SOLEIL: Status & Upgrade

Laurent S. Nadolski
on behalf of the Accelerators and Engineering Division
• **SOLEIL 3GLS facility**
  – SOLEIL operational status
  – Selected highlights
  – CoViD-19 challenges on organization and operation

• **SOLEIL upgrade Status towards 4GLS**
  – CDR phase
  – Challenges
  – Tentative schedule
Location: France

Circumference: **354 m**

**24 straight sections**
(variable length)

- SDL: 4 x 12 m
- SDM: 12 x 7 m
- SDC: 8 x 3.6 m

One long straight section (SDL13, accommodating 2 canted long beamlines) has been modified
# Beam Time Schedule in 2020

**Beam availability:** 98.7%

**MTBF:** 100h

<table>
<thead>
<tr>
<th>CoViD-19 lock-down: 7 weeks</th>
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## Beamline and radiation safety test (4096 hours)

Beam time according to filling patterns

### 29 beamlines

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<tr>
<th>CoViD-19</th>
<th>Beamlines</th>
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<tbody>
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<td>29</td>
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### Radiation tests

- **1 bunch:** 0.4%
- **8 bunches:** 3.5%, 3.5%

### Beamline Types

- **Unif orm**
- **Hybrid**

### accelerator types

- **8 bunches**
- **1 bunch**
- **Low - Alpha**

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28th ESLS Meeting (ESRF), 16-17 December 2020, L. Nadolski
Efficiency during beamlines and radiation safety sessions in 2020

3825 hours of beamtime delivered
represent a beam availability of 98.7 %
until the 6th week of RUN 5

98.7% 98.9% 98.9% 98.3% 98.8% 99.1% 99.5% 98.7%
1.3% 1.1% 1.1% 1.7% 1.2% 2.0% 0.9% 0.4% 1.3%

2017 2018 2019 RUN 1 RUN 2 RUN 3 RUN 4 RUN 5 2020

80% 90% 100%

Dead time due to failures
Injections
Available beam

Efficiency during beamlines and radiation safety sessions in 2020
3825 hours of beamtime delivered
represent a beam availability of 98.7 %
until the 6th week of RUN 5
Origin of the 50 hours without beam in 2020
(until the 6th week of RUN 5)

Utilities 14h21
(28.60%)

Power outage 02h17
(4.55%)

Others 02h04
(4.12%)

Human errors 00h56
(1.86%)

RF 07h58 (15.88%)

Power supplies
02h02 (4.05%)

Magnets and IDs
02h08 (4.25%)

Electronics and
Acquisition (ECA)
01h49 (3.62%)

Controls (ICA)
00h20 (0.66%)

Vacuum 01h48
(3.59%)

Diagnostics 01h20
(2.66%)

Beamline 01h29
(2.96%)

PSS 10h26 (20.80%)

Control Room 01h12
(2.39%)
Radiation induced aging of many water cooling hoses

Preventive and corrective maintenance

Exuding water along the hose (1 drop/sec)

All hoses downstream to dipoles and located on the external side of the tunnel are to be replaced
An aging facility: increase of flowmeter faults

Clogging of waterflow reducers leading to an increase of flowmeter faults

Even with a large cleaning campaign 2 years ago for all the BPMs

ELETTA flowmeter: retuning regularly by reaching the lower limit (radiation damage of the membrane ?, calibration), need of a dedicated maintenance or partial replacement after more than 15 years of operation

CuO deposit (black) blocking the diaphragms of the 21°C water cooling circuit
Selected Highlights

Major update since ESLS’19

- New coupling feedback with white noise
- Multipole Injection Kicker project
- Superbend project
- Photo Desorption “BeamLine”
- New set of beam loss monitors

New Beam size Feedback

- Use of noise generator at minimum of coupling (TFB processor) instead of exciting a vertical dispersion wave
  - Step 1: Slow feedback 2 Hz (in operation)
  - Step 2: Fast feedback (to be evaluated)
Installation of the MIK @ SOLEIL

