STATUS OF THE SWISS LIGHT SOURCE

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Abstract

The Swiss Light Source (SLS) is a 3^{rd} generation synchrotron light source in operation since 2001. The paper will point out the recent activities to enhance machine operation and provides an overview about the new beamlines currently under construction at the SLS.

INTRODUCTION

The SLS has a 2.4 to 2.7 GeV storage ring with a 3 Hz, full-energy injection system. The injector consists of an 90 keV electron source, a 100 MeV Linac and a full energy booster operating at 3 Hz. The booster has a 270 m circumference and shares the tunnel with the storage ring [1].

The storage ring has a circumference of 288 m and a design current of 400 mA. The accelerating RF is based on four normal conducting 500 MHz cavities. A 3^{rd} harmonic superconducting, passive Landau cavity is used to increase the lifetime up to a factor of three. The machine is operated in Top-up mode, i.e. the beam current is kept constant down to a few permille by refill injections done every other minute (See Fig.1). This provides an excellent photon beam stability at the experiment, since it keeps the thermal load on the accelerator and on the beamline optics constant.

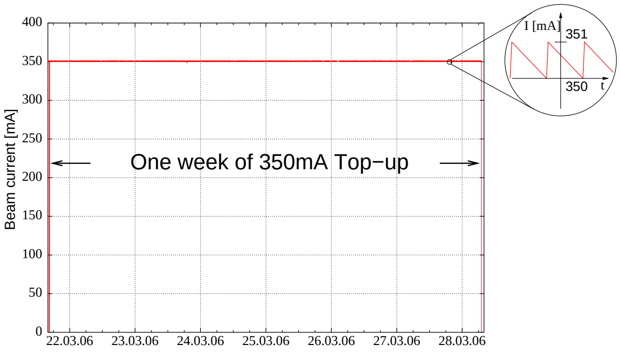

Figure 1: Beam current plot of the SLS in Top-up operation

OPERATION STATISTICS

In 2005 we reached an average availability of 98.4% and a mean time between two beam losses (MTBF) of about 73 hours (See Fig. 2). In 2003 one single event, a vacuum leak, caused about 50% of the down-time. Therefore we introduced "user reserve time": users affected by longer outages of the machine can now be rescheduled within the same year and don't need to apply again for beam time. In 2004 we were able to provide 175 hours compensation for 190 hours of down-time. In 2005 the reserved 176 hours were twice as much as our actual down-time of 82 hours.

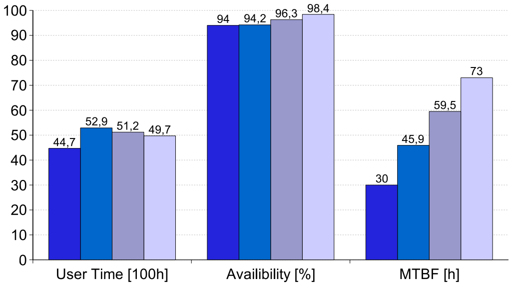

Figure 2: SLS Operation Statistics from 2001 to 2005

The average availability in 2006 was 94% so far. It suffered from a vacuum leak again: an RF window broke due to a failure of the air cooling of this window. This failure alone contributed 75 hours or two third of the down-time of the first half of this year.

BEAMLINES

Seven new beamlines go into operation within this year. The first one of those is FEMTO, a beamline to generate sub-picosecond X-ray pulses. The new infrared beamline will put high demands on the beam stability at the dipole. The tomography beamline /it Tomcat requires the installation of a so called superbend magnet, i.e. a dipole will be replaced with another of the same field integral but with more than twice the peak field of the normal dipols in the center. In total three of those superbends are foreseen. The /it PolLux beamline will require several Hertz alternation of local orbit bumps for fast polarization switching [2].

Table 1 gives an overview of all SLS beamlines in operation or going into operation this year.

FEMTO

The sub-picosecond X-ray source FEMTO started first femto second slicing operation in April this year [3]. A high power, femto second laser pulse interacts with the electron beam in an wiggler and generates an energy modulation of a small fraction of the beam. This fraction is then separated by dispersion from the main beam and generates an X-ray pulse of about 50 fs in an U19 in-vacuum undulator. The X-ray pulse is synchronous to a second high power, femto second laser to allow for pump-probe experiments with a time resolution of fractions of a picosecond. The sliced electron beam generates Terahertz radiation that proved to be a valuable diagnostics for an optimization of the slicing process [4].

