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SIRIUS LIGHT SOURCE STATUS REPORT

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Abstract

Sirius is a Synchrotron Light Source Facility based on a 4th generation 3 GeV low emittance electron storage ring that is under construction in Campinas, Brazil. Presently the main tunnel for the accelerators is ready to start installations. The Linac tunnel was delivered earlier and the 150 MeV Linac from SINAP is almost ready to start commissioning early May. Commissioning of the storage ring is expected to start by the end of this year (2018). In this paper we briefly review the overall project parameters and design concepts and focus on highlights from the main subsystems.

INTRODUCTION

The Sirius Light Source Facility is under construction at LNLS, in Campinas, Brazil. The first lattice design studies for a new source in Brazil began in 2008 where a TBA lattice structure was explored. In 2012, the TBA was replaced by a 5BA lattice [1] after a recommendation at the first MAC meeting. As a result, the horizontal emittance dropped from 1.7 to 0.28 nm.rad, and then to 0.25 nm.rad, and all subsystems underwent major changes and needed to be redesigned to meet the much tighter requirements and tolerances of 4th generation storage rings. Since then, the machine optics design [2] has evolved to optimize the light source performance with a strong interaction with beamline scientists: the peak field in the superbend increased to 3.2 T (corresponding to 19 keV critical photon energy) and both horizontal and vertical betatron functions in 15 out of 20 straight sections have been reduced to 1.5 m, allowing for a better phase space matching of electron and photon beams from undulators, and also allowing for installation of delta type undulators, adjustable phase insertion devices that require small horizontal as well as vertical gaps. The Sirius dynamic aperture is still sufficiently large to allow for off-axis injection in the horizontal plane. A non-linear kicker will be used for beam accumulation. Over the last 5-6 years, most of the subsystems had the equipment prototyped and tested, and are now either ready for installation or under production. The Sirius injector consists of a 150 MeV linear accelerator and a full energy synchrotron booster installed in the same tunnel and concentric with the storage ring. The Linac was purchased from SINAP (Shanghai Institute of Applied Physics, China) and is currently being commissioned. The main tunnel is now ready for machine installations and booster magnet supports already started to be fixed on the tunnel inner wall. The storage ring installation is expected to extend until the end of 2018, when beam commissioning is expected to start.

Figure 1 shows an aerial view of the construction site as of January 2018, and Figure 2 shows the Linac installation and the main accelerator tunnel in April 2018.

Figure 1: Aerial view of the Sirius construction site as of March 2018.

Figure 2: Top: view of Sirius main accelerator tunnel, ready to start machine installations. Bottom: 150 MeV Linac from SINAP ready for commissioning. Pictures were taken in April 2018.

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The storage ring main parameters are summarized in Table 1 and optics functions are shown in Figure 3 for a high beta and a low beta section.

Table 1: Sirius Storage Ring Main Parameters

Energy	3.0	GeV
Circumference	518.4	m
Number of superbends	20	
Number of straight sections	20	
Number of low beta sections	15	
Optics symmetry	5-fold	
Horizontal emittance	0.25 → 0.15	nm
Betatron tunes (H/V)	49.11 / 14.16	
Natural chromaticity (H/V)	-119 / -80	
Natural energy spread	0.085	%
Natural bunch length	2.4	mm
Momentum compaction	1.64e-4	
Beam size* @superbend (H/V)	9.5 / 3.5	µm
Beam size* @low beta (H/V)	19.1 / 2.0	µm

*Beam size (rms) for zero current and 1% coupling.

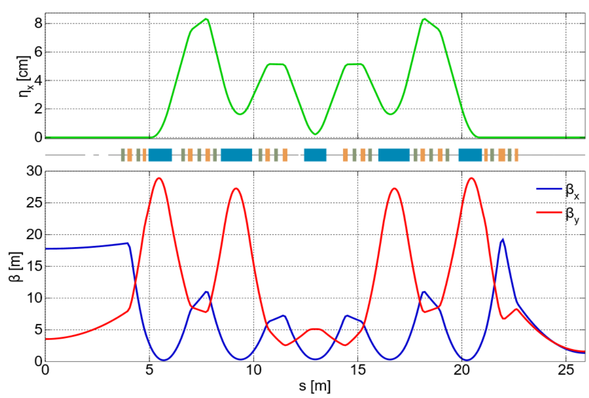

Figure 3: Optical functions for Sirius with 1/2 high beta straight to the left and 1/2 low beta straight to the right.

