

SOLEIL UPDATE STATUS

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Abstract

SOLEIL is both a 2.75 GeV third generation 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. It provides today extremely stable photon beams to 29 beamlines complementary to ESRF. We present the performance of the facility, the ongoing projects and the important achievements of the last two years. Major R&D areas will also be overviewed (Superbend, MIK, Beam size FB, Beamloss Monitors, NEG).

OPERATION

SR Parameters and Optics Evolution

The SOLEIL facility [1] delivers extremely stable, high average brightness photon beams to 29 beamlines (BLs) – 20 on insertion devices (IDs), 9 on bending magnets – with 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 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, accommodates 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	2.75 GeV
Circumference	354.097 m
RF frequency (harmonic number)	352.197 MHz (416)
Natural Emittance	4.0 nm rad
Symmetry	1
Tunes (H/V)	18.155 / 10.229
Natural chromaticities (H/V)	-53/-19

The SR lattice is based on a modified double-bend achromat structure with the leakage of the horizontal dispersion in the straight section [2]. It features a one-fold symmetry: The long straight section SDL13 hosts two canted long 5.5 mm gap in-vacuum cryogenic permanent magnet undulators (CP-MUs) accommodating a double low-vertical beta function

to allow the simultaneous closure of the two 2 m long CP-MUs [3–5]. Moreover since February 2019, the vertical beta function at the middle of the short section SDC03 has been lowered down from 3 m to 1 m to allowing the closure of the in-vacuum wiggler WSV50 at a magnetic gap value of 4.5 mm (flux by increased 30% at a photon energy of 70 keV) (Fig. 1). In multi-bunch filling pattern (500 mA), the average lifetime is on average 10 h (1% coupling and 2.8 MV RF-voltage) and the injection efficiency is 80%.

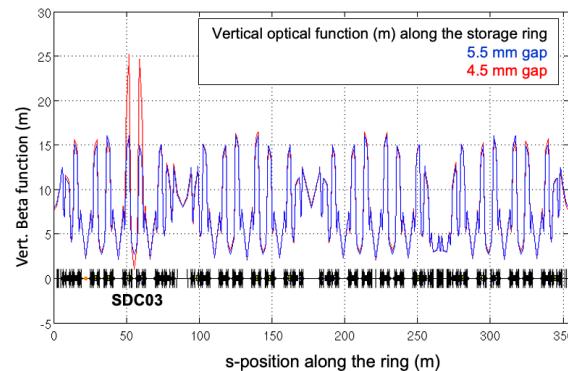


Figure 1: Vertical beta function along the storage ring before (blue) and after (red) adapting locally the focusing to allow the closure at 4.5 mm gap of the 2 m long in-vacuum undulator WSV50 installed in SDC03 short straight section.

Impact of the CoVid-19 Pandemic

The CoViD-19 crisis has impacted the 2020 calendar with a national lockdown of 7 weeks (reduction of the user beam and shortening of the May technical shutdown). The facility was successfully back online while establishing strict safety rules and protocols for the staff and the users. The control room was modified and side control room was created; remote access capability was enhanced, concurrent activities were minimized, with extended time during the start-up period after a shutdown and during the technical operations. Only few accelerators' projects were delayed, many were pursued thanks to the dedication of all the technical teams.

Accelerator Performance

Despite this very difficult national and international context with many restrictions, a total of 4096 hours was provided to the beamlines: 45.2% hybrid (450 mA), 47.4% uniform (500 mA), 3.5% 1 bunch (16 mA) and 3.5% 8 bunch (100 mA) filling patterns, and 0.4% for BL safety tests (Fig. 2). The beam availability of 98.8% and a large

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105 hours mean time between failure. With 18 weeks with more than 99% (including 9 weeks at 100%) beam availability, the performance was remarkable. Overall, since mid-May 2020, the original beam calendar has been respected, meeting to the high demand of user projects (All BLs requesting photon beams in addition to the contribution to national CoViD-19 effort).

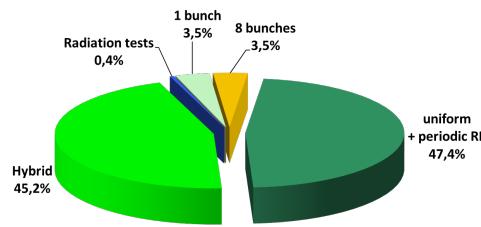


Figure 2: Filling pattern distribution during the year 2020.

