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SOLEIL STATUS REPORT

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Abstract

SOLEIL is both a synchrotron light source and a research laboratory at the cutting edge of experimental techniques dedicated to matter analysis down to the atomic scale, as well as a service platform open to all scientific and industrial communities. This French 2.75 GeV third generation synchrotron light source provides today extremely stable photon beams to 29 beamlines (BLs) complementary to ESRF. We report facility performance, ongoing projects and recent major achievements. A significant work was performed in order to secure the operation of the two canted 5.5 mm in-vacuum cryogenic permanent magnet undulators (CPMUs). Major R&D areas will also be discussed, and progress towards a lattice baseline for making SOLEIL a diffraction limited storage ring.

OPERATION UPDATE

Introduction

The SOLEIL facility [1] delivers extremely stable photon beams of high average brightness to 29 beamlines using photon energies in a range of ten orders of magnitude from the IR–UV–VUV up to hard X-ray. In daily operation, 27 diverse insertion devices (IDs) are freely controlled (gap/phase) by the users with the exception of an out-of-vacuum wiggler (W164) and an in-vacuum wiggler (WSV50) operating at fixed gaps. The storage ring (SR), whose main parameters are given in Table 1, hosts 2 in-vacuum CMPUs, 6 in-vacuum undulators (IVUs), 13 Apple-II type undulators, and 4 electromagnetics IDs in addition to the two wigglers.

Table 1: Storage Ring Main Parameters

Parameters	Values
Energy [GeV]	2.75
Circumference [m]	354.097
Natural Emittance [nm.rad]	4.0
Symmetry	1
Tunes (H/V)	18.155 / 10.229
Natural chromaticities (H/V)	-53/-19

Performance

Twenty-nine beamlines are now allowed to take photon beams after the last radiation safety tests for the PUMA and ANATOMIX beamlines. In 2017, 6228 hours were delivered with 5028 hours for beamlines. This year has been the second-best year ever in terms of performance with a beam availability of 98.7%, a meantime between failure of 92 hours and a meantime to recover of 1h12. Top-up injection was provided with a quality of service of 99.74% in all five very diverse filling patterns (Fig. 1) with the addition of the new Femtoslicing mode for the beamlines soft X-ray (TEMPO) and hard X-ray (CRISTAL) BLs.

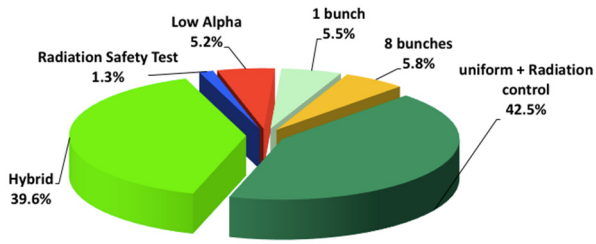

Figure 1: Distribution of the filling patterns for the Year 2017.

Improving Operational Processes

A special effort is being made in order to improve further more the operational processes in case of incident and problem management leading to a better traceability, better exchange of information. This allows the building of a knowledge database for maintenance of the current facility and for the construction of the forthcoming one.

FACILITY AGING AND MAINTENANCE

Facing an Increase of Water Leaks

During the last years the occurrence of low conducting water (LCW) leaks has been increasing. The locations of these are mainly focused on brazing joints, LCW hoses and their connections (SR quadrupole, sextupole, Booster dipoles, LINAC buncher, etc.). A task force has been freshly formed to address this issue and to study the LCW chemistry and specially its interaction with Cu cooling components. Control and follow-up of dissolved oxygen, pH regulation, corrosion are examples of parameters considered devising countermeasures to prevent any future major operational impact.

Maintenance, Redundancy, and Backup Modes

A special care is taken in terms of aging and forthcoming obsolescence of the facility in order to decide the type and the amount of maintenance to perform during shutdown periods for keeping the overall accelerator performance.

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Storage Ring RF-System

The refurbishment of the storage ring solid-state power amplifiers (SSPAs) continues at a rhythm of 2 towers a year; the use of new transistors leads to an efficiency increase from 50 up to 60% [2]. The last of the four new power cavity couplers was installed in January 2017 and tested as others up to 260 kW. In addition, modifications of the waveguide network with the use of SOLEIL Magic switches allow us to combine the power of 2 amplifiers per cavity. New backup modes are then available to maintain the maximum beam current in the hybrid filling pattern (450 mA), in case of an incident in one of the four RF plants or using only a single cryomodule. This will also be feasible in uniform filling pattern (500 mA) after completion of the SSPA refurbishment.

