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SOLEIL OPERATION AND ON-GOING PROJECTS

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Abstract

The 2.75 GeV synchrotron light source SOLEIL delivers photons to 27 beamlines; 2 new ones are under construction together with the FEMTOSLICING project of which commissioning started in January 2014. Five filling patterns are available for the users in Top-up injection mode. The storage ring is running with an upgraded optics less sensitive to insertion device (ID) configurations and giving both better beam lifetime and injection efficiency. The beam position stability remains excellent with a focus on electron vertical beam-size stability for the new very long beamlines. A gating system during Top-up injection improves significantly the quality of the spectrum on an infrared beamline. Several heavy actions of maintenance and upgrades on crucial subsystem equipment are underway. Others accelerator projects are going on such as the design and construction of new IDs, new Multipole Injection Kicker, radiation damage studies as well as R&D on solid-state amplifiers.

OPERATION

Today, 27 beamlines are getting photon beams, among which 25 are opened to the users. The last four beamlines NANOSCOPIUM, ANATOMIX, ROCK and PUMA will be available to the users between now and 2015. Unusually, in order to save space in the beamline, the first ROCK mirror is located directly in its frontend, inside the storage ring. The installation of the FEMTOSLICING project, both outside and inside the storage ring went without a hitch and the first equipment tests began late 2013. The out-of-vacuum W164 wiggler [1] serving as a "modulator" for this FEMTOSLICING operation and as a photon source for the PUMA beamline, was installed successfully in October 2013. The commissioning with electron and laser beams has started early 2014 and it is under progress [2]. Five electron beam filling patterns are routinely delivered during user operation in Top-up injection mode (see Table 1 and Figure 1).

Table 1: Five Different Filling Patterns for SOLEIL Users

Filling pattern	2013 user operation	Achieved ultimate performance
Uniform (416 bunches)	430 mA	500 mA
Hybrid (312 + 1 bunches)	425 + 5 mA	420 + 10 mA
8 bunches	88 mA	110 mA
1 bunch	15 mA	20 mA
Hybrid Low-Alpha (bunch length/bunch current)	4.7 ps RMS, 65 µA/ bunch	2.5 ps RMS, 10 µA/bunch

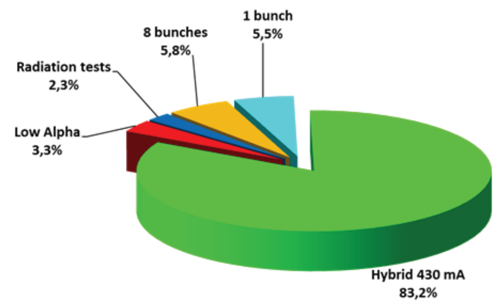

Figure 1: Time distribution of the filling patterns delivered to users during 2013.

The multibunch hybrid filling pattern was overwhelmingly requested: 83.2 % of the total number of shifts. The time allocated to Low-Alpha operation has been increased from 2.3 % in 2012 to 3.3 % in 2013.

The statistics of the different quality metrics of the operation are rather good for the year 2013. The availability of the photon beams for the beamlines has reached 98 %, which corresponds to a total of 4 912 hours out of the 5 015 scheduled hours. As shown in Figure 2, electrical power drops are once again the main source of beam interruption (29 % of the total) with 18 beam trips. Even if their duration was shorter than 1 second long, they resulted in a total of 30 hours of beam interruption. The second main source of beam interruption (28 %) was erratic short transient current spikes of a few quadrupole power supplies. The problem has been solved after meticulous investigation (see below). This led in turn to 21 hours of beam loss during the first week of the year.

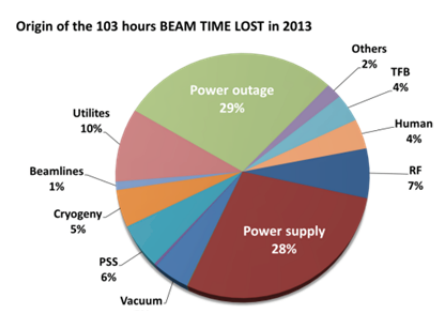

Figure 2: Pie chart of the distribution per domain of the beam loss origin during 2013.

Hopefully the rest of the year, and particularly its end, was conversely of exceptionally high beam quality. The record for the longest user beam was hit twice in a row during the last run of the year as illustrated by Figure 3. This record level of 542 hours of uninterrupted user beam

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time significantly exceeded the previous 360 hours reached during the year 2011.

The Mean Time Between Failures (MTBF) has reached a record of 68 hours. Within the 35 weeks of operation, an efficiency above 99% has been obtained during 21 weeks, 9 of which reaching 100%. The praiseworthy reliability and performance have to be credited to the teams working around the accelerator facilities.

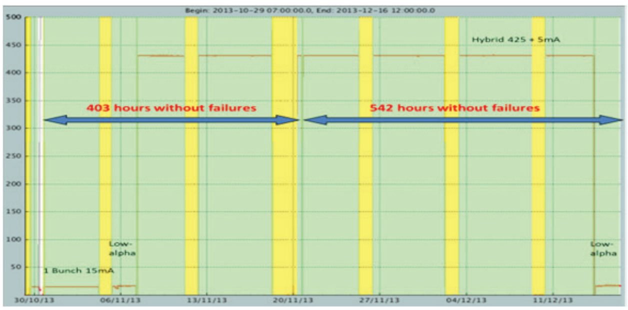

Figure 3: Two subsequent record levels of uninterrupted user beam reached during the last run of 2013 (yellow parts are machine dedicated periods).

New Optics

Since more than two years, the storage ring is running with a new optics where one of the four long straight sections has been modified to create a double minimum of the vertical beta function in order to focus the electron beam in the center of two canted in-vacuum undulators [3]. Although of good performance, this new optics was sensitive to the effect of the increasing number of insertion devices and it was skew quadrupole settings dependent. In addition, the electron beam losses due to the lifetime were mainly localized at the entry of a short straight section (SDC15), which is not favorable for the undulator in place. This optics has then been tuned further using quadrupoles and sextupoles in order to make it less sensitive to these effects, leading to significant improvements. The excess of activation in SDC15 has effectively been suppressed, the sensitivity to a possible skew corrector failure has been discarded and today, whatever insertion devices configuration, during user operation, the injection efficiency and beam lifetime are routinely kept above 80% and 13 h (for the 430 mA hybrid filling pattern mode) respectively.

Top-up Injection Gating

Until 2012, thanks to the excellent performance of the injection system of the storage ring, the perturbation on the position of the stored beam during Top-up injection was small enough to be accepted by the users. For some specific experiments requesting higher beam stability, few beamlines expressed the need to be able to freeze the data acquisition during the injection process. To fulfill this need, the Diagnostics group designed the “TimEX3” board which was integrated into the timing system in order to allow the gating of the Top-up injection. The Top-up gating which is detailed in [4], has improved the signal to noise ratio of the spectrum by a factor of 12 to 15 for the SMIS infrared beamline, which is a significant enhancement for the data quality of this beamline.

SUBSYSTEM MAINTENANCE AND UPGRADES

Maintenance and upgrades are a critical consideration for our facility since the injector complex is already 10 years old and most of the storage ring equipment is approaching the same age.

Power Supplies

The lifetime of the IGBT modules used in the output stage of the Booster 3 Hz power supplies is about three years. This short lifetime is caused by the high thermal stress generated by the 3 Hz excursion of the IGBT chip's junction temperature. A new design has then been developed in house and is being implemented. This new design is based on the use of 1200V / 2500A IGBT modules which are suitable for high power cycling applications. An increase of the 30 °C cooling water flow and implementation of efficient water plates are also intended. Changing the current 16 racks will be gradual and will spread to next October shutdown. Figure 4 shows the aspects of the new racks.

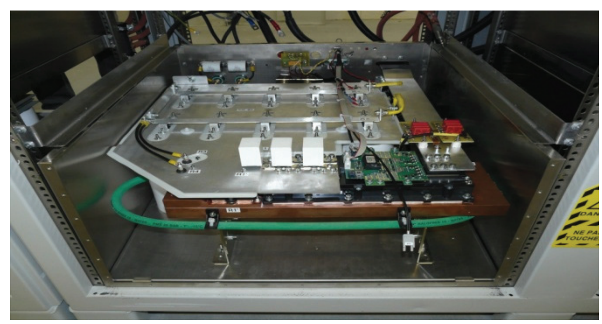
Figure 4: New 3Hz racks for the Booster power supplies.

In the storage ring, the correction of the bug in the regulation card firmware which was responsible of troubleshoot events cited above has been generalized to all the quadrupole power supplies. Improvement of the rack EMC is also ongoing.

