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SOLEIL Upgrade Project and Foreseen Beam Instrumentation

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Abstract

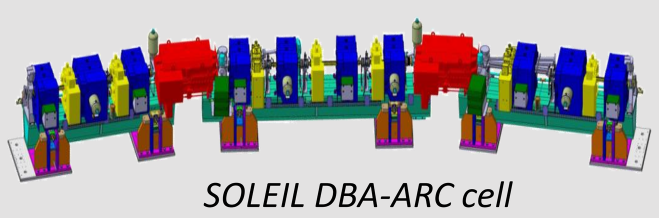
SOLEIL Synchrotron has an upgrade plan to replace its storage ring by a new one based on multi-bend (7/4BA) achromat lattice. The Conceptual Design Report (CDR) has been published recently and the Technical Design Report (TDR) phase should be finished for the end of 2023.

For the beam instrumentation, most of the equipment will have to be replaced, to overcome cases of electronics obsolescence and to fulfil the new tight requirements. Among them, the most challenging ones are the micron resolution transverse beam size measurement, the beam position monitoring and the stability feedbacks. The present machine will be used to validate some prototypes and it is planned to upgrade part of the diagnostics ahead of the dark period to speed-up the commissioning of the new storage ring.

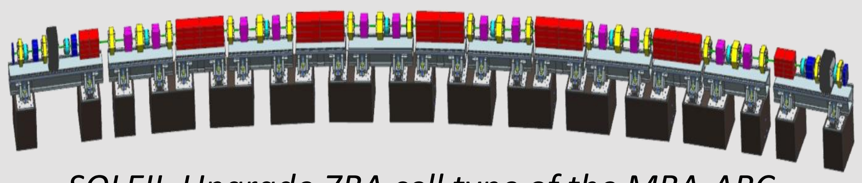
This poster presents the diagnostics systems that are foreseen for the SOLEIL upgrade project.

SOLEIL UPGRADE PROJECT

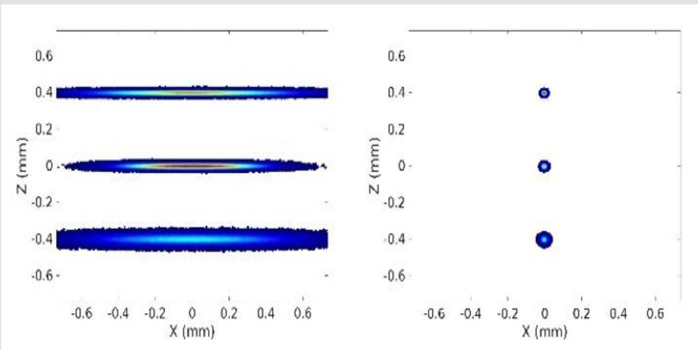
- **Multi-Bend Achromat lattice: Horizontal natural emittance: ~80 pm.rad at 2.75 GeV (wo IDs)**
- **20 alternating 7BA and 4 BA higher order achromat cells.**
- **Emittance reduction by two orders of magnitude at source points.**
- **ID source point position unchanged to reuse the existing tunnel.**
- **Vacuum chamber aperture: 12 mm**
- **CDR published in July 2021.**
- **TDR for the end of 2023.**



SOLEIL DBA-ARC cell



SOLEIL-Upgrade 7BA cell type of the MBA-ARC



Comparison of the transverse beam profiles of the pre-sent SOLEIL (left) for the three straight sections with 1% coupling and SOLEIL Upgrade CDR reference lattice (right) with 50 pm.rad emittance in each plane.

Current and future beam and machine parameters (most relevant):

	SOLEIL	SOLEIL-Upgrade
H. Emit. [pm.rad]	4000	80
V. Emit. [pm.rad]	20.3	80
H. Beam Size (min value at source point) [µm rms]	180	7.4
V. Beam Size (min value at source point) [µm rms]	8	2.8
BPM Aperture [mm]	84x25	16
Pos. and Angle Stability (wrt size and divergence)	10%	2-3%
Orbit Feedback Efficiency	200 Hz	1 kHz