Installation of the MIK in an available Short Straight Section

Courtesy of Rachid Ben El-Fekih

Update (since ESLS 2019)
- Ti coating of Sapphire Chamber (ESRF)
- In-house magnetic measurements
- Test of new types of absorbers

Installation: January 2021 (preparing the upgrade)
- Test the MIK concept on SOLEIL: efficiency, orbit perturbation.
- Test of injection schemes in the framework of the upgrade studies
- On axis Injection with Transverse kick combined with longitudinal kick with the RF

Same geometry as the one installed at MAX-IV
https://doi.org/10.1016/j.nima.2020.164739

CâV  Vanne  Taper (Amont)  Mini-absorbeur (Amont)  MIK  Mini-absorbeur (Aval)  Taper (Aval)
Dedicated Photo Desorption Beamline for the upgrade

Balance between Photon Stimulated Desorption yield $\eta$ & the NEG Pumping speed / saturation-capacity

$\Rightarrow$ For 10 mm diameter chamber $\Leftarrow$

On the ring
PSD $\eta / \text{Dose}$ of photons
- Activation NEG with SR ?
- Pumping CH4?

In the LAB
- Intrinsic pumping speed of the NEG $S^{\text{NEG}}$
- Capacity/saturation with Injection gas pure/µleak H2, CO, CO2, CH4.....

What would be the dynamic pressure and its evolution with the photon DOSE

2 TEST BENCHES @SOLEIL

First chamber tested (63 mm diameter)
Successfully during fall 2020

Characterization bench

28th ESLS Meeting (ESRF), 16-17 December 2020, L. Nadolski
3T Superbend Project (ROCK BL)

Permanent magnet dipole (NdFeB)
Length 1.260 m

Gap 16.1 mm
B = 2.84 T

Gap 23 mm
B = 1.81 T

A C-shape yoke which allows the removal of the magnet for bake out

Inside storage ring

Magnet remove device for bake out

Installation: January 2021

Installation in August 2021

Courtesy of Pascale Brunelle

Calculation at 8700 mm from the source point for an opening of 13 x 2.4 mm².

Present bending magnet: 1.71 T

Superbend: 3 T

Flux (photons/s/0.2%bw)

Energie des photons (keV)

28th ESLS Meeting (ESRF), 16-17 December 2020, L. Nadolski
80 New Beam Loss Monitors across the storage ring

- Average data (13 Hz)
- Turn by turn (injection)
- Fast measurement

Upgrade: radiation safety
Measurements vs FLUKA simulations for qualifying the shielding walls
CoViD-19 impact

• Coordination and organization
  – Crisis Meeting once a week
  – Heavy work (safety, communication, crisis cell) to produce adequate documentation, safety and training sheet, answering questions...
    • On-line training for all the staff & making the working environment safe
    • Psychosocial risk (PSR), etc.
  – Maintaining the link with the employees: a newsletter « Informations Confinées ».
  – Facility Shutdown (national lock-down) for 7 weeks (16 March – 11 May)
  – 11 May : going back progressively to work (4-5 main phases)
    • Phase 0 (May 11th - June 22nd): operation with highest priority.
    • Phase I (June 22nd – July 6th): ~50 % of technical staff on site. Everybody has to come back at least once. Authorization still necessary to enter the site.
    • Phase II (June 22nd - July 6th): staff at least present 2 days a week. Number of people in a room only limited by the 4m² rule, or mask.
    • Phase III (from August 31st): Max of 2 days home office per week.
    • Phase IV (from October 30th) : 2nd lock down. Almost normal operation. Teleworking is the rule when possible. A few cancellations (Users).

  – Supporting the economic activity
    • From June 2nd, service provider back on site
    • Corporate restaurant, guest House, etc.

