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SIRIUS ACCELERATORS STATUS REPORT

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Abstract

Sirius is a 3 GeV synchrotron light source that is being built by the Brazilian Synchrotron Light Laboratory (LNLS). The electron storage ring is based on a modified 5BA cell to achieve a bare lattice emittance of 0.27 nm.rad in a 518 m circumference ring that contains 20 straight sections of alternating 6 and 7 meters in length. The 5BA cell accommodates a thin permanent magnet high field (2 T) dipole in the center of the middle bend producing hard X-ray radiation (ε_c=12 keV) with a modest contribution to the total energy loss.

In this paper we discuss the main achievements and issues for Sirius accelerators. Developments in beamlines are not discussed here.

INTRODUCTION

Over the last year the earthwork at the Sirius site was completed and the building foundation work has began just after the groundbreaking ceremony on Dec. 19, 2014. See Fig. 1. The project underwent an overall budget and schedule revision after the detailed engineering design of the building was concluded. Start of machine installations is now scheduled for the end of 2017.

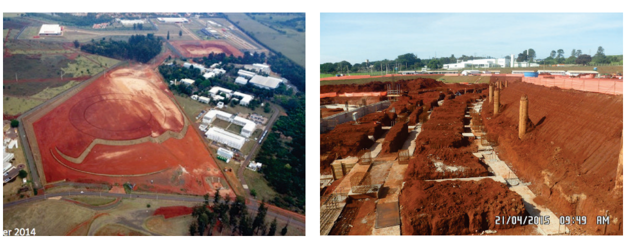

Figure 1: Aerial view taken in October 2014 of the Sirius site with earthwork completed (left) and construction of building foundation as of April 2015 (right).

The storage ring design optics has been upgraded to improve the matching in phase space between the electron beam and photon beam from insertion devices [1]. The main parameters for this new mode are summarized in Table 1. Most of the accelerator subsystems are in R&D and prototyping phase; a few are already under production, such as the booster magnets.

MAGNETIC LATTICE

A few modifications in the magnetic lattice have been implemented to optimize the design and fabrication of the magnets as well as to provide more space in the arc: the quadrupole lengths have been reduced, the slow orbit correctors and skew quadrupoles have been combined into the sextupoles, the different types of dipoles have been segmented into a rectangular unit block, and the horizontal and vertical fast orbit correctors have been combined to minimize the length of special vacuum chambers. The BPMs adjacent to the insertion straight sections have been moved closer to quadrupoles to optimize the beam-based alignment process and the BPM downstream the central dipole has been removed to avoid synchrotron radiation power. The optical properties for the new lattice are described in more detail in ref [1]. The injection straight section has also been optimized for injection with a pulsed multipole magnet. In this case, the conventional four kickers are not necessary and more space is available to optimize the pulsed magnet injection. A single kicker is kept for on-axis injection during commissioning.

Table 1: Sirius Storage Ring Main Parameters

Energy	3.0	GeV
Circumference	518.4	m
Horizontal emittance	0.19 - 0.27	nm.rad
Betatron tunes (H/V)	48.14 / 13.12	
Natural chromaticity (H/V)	-126.1 / -79.4	
Natural energy spread	0.076	%
Natural bunch length	2.3	mm

VACUUM SYSTEM

The vacuum system design for a standard storage ring sector is complete. Prototypes for bellows, BPMs, fast orbit correctors, multipoles and dipole vacuum chambers have been produced and prototypes for crotch absorbers and dipole chambers with narrow antechambers are under production. Pumping for Sirius will be based on NEG coating with in-house deposition. The NEG coating procedure has already been developed and optimized for most chamber geometries; even the 6 mm height narrow dipole antechamber already showed good activation results. For in-situ NEG activation a special 0.4 mm thick heating jacket has been developed by EXA-M. The jacket, which fits in the narrow gap between the vacuum chamber and the magnet poles, includes an external radiation shield to reduce heat transfer to the magnet. Further R&D work is being devoted to the optimization of crotch absorbers, bellows and BPMs.

The booster dipole vacuum chambers have been contracted to a local company (FCA Brasil).

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Further details about the Sirius storage ring vacuum system are described in ref [2].

BEAM DIAGNOSTICS AND TIMING

The Sirius in-house developed open source BPM electronics has been tested using real beam signals at SPEAR3. The results show a noise floor below 80 nm rms (0.1 Hz – 1 kHz) and long term stability better than 140 nm rms [3]. Long-term reliability tests of a complete MicroTCA.4 crate with BPM electronics for one storage ring sector are being performed.

The storage ring button BPM pick-ups have been successfully prototyped in-house (Figure 2). A benchmark between the devices manufactured by LNLS and by external companies is underway.

