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SIRIUS STATUS UPDATE

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Abstract

Sirius is a 4th generation 3 GeV low emittance electron storage ring that is in its final installation phase at the Brazilian Center for Research in Energy and Materials (CNPEM) campus in Campinas, Brazil. Presently the injector installation is complete, and the storage ring installation is being finalized. Most subsystems are under test and tuning in real working conditions. Six beamlines are also under construction. In this paper we report on the Sirius main subsystems installation status.

INTRODUCTION

Sirius is a new light source in Brazil based on a low emittance 3 GeV electron storage ring with 518 m circumference. The storage ring natural emittance of 0.25 nm.rad is reached with twenty 5BA lattice cells and it can be further reduced to 0.15 nm.rad as insertion devices are added. Sirius will be an international multiuser research facility with up to 37 beamlines: 20 from permanent magnet superbends reaching peak magnetic field of 3.2 T (and therefore 19 keV critical photon energy); 4 from insertion devices at high beta sections and 13 at low beta sections. The low beta sections are optimized to maximize brightness from insertion devices by matching the electron beam and undulator radiation phase spaces. In these low beta sections, where the horizontal and vertical beta functions are simultaneously reduced to 1.5 m in the center, small horizontal gap devices such as Delta undulators can be installed. Sirius main parameters can be found in [1].

The injection into the storage ring will be based on conventional off-axis accumulation in the horizontal plane using a non-linear kicker (NLK). The injection system is composed of a 150 MeV Linac and a full-energy synchrotron booster with 497 m circumference, built in the same tunnel and concentric with the storage ring. The booster has a very small emittance of 3.5 nm.rad at 3 GeV that is essential for a high injection efficiency using the NLK.

The Sirius project has effectively started in July 2012 when the decision to change to a low emittance 5BA lattice was taken. Presently the injector installation is complete, and the storage ring installation is being finalized. Most subsystems are under test and tuning phase in real working conditions, in particular, the high-level control system, the booster ramped and pulsed power supply systems, the single-pass and turn-by-turn diagnostics, the timing system, the radiation and personal protection systems and hydraulic and air conditioning systems. A 150 MeV beam from the Linac has already made several turns in the booster, but with no stored beam since the RF system is not ready yet. The storage ring installation activities in the same tunnel also limits the available periods for booster tests with beam. Storage Ring commissioning with beam is expected to start September this year. Six Phase-I beamlines, described in [2], are under construction.

Figure 1 shows an aerial view of the Sirius site and Figure 2 shows part of the experimental hall. Figure 3 shows the main accelerator tunnel.

Figure 1: Aerial view of Sirius building with the city of Campinas in the far background and CNPEM campus on the right near background.

Figure 2: View of Sirius experimental hall with the experimental hutch of beamline MANACA under construction.

MAGNETS

All Sirius electromagnets, fabricated using stacked laminations by the Brazilian company WEG, have been measured and achieved the required mechanical and magnetic tolerances. These magnets are aligned by mechanical design on the girders, using reference surfaces, with no adjustment flexibility. All electromagnets are already installed on the girders and the girders, in turn, have been pre-aligned on concrete blocks in the tunnel. Presently the

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vacuum chambers are being installed. The permanent magnet superbends in the center of the achromatic arc will be the last magnets to be installed for safety reasons.

The 20 permanent magnet superbends where fabricated in-house and reached an average peak field of 3.28 T. The measured rms spread of the integrated dipole component is 0.01% and for the quadrupole component the rms spread is 0.06%. These numbers are within specification tolerances.

Figure 3: Accelerators tunnel with the completed booster installation (inner accelerator) and a storage ring sector being assembled.

ALIGNMENT

As for the alignment, current work is concentrated on the pre-alignment of the Storage Ring. The 220 girders that support the magnets are already in place, and the magnets were previously positioned on them by mechanical design. This assembly approach relies on precise reference surfaces and is performed using specific mechanisms to speed up the process and guarantee an internal alignment within specification [3]. The positioning of the girders was a standard measurement assisted operation guided by laser trackers. This procedure, however, used the external faces of the magnets to mount fit-for-purpose target holders, without the need of fixed fiducials on any component [4]. The alignment team is now occupied with the correct positioning of BPMs and pumping stations, and these activities are being conducted sequentially as the vacuum system is being installed.

As soon as the HVAC system is online and the tunnel temperature is stabilized, survey campaigns will be conducted in order to update the alignment reference network. Fine alignment will follow right before the beginning of the commissioning phase.

VACUUM SYSTEM

The installation of the vacuum system for the booster and LTB transfer line was completed in October 2018. All vacuum pressures on the injection system are lower than 5·10-9 mbar without beam, which is in accordance with the specifications. The vacuum system installations for the storage ring started in April this year (see Figure 4). Two achromatic arcs of the machine are installed, and the NEG activation is already successfully accomplished for the first one. The NEG activation process was carried out by an in-situ bake-out with the magnets in place, and by using a custom developed heating system [5]. The NEG-coated chambers were heated up at a temperature of 185 °C for 24 hours. The bake-out cycle and the vacuum pressure evolution can be seen in Figure 5. Although there was a leak in a Pirani gauge during the cooling down, the attained pressure, measured about 6 meters from the leaky gauge, can be considered reasonably good, 5·10-11 mbar. The leaky Pirani gauge was replaced after successfully venting the sector with CERN's developed Neon venting procedure [6]. 24 hours after the vacuum intervention, the pressure recovered the previous value, $6 \cdot 10^{-11}$ mbar.

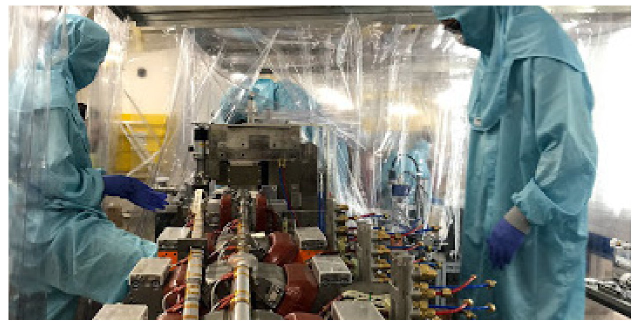

Figure 4: Installation of the Storage Ring vacuum system.

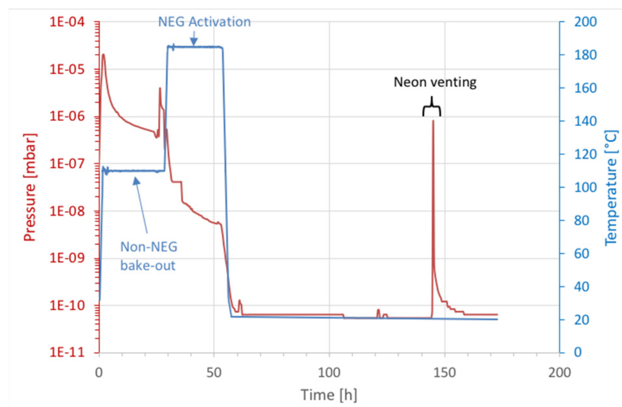

Figure 5: Bake-out cycle and vacuum pressure evolution in the first assembled Storage Ring sector.

The vacuum installations are advancing smoothly, and the Storage Ring should be completely assembled in July this year.

DIAGNOSTICS

The LTB and booster beam diagnostics components and cabling have been installed: energy slits, stripline and button BPMs, screen monitors, tune measurement system and visible light monitor. They are being regularly used during beam test shifts. For the Storage Ring, all in-vacuum diagnostics components are ready to be installed: button BPMs, shakers and stripline pickups for tune measurement system and bunch-by-bunch feedback (BbBFB) stripline and cavity kickers, with the exception of beam scrapers and post-septa screen monitor, which are still undergoing prototyping. The Streak camera, which is from the old machine and

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had its RF frequency customized for Sirius, will be delivered to LNLS within the next few months. Both BbBFB and tune measurement system racks are fully assembled and ready for measurements with beam.

