SPOTLIGHT ON

SOLEIL accelerators
specificities and innovative aspects

In the booster tunnel.

Ten years after the starting of its construction and after five years of operation, SOLEIL delivers photons to 27 beamlines with five possible filling patterns, all in Top-up injection mode. Their characteristics and performances are summarized in Table 1. The transverse feedback (bunch by bunch digital feedback system) is essential at SOLEIL in order to keep a high intensity beam stable together with transverse dimensions close to the theoritical ones. The systems that have been developed are highly efficient in multibunch, hybrid, 8 bunch and single bunch modes. The targets of 500 mA stored in 416 bunches, 100 mA in 8 bunches and 20 mA in a single bunch, have been achieved with good performances in terms of beam position stability, beam size stability, injection efficiency and beam lifetime.

The availability of the photon beam during user operation and the mean time between failures (MTBF) are improving year after year as shown in Figure 1, and have reached in 2011 record values of 98.4% and 56 h respectively.

Unprecedented approaches have been successfully applied in the design of accelerators and have showed, after several years of operation, good performances:
• High ratio (45%) of insertion device (ID) straight section length over a total 354 m circumference.
• Intensive use of Non Evaporable Getter (NEG) coating vessels in all the Al chambers (56% of the circumference).
• Development of a dedicated "HOM free" Superconducting RF cavity.
• Development of 180 kW 352 MHz solid state amplifiers.
• Innovative Insertion Devices.
• Extremely tight requirements for beam position stability and transparent Top-up operation.
• New type of beam position moni-

Table 1: the different operation filling patterns proposed at SOLEIL.

MODE OF OPERATION	USER OPERATION	ULTIMATE PERFORMANCE ACHIEVED
Multibunch	430 mA	500 mA
Hybrid	425 mA + 5 mA	425 mA + 10 mA
8 bunch	88 mA	100 mA
1 bunch	12 mA	20 mA
Low α (Hybrid): bunch length and bunch current	4,7 ps RMS and 65 µA per bunch	2.5 ps RMS and 10 µA per bunch

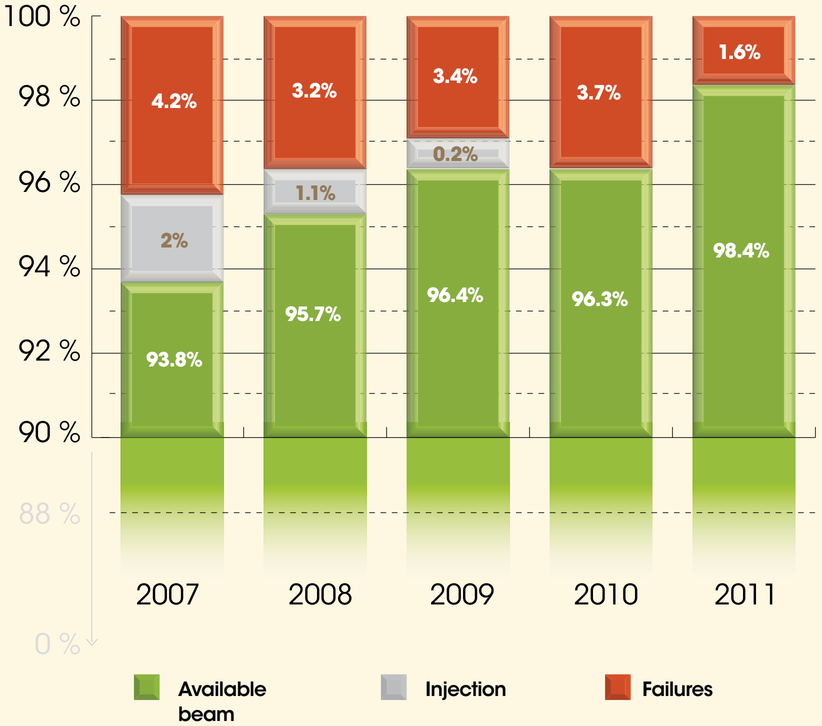


Figure 1: Photon beams availability in user operation.