The Sirius timing system has been developed in collaboration with the Shanghai Institute of Applied Physics (SINAP). SINAP will provide the event generators, event receivers and signal converters while LNLS is responsible for designing the remaining electronics that will deliver clocks, triggers and events to BPM electronics, general diagnostics instruments and beamlines. Most of the equipment has already been manufactured and is currently under test at LNLS.

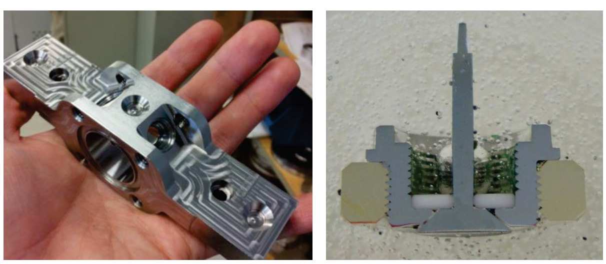

Figure 2: Sirius storage ring BPM body (left) and button metallographic section (right).

CONTROL SYSTEM

After several performance tests, the following Sirius control system parts have been defined: the connectivity equipment, the low-level hardware, the physical communication medium, the communication protocols and the Single Board Computer (SBC) connections and interface. The system will be based on a mesh topology with redundancy and possibility of dynamic routing. The main branches will use 10 Gbps rate optical fibers. There will be two main client servers running on 10 Gbps networks. The high-level control software will be based on EPICS. Presently the developed hardware, firmware, and the protocol for interface between software and physical media are being tested.

MAGNETS

The booster and storage ring magnets have been contracted to a local company (WEG). A number of booster magnets have already been delivered and the remainder are under production (Figure 3). Storage ring magnets are being detailed and will soon be prototyped. Special attention has been given to increasing the fundamental resonance frequencies of quadrupoles and sextupoles by, for example, lowering their center of gravity with respect to the fixing point in the girder and increasing the stiffness of the clamping fixtures (Figure 4). Preliminary finite element simulations show that first harmonic modes above 300 Hz can be obtained for the quadrupoles.

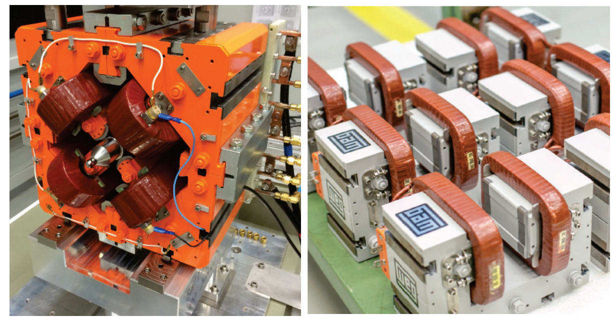

Figure 3: Booster quadrupole on measurement bench and booster horizontal/vertical correctors.

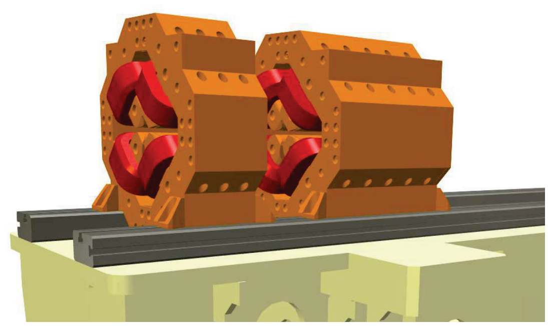

Figure 4: Integrated design of storage ring quadrupoles and girders. To increase the fundamental resonance frequency of the system, the center of gravity of the magnets with respect to the fixing point in the girder has been lowered and the stiffness of the clamping fixtures has been increased.

POWER SUPPLIES

A digital 150 ps resolution PWM controller for the power supplies has been developed and tested with a ±10 A power supply. The results show a long-term stability (60 h) better than ±10 ppm after a warm-up time of 3 hours, during which the drift is -30 ppm. The measured ripple from 10 Hz to 1 kHz is 10 ppm rms and the non-linearity is less than ±15 ppm with respect to full scale.

RF SYSTEM

Following LNLS experience with the existing storage ring, both Sirius booster and storage ring 500 MHz RF cavities will be driven by solid-state amplifiers (SSA). The booster 50 kW SSA for the Petra 5-cell cavity is being assembled and will be tested with a resistive load by the end of 2015.

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PULSED MAGNETS

A prototype for the booster kickers has been produced and characterized. This first prototype, that produces a trapezoidal waveform using thyratron tube as switch and coaxial cable as pulse forming line, was measured with a titanium coated ceramic chamber. Although the results met the specifications, a second prototype version that produces a half-sine waveform and uses thyristor as switch and capacitors as pulse energy storage, was assembled and is under test. The ceramic wall thickness will be reduced from 6 to 3 mm in this second version.