MECHANICAL DESIGN AND MAGNET ALIGNMENT

The design of the mechanical structures of the storage ring is such that the magnet-to-magnet alignment will be achieved by construction. This means that there will be no adjustment for individual magnets. This feature can only be achieved with a high precision manufacturing process for both magnets and girders. Also, the magnetic centreline must be coincident to the geometric centreline in order to avoid the need for shimming. Indeed, the flatness of the girders surfaces is being kept to better than 10 µm, and the geometric and dimensioning deviations of the magnets are held below 20 µm. The magnetic measurements point that the deviation between magnetic and geometric centres of the storage ring magnets is below 10 µm.

One of the main design guidelines for all the components of the magnets support, such as girders, levelling wedges and concrete supports, is stiffness. This characteristic of the components directly affects the vibration stability of the machine. The measured first mode frequencies for Sirius unloaded girders is 511 Hz while for the loaded system, including quadrupoles and sextupoles, the first measured modes are 152 Hz and 268 Hz respectively for the horizontal and vertical planes.

MAGNETS

The Sirius magnets have all been prototyped and are being produced by a Brazilian company, WEG. The magnets are constructed by stacking laminations that are held together by a tightening rod. The achieved mechanical and magnetic precision of the magnets, resulting from an extensive LNLS-WEG R&D collaboration, enables our initial target of magnet alignment on girder by construction, as can be seen in one family of quadrupole measurements, shown in Figure 4.

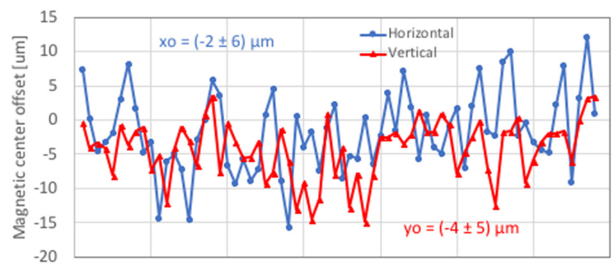

Figure 4: Magnetic centre measurements of Sirius storage ring quadrupoles Q14.

POWER SUPPLIES

Sirius power supplies were prototyped and tested at LNLS and are now under production at a Brazilian company. The last batches of storage ring and booster supplies will be delivered by the end of May. The units already delivered are now being integrated in the respective racks. The main parameters for Sirius power supplies are given in Table 2.

Table 2: Sirius Power Supply Main Parameters

Model	FBP	FAP	FAC
Desc.	Low cur 4Q	DC high cur 1Q	DC high cur 4Q
Usage	Cors, trims	SR magnets	BO magnets
Quant.	737	45	6
I [A]	10	150 - 700	30 - 1100
P [kW]	0.05	1.5 - 180	1.5 - 333

VACUUM SYSTEM

The Sirius storage ring vacuum system will be based on NEG coated copper chambers with in-situ baking for activation. The vacuum components have all been prototyped and tested. The process for in-house NEG deposition has been defined after extensive R&D, including coating of the narrow light extraction channel in the dipole keyhole chambers. The NEG coating facility, licensed by CERN, has been operating routinely in average 20 hours per week and has already accumulated about 730 running hours. Recently, the capacity of the NEG coating facility has been increased to 30 hours per week.

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The Sirius vacuum system is in the final production stage. All the commercial equipment (vacuum gauges, RGAs, ion pumps, NEG pumps and valves) have been delivered and the fabrication of vacuum chambers and components for the storage ring should be finished by June. Still under production are the keyhole dipole chambers with photon beam extraction channel, RF shielded bellows and special components for the storage ring injection sector like the non-linear kicker, on-axis kicker, horizontal and vertical scrapers, and transitions.

PULSED MAGNETS

The Sirius injection system is composed of a 150 MeV Linac and a full energy 3 GeV synchrotron booster. The system is planned to operate in top-up mode with 2 Hz repetition rate. Beam injection and accumulation into the storage ring will be off-axis in the horizontal plane. A non-linear kicker will be used to minimize the disturbance on the stored beam during injection. Nevertheless, a dipolar kicker will also be installed for on-axis injection during commissiong. This kicker will be later converted to a horizontal pinger. The pulsed magnets for beam injection and extraction are being tested.