Table 1: Beamline in operation and planned at the SLS

Beam-line	*Science*	*Source Magnets*	*Status*
PXI	Macromolecule Crystallography	ID: U19	In operation
PXII	Macromolecule Crystallography	ID: U19	In operation
MS	Materials Science	ID: W61	In operation
Tomcat	Materials Science: Tomography	Superbend	Start Jul.06
Lucia	Environmental, Material Science	ID: UE54	In operation
μXAS	Environmental, Material Science	ID: U19	In operation
PolLux	Environmental, Polymer Physics	Bending	Start Jul.06
SIM	Surface/Interface Microscopy	2 IDs: UE56	In operation
SIS	Surface/Interface Spectroscopy	2 IDs: U212	In operation
Femto	Femtosecond slicing	2 IDs: W138/U19	In operation since Apr.06
IR	Infrared	Bending	Start Jul.06
Adress	Correlated electron spectroscopy	ID: UE42	Start End 06
cSAXS	Coherent small angle X-ray Scat.	ID: U19	Start Sep.06
VUV	Vacuum ultraviolet	Bending	Start End 06
Diag	Machine Diagnostics	Bending	In operation

MACHINE ENHANCEMENTS

Booster Power-Save Mode

A new power-save mode was introduced for the booster power supplies. The injector system has to be kept operational during the whole user run for top-up injections. The power consumption for the cycling magnets is about 160 kW. Seven magnet power supply circuits are ramped, but the main power consumtion stems from the 1 MW peak power supply for the combined function magnets of the booster. For the power-save mode the magnet ramps are only started for the actual injections and stopped automatically afterwards. The 1 MW magnet power supply ramps the current amplitude up or down within six cycles of 320 ms (See Fig. 3). The number of full power cycles is adjusted according to the desired injection charge. This scheme saves about 1 GWh or 80 $k\in$ per year.

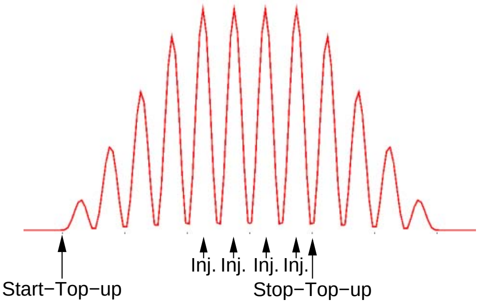

Figure 3: Booster dipole magnet power supply current as a function of the time in the booster power-save mode.

Fast Orbit Feedback Enhancement

The SLS Fast Orbit Feedback (FOFB) runs since November 2003 during user operation [5]. Orbit perturbations in a frequency range up to 100 Hz are corrected down to a micro meter level. This global orbit feedback was designed to calculate corrections from 72 BPMs and set them to 72 correctors per plane at a rate of 4 kHz. The system has now been extended in order to be able to integrate additional BPMs and correctors, since a 73^{th} BPM and corrector pair is required for the FEMTO project. In addition we want to integrate the Photon BPMs into the FOFB.

Photon BPM Feedback

The FOFB is complemented by a local photon BPM (XBPM) feedback. The XBPM displacements at closed insertion device gaps are translated into source point angular distortions and the reference orbit for the FOFB is changed to compensate those distortions. The changes of the reference orbit are currently done at 1 Hz, in order to decouple the FOFB and the XBPM feedback in frequency range. Currently this type of feedback is in operation for three beamlines: two macromolecule crystallography beamlines have it operating with U19 undulators in both planes and a material science beamline operate it only vertically at a W61 wiggler. We are planning to integrate the XBPMs directly into the FOFB, in order to further enhance the performance of the system.

Local Orbit Bumps for Beamlines

Currently the application of the XBPM feedback is limited to those beamlines that operate at a rather limited gap range, since wide variations in the photon energy have a strong impact on the position readings of the X-blade XBPMs. New monitors are developed to overcome this problem [6] but for manual beam adjustments we enabled the beamlines to adjust their source point position by changing the reference orbit at their beamlines on-the-fly. The changed reference positions are applied by the FOFB, therefore this orbit bumps are transparent to the other beamlines. This new scheme helped to speed up the beamline optimization process after each shutdown, where local orbit adjustments of up to 50 μm are regulary desired by some beamlines.

