ENHANCEMENTS OF TOP-UP OPERATION AT THE SWISS LIGHT SOURCE

B. Kalantari, T. Korhonen, A. Lüdeke, Ch. Quitmann

Since the first experience in 2001, Top-up is the standard mode of operation at the Swiss Light Source (SLS) for users. In order to fulfill the ongoing demands of machine experts and experiments we have had to add more functionality to the Top-up mode thus making it more flexible. Some time-resolved experiments require a constant charge in a single isolated bucket in the gap of the normal filling of a bunch train of 80% of the circumference of the storage ring. Therefore the Hybrid application was developed that keeps the beam current distribution constant in this mode. We developed a maintenance mode, to allow working continuously on the Linac and booster - for example to optimize injection - without disturbing the Top-up for user operation. Even beam destructive experiments at the Linac during Top-up or Hybrid operation are supported, where the Linac can be used between successive refilling operations of the storage ring. The flexible control and timing systems at the SLS made these applications feasible.

INTRODUCTION TO TOP-UP MODE

The so called top-up injection mode is becoming the standard mode of operation in most of the advanced third generation light sources. The basic goal in this type of operation is to define a beam current threshold (e.g. 300 mA) and a dead band (e.g. 1 mA) and to control the whole injection and extraction process from the electron source to the storage ring in the following way:

1. Start injection to the storage ring if beam current is less than the defined current threshold e.g. 300 mA.

2. Stop injection when the beam current reaches the current threshold plus dead band e.g. 300 + 1 mA

At the SLS, the precise timing system, flexible control system, sophisticated diagnostics and well designed pulsed magnets not only provide us with the implementation of such an operation mode but also give us the possibility to go farther and develop other top-up based modes for different uses and purposes. In the following sections we describe these modes and their implementation and the software and/or hardware involved.

TOP-UP PLUS DIAGNOSTIC MODE

This mode - at the SLS known as TOPUP+DI - is used to calibrate or make on-the-fly fine adjustments of any beam transfer component up to the booster extraction pulsed magnets. For example it can be used during user operation to optimize the injection efficiency without disturbing the stored beam in the ring. In principle by switching the accelerator operation to this mode, the gun is continuously triggered and produced electrons are injected into the synchrotron booster. Meanwhile if an injection into the storage ring is required e.g. if the beam current goes down to the threshold level the booster extraction and ring injection pulsed magnets are activated in order to top up the stored beam. In practice this has proved to be very useful and even RF experts are using this mode in order to adjust the electron gun RF phase to get to the right operating point. The controls of this mode involve mainly software based on the plain EPICS databases which checks the conditions to enable or disable the injection/extraction upon certain conditions and have interaction with the timing system, diagnostics components and pulsed magnets.

HYBRID (CAMSHAFT) MODE

In Top-up mode, only 390 buckets out of 480 (81.25 %) are filled in the storage ring. There are some time-resolved experiments (at the beamlines) that require a constant charge in a single isolated bucket. In the so called camshaft mode one isolated single bucket is filled in the middle of the gap (Fig. 1).

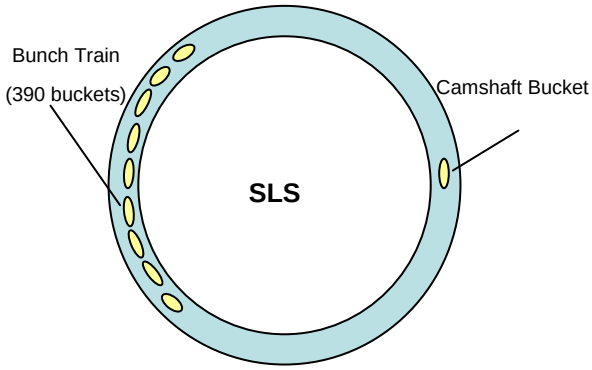

Fig. 1: Storage ring filling in hybrid mode

This single bucket can be filled manually (single shot), periodically or using a feedback method. We are topping-up the camshaft bucket to keep its charge constant. The SLS timing system provides the ring revolution clock as a bunch marker for the experiments to be synchronised with the camshaft or any other bucket. This signal is available at any location of the SLS complex. The following points are important to the hybrid mode users:

1. The timing system allows synchronizing experiments to the bunch marker and/or the 500 MHz RF relatively easily.

2. The 500 MHz of the main RF is used to phase lock a pulsed laser using a PLL (Phase-locked-loop) and using the bunch marker a pulser is triggered.

3. The ability to top up the hybrid pulse means the measurements are done with constant intensity over hours or days, (the experiments may take 10-20 hours).

4. The hybrid mode means we can do all the alignment of the experiment using the full beam current without the time resolution and once the experiment is tuned we turn on the time resolution. Since the hybrid pulse is ~2 mA compared to the regular 330 mA this means the alignment is done with a factor of greater than 100 more intensity making it much easier.

5. Also we can do time resolved experiments during regular user shifts. There is no need to wait for dedicated single bunch beam time.

6. We blank out the regular pulses by gating our detector with a 1 MHz, 400 V supply providing ~30 ns pulses synchronized to the bunch marker.

In the following picture (Fig. 2) the avalanche photo diode (APD) monitor of the time resolved experiment has been shown.

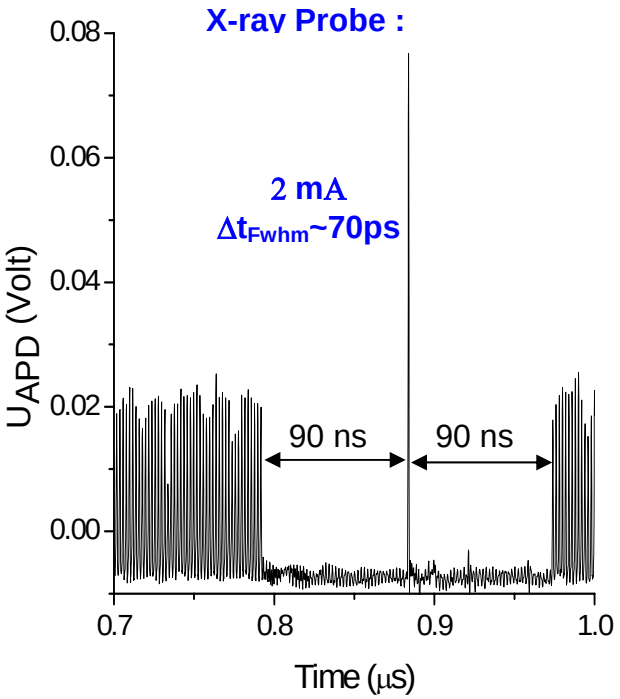

Fig. 2: Avalanche photo diode read-out

It shows the relative intensity of each electron bunch in the SLS storage ring. Using the hybrid mode we have measured the response of micron sized magnetic particles to very short magnetic field pulses of 150 ps rise-time. We can do this with less than 100 ps time resolution. The particles show interesting domain motion and excitation of magnetic modes. All the experiments were done during regular user shifts.

TOP-UP PLUS EOA

This mode allows the use of the linac beam for experiments that run in parallel to the top-up operation. Injection into the linac can be used in this case in the intervals (~ 3 minutes) between the storage ring injections for an electro-optical autocorrelation experiment. The linac trigger and a Nd:YAG laser have to be synchronized for that purpose.

The timing system always gives an indication for start and end of the injection in top-up mode by distributing predefined events. Then all the current top-up injection related parameters are saved for the next injection. Then the gun trigger delay is changed to fit the EOA experiment and at the same time a screen monitor is inserted into the Linac. In time for the next Top-up injection all the timing parameters are restored, the screen monitor is taken out and the storage ring can be filled again.

CONTROLS SOFTWARE

The control system at the SLS uses EPICS [1]. The timing system of the SLS [2] is based on the global timing event distribution (APS compatible) and is fully integrated in the control system. Almost all the timing parameters can be controlled or monitored in the control system. Most of the required algorithms are implemented by plain EPICS databases. The ability to control and monitor all the required accelerator parameters and adjusting all the required timings for all the components contributing in the injection process, enables us to target each bucket easily for an injection.

CONCLUSION

The requirements for Top-up operation are rapidly changing with new ideas for experiments coming up. The flexibility of the control system, the extensibility of the timing system and the ability to add and to enhance diagnostics eventually determine the feasibility of those experiments.

The very well integrated control- and timing system of the SLS allows fulfilling the increasing demands for new experiments.

REFERENCES

[1] http://www.sls.psi.ch/controls/

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[3] B. Kalantari, V. Schlott, T. Korhonen, *Bunch pattern control at the Swiss Light Source*, Proc. EPAC'04. Lucerne, Switzerland.