (right).

ARC TRANSPORT AND ACTIVATION

Each arc will be assembled in a clean room and then suspended from a supporting frame with chains. The frame and arc assembly are then to be transported with the SLS building crane to an oven where the arc will be baked out and activated. The arcs are then to be stored under vacuum until final assembly on the girders.

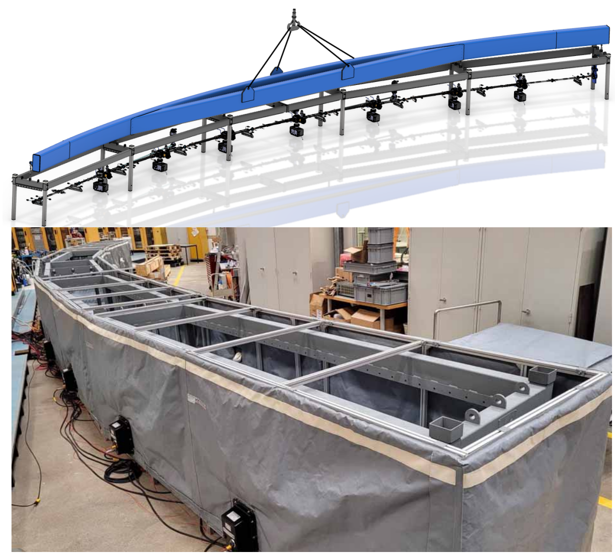

Figure 9: 3D view of the vacuum arc attached to its lifting girder (top) and baking oven in SLS building (bottom).

VACUUM COMPONENTS IN STRAIGHTS

The straight components and especially the undulator vacuum chambers are still in the design phase. An aluminium extruded pipe with a 9mm ID, and NEG coated, will be used for the soft X-ray undulators' vacuum chambers. The hard x-ray in-vacuum undulators have a special design where their vacuum chambers are incorporated in the magnet array supporting frame. The vacuum chamber for the superconducting undulator, with an ID of 4 mm, a wall thickness below 0.2 mm, and a length of 1.4 m, will certainly be an engineering challenge.

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