OPERATION IMPROVEMENT

Thanks to a multi-year refurbishment of the solid state power amplifiers (SSPA) combined with the improved power combiners and the new cavity input power couplers (300 kW), the SR RF-system allows new backup modes of operation: 500 mA even if 1 of the 4 RF-stations is unpowered and 450 mA with a single cryomodules combining 2 SSPAs on each cavity.

A new versatile transverse feedback processor (SOLEIL/TED/SPring-8 collaboration) has been commissioned and installed to guarantee beam stability against collective effects. The system is based on 2 cascaded Virtex7, 11 fast ADCs and 12 DACs [6]. The system enables the development of additional features: the bunch cleaner, extended postmortem function; In July 2020, white noise capacity was added to be used in a beamsize feedback (see Project part).

Finally a new type of beam loss monitors has been installed inside the tunnel, all around the storage ring: 80 plastic scintillators with photomultiplier tubes allow accurate monitoring of slow losses by lifetime and fast losses during the injection. They are key diagnostics for the accelerator characterization and optimization [7]. Moreover, they will be intensively used by the radiation safety group to qualify the shielding walls for the SOLEIL upgrade.

OBSOLESCENCE

For several years, PLCs driving the IDs have been upgraded from TLCC to TM258 and a better management of the hardware errors in a reduction of the ID losses by more than a factor 2. As a preventive maintenance, the 4 permanent magnets chicane of the two long beamlines in SDL13 was replaced and commissioned in January 2020. Several systems are reaching the end of their life due to hardware obsolescence: timing system, BPM electronics, corrector power supplies, centralised technical management system of the fluid station. All these systems are scrutinized carefully

and an upgrade strategy compatible with the forthcoming upgrade is being built.

Regarding the future standard for the power supplies a collaboration the foreseen strategy for the control of all the needed power supplies is to use a universal control electronics platform. Having a single standardized controller is indeed a major advantage in terms of cost reduction, human resources / time required for system implementation, operation and maintenance, as well as obsolescence management. Amongst the solutions currently being studied, the CERN power converter control system [8] is notably being evaluated on the existing machine. This control platform, now available through licensing, is the standard at CERN in the medium and long term (2035 at least). After tests in a laboratory bench, first tests on the SR are ongoing.

MAJOR PROJECTS

Vertical Beamsize Feedback Upgrade

In addition to the requirement for position and angle stability of the BL photon source points, a few beamlines (PX1, PX2, ANATOMIX and NANOSCOPIUM) require a higher beam-size stability than currently achieved. The main perturbation is related to the ID configuration freely controlled by the BLs. Since July 2020, a new type of feedback has significantly improved the vertical beam size stability. Instead of modulating a vertical dispersion wave, a white noise is injected onto the beam using the new bunch by bunch transverse feedback processor: a 2 Hz feedback improved the vertical beam size variation to 0.7% and less than 2% during slow and fast ID motions, respectively (Fig. 3).

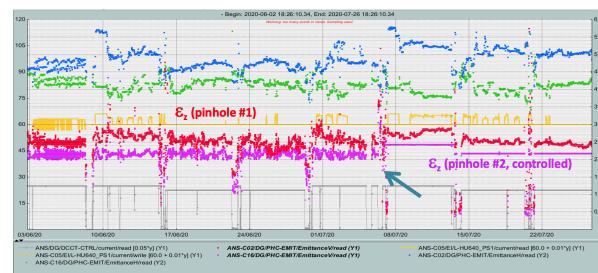


Figure 3: Vertical beam size stability improvement before (left) and after (right) the upgrade of the feedback.

Multipole Injection Kicker

As a key element for making a compact injection scheme, the Multipole Injection Kicker (MIK) has been fully assembled and magnetically characterized. Its sapphire chamber was coated at ESRF with a thin Ti layer to allow the image current to flow (Fig. 4). This MIK version is a copy of the device designed for MAX-IV and used in daily operation [9]. Its installation was scheduled in January 2021. First injection and accumulation with 87% efficiency were reached in April 2021 as further detailed in [10].

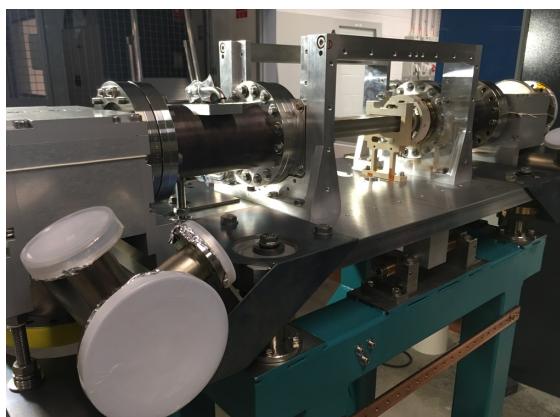


Figure 4: MIK element with its CuCr1Zr absorber installed on its chassis before installation into the storage ring.

Photo Stimulated Desorption Front-End

Finally, a photo stimulated desorption beamline was installed on the exit port of a dipole in the ARC08 (Fig. 5) aiming to qualify narrow NEG coated chambers by measuring the dynamic pressure as a function of the photon dose. Two chambers of 63 mm and 20 mm diameter were already tested successfully showing the expected conditioning behavior. Smaller diameter chambers (10 and 6 mm) foreseen for the upgrade [11].

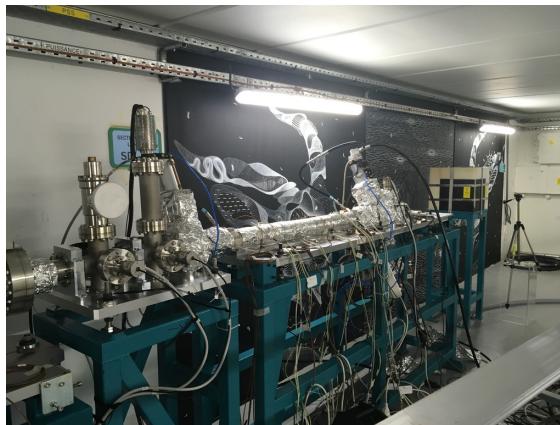


Figure 5: Photo Stimulated Desorption beamline using the photon beam produced by the 1.71 T dipole source D08-1 with its first test chamber (diameter 63 mm).

PM-based Superbend for the ROCK Beamline

The superbend project for the ROCK BL is well on track: a 11.25° dipole will be replaced by a C-shaped permanent magnet (PM) based superbend. Fully designed and assembled in-house, magnetic measurements have started (Fig. 6). Its magnetic field will rise locally from 1.71 to nearly 2.8 T (reduced gap of 16.1 mm) allowing a factor 5 increase in flux at 40 keV photon energy. The vertical narrower gap dipole chamber was installed early 2021. The 10-day superbend commissioning is expected in late August 2021. This work provides the know-how to build PM-based magnets

which will be one of the core technologies for the SOLEIL upgrade [11].



Figure 6: ROCK permanent magnet-based dipole ready waiting magnetic measurement.

Funding of a New Cooling Station

At the end of 2020, the construction of a new cooling station with its building was financed (12.7 M€) by the French economic recovery plan. This large-scale project will make it possible to deal with the serious obsolescence of the present cooling station and to achieve significant savings (water consumption reduced by 80%, and significant electricity savings thanks to environmentally-friendly technology and energy-saving equipment). Civil work will start early 2022 and the new station will be connected to the main technical infrastructure in the second part of 2024 while being compatible with the upgrade project of the accelerators and beamlines.

UPGRADE TO A DLSR

The upgrade project is at the end of the conceptual design phase report [11, 12]. It aims to transform the SR into a diffraction limited light source (DLSR) providing round beam with an emittance of 50 pm rad in both planes using a very compact 7BA-4BA lattice [13]. This new facility shall be complementary to ESRF-EBS [14]; the scientific case is organized in the four areas which have been identified as key to meet the challenges our society is facing (advanced materials, sustainable energy, biology and health, earth and the environment). A more detailed description of the project with the expected performance and the very intense R&D effort that accompanies it are described in detail [11–13, 15–19]. An outcome of the study is the need to upgrade also the booster ring to reduce the emittance value from 147 down to 10 nm · rad [20].

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