• Remote Access
  – Allowing a maximum number of people to telework
    • Generalization of remote Access to the Accelerators
  – Rescaling of IT architectures and purchasing VPN, Microsoft TEAMS, etc. licenses.
  – Adaptation of workplaces
  – Creation of a task force for remote access of the beamlines (29 BL working, 5 CoViD BLs, 1/3 Mail-In, 1/3 partial or total remote access)
SOLEIL Upgrade News and Status

Reference:
R. Nagaoka, SOLEIL Upgrade, 8th Low Emittance Rings Workshop LER2020, INFN-LNF, Frascati, Italy, 26-30 October 2020

Emittance comparison for 3rd and 4th Generation Light Sources on Storage Ring

Horizontal emittance (nm.rad)

Circumference (m)

3rd Generation

4th Generation

CDR Lattice Reference (V0313)

Injection

$\beta_x \sim 11m$
$L = 7.35m$

$\beta \sim 1.5m$
$L = 4.150m$

$\beta \sim 1.1m$
$L = 2.730m$

$L = 7.65m$
Chicane and quadrupole triplet to be added

80 pm.rad  2.75 GeV  354 m  7BA - 4BA
20 cells
20 beamline source points on Insertions.
4 superbend (3 T) beamlines.
Several beamlines on 1.7 T
2 IR + 1 UV beamlines
All photon extractions compatible with shielding walls
Entire layout of the CDR lattice: “HOA 7BA-4BA symmetry 2”

Main characteristics of the magnets used for the CDR lattice
- **Permanent magnets** for dipoles and reverse bends
- Need of **strong** sextupoles and octupoles
Present CDR reference lattice [2/3]

Lattice CDR lattice upgrade Current lattice

| Symmetry | 2 | 1 |
| Energy [GeV] | 2.75 | 2.75 |
| Circumference [m] | 353.74 | 354.10 |
| Straight ratio [%] | 24 | 46 |
| Number of straight secs | 20 | 24 |
| RMS Natural H. emittance [pm rad] | 81 | 4000 |
| RMS Coupled H&V Emittance [pm rad] | 53 | |
| RMS Energy spread [%] | 0.09 | 0.10 |
| RMS Natural Bunch length [ps] | 9.182 | 15.17 |
| | [mm] | 2.7 |
| Harmonic number | 416 | 416 |
| Main RF frequency [MHz] | 352.56 | 352.20 |
| Energy loss per turn W/o ID [keV] | 490 | 917 |
| RF Voltage [MV] | 1.38 | 2.9 |
| Momentum compaction factor [-] | 9.1E-05 | 4.4E-04 |
| Synchrotron frequency [kHz] [turns] | 1.4 [600] | 4.5 [190] |
| Damping times (H/V/L) [ms] [turns] | 7.3 / 13.1 / 11.7 / 6000 / 11000 / 10000 | 6.9 / 8.9 / 3.5 / 5800 / 5600 / 2900 |
| Nominal tunes (H/V/L) | 54.2 / 18.2 | 18.16 / 10.22 |
| Natural chromaticities (H/V) | -108 / -65 | -53 / -19 |
| Corrected chromaticities (H/V) | +1.6 / +1.6 | +1.3 / +2.2 |

On-momentum Frequency Map Analysis (FMA) at injection point

Off-momentum Frequency Map Analysis (FMA) at injection point

Left: Local energy acceptance along ¼ ring

$\tau_{\text{Touschek}}$ at 500 mA:
~3.5 hours **100% coupling**
~1.5 hours **10% coupling**
w/o bunch lengthening
Present CDR reference lattice [3/3]

Half physical aperture along the ring including in-vacuum insertion device gaps

Studies of
- Lattice tuning flexibility
- 1st-turn steering
- Robustness against errors launched with specific BPM-correctors (dipolar, normal and skew quadrupolar) configurations
Top-up Injection schemes developed [1/2]

- Two injection schemes are developed and studied at SOLEIL using a MIK (Multipole Injection Kicker), with the experience of developing one which gave success at MAX-IV: “betatron off-axis” and “synchrotron on-axis” injections

- In both cases, MIK deflection at $\Delta x = -3.5 \text{ mm}$ from the stored beam location