Filling Pattern Feedback

In Top-up operation it is important to have a feedback on the charge distribution in the storage ring, the filling pattern. A cyclic refill can easily result in a distortion of the filling pattern, since the lifetime varies for the individual buckets and a temporary injector failure would generate undesired gaps in the filling.

An avalanche photo diode with 160 ps risetime is used to measure the charge distribution. The digitized waveform is transformed and normalized into an array of 480 bucket charge values. This array is compared to a reference filling pattern and a list of bucket numbers with the largest differences from the reference is generated. The timing allows for shot-by-shot programmable, single bucket injections. At each injection cycle we inject in this calculated order [7].

This scheme allows for arbitrary target filling pattern. The application allows for an easy programming of standard patterns by a small number of parameters: the length of the bunch train *b*, position of an additional single bucket *s* and proportional height of this single bucket compared to the bunch train *h* (see Fig. 4). A new ”comb” mode is currently evaluated with a number of equidistant single buckets and an optional high charge bucket in a larger gap.

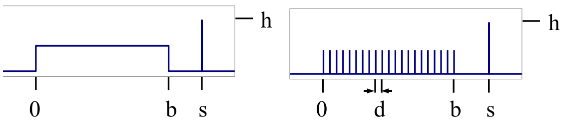

Figure 4: Parameters of the standard hybrid filling pattern and the so-called ”comb-mode”

In order to maintain those standard filling patterns even during failure periods of the filling pattern measurement, a fallback scheme takes automatically over in case of failures: the injections are then done according to the integer proportions of the values in the reference waveform.

BEAM DYNAMICS STUDIES

The recent machine development activities are described in the following sections.

Acceptance Studies

Scraper measurements revealed a significantly reduced vertical acceptance of the storage ring. A misalignment of a wiggler vacuum chamber was found to be acceptance limitting. A careful realignment of this chamber increased the vertical acceptance from 0.9 to 1.8 $\mu m\ rad$. The elastic scattering lifetime at the beam current of 350 mA doubled to 62 hours. With a Touschek lifetime of about 20 hours at 0.7% coupling this increased the actual beam lifetime at 350 mA from 12 to 15 hours.

Local orbit bump scans suggest that the clearance of the vacuum chamber is only 4 mm instead of the nominal 5 mm.

Emittance Measurements

In order to optimize our coupling and to have a non destructive coupling measurement a special emittance diagnostic beamline was built [8]. It allows online optimization in contrast to the scraper measurements [9]. The beamline consist of two branches giving two independent measurements of the beam sizes, one in the visible region, and one in the X-ray region of the synchrotron radiation spectrum. The visible measurement uses the vertically polarized component of the synchrotron radiation to form a diffraction dominated image of the beam, where an intensity modulation is related to the vertical beam size. The X-ray measurement is based on the old pinhole camera principle. Wave-optics based calculations (the SRW code) are used to interpret the images. In preliminary tests the two branches seem to give consistent results down to the order of 0.1% coupling.

Coupling Reduction

The measured coupling of about 0.7% in user operation was domintated by local orbit bumps provided to the beamlines to adjust their source points to their beamline. We identified the contributions of the different beamline bumps and realigned the beamlines with the highest contributions in order to remove their bumps. Just removing the first bump reduced the coupling to about 0.4%. Preliminary measurements with the new emittance diagnostic beamline [8] indicates that the remaining user bumps now might have a minor contribution to the coupling. However, further coupling correction could be achieved with the help of our 6 skew quads. We already reached a coupling in the order of 0.1% in the first attempts. It was also seen that the lifetime, which is partly limited by vertically lost Touschek scattered electrons, was increasing again even at those smaller beam sizes.

SUMMARY AND OUTLOOK

The number of beamlines at the SLS will double within this year. Operation at 2.7 GeV and special new filling modes will be required for some experiments. The main goal will be to maintain the excellent availability of the past years. At the same time we will try to reduce the coupling to about 0.1% to further increase the brilliance for the users.

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