The pulsed septa are composed of 0.5 mm FeSi-E233 laminations with 0.3 mm 316L stainless steel vacuum chambers. The kickers use CMD5005 ferrite cores with Ti coated ceramic chambers. The most challenging device is the non-linear kicker, that is similar to the Bessy II design [3] and is being prototyped using a single piece ceramic tube manufactured by a Brazilian company, Engecer.

BEAM DIAGNOSTICS

All current transformers (DCCT, ICT and FCT) and beam loss monitor sensors, RF amplifiers for beam excitation, bunch-by-bunch (BbB) feedback processors, spectrum analyzers, CMOS cameras for screen monitors, motion systems for screen monitors, slits and scrappers, digitizers and oscilloscopes for injection diagnostics and filling pattern monitoring as well as IOC server computers have been acquired and are ready for installation. Similarly, all storage ring, booster and transfer lines button and stripline BPMs and their corresponding supports have been manufactured and are currently stored at LNLS.

The in-house developed BPM electronics is in its final integration stage. All MicroTCA crates, FPGA boards, fast digitizer ADC modules and analog front-ends, including commercial pico-ammeter modules for beamline front-end photon BPMs, have been manufactured and delivered to a local company for rack assembling and final integration tests. The 22 fully integrated BPM electronics racks, comprising 249 electron BPMs and 30 photon BPMs, will be shipped to LNLS from May 2018 to August 2018, in 4 batches.

There are a few components in production or procurement phase: RF cables, streak camera RF frequency customization, tune shakers and stripline pickups, BbB stripline kickers, electron beam slits and screen monitor mechanics. Scrapers and BbB cavity kicker are in prototyping stage.

A continuing work on EPICS IOC for the several beam diagnostics developments is in place. The baseline solutions for all beam diagnostics have been developed. Nevertheless, there is an active development for enhancing software functionalities, operator interfaces and automated IOC deployment procedures.

RF SYSTEM

In its final configuration Sirius RF system will operate with two SC cavities, providing up to 3 MV gap voltage and 480 kW of RF power at 500 MHz to the electron beam. The cavities are being produced and are planned to be installed in the machine in 2020. For commissioning and initial operation for beamlines a 7-cell PETRA cavity will be used driven by a 120 kW solid state power amplifier. With this setup it will be possible to store more than 20 mA operating with a gap voltage of 1.7 MV.

The booster RF system was tested and it is ready for installation (see Fig. 5). The storage ring SS amplifiers are being assembled and will be tested and ready by the end of June. The low level system is a new version of ALBA digital LLRF [4] and was tested with the booster RF system.

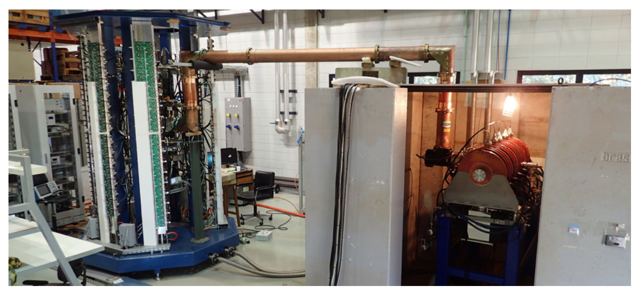

Figure 5: Setup for RF conditioning of the booster 5-cell Petra cavity with 500 MHz SS amplifiers.

BEAMLINES

Eighteen beamlines are currently planned for Sirius operation Phases I and II, covering scientific applications in Brazil's most strategic areas such as energy, agriculture, health, water and environment. To deal with the high brightness and coherent fraction of the delivered photon-beam [5] high-stability monochromators [6, 7] and mirror systems [8] were developed, as well as especial radiation enclosures [9] and infrastructure in the experimental hutches.

The installation of the frontends for the 6 first beamlines (Phase I-A) starts next May and first photon beams are foreseen for the second semester of 2019. Procurements for Phase II are planned to start in September this year and Phase I-B for the next year upon decommissioning of the existing beamlines at the UVX storage ring.

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