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TOP-UP OPERATION AT ALBA SYNCHROTRON LIGHT SOURCE

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Abstract

The ALBA light source has been operating in decay mode since May 2012. Now it is ready for top-up operation, which should become the standard operation mode for users from middle of 2014. In this paper we are going to summarise the different steps that have taken place before the start of top-up operation: radiation safety simulations and measurements, upgrade of hardware and software interlocks, control software and injection optimisation.

INTRODUCTION

ALBA is a 3rd generation synchrotron light source in operation since 2012 in Cerdanyola del Vallès, near Barcelona (Spain). The ALBA storage ring is a 3.0 GeV electron accelerator with an emittance of 4.5 nm·rad and a circumference of 268.8 m providing a photon beam to 7 beamlines [1]. Two new beamlines are under construction.

The ALBA injector, which was already designed to work under top-up conditions, consists of a 100 MeV linac, capable of providing a multi and a single bunch beam and a full energy booster which is installed in the same tunnel as the storage ring and has therefore a large circumference (249 m) and an emittance as low as 9 nm·rad. ALBA has been operating in decay mode until now, with 2 injections per day, and it is now ready to switch to top-up injection.

There are several issues that need to be considered before a facility like a synchrotron light source goes into top-up: the first one is radiation safety since in top-up injection is done with the front ends open and it must be ensured that the injected electrons cannot reach any beamline under any circumstance. In addition under top-up injection the injector is almost in continuous operation, its reliability and performance are also issues to be addressed.

RADIATION SAFETY CONSIDERATONS

Safety simulations were done and reported in this conference series last year [2]. Particle tracking simulations were performed to determine realistic scenarios that could bring an injected beam of electrons down an open beamline front end (FE). Realistic magnetic field, trajectory, aperture and energy errors were taken into account over a large range of faulty conditions.

For the ID beamlines simulations an aperture boundary enclosing all FE apertures was defined by enlarging by a safety margin of 20% the second mask aperture of the FE with the largest aperture. If top-up is demonstrate to be safe for this configuration, then all other ID beamlines must also be safe. The bending magnet beamline required an additional simulation. The simulations demonstrated that the stored beam interlock is sufficient to guarantee that neither a single error nor more combined events could lead to a top-up accident.

Even with these results at hand, it was decided to implement a hardware interlock to ensure energy matching between the transfer line (BT) and the storage ring (SR).

Radiation doses have been acquired, using the ALBA network of radiation monitors, during injection with the front ends open for each beamline under different working condition:

- IDs open/close,
- different settings of slits at the FEs
- different injection efficiencies, from 10 to 100%

ALBA has a network of fixed radiation monitors covering the experimental hall and the service area. There are a total of 23 monitors, all of them detecting gamma radiation, and 9 of them detecting also neutrons. In addition there are up to 9 movable trolleys which can be moved around the hall to provide additional data.

For 6 out of 7 beamlines there has been no detectable increase of radiation measured outside the optical hutches, however for BL29, which uses an elliptical undulator as a photon source an increase in radiation dose around the optical hutch has been measured under bad injection conditions (injection efficiency less than 50%) together with a closed ID gap and closed masks. In any case the integrated dose has always stayed below 2 uSv in 4 h, which is the public dose limit. On this specific FE due to space restrictions, the movable masks are placed in the optical hutch. Under these circumstances any misaligned/blow up photon beam coming from the SR will be stopped first at the optical hutch. An additional shielding has been designed and its implementation is ongoing.

HARDWARE PSS INTERLOCKS

In preparation for top-up operation the Personal Safety System (PSS) has to validate the following set of conditions before top-up is permitted:

1) Top-up key inserted in the PSS panel
2) Minimum stored beam in the SR: 20 mA. The presence of a stored beam of 20 mA will ensure that the storage ring is working under nominal conditions. The beam current is measured by two different means: a DCCT and an FCT both from Bergoz.

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3) Energy matching between BT and the SR: A current comparator has been installed on the 2nd bending of the BT, its value shall be within ±3 % of its nominal value to ensure proper energy matching between the injector and the storage ring. If this is not the case, top-up is disabled and the machine reverts to decay mode.
4) Any fixed radiation monitor reaching a warning level of 1.5 uSv accumulated in 4 h will disable top-up. The storage ring will run in decay mode, and top-up will not be permitted until the 4 h period is over.
5) Any fixed radiation monitor reaching the alarm level of 2 uSv in 4 h will close the FEs and kill the beam. Re-injection is then only possible after the 4 h period is over.

SOFTWARE PRE-CONDITIONS

To avoid reaching the PSS hardware interlocks described above a set of pre-conditions are continuously checked during top-up operation. Top-up is only enabled if these pre-conditions are fulfilled.

1) Lifetime should be at least 50% of the nominal lifetime for the given filling pattern. This ensures that the storage ring is operating under nominal conditions. The lifetime is checked at the start of any injection cycle and if it is not ok. top-up will be stopped.
2) Minimum injection efficiency: To ensure that injection conditions are good, for each injection cycle a linac to storage ring injection efficiency is calculated. With this number for cycle (i-1) an estimation of the time it will take to inject under the same conditions at cycle (i) is calculated. An extra margin of 10% is added and if the injection in cycle (i) takes longer than the calculated time then top-up is stopped and before starting again a corrective action by the operator is required.
3) A pre-alarm level has been set at 1 uSv in 4 hours for any radiation monitor. It will not abort injection but will inform the operator so that he/she can take corrective action.

TOP-UP OPERATION

The present filling pattern used at ALBA consists of 10 trains 32 ns long each with a gap in between of 22 ns, as shown in Fig. 1. The linac beam is a multibunch beam, 32 ns long. ALBA will start operation in top-up mode with such a multibunch filling.

A high level application, which interfaces with the injector sub-systems and the timing generator, has been written in Python. The same application and GUI is used for injection in decay mode, by disabling the top-up check box. Figure 2 shows a snapshot of the top-up GUI

Figure 1: FCT signal showing the filling pattern.

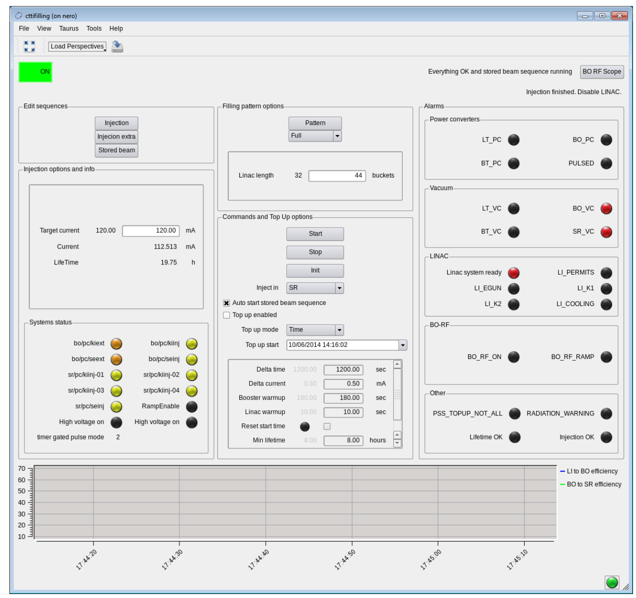

Figure 2: Top-up graphical users interface.

There are a number of fields that can be chosen by the operator, like the nominal current, the injection mode, if during top-up, injection cycles should occur at fixed time or at fixed delta current. On the right side of the GUI the status of the injector sub-systems is shown and the graphic at the bottom shows continuously the injection efficiency.

The GUI has been tested and debugged during machine development shifts, an example of such tests is shown in Fig. 3.

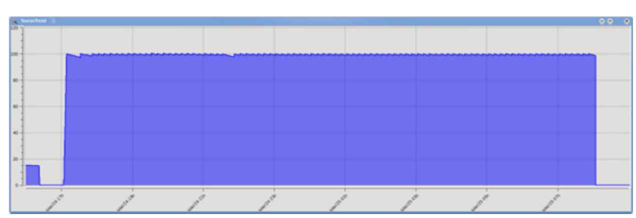

Figure 3: Current in the SR during an 8 h top-up test.

It is extremely difficult to have an injection process which is fully transparent for all of the beamlines, therefore beamlines have been provided with software signals that indicate the different steps during an injection cycle. The beamlines may use these signals to gate the top-up process.

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First tests with the beamlines indicate that they prefer to do injection at fixed time (every 10min, approx. 1 mA) instead of at fixed delta current.

INJECTOR OPTIMISATION

To reduce the influence of the top-up injection in the user's experiments the residual kick on the stored beam during injection should be minimised.

With the installation of timing boards with a resolution of 10 ps for the injection kickers, the injection bump can be closed with a residual orbit oscillation at the straight sections of 100 um rms in the horizontal plane and 30 um rms in the vertical plane, as shown in Fig. 4. Typical values during operation are 200 um rms in the horizontal plane and 50 um rms in the vertical plane. The oscillations are dumped after a few ms. The influence of the injection septum is negligible.

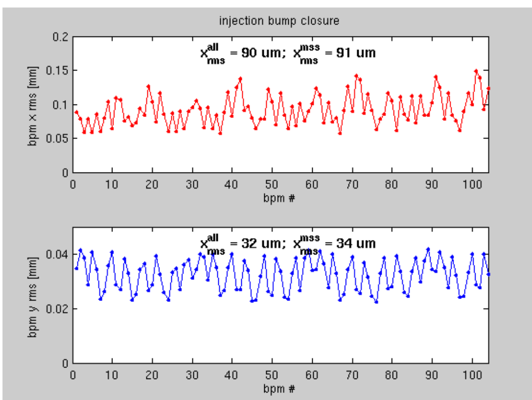

Figure 4: RMS value of residual oscillations around the storage ring due to the non-perfect closure of the injection bump.

PREPARATION FOR SINGLE BUNCH INJECTION IN TOP-UP

Top-up injection in multibunch has the drawback that all buckets are filled uniformly and there is no possibility to select in which bucket to refill. In order to be able to do this selection first a quantitative charge measurement is required. An estimation is today provided by a data analysis of the FCT signal. To improve the results and obtain a higher dynamic range other techniques have been tested using the visible part of the synchrotron radiation. The one providing the best results is the Time Correlated Single Photon Counting. The technique was tested in the ALBA diagnostic beamline, and a definitive version will be installed inside the tunnel in summer. Preliminary results can be found in [3]. It is expected that top-up injection with bucket selection will be implemented in the next year.

SUMMARY

Commissioning of the top-up injection process at ALBA has been completed. All additional interlocks and pre-conditions have been successfully tested. The high level application and GUI fulfil the requirements. A one week test with users is foreseen for June 2014 and routine top-up operation for users at ALBA will commence after summer of 2014.

ACKNOWLEDGMENTS

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