BEAM OPTICS MEASUREMENTS DURING ALBA COMMISSIONING

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Abstract

The synchrotron light source ALBA is in the final stage of the Storage Ring commissioning [1, 2], with the beamline commissioning well under way. This paper reviews the results of the modeling of the lattice and the agreement with the LOCO measurement of the machine; the performance of the beta beating correction (critical in the ALBA case due to the large gradient in the bending magnet and the low number of quadrupole families), including effect of insertion devices; the lifetime measurement and the general agreement of the machine to the model using the design.

WORKING POINT

Historical Background

Before starting the commissioning of the ALBA storage ring, the reference lattice had a design working point (18.15, 8.38). This working point was changed to ease the injection (higher horizontal fractional tune implies better suppression of the non-closed injection bump and clearance of the septum sheet). The working point was set then to (18.24, 8.39). Unfortunately, the tune seemed to move along the days, and that working point had dangerous resonances close by, in particular the third order 2Qy + Qx = 35. Once the injection improved, it was decided to study returning closer to the original working point, as according to simulations that original working point was optimum for the dynamic aperture (Figure 1).

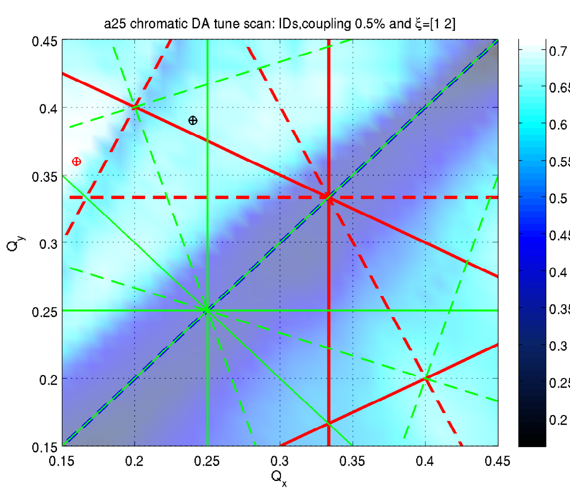

Figure 1: Chromatic dynamical aperture simulations as a function of the working point. The starting working point is repesented by a black cross while the new working point is in red.

Change of the Working Point

The working point was changed from (18.24, 8.39) to (18.16, 8.36). The main reason was moving apart from resonance 2Qy + Qx = 35. It has been seen that, in presence of IDs, when close to this resonance the beam can be easily lost or the lifetime reduces drastically. This has been confirmed with simulations as shown in Fig. 2.

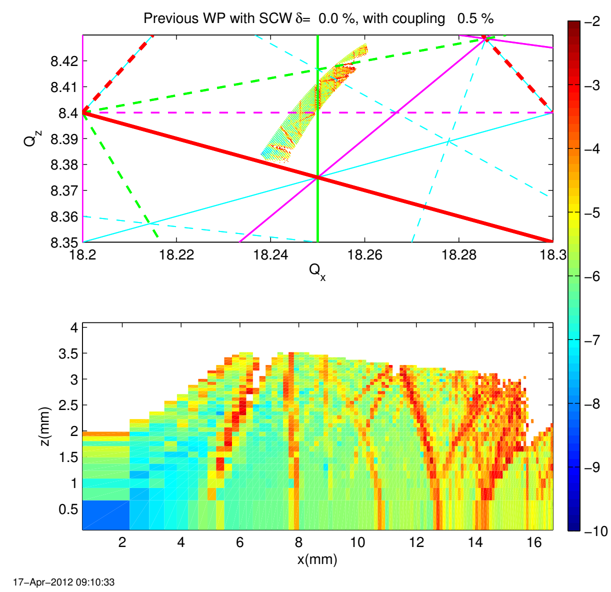

Figure 2: Frequency map for the Alba Lattice including IDs when the tune is close to resonance 2Qy + Qx = 35. In this case, the effective elastic lifetime would be considerably reduced.

The beam lifetime normalized by the beam size (the beam gets smaller when getting far from the main coupling resonance Qx - Qy = 10) was used as a figure of merit to choose the new working point. Only those tune regions already good for the model were actually scanned in the real machine.

LATTICE MODELLING

LOCO Analysis and Calibrations

The improvements in the LOCO analysis that were presented in reference [3], using the scaled Levenberg-Markard [4] method with lambda of 0.1 and all the singular values , eventually have been successfully implemented after October 2011. Figure 3 shows the powered current variations applied to the quadrupoles to symmetrize the optics. With this adjustment of the SVD fit, the variation of the single quadrupoles with respect to the nominal family value

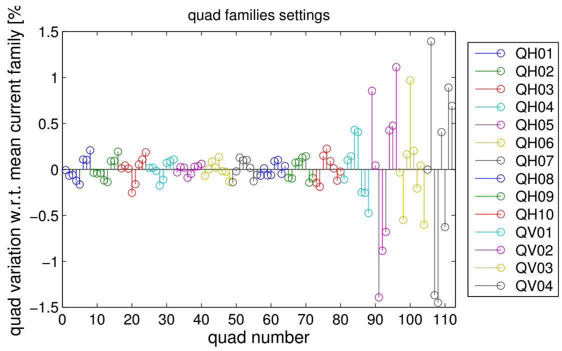

Figure 3: Quadrupole change applied to symmetrize the ALBA storage ring optics with LOCO.

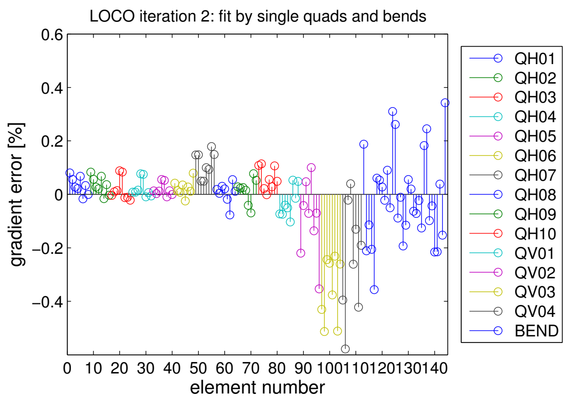

Figure 4: Calibration errors in the 112 quadrupoles and 32 gradient dipoles fit by LOCO.

has been reduced in the doublet of focusing quadrupoles of the matching sections, from the previous $\pm 5\%$ (using lambda 0.001) to only $\pm 0.2\%$ (with lambda 0.1), avoiding high current changes fighting each other. In the defocusing quadrupole families the applied current variation is higher, $\pm 1.5\%$, due to the fact that they are used as correctors of the combined dipole gradient errors.

Finally, the calibration errors fit by LOCO in the 112 quadrupoles and 32 gradient dipoles are shown in Fig. 4.

Optics Correction

In 2012, the LOCO correction has been applied only after machine shutdowns of one or more weeks. The beta beating with the quadrupoles at a common starting value within each family is 20 % peak-to-peak in both planes, then the lattice is symmetrised in 2-3 LOCO iterations achieving a beta beating of 1% peak-to-peak.

During each run, a complete data set for the LOCO analyis has been measured every week to evaluate the beta beating stability. After introducing the RF frequency in the slow orbit feedback loop, minimizing the change in the circumference of the machine, the beta beating is maintained within $\pm 2\%$ peak-to-peak within runs of 3-4 weeks and the tunes are stable within ± 0.005 .

Emittance

The storage ring beam size can be measured using the synchrotron radiation produced by bending magnet through a pinhole. At that position the emittance is estimated using the beta functions fit by LOCO. The measurement 4.7±0.3 nm·rad is in good agreement with the model value of 4.6 nm·rad.

Insertion Device Effect

The effect of the superconducting wiggler SCW31 and the multipole wiggler MPW80 [5] on the betas has been measured with LOCO. The difference of the betas reconstructed by LOCO with and without the insertion device is in good agreement with the model as well as the tune change [6]. Figure 5 shows a comparison between the beta beating according to the model and the measured one in the case of the superconducting wiggler. The measured vertical tune shift is $\Delta Q_y = +0.004$ close to the model $\Delta Q_y = +0.005$.

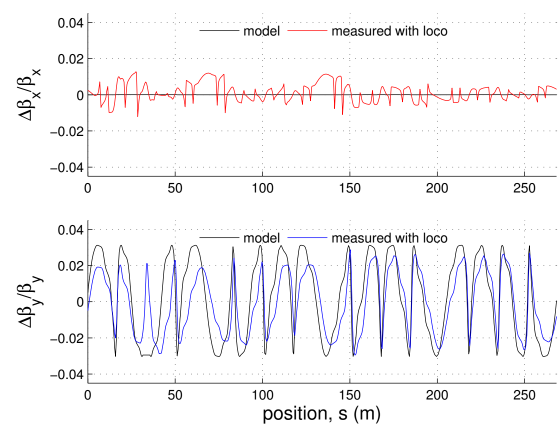

Figure 5: The horizontal (top) and vertical (bottom) beta beating intruduced by the supeconducting wiggler: the model values are compared with the measured ones.

LOWER EMITTANCE OPTICS

A lattice with lower emittance has been tested in the ALBA storage ring. The emittance is reduced to 3.5 nm·rad instead of the nominal 4.6 nm·rad. In this new optics the dispersion changes a bit leaving the effective horizontal emittance about the same and reducing the effective vertical emittance. Figure 6 shows the comparison with the standard lattice used. The new optics has been applied and corrected with LOCO up to a 1% beta beating. The measured emittance agrees very well with the model value.

Further tests will be done with the two lattices in order to cross-check the quadrupole calibrations with different lattices.

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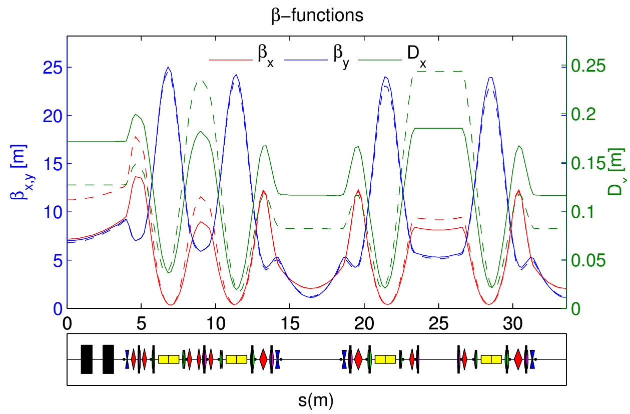

Figure 6: Optic functions comparison between the nominal (dashed lines) and the new optics (continuous lines). One eighth of the machine is shown.

LIFETIME

At ALBA, the measurement of the beam lifetime is performed using the DCCT signal.

Several tests have been performed including the dependence of lifetime with respect of the vertical and horizontal apertures, RF cavity voltage, current per bunch. In general, the measured lifetime does not fit the model which is optimistic by a factor around 30%. The Piwinski model [7] is used for the determination of the Touscheck lifetime. It seems to fit better the results than Brück's and Völkel's formulas. The calculation of the gas lifetime (elastic and inelastic) relies on the measured pressure, which at the moment is not very precise. Also, the bunch length measurement with the streak camera does not agree with the model by a factor 1.5 (the measured is around 35 ps, for a theoretical of 19 ps), the model bunch length is used in the calculations.

Presently, the voltage achievable in the cavities is around 2 MV which is equivalent to 20 h Touscheck lifetime at 100 mA. A factor 2 has to be included in the gas scattering lifetime components to match the measured lifetime of 13 to 15 h.

ELECTRON BEAM ENERGY FROM UNDULATOR SPECTRUM

The magnetic measurements combined with the measurement of emitted light spectrum allowed to indirectly determine the ALBA energy as well as the energy dispersion. Measurements were made at NCD beamline, feeded by the in-vacuum undulator IVU21 [5]. Figure 7 shows the spectrum corresponding to the fifth harmonic of the in-vacuum undulator, for a gap of 6.4 mm. The measured magnetic field corresponding to this gap is $B_0 = 0.7170$ T, and the measured period length is 21.6 mm. The fit spectrum corresponds to the light delivered through a squared aperture of 23.361 mrad by an ideal undulator with the given parameters inserted in the medium straight section of ALBA with nominal parameters: ϵ = 4.5 nm·rad, 1% coupling, β_x = 1.997 m, β_y = 1.219 m, D_x = 0.07797 m, σ_E = 0.001. Using these parameters, fitted machine energy is E = 2.998 GeV.

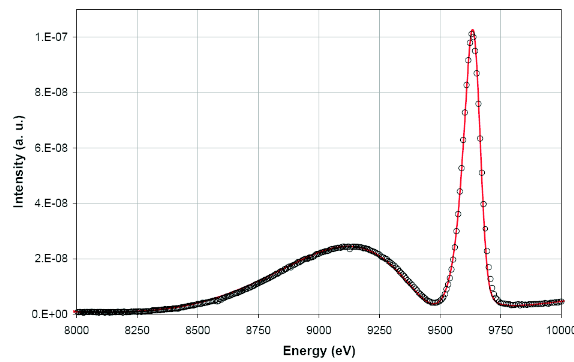

Figure 7: Comparison of the theoretical spectrum to the measured one for one of the in-vacuums undulators. All the nominal settings agree well, with just the energy fitted to 2.998 GeV.

CONCLUSIONS

The optics of the ALBA storage ring is corrected now routinely to the theoretical one, using the LOCO technique, with a remaining beta beating of the order of 2 %, including the effect of the insertion devices. Using the measures of lifetime and chromaticity, it seems that there is also a good agreement in the energy acceptance and dynamic aperture provided by the machine.

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