INJECTION INTO THE ALBA STORAGE RING

G. Benedetti, D. Einfeld, E. Huttel, M. Muñoz, M. Pont, CELLS-ALBA, Bellaterra, Spain.
E. Huttel, FZK-ANKA, Karlsruhe, Germany.

Abstract

Injection into the ALBA Storage Ring is performed at an energy of 3 GeV in a 7 m long straight section. The injection bump is performed with four kickers. Pulsed magnets characteristics are described. Tracking of particles has been simulated over a large number of turns, taking into account the magnet errors, the sextupole fields and the physical apertures all along the machine. The low emittance of the beam injected from the booster provides high injection efficiency. Specific requirements for top-up injection have been examined, such as a perfect closure of the injection bump, the residual vertical field and the leakage fields from the septum.

INJECTION LAYOUT

BTS Transfer Line

The Booster to Storage Ring (SR) transfer line is 26.8 m long and consists of 2 equal dipoles and 7 independent powered quadrupoles. Two pairs of horizontal and vertical corrector magnets, one BPM and a screen monitor before the injection septum (Figure 1), allow controlling and adjusting the beam parameters at the injection point.

Injection Scheme

The injection into the SR is done in the horizontal plane from the inside of the ring, in a 7 m long straight section with finite dispersion. The stored beam is bumped by four fast kickers, while the beam from the BTS is injected of axis through an active pulsed septum of 9°. The septum sheet is movable over a range of ±5 mm around the nominal distance of -16 mm from the ring axis, allowing using lower currents in the kickers in the first phase of the commissioning, and then increasing the distance as much as necessary to not affect the Touschek lifetime.

MAGNET SPECIFICATIONS

Storage Ring Injection Septum

The storage ring injection septum is based on an active septum with an internal thin walled stainless steel pipe. The beam pipe for the stored beam is made of mild steel and acts as a magnetic screen. The laminated yoke and the coil are outside vacuum. The magnet will be build by Danfysik A/S.

Storage Ring Injection Kickers

The four storage ring injection kickers have been designed to be identical except for polarity. The specified parameters are listed in Table 1. The kicker magnets design is based on a C-shaped ferrite yoke and is installed around a ceramic vacuum chamber. This arrangement comprises a single current conductor to drive the magnet and an outer passive (eddy current driven) conductor. This configuration ensures a low drive voltage, where the magnet stray induction is kept low. The ceramic vacuum chambers will be coated with a thin layer of Ti. A thickness of 400 nm has been proposed. The kickers will be built by Danfysik A/S.

Table 1: Pulsed Magnets Main Parameters

	Kickers	Septum
Deflection angle (mrad)	9	157
Nominal field (T)	0.129	0.9
Magnetic length (mm)	700	1744
Magnet aperture HxV (mm)	95x38	14x11
Max. current (A)	4700	10500
Repetition rate (Hz)	3.125	3.125
Pulse length (μs)	6	360

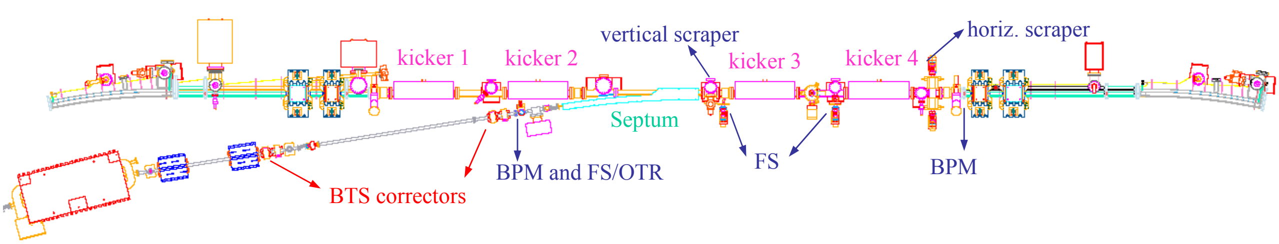

Figure 2: Injection straight section with pulsed magnets and diagnostics elements. The distance taken up from kicker 1 to the horizontal scraper is 6.96 m.

PULSER SPECIFICATIONS

All power supplies have the same structure built up by PPT GmbH and will have the same structure build up by three main components:

- Control unit
- High voltage power supply
- Pulser unit

While the control unit and the HVPS will be installed outside the tunnel to avoid radiation damage, the pulser unit will be installed inside the tunnel, integrated into the magnet girder to minimise the inductance.

Storage Ring Injection Septum

The power supply for the SR injection septum is a low damped LC ringing circuit switched by a single GCT-like fast current thyristor from ABB, SPY 15F4502ES.

Storage Ring Injection Kickers

Four independent power supplies are foreseen for the kickers. The identity between the four pulsed has been specified to better than 0.1%, with a jitter lower than 5 ns (FWHM).

The pulser unit consists of a capacitor bank constructed from a series and parallel combination of 40 capacitors from the company AVX switched by a stack (4) of solid state GCT-like thyristors, SPY 15F4502 from ABB, connected in series which will produce a half sine pulse with a resistive damped reverse path.

The importance of having a closed bump for the injected as well as for the stored beam will be achieved with the help of three variables that can be adjusted independently for each kicker: the peak amplitude, the delay and an inductor placed in parallel for each magnet which allows to change the inductance of the magnet.

INJECTION TRACKING

Simulated Conditions

Simulations of the injection process have been carried out using the Accelerator Toolbox (AT) for Matlab [1] at nominal working point (18.18, 8.37) and chromaticities corrected to (+1, +1) [2]. A reference set of random errors has been used and the orbit corrected with 88 horizontal and 88 vertical correctors. No correction of coupling is considered. In these conditions, the residual orbit is about 30 μm rms at the magnets locations and the global coupling about 0.5%.

The septum sheet is positioned at the nominal distance of -16 mm from the SR axis and the stored beam bumped at -10 mm. The vacuum chamber apertures all along the ring are also included: in particular, the absorber horizontal apertures of +18 mm in the straight sections and +22 mm and +26 mm in the injection section, and the in-vacuum undulator vertical gap of ±2.75 mm.

The insertion device field and high multipoles are not included in the simulations.

First Turns

A half sine kicker pulse of 6 μs is considered, that means that the bump stays on 3.3 turns after the injection (T_{rev} = 0.9 μs), while the horizontal fractional tune (0.18) makes that the beam returns at its original phase space position x-x' every 5.5 turns.

Figure 2 shows the sequence of the horizontal phase space snapshots at the injection point before and after the 1_{st} turn. In order to not hit the septum after the 1_{st} turn the beam must be injected at a horizontal angle x' > -0.2 mrad, on the other hand, to not lose the beam on the septum when returning in the phase space at the 5_{th} turn, the injection angle must be x' < 0.8 mrad. The best compromise is then injecting at a small angle of about 0.2 mrad as shown in Figure 2 (top). Such an angle can be tuned using the two correctors in the BTS transfer line before the septum, but it requires septum field stability better of 0.1%.

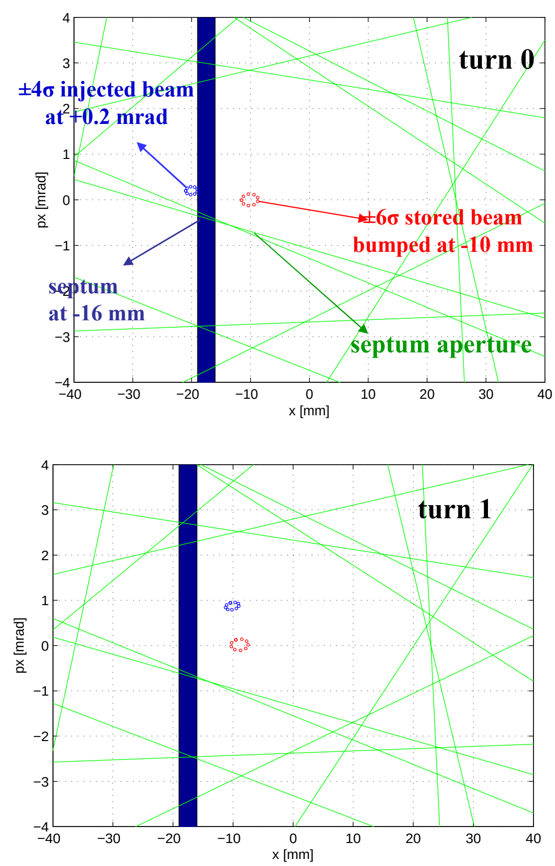

Figure 2: Injected and stored beam in the horizontal transverse phase space at the injection point. The projection of the apertures of the septum and the absorbers are represented by the green lines. Injecting at an angle of 0.2 mrad (top), the beam returns far away of the septum after the first turn (bottom).

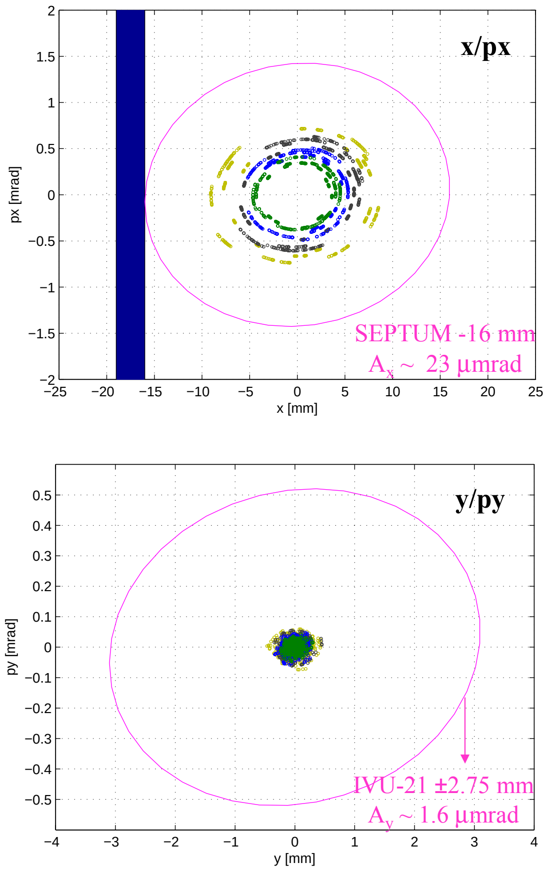

Figure 3: 6-D tracking over 5000 turns in the horizontal (top) and vertical (bottom) phase space. The particle distributions are plotted every 1000 turns in different colours.

6-D Tracking

Assuming an injected beam from the booster with an emittance of 9 nm and 10% of coupling, and with a bunch length of $\sigma\tau_{booster}$= 72 ps, 300 particles uniformly distributed on an ellipsoid in (x, x', y, y', z, z') enclosing 4σ have been 6-D tracked over 5000 turns (about one damping time) with damping. Figure 3 shows the beam evolution during the tracking, the element limiting the ring acceptance is the septum sheet, horizontally, and the in-vacuum undulator vertically. The small injected emittance is responsible for the absence of particle losses due to machine sextupole non-linearities or resonances.

TOP UP REQUIREMENTS

Even if tracking simulations indicate that the good injection efficiency allows top up operation, the request of beam stability of 10% of the beam size in both planes (typically for ALBA, in the long straight section 20 µm horizontal and 1.6 µm vertical) imposes demanding specifications for the injection elements. Some simulations have been performed considering the following issues.

Closure of the Injection Bump

The four pulses of the kickers are assumed to have stability better than 0.1% and a maximum time jitter of 5 ns. An alignment accuracy of 100 µrad around the longitudinal axis, which gives rise to horizontal field errors, has been considered.

Combining statistically all these source of errors the calculated beam stability exceeds the requirements by a factor 10 on both planes, in agreement with results obtained at other light sources [3]. Nevertheless, improvements and dedicated tests will be needed to fulfill the stability requirements for top up.

The field leakage of the septum magnet has been specified to be less than 50 µT·m and must be confirmed by measurements on the real magnet. Its effect on the closure of the injection bump is under evaluation.

CONCLUSIONS

The pulsed magnets and pulsed power supplies are under construction and delivery is expected before the end of 2008.

Injection calculations performed on the ALBA nominal lattice with errors and main non-linearities with conservative injected beam indicate that very high injection rates can be achieved. In fact, the low emittance beam from the booster makes that no particle loss over a large number of turns is observed in the simulation.

Work to implement top up operation is needed and has to concentrate on the performances of the pulsed elements, especially stability, alignment, and shielding.

REFERENCES

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[2] M. Muñoz and D. Einfeld, "Lattice and beam dynamics of the ALBA storage ring", ICFA Beam Dyn. Newslett. 44, 2007.
[3] M-A. Tordeaux, private communications.