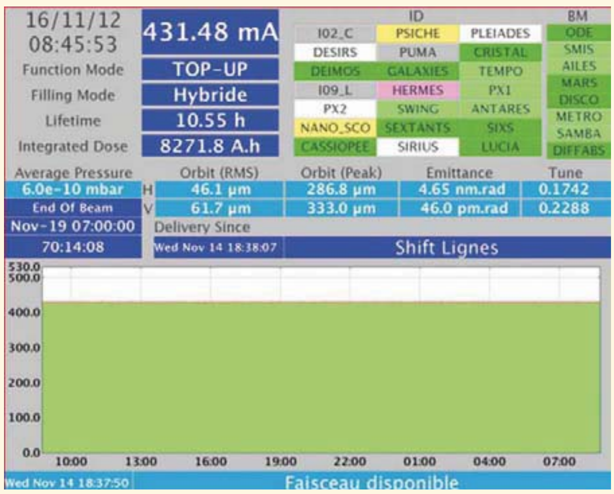
tor (BPM) digital electronics: LIBERA modules.

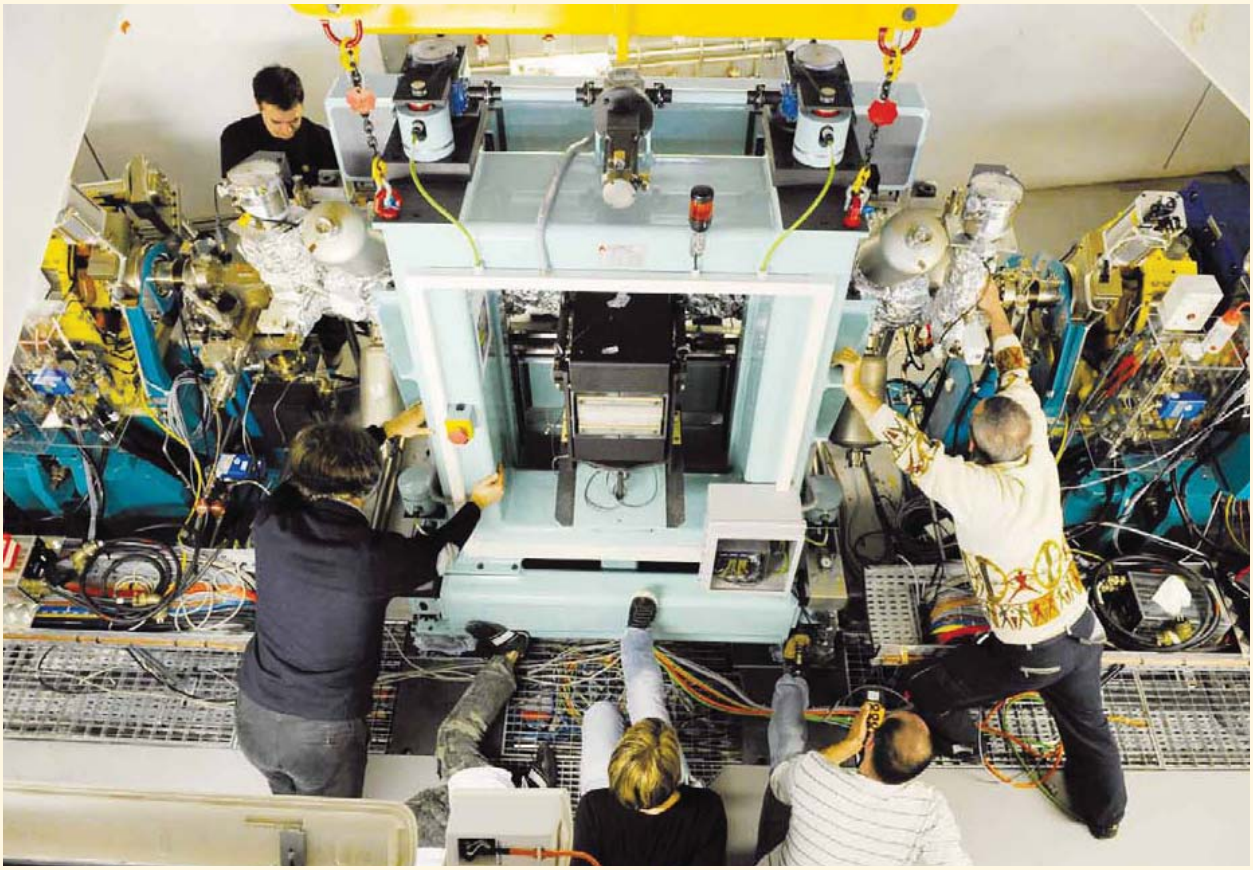
SOLEIL has been designed as a low emittance synchrotron light source with a modified Chasman-Green optics accommodating a total length of 162 m for straight sections, over a circumference of 354 m. The optics of the Storage Ring is continuously optimized to restore the nominal performances inherently affected by increasing number of IDs used during operation. In 2011, an additional quadrupole triplet and a 4-magnet chicane have been installed in one long straight section allowing the installation of two canted 5.5 mm gap in-vacuum undulators providing two independent beamlines (Nanoscopium and ANATOMIX) from a single straight section. This new optics is routinely and successfully used in operation since January 2012. A short bunch length operation based on “Low Alpha” mode has been developed and is available as a routine user operation. More recently, a coupling correction has been implemented in order to maintain the ratio between the vertical and horizontal emittances at a fixed 1% value for any IDs configuration.

The position stability of the photon beams delivered to the beamlines is one of the criteria of quality expected by the synchrotron radiation users. Suited solutions have been sought to minimize the effects of each type of instability since the design of the facility. In addition, two active orbit feedbacks (Slow Orbit FeedBack and Fast Orbit FeedBack) are operating together thanks to a sophisticated protocol. The long term position stability (8h) at all the source points, is within 1 µm RMS in both planes and the low frequency noise sources have been identified and minimized, which allowed reducing the 0.01 Hz to 500 Hz noise below 200 nm RMS at the IDs locations. Special care has been given to the new 160 m long beamline Nanoscopium. Meetings called “Relation de Conjugaison” take place regularly since January 2012 between Machine people and Beamline scientists in order to improve further the stability criteria.

SOLEIL Storage Ring was designed to operate in Top-up injection mode since the design phase. All equipment involved in the injection system have been specified to generate as small as possible perturbations on the stored beam. This concerns many aspects of the design and realization of the injection pulsed magnets, their vacuum chambers, their pulsed power supplies and timing electronics. All the pulsed power supplies, designed at SOLEIL, are based on solid-state switches even for high voltage ones, and demonstrate an outstanding reliability with a contribution close to zero to storage ring beam time loss. Extensive work has been done on systematic measurements, analysis of each phenomena, tuning or modification of each device until we reached good and acceptable

Figure 2: Parameters of the electron beam in the storage ring during user operation (Top-up mode, hybrid filling).





Installation of an undulator in the storage ring tunnel.

results for the users: the residual bump at storage ring injection has been reduced to < 100 µm RMS in horizontal and to < 40µm RMS in vertical. Efforts are still devoted to further improve these results and particularly in the vertical plane where a pulsed dipolar corrector is installed and is planned to be tested soon.

As mentioned above, the SOLEIL Storage Ring presents a very high fraction of its circumference dedicated to accommodate IDs. Presently 26 IDs from various types are installed in the Storage Ring, several of them being unique. The UV-VUV region is covered with electromagnetic devices (HU640 + three HU256), offering tunable polarizations. An electromagnet/permanent magnet undulator (EMPHU) using copper sheets coils for fast switching of the helicity is under commissioning. Thirteen APPLE-II type undulators, with period ranging from 80 down to 36 mm, provide photons in the 0.1-10 keV region, some of them featuring tapering or quasi-periodicity. Five U20 (and one U24) in-vacuum undulators cover typically the 3-30 keV range whereas an in-vacuum wiggler (WSV50), with compensation of the magnetic forces via adequate springs, covers the 10-50 keV spectral domain. An R&D cryogenic in-vacuum undulator (U18) made of $Pr_2Fe_{14}B$ magnets has been built and successfully tested on the machine. Other projects in construction or in design phase are going on and will be presented in a future communication.

The RadioFrequency system of the Storage Ring is based on superconducting cavities which make the damping of the parasitic high order modes (HOM) easier, and therefore helps improving the beam stability. The SOLEIL cryomodule relies on a "home-made" design, based on a pair of 352 MHz "HOM free" cavities inside a single cryomodule. For their RF power sources, it was thought that, although quite innovative and challenging for the required power range (total of about 600 kW), the solid state technology could offer significant advantages as compared to the vacuum tubes. Moreover, the absence of commercially available vacuum tubes at 352 MHz in the desired power range and the acquired expertise on Solid State Amplifier (SSA) prototypes at LURE, led us to choose powering each of the four Storage Ring cavities with one 180 kW SSA and the Booster cavity with one of 35 kW. These SSA proved to be very reliable as well as easy and flexible in operation, featuring an outstanding operational availability and MTBF (> 1 year).

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