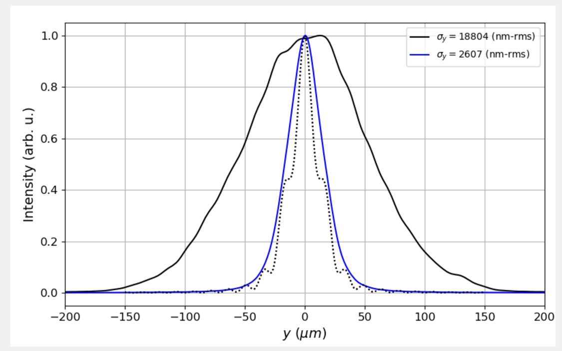
FORESEEN BEAM INSTRUMENTATION

SOLEIL Upgrade diagnostics systems:

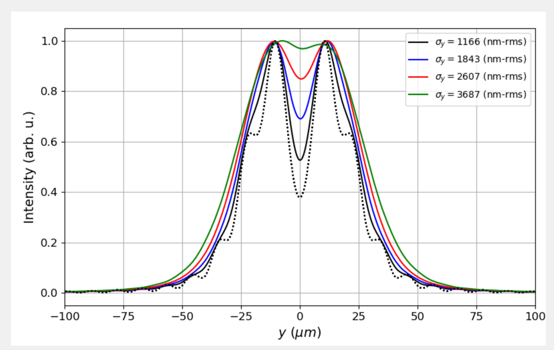
Parameter	Type	Quantity
Emittance	X-ray: PHCs/Fresnel Visible: Interferometry/Pol.	2 1
Position	RF-BPM X-BPM	~176 ~30
Current	DCCT	2
Filling	BPM + fast digitizer APD + fast digitizer	1 1
Purity	APD +TCSPC	2
Length	Streak Camera	1
Losses	Scintillators + PMT	~80
Dosimetry	RadFET	~40
Tune	BPM + Shaker Magnet	1

Transverse Beam Size:

- Two modes for the X-ray measurement:
  - **High repetition rate** (~100 Hz) for user operation ⇨ **Pinhole camera**
  - **High resolution** (~1 µm) for machine studies ⇨ **Fresnel diffraction**
- 2 identical systems for redundancy
- High field (3T) dipole for the source
- Additional measurement in the visible can be implemented (direct imaging or diffraction in σ/π polarization)

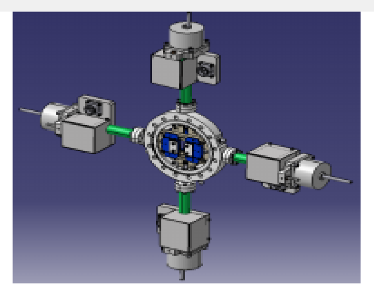


Expected resolution with a pinhole: 5 µm RMS with enough flux for a ~100 Hz repetition rate. SRW simulations.



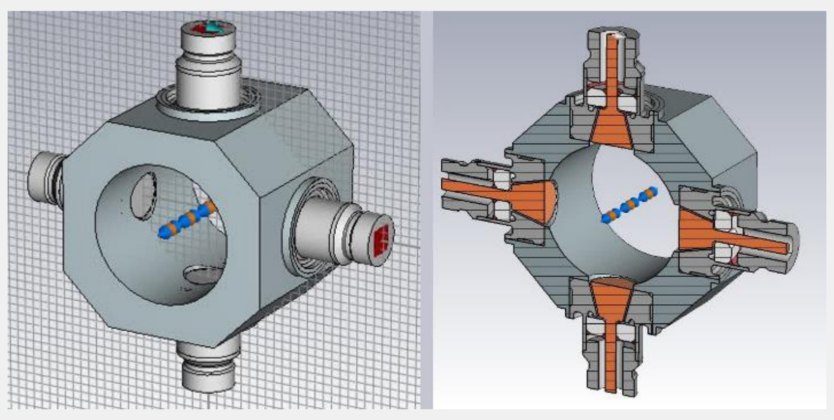
Expected resolution with Fresnel diffraction: 1 µm RMS with reduced flux (~10 Hz repetition rate). SRW simulations.

- Forthcoming prototypes on the current machine:
  - New visible light extraction mirror
  - Setup for Fresnel diffraction on an available X-ray port.
  - Adjustable pinhole with µmetric movable blades
  - Test bench for a HW/FW low latency video acquisition and processing



Foreseen pinhole design with adjustable slits.