After undergoing a 100-hour burn-in and performance tests procedure [7], all Sirius BPM electronics were successfully deployed. They are now fully operational and have been used for LTB and booster tests, as can be seen in Figure 6 and Figure 7. At present, all Storage Ring beam diagnostics cabling is being installed.

EPICS IOCs developments for beam diagnostics are now deployed and being improved to provide enhanced features for commissioning. For the next months, focus will be improving tune measurement and injection efficiency systems as well as implementing the fast orbit feedback system.

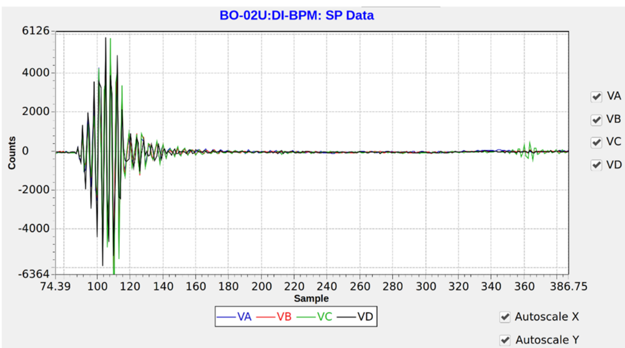

Figure 6: Signal from BPM showing the beam first turn in the Booster.

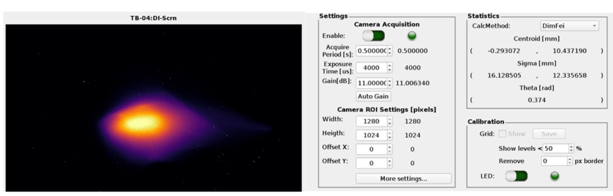

Figure 7: Beam image viewed in the last LTB screen.

CONTROL SYSTEM

Installation of the control system for Sirius accelerators started in March 2018, with the Linac assembly. Currently it is fully operational for the Linac, LTB transfer line and booster. The control system comprises 60 Ethernet switches connected through a 10 Gbps backbone, 2 servers and 140 BeagleBone Black embedded single-board computers. About 30000 process variables are available, which generate 40 GB of data per day in the archiving system.

Along with the deployment of storage ring control system, improvements are continually being made to the already working IT infrastructure, analog and digital hardware systems, EPICS IOCs, support applications and operator interfaces. The commissioning of all machine subsystems has provided good feedback information for the refinement of the control system. A more complete description is given in [8].

RF SYSTEM

The storage ring RF system is designed to operate with two SC cavities operating at 500 MHz. The design gap voltage is 3 MV and each cavity will be driven by 240 kW solid state amplifier. The cavities are being manufactured and are scheduled to be installed in the machine in 2020. For commissioning and initial operation for the beamlines a 7-cell cavity delivering 1.8 MV will be used with two 60 kW solid state amplifiers to drive it. These amplifiers were assembled in 2018 and were thoroughly tested at full power in the RF lab with a water-cooled load. The low-level system is a new version of ALBA digital LLRF. They were assembled and tested in the RF lab. See Figure 8. The booster and the storage ring RF systems are ready for installation. The booster 5-cell cavity is installed and under vacuum. The two systems will start to be assembled by mid-May 2019.

Figure 8: Storage Ring 60 kW SSA stored in the RF room on the left, and interlock and LLRF systems in the RF lab waiting for installation on the right.

POWER SUPPLIES

The Sirius power supplies (PS) were designed in-house and contracted to Brazilian companies for fabrication. The injection system PS are already installed and being tested for booster ramping conditions. The Storage Ring dipole PS are being installed, and the quadrupole and sextupole ones are being integrated to be tested before installation. Figure 9 shows a picture of Sirius PS room, with booster dipole PS at the forefront.

Figure 9: Sirius power supply room, with booster dipole PS at the foreground.

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