RF-System

The storage ring RF-system is also undergoing maintenance and upgrade operations [5]. They concern the RF-cavity input power couplers (IPCs), the power amplifier, and the cryogenic system. The original IPC used at SOLEIL, is a LEP2 type antenna which can handle up to 200 kW CW at 352 MHz. An improved version of this design, capable of transmitting higher power, was later developed by CERN at 400 MHz for the LHC. That led us to conclude in June 2011 a collaboration agreement with CERN and ESRF to develop a new 352 MHz version, based on the LHC design and capable of handling up to 300 kW. In April 2013, the first pair of upgraded IPCs, built at CERN for SOLEIL, was successfully conditioned with RF power

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using a copper test cavity from CERN. In August 2013, one of the pre-conditioned IPCs was mounted in Cryomodule 1 (CM1), in situ, without removing the CM out of the ring, under external laminar air-flow and slight N_2 gas overpressure inside the cavity. After only few days of RF conditioning the cavity could provide up to 1.5 MV with 150 kW CW in full reflection. End of August 2013, when restarting the SOLEIL operation, we could quickly store up to 500 mA without any trouble. Nevertheless, after approximately one week of operation, multipacting process appeared on the new IPC around 110 kW, which sometimes triggered vacuum interlocks. During user's sessions, we operate the corresponding cavity below 110 kW and we compensate with the other cavities. After two successive "re-conditionning" during shutdown periods, the same scenario repeated itself; no problem at the beginning of the following RUN, then a kind of "de-conditionning" after a couple of weeks. During last shutdown (April 2014), a device was implemented for generating a bias DC-field at the ceramic window location, aimed at destroying multipacting resonant conditions. The multipacting indeed fully disappeared when applying a DC voltage > 1 kV. It needs to be confirmed over the long term. We plan to replace the second IPC of CM1 during August 2014 shutdown. The other pair, under construction at CERN, should be installed in CM2 during shutdown of January 2015.

The RF power Solid State Amplifiers (SSAs) proved to be very reliable: after ~40 000 running hours over 8 years, only 5 short downtimes occurs corresponding to ~100% operational availability and a MTBF longer than 1.5 year (for the 4 amplifiers). In spite of these good results, an upgrade is being performed taking advantage of the new transistor of 6th generation, the BLF574XR from NXP, which is much more robust and has higher performance than the LR301, at relatively low cost: the electrical power savings resulting from the higher efficiency shall compensate for the upgrade cost after less than four years. Moreover, the expected lower failure rate shall lead to savings in maintenance cost and the higher power capability shall provide additional operational flexibility as, for instance, storing 500 mA using 3 out of 4 cavities.

Concerning the cryogenic plant, we plan to improve the process control and to increase the He gas storage capacity for providing an autonomy of 5 hours under normal operating conditions while the liquefier is stopped and to enhance the reliability of the compressor utilities.

ON-GOING PROJECTS

Twenty-seven very diverse insertion devices (IDs) are now installed in the storage ring. Others are under construction, such as the U18 cryogenic undulator for the ANATOMIX long beamline and a spare U20 in-vacuum undulator for high photon energy beamlines Two other IDs are being designed, in the frame of collaboration between SOLEIL and MAX-IV laboratories: an aperiodic in-vacuum wiggler (WSV50) and a 3m-long U15 in-vacuum cryo-ready undulator with a 3 mm gap.

In the framework of the same collaboration, the magnetic and mechanical design of a Multipole Injection Kicker (MIK) that can inject without disturbing the stored beam is now finalized together with the pulsed power supplies. The detailed drawings are underway and the results of the mockup tests are expected by July 2014. The installation of the first one in the 3 GeV MAX-IV storage ring is foreseen in 2015.

The stability requirements for the position and size of the photon beam on the 155 m long NANOSCOPIUM beamline are under experimental evaluation. As a first step, an upgrade of the coupling feedback is foreseen. If needed additional resources will be made available to meet the stringent specifications on the vertical beamsize.

With respect to the storage ring equipment, an unexpected high rate of radiation-induced damages was discovered. Detailed investigations enabled us to understand that the dipole synchrotron radiation (less than 10 %) is intercepted by the so-called aluminum "quadrupole" vacuum chambers; X-ray fluorescence is then emitted by the material components of the NEG coating; the energy of theses X-rays is too high to be significantly attenuated by the aluminum material [6].

A study of the adaptation of a long straight section to produce round photon beam is underway.

Finally, we are continuing very preliminary investigation studies of a new lattice for the storage ring upgrade, aiming to reach ultra-low horizontal emittance by using Multi Bend Achromat structures [7].

R&D with the SSA's is going on. Two 500 MHz SSAs are under construction at SOLEIL, one 50 kW for THOMX [8] and one 80 kW for SESAME. At the end of 2013, a know-how license agreement for the manufacture of RF power SSAs was concluded with the French company SIGMAPHI ELECTRONICS

PERSPECTIVES

It is worth noting that the transition to a stored beam current of 500 mA will be offered to users soon. Maintenance and upgrades of equipment will continue to assure the highest availability and reliability for the accelerators. First users operation in FEMTOSLICING mode is foreseen before the end of the year.

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