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SLS 2.0 STORAGE RING COMPONENTS OVERVIEW BEFORE INSTALLATION

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Abstract

The Swiss Light Source SLS will have a 15 months shutdown starting in October 2023 in order to install the new storage ring SLS 2.0. The delivery of the large series of components, i.e., magnets, power supplies, RF and vacuum chambers has started, and the design of more specific components such as the thin septum and the undulators is close to completion. This paper will give an overview of the key components design and first tests before final installation.

PROJECT GOALS AND SCHEDULE

The main difficulties and challenges of SLS 2.0 are common to other diffraction limited storage rings [1-3]: magnet cross talk issues due to the very short distances between magnets especially with permanent magnets, heat dissipation issues in the small aperture vacuum chambers due to synchrotron radiation and RF heating, and in general, beam instabilities issues due to wakefield perturbations. All of the components have been designed to withstand these constraints. The project consists in the installation of a full new storage ring including new booster to ring transfer line and new front ends [4]. Some existing beamlines will also be renewed or relocated [5]. The linac and booster, and the concrete tunnel will remain unchanged.

Design Parameters

The main goal of the upgrade is to increase the brightness of the beam delivered to the users by a factor 100 at 10 keV. In order to achieve this, a seven bend achromat lattice with longitudinal gradient bends as well as reverse bends has been designed. This should reduce the horizontal emittance by a factor 40 in comparison to present SLS. The design parameters are summarized in Table 1.

Table 1: SLS 2.0 Design Parameters

Parameter	Value
Beam Energy	2.7 GeV
Lattice	7 Bend Achromat
Current	400 mA
Circumference	288 m
Natural Emittance	158 pm.rad (w/o IDs)
Lifetime	9 h

General Layout

The ring has 12 identical arcs (Fig. 1) distributed in a three folds symmetry such that there are 3 different types of straight lengths representing a total of 83.6 m. Four new 500 MHz RF cavities with high order modes damping [6] are installed in a row in the long straight X05L, while the two-cell passive superconducting 3rd harmonic cavity (from SLS) is located in the long straight X09L. The last long straight is dedicated to injection (X01L).

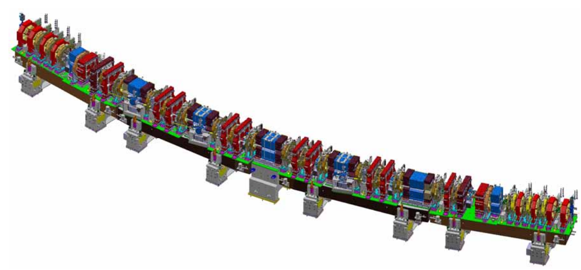

Figure 1: 3D view of an SLS2 arc.

Dark Time Milestones

One of the first challenge of SLS 2.0 is to complete the installation before the end of the planned dark time. The delivery of components has suffered some delays due to worldwide material supplies delays. However, the SLS1 will be in shutdown at the end of September 2023 (Fig. 2) and the first beam turn in the new ring of SLS 2.0 is scheduled for December 2024. In the phase 2 of the project two superconducting superbends and a superconducting undulator will be installed.

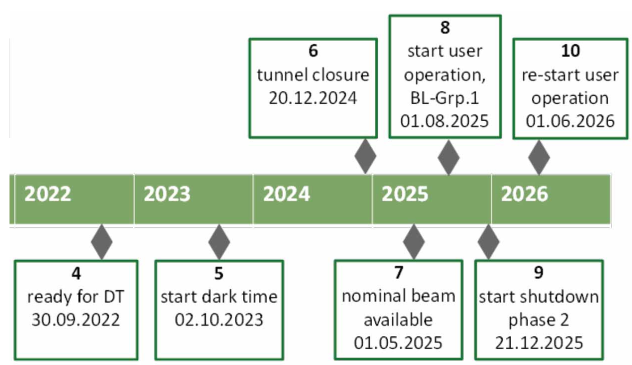

Figure 2: Milestones of SLS 2.0 project.

Presently, the critical path for the installation completion is the assembly and measurements of the permanent magnets Longitudinal Gradient Bends (LGB).

COMPONENTS PROCUREMENT

The procurement of large series components started in 2022 and the status of the most critical components is discussed in this section.

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Mechanical Supports

The motorized girders consist of rigid steel bodies filled with damping material (Fig. 3). They are mounted on flexor supports which can be adjusted vertically thanks to motorized wedges. Four such units allow girder vertical height and girder pitch angle adjustment.