Beam Position Monitors:



First drawings of the beam position monitor for SOLEIL-Upgrade. Internal BPM diameter is 16 mm, button diameter is 5 mm.

BPM Specifications (rms values):

	Bandwidth	Specification
Resolution	10 Hz 2 kHz TbT TbT	1µm @ 0.1 mA 50 nm @ 500 mA 100 µm @ 0.1 mA 1 µm @ 500 mA
Beam current dep.	-	10 µm
Absolute accuracy	-	< 500 µm
Stability	One day One week	500 nm 1 µm
Temperature dep.	-	500 nm/°C
Latency (FOFB)	-	50 µs

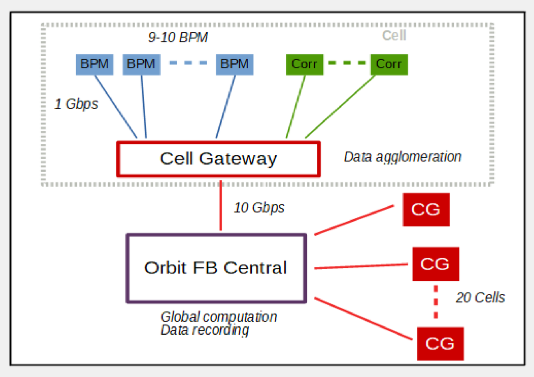
- Mechanics
  - Bloc and buttons are under design (electromagnetic and thermal simulations)
  - Circular shape: 16 mm.
  - Button diameter: 5 mm
  - Low thermal expansion supports
  - Fixed points of the vacuum chamber (at least one below between two BPMs)
- Electronics
  - Current (Libera Electron) system to be replaced before the machine shutdown
  - Improved resolution
  - Latency reduction by a factor 10 (target 20 µs) for fast orbit feedback data.

X ray Beam Position Monitors (ideas):

- Diamond blades downstream planar magnetic devices:
  - Diamond blades in photo-conductive modes.
  - Possible refurbishment of existing XBPM heads?
- Diamond imaging downstream helical magnetic devices:
  - Quasi imaging of the complex photon beam distribution
- Prototyping foreseen during the TDR phase

Fast Orbit Feedback:

- Move the currently BPM embedded system on an external platform before the upgrade of BPM electronics.
- Prototype under development
- Flexible flatform: µTCA + FPGA board + FMC cards
- Cell gateways for data aggregation
- Central for processing
  - Complex controller scheme possible.
  - Additional meas. (X-BPMs, injection events…) can be added later if necessary
- Corrector settings distributed back and archived on the same network.
- Open-loop bandwidth > 1 kHz
- Latency < 100 µs (FOFB loop), < 10 µs (data distribution)

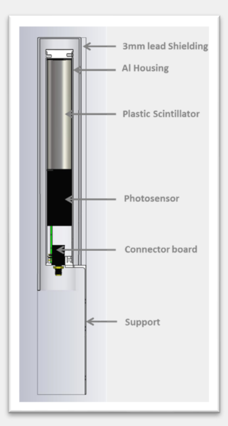


FOFB network topology for data distribution latency < 10 µs

Prototype of FOFB platform: µTCA crate + FPGA board (with SOC) + FMC cards for SFP and serial interfaces

Beam Loss Monitors:

- Key diagnostics for the commissioning
- Re-use of the 80 freshly installed BLM:
  - Plastic scintillator combined with fast photosensor module and dedicated commercial acquisition electronics.
  - High sensitivity and short temporal response
  - Relative calibration
- Current machine BLM measurements are used to crosscheck results of radioprotection simulation codes



BLM detector

CONCLUSION

Cutting-edge instrumentation must be designed to answer the SOLEIL Upgrade tight specifications. On such a compact machine the mechanical integration of the diagnostics will also be a challenge and must be anticipated (beam extraction, pinhole integration as close as possible to the source, etc…). In order to ease and speed-up the commissioning of the new machine the FOFB and the BPM electronics will be upgraded ahead of the machine shutdown. The current machine will also be used as a testbench to validate concepts of Fresnel diffraction and adjustable pinholes for beam size measurements, and the BPM feedthrough prototypes.