- Injected beam at $\delta = -2\%$ for synchrotron on-axis injection

In betatron off-axis injection, nonlinear tune shifts with amplitude are adjusted to enable “dissonance” for the injected beam

Left: Horizontal beta bump for betatron off-axis injection with tunes (54.20, 18.20). Right: Horizontal dispersion bump for synchrotron on-axis injection with tunes (54.16, 18.16)

- In both schemes, beam is injected to a ring tuned to a coupling resonance and the stored beam is fully betatron coupled
H and V beam envelopes over 900 turns after injection for both injection schemes, w/o error at injection nor in storage ring. Ring working point is set at full coupling. $(\epsilon_H)_{\text{inj}} = (\epsilon_V)_{\text{inj}} = 5 \text{ nm.rad}$, $\sigma_L = 25$ ps for betatron and 35 ps for synchrotron injections.

<table>
<thead>
<tr>
<th>Positive aspects</th>
<th>Negative aspects</th>
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| **Betatron off-axis** | • Allow straightforward implementation in injection straight  
• Pulse magnets specs comfortable | • Sensitivity to lattice errors  
• Need of a large DA  
• Injection beam envelopes have smaller margins against ID gaps |
| **Synchrotron on-axis** | • Relaxed DA requirement  
• Less sensitivity to lattice errors  
• Reduced injection beam envelopes | • Explicit lattice modifications with a dispersion bump  
• Need of larger off-momentum DAs  
• More demanding MIK specs |

⇒ Both schemes to be pursued further
Magnet Prototypes

Quadrupole = 140 T/m (7 X today) Sextupole = 8000 T/m² (25 X today)

Extensive use of permanent magnets

- **Quadrupole**
  - Procurements by the end of 2020
  - In-house assembly by the end of 2020
  - Magnetic measurements First semester of 2021

- **Combined dipole (Permanent magnet)**
  - Assembly and magnetic meas. Mid 2021

- **Multipurpose sextupole**
  - Assembly and magnetic meas. Mid 2021

- **Multipurpose octupole**
  - Assembly and magnetic meas. Mid 2021
Main CDR Milestones

• 4 reviews held during the last 6 months
  – Ultra-vacuum system review (11-12 June 2020)
  – Magnet Review (2-3 July 2020)
  – Lattice and Injection Review (7-8 September 2020)
  – Girder Review (17-18 November 2020)

• SOLEIL SAC (16-17 November 2020)

• SOLEIL council (14 December 2020)

• Mini-MAC to close the CDR phase (February 2021)
Tentative Planning and Objectives

December 2018
Council authorization to produce the Conceptual Design Report (CDR)

December 2020
Decision to launch a Technical Design Report?

2022
Decision on the realization of the SOLEIL Upgrade?

End 2027
Restart of SOLEIL

2016 - 2018
Preparation of the SOLEIL Upgrade project (Documents, etc.)

Writing of the CDR

2021 – 2022
Writing of the TDR

2023 – 2027
Implementation of the SOLEIL upgrade
Conclusions

• **Despite a very special year due to CoViD-19 crisis**
  – Operation with extremely good performance (7 weeks operation lock-down)
  – All 29 beamlines work 24/7
  – Small delays concerning major projects of the accelerators

• **Upgrade**
  – Ending the CDR period:
    • a first strong lattice candidate answering major criteria (performance, impact on shielding, number of BLs)
    • A strong scientific case
  – Preparing TDR phase
    • Entering prototyping phase (magnet, vacuum, girders, injection, diagnostics, RF-system, insertion devices, etc.)
    • **Critical phase for the mechanical integration**, extraction of the photo beams, etc.
    • Robustness and tuning capability of the lattice
    • Choice of ex/in situ backing out, NEG and pumping capacity of 6-10 mm diameter chambers
    • New Booster design
    • …
Questions?

Acknowledgments

- A. Nadji, R. Nagaoka
- X. Delétoille, J-F. Lamarre
- Accelerator Physics Group