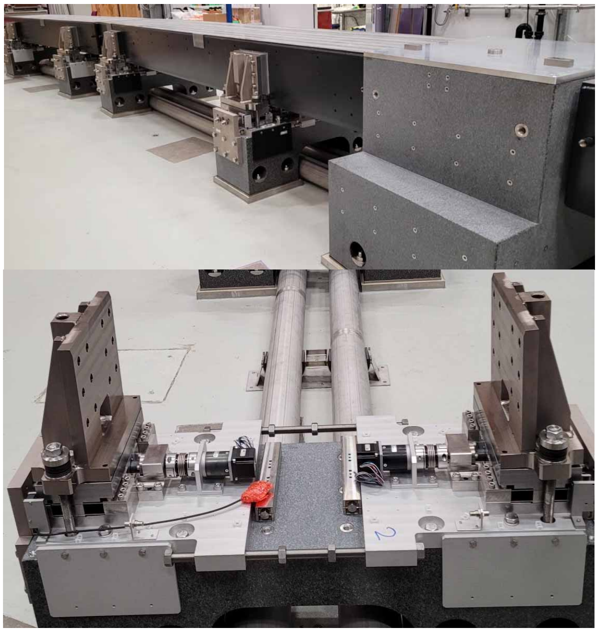

Figure 3: Pictures of half arc girders (top) and of the girder adjustment system (bottom).

Vibrations measurements on a prototype were carried out and the main results can be summarized as follows:

- Integrated transverse displacement (5-200 Hz) at girder surface: < 30 nm RMS
- Amplification factor floor to girder surface (5-200 Hz): 2.5 transversally
- First resonance frequency of full assembly: 23.1 Hz transversally

The SLS 2.0 girder should have a factor 2 less displacement amplitude in comparison to the girder of SLS1. In addition to the reduced girder motion each magnet will sit on manually adjustable individual supports allowing for fine positioning. These supports can be reached from the inner ring side facilitating positioning when neighbour magnets are already in place.

Magnets and Power Supplies

The bending magnets as well as the reverse bend magnets are designed with permanent magnet blocks in NdFeB. The LGB bending magnets consist of an assembly of 3 magnets: a dipole at the center, and two transversally shifted quadrupoles providing a quadrupole and a dipole function (Fig. 4). The minimum magnet gap / bore diameter is 22 mm. The quadrupoles, sextupoles, octupoles and correctors are electromagnets with main parameters summarized in Table 2 (maximum values). The octupole magnets combine multiple functions: octupole, quadrupole, and skew quadrupole functions by means of additional windings.

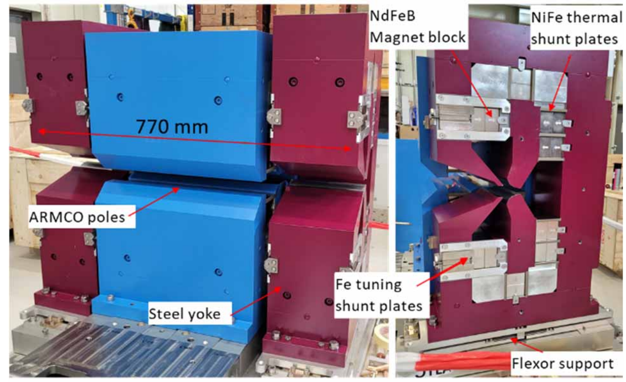

Figure 4: Longitudinal gradient bending magnet (so called triplet) seen from front (left) and side (right).

Table 2: Magnets Specifications of Largest Series

Type	Field Strength / Gradient	Quantity
Triplet bend	1.35 T / 0.85 T	56
Reverse bend	0.27 T, 77.6 T/m	144
Sextupole	5850 T/m^2	288
Octupole	63000 T/m^3 & 5.6 T/m	264
Quadrupole	< 98 T/m	108
Correctors	600 µrad max	115

The triplets measurements with a moving wire has just started. All quadrupoles and corrector magnets have been already delivered and measured at PSI. In order to meet the orbit stability requirements the 115 corrector pairs will be powered by 5 A Power Supplies (PS). These PS are stable within 5 ppm RMS for the frequency range 10 Hz – 10 kHz. The fast orbit feedback (FOFB) is assumed to be able to fight the corrector noise for <10 Hz. The serial production of 1100 PS has started (Fig. 5).

Figure 5: Five amperes PS racks with 36 units (left) last batch of X-Y corrector pairs (right).

Vacuum Chambers

The vacuum chamber has a nominal inner diameter of 18 mm and 1 mm minimum wall thickness, allowing only

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0.3 mm gap to the magnet pole surface at some locations [7-9]. Such a relatively small diameter reduces the pumping conductance, and thus requiring Non Evaporable Getter (NEG) coating of the inner surface. In addition, the deposited power to the inner surface of the vacuum chamber due to synchrotron radiation becomes larger than in SLS1 with about 150 W every 2 meters of a unit cell. As a consequence copper was chosen as base vacuum chamber material to ensure good heat conduction. Another consequence of such small chamber diameter is the increased sensitivity to wakefield issues, requiring careful simulation of every cross section transition [10].