Pulsed Multipole Magnet

A pulsed multipole magnet (PMM) for injection into the storage ring has been designed and a prototype is under production. The design aims at producing a pulsed B_y magnetic field with a flat zero field region in the center and a maximum 8 mm away from it. A vertical aperture of 9 mm has to be preserved for the beam. A nonlinear field distribution similar to that achieved at Bessy-II [4] but with closer and stronger maximum is obtained with the configuration shown in Figure 5. A pulser circuit has been designed to provide a half-sine pulse of 1.64 µs, 1 kA and 6 kV. The PMM design requires the fabrication of a challenging alumina tube with length of 0.5 m, top and bottom wall thickness of 1 mm and tight mechanical tolerances. Figure 6 shows a very promising prototype alumina tube that was produced by a Brazilian company (ENGECER).

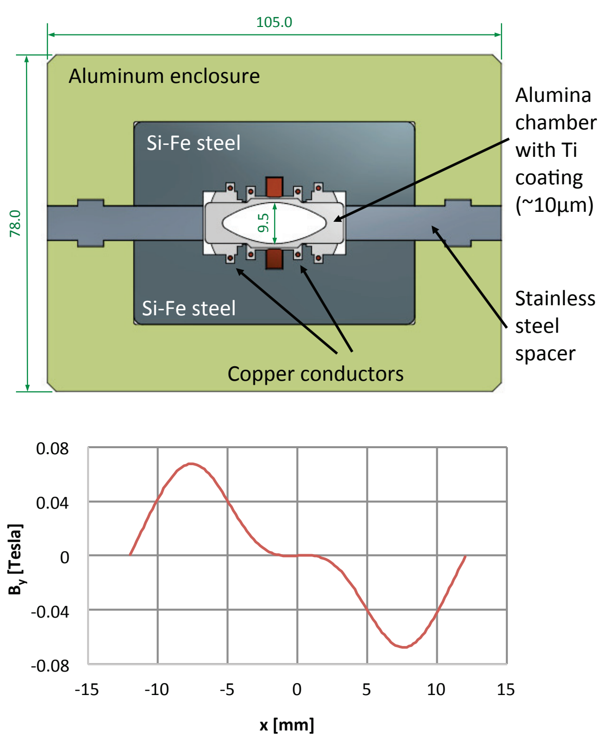

Figure 5: Pulsed multipole magnet design and calculated B_y magnetic field profile. A peak field of 70 mT is obtained at x=7.8 mm from the center.

Figure 6: Prototype of alumina tube for the pulsed multipole magnet produced by ENGECER.

GIRDERS

A setup for characterization of a first girder prototype has been assembled to measure its resonance frequencies and its interaction with the concrete pedestals and floor (Figure 7). Loads have been placed on the girder with the same mass and center of gravity as the real magnets. By locking the girder to the pedestals it is possible to reach 120 Hz for the first vertical mode and 60 Hz for the horizontal. The cause for the low horizontal frequency has been identified (it is related to the pedestal) and a second version is being developed in an integrated way, including the girders and the final design of the magnets.

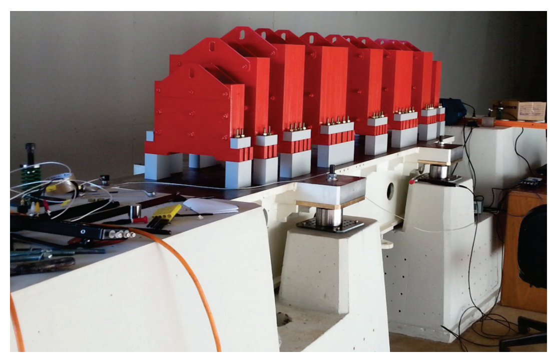

Figure 7: Setup for characterization of the initial girder and pedestal prototypes.

MACHINE FLOOR

After a thorough analysis of the different solutions adopted for the floor at other facilities, two models were selected for prototyping at LNLS site: one similar to Diamond/Soleil with piles and another similar to MAX-IV with a thick layer of soil-cement. The results show that although both types have similar performance regarding vibrations generated far away from the floor, for vibrations generated on the floor itself, the MAX-IV-type has a considerably better response. The final choice for Sirius is a combination of the two types, with piles for the long-term floor stability and with a 4-meter thick layer of soil-cement to improve the response to vibrations.

ACKNOWLEDGEMENTS

The design and construction of Sirius is a collective work that involves the entire LNLS team. We would like to acknowledge everyone who has been contributing to the development of this project.

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