Power Supplies

A new power unit (± 35 V / ± 30 A / 1 kW) built in house was deployed to feed ID-FFWD correctors. Besides, work for improving reliability and redundancy of power supplies (PSs) continue with the construction of a spare PS for SR sextupole, BOO-to-SR transfer line dipole. Another type of spare PS will be built for electromagnetic IDs (HU640 and HU256).

Other Topics

A major upgrade of the software controlling the full chain of the LINAC was achieved last year. This is the result of more than 10 years feedback. Upgrade of the SF6 system, adding a new RF-coupler shall be done shortly.

A new processor from SPring8 is being integrated in the SOLEIL control in order to upgrade the three chains of the transverse bunch-by-bunch fast feedback.

Feasibility studies are starting to a major upgrade of two very sensitive and complex system facing hardware obsolescence viz. the control of RF-cryogenic plant of the SR and the main CTM/HVAC system. Technical solutions and strategy are under consideration in order to minimize the impact on the operation calendar.

MAJOR ACHIEVEMENTS

SDL13 Canted Straight Section Update

The long-term project of operating two canted long 5.5 mm gap in-vacuum CPMUs in a long straight section for long beamlines is reaching its end. The optics of this section presents a double low-vertical beta function to allow the simultaneous closing of the two 2 m long CPMUs [3, 4]. A dedicated CVD imaging diagnostics designed and constructed at SOLEIL for metrology purpose was installed in the frontend of the latter beamlines during the last summer shutdown. It is complementary to the double XBPM and can handle a maximum stored current of 6 mA. A new cryogenic U18 undulator designed, assembled, corrected, and measured at SOLEIL has been installed at the end of December 2017 and commissioned with success for the ANATOMIX nano tomography BL. This third built in-house CPMU, realized without pole shimming, shows a phase error below 3° at 77 K [5, 6], and extremely low magnetic errors (on-axis field integrals less than 0.15 G.m in both planes, integrated gradients less than 30 G and the off-axis horizontal field integrals less than 0.5 G.m and 0.4 G.m in horizontal and vertical plane). After an intermediate phase of operation with a 7 mm gap, the final beamline radiation safety tests with 5.5 mm gap shall happen during 2018.

Booster RF-System Upgrade

The present low-alpha operation mode suffers from a low injection efficiency (15-20%) due to the long Booster bunches getting partially lost during synchrotron oscillations in the SR. This puts heavy constraints on operation, requires safety radiation tests both for the accelerators and the BLs, and prevents more BLs to join this operation mode. To alleviate this problem, a second RF-system was first in-situ conditioned (inside a new safety radiation hutch) and then installed and put in operation during the first trimester of 2018. The new system consists of a 5 cell Cu RF cavity (a spare CERN cavity), a new 60 kW 352 MHz SSPA tower identical to the SR ones (10 dissipaters of 16 modules using 160 RF-modules of 400 W, based on BLF574 transistors and their DC-DC convertors); in addition the existing SSPA tower was powered up to 35 kW to increase the RF voltage from 1 MV to 1.2 MV. The primary goal is to increase the longitudinal focusing of the injected Booster to shorten their length. The expected gain in injection efficiency in the low-alpha mode is a 1.5 to 2 factor. As a secondary goal, this provides us with an operational spare cavity for daily operation if any failure occurs in one of the two RF-systems. Low-alpha mode commissioning and operation with this double RF-system and additional beamlines are expected in the coming months.

Femtoslicing Progress Status

Five weeks of Femtoslicing operation were delivered between June 2016 and February 2017. Starting from late 2016, two beamlines (soft and hard X-ray) can simultaneously benefit from this operation mode [7]. Since then the Femtoslicing operation is shut down for a major upgrade of the laser whose pattern will change from 25 fs/5 mJ per pulse/1 kHz up to 40 fs/4 mJ per pulse/10 kHz. Site acceptance tests are expected in autumn 2018 with a return in operation during the second 2019 semester. Meanwhile a dedicated THz beamline is being designed to follow online the electron/laser beam interaction. A new dipole vacuum chamber, slit Cu mirror and its optics similar to the current IR beamline shall be installed during the 2018 summer shutdown period.

Coupling Correction

Work to stabilize the vertical beam size irrelevant of the ID field values is progressing. With the addition of the second fully operational pinhole system, the coupling measurement repetition rate was increased to 50 Hz. It allowed the test of new feedforward systems installed around two IDs, consisting of dedicated air coils and

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Profibus control (HU36, 60 Hz control for 4 mm/s gap variation since 2016) and analog control (10-meter long HU640, fast switching of the main field at 1500 A/s, still in progress). In parallel, active work is realized to control the global coupling by using the Fast Transverse Feedback. It aims to excite a white noise instead of modulating a vertical dispersion wave. Final stability should fulfill the very stringent requirement of ±2% vertical beam size variation over 8 hours for Nano-BLs.

PROJECT UPDATE

A 2.75 T permanent magnet dipole will be designed and built for replacing the normal 1.71 T dipole source of the beamline ROCK. This BL works in absorption spectroscopy in the 4 to 43 keV energy range and wishes to increase its photon flux in the hard X-ray regime (factor 5 at 40 keV). The vacuum chamber design will also be modified to accommodate locally a magnetic gap of 17 mm (instead of 37 mm presently). The final design of the dipole is under study; the project shall end in 2020.

TOWARDS A MAJOR SR UPGRADE

A new candidate for the storage ring lattice of a diffracted limited synchrotron light source at SOLEIL is proposed [8]: a 72 pm.rad emittance lattice (50 pm.rad if a round beam is considered) of the 2.75 GeV storage ring would enable us with a 500 mA stored beam current to provide the highest coherent flux of any existing or currently planned storage rings in the selected photon energy range of 1 to 3 keV. The photon brightness exceeds by 2 orders of magnitude the present lattice one, with a value of 10^{22} photons/s/mm2/mrad2/0.1%bw. The photon beams are almost 100% coherent up to 200 eV, reaching 41% at 1 keV and 14% to 3 keV. First investigation showed that this emittance could be preserved if the IBS (Intra Beam Scattering) is mitigated using a harmonic cavity giving a factor of 5 bunch lengthening at 500 mA. Single bunch and 8 bunch operations are aimed to be preserved. Novel schemes of injection are proposed and still need to be demonstrated. Much more qualification work is needed to assess the robustness of the lattice with inevitable errors, and R&D needs to be carried out to assure the feasibility of such lattice (RF-system, mechanical integration, magnets, vacuum chamber, introduction of several 3 T dipoles for bending beam lines, dedicate extraction chambers for IR and VUV beamlines).

COLLABORATIONS

LUNEX5 Project

In the frame of the COXINEL project, undulator radiation from a transported laser-plasma accelerated beam has been observed [9-11]. Design and the characterization of high gradient permanent magnet quadrupoles with variable strength are reported in [12, 13]. Within the LUNEX5 project [14], the R&D LUCRECE was launched: it is a RF technology project for a CW LINAC (2016 – 2020) with the goal parameters: 20 kW 1.3 GHz SSPA using GaN instead of LDMOS transistors and LCLS2 type cavity.

ThomX Collaboration

Several groups still actively prepare the commissioning of the ThomX compact Compton Back-scattering light source of LAL laboratory [15]. The magnets and girders are installed (magnetic measurements are reported in [16]) and the pulsed magnets designed by SOLEIL team are being constructed by SIGMAPHI. There is currently involvement in the installation and commissioning of the 50 MeV LINAC; SR beam commissioning is expected in the beginning of 2019.

SESAME Collaboration

The four 500 MHz 80 kW SSPA's [2], supplied to SESAME [17] are in operation. The first one was designed and built by SOLEIL as a demonstrator; the 3 others were built on the same model by Sigma Phi Electronics (SOLEIL licensee). SOLEIL is also part of the OPENSESAME project to support the facility and maintain expertise on the machine in beamline side. SOLEIL conceived and designed the optical and mechanical design of the SESAME infrared beamline which is currently installed and shall be commissioning soon.

SOLEIL/MAX-IV Collaboration

Short period 3-meter long CPMU U15 is being built in the framework of the SOLEIL/MAX-IV collaboration [5-6]. A new SAFALI bench [18] will be used for the magnetic measurements at cryogenic temperatures.

The first prototype of a 400 mm long multipole injection kicker designed, assembled and tested with its control system at SOLEIL was successfully commissioned in MAX-IV [19] 3 GeV storage ring allowing a significant reduction of the beam orbit perturbation during Top-up operation. Magnet assembly and magnetic measurements were performed at SOLEIL. Residual orbit distortion reached values ± 13 and ±8 µm peak-to-peak values respectively in the horizontal and vertical planes at the center of the standard straight section. The final kicker is planned to be built by the end of 2018 and another device will be later installed in the SOLEIL SR. Investigation of anomalous heating observed on the kicker installed in the MAXIV 3 GeV ring is made in collaboration with MAXIV, along with other general instability issues.

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