The most complicated SLS 2.0 vacuum chamber, the ones for the bending magnets are produced and NEG coated in-house (Fig. 6). The rest of the chambers are produced by our external partner FMB GmbH [11] (Fig. 7). In total, about 500 chambers are required to assemble the whole ring. The NEG coating should speed up the commissioning time by a factor 10 since it reduces the photon stimulated desorption by almost two orders of magnitude. Molflow [12] simulations predicted that a pressure below 1.10^{-9} mbar can be reached in an arc after 100 A.h.

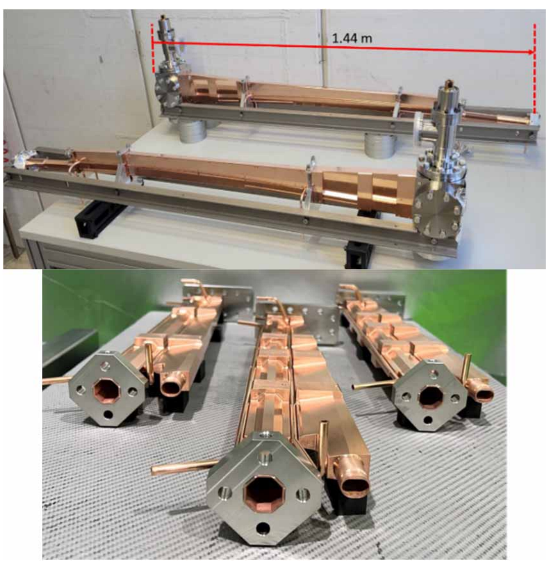

Figure 6: Bending magnet vacuum chamber produced at PSI (top) and reverse-bend chambers before brazing at FMB site (bottom).

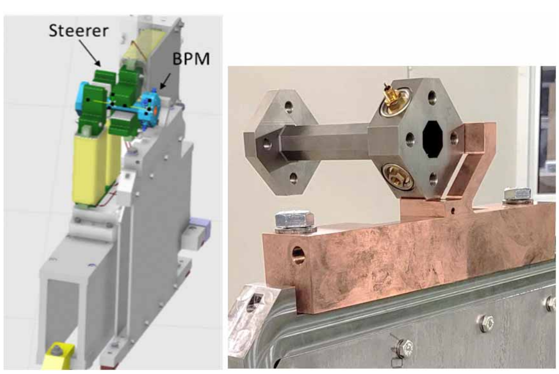

Figure 7: 3D model of the stainless steel BPM vacuum chamber and the fast correctors (left) and prototype (right).

Beam Position Monitors

There are 129 Beam Position Monitors (BPMs) in the ring to monitor and stabilize the beam orbit. Each BPM is positioned beside a corrector pair (Fig. 8). The goal is to reach a position stability of 50 nm RMS up to 1 kHz at the BPMs within the FOFB loop which puts corresponding constraints on the noise figures for correctors and BPMs.

Injection Layout

To inject beam in the ring, a conventional septa / 4-kicker bump scheme is foreseen in the first phase. A thick and a thin septum bring the injected bunch very close to the temporarily-bumped stored beam. The thick septum consists of two Permanent Magnet (PM) dipoles, an adjustment electrical dipole and magnetic screen. The thin eddy current septum has only 1 mm septum wall to enable injection in the small SLS2 aperture.

Cross Talk

The most severe design issues revealed during the last years were related to cross talk between adjacent magnets. The magnetic field leaking longitudinally out of the strong PMs couples to the neighbouring electromagnet's yoke degrading the performance of the PM magnet and saturating the yoke of the electromagnet. Twelve such dangerous interactions have been identified and required design changes such as:

- Increasing the distance between the reverse bend and octupoles /corrector magnets by 10 mm, achieved by reducing the sextupole length.
- Implementing a shielding plate in front of corrector's return yoke.
- Poles chamfering for some PM magnets

The main issues due to these cross talk effects should be already solved, but simulations are still on-going to optimize the field profile by minor position changes (within a millimeter). Assemblies of 3 to 4 magnets are being simulated with finite element simulation tools. The obtained field maps are then integrated in tracking codes to check compatibility with beam dynamics. After several iterations the optimum position of each PM is obtained taking into account the interaction with its neighbours.

CONCLUSION

In conclusion, the preparation of large series components, including measurements and pre-assembly has been started in 2023, but the largest part will continue in parallel to the final assembly in the tunnel in 2024.

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