TIARA-CONF-WP6-2012-002

Test Infrastructure and Accelerator Research Area

Conference Contribution

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21 June 2012

The research leading to these results has received funding from the European Commission under the FP7-INFRASTRUCTURES-2010-1/INFRA-2010-2.2.11 project TIARA (CNI-PP). Grant agreement no 261905.

This work is part of TIARA Work Package **6: SVET R&D Infrastructure**.

TESTS OF LOW EMITTANCE TUNING TECHNIQUES AT SLS AND DAΦNE*

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Abstract

The SuperB collider design is based on extremely low emittances, comparable to those of synchrotron light sources. A Low Emittance Tuning (LET) algorithm was developed for SuperB and has been tested last year at DIAMOND. This paper will report on the results of the application of LET to SLS (PSI) and DAΦNE (LNF) in order to compare and confirm the previous results. In this tests, the correction of orbit, dispersion and coupling is applied simultaneously to the detection of Beam Position Monitors tilts. The results of the beam based alignment performed at DAΦNE for the new KLOE run will also be presented.

INTRODUCTION

In this paper we present the work done to test the Low Emittance Tuning (LET) procedure developed for SuperB [1]. SuperB is an asymmetric e^+e^- collider (6.7 GeV e^+, 4.18 GeV e^-) that is intended to provide a luminosity $\mathcal{L} = 10^{36}\ cm^{-2}s^{-1}$. This luminosity is mainly determined by the very low beta at the IP, and by a very low emittance lattice (2 nm·rad in the horizontal plane and 5 p·mrad in the vertical plane). The determination of a procedure to obtain and maintain the reference emittances is the main objective of this study. In the following we present the status of the tests of LET recently performed (also in the TIARA framework [2]) at the Swiss Light Source and at DAΦNE [3]. In the case of DAΦNE, the results of the beam based alignment are also presented.

LET ALGORITHM

The LET correction scheme [4] is a modified response matrix method that extends the Dispersion Free Steering (DFS) technique [5]. The correction is based on the SVD inversion of the response matrix $\mathcal{M}$ determined by the relations:

$$\left(\begin{array}{c}(1-\alpha-\omega)\,\vec{y}\\ \alpha\,\vec{\eta}_y\\ \omega\,C_{ij}]_{(N_i\times N_j)\times 1}\end{array}\right) = \mathcal{M}_v\left(\begin{array}{c}\vec{\theta}_V\\ \vec{K}\end{array}\right) \qquad (1)$$

$$\left(\begin{array}{c}(1-\alpha-\omega)\,\vec{x}\\ \alpha\,\vec{\eta}_x\\ \omega\,B_{ij}]_{(N_i\times N_j)\times 1}\end{array}\right) = \mathcal{M}_h\left(\vec{\theta}_H\right)$$

where $\vec{x}, \vec{y}$ are orbits, $\vec{\eta}_{x,y}$ are the dispersions, θ and K are respectively corrector strengths and skew quadrupoles gradients. The matrices $C_{i,j} = \partial x_i/\partial c^v_j$ and $B_{i,j} = \partial x_i/\partial c^h_j$ (where x_i is the horizontal orbit and $c^{(v,h)}_j$ is a vertical/horizontal corrector kick), represents respectively the variation of the off diagonal and the on diagonal blocks of the response matrix respect to their theoretical values. All the left hand side matrix elements are recorded at the location of beam position monitors (BPMs). The LET method is flexible to plug in the measured matrices $C_{i,j}$ and $B_{i,j}$ of arbitrary size ($N_j = 2$ is the minimum). It is noted that the larger matrix size may result in the better correction determination at the expense of the longer data acquisition time. The matrices C_{ij} and B_{ij} are mainly determined by the skew quadrupole and normal quadrupole terms generated by the vertical or horizontal passage off axis in sextupoles, and thus allows to consider the effect of sextupoles in the evaluation of the correction. To be able to exploit the SVD to solve the system, the matrices are reshaped to vectors of size $(N_i \times N_j) \times 1$, where N denotes the number of monitors or correctors respectively. It is to be noticed that in this method N_j may be much less than the total number of correctors. The parameters α and ω and the number of SVD eigenvectors are chosen, in order to identify the settings producing the best overall correction, since coupling and optics correction are obtained at the expense of a small orbit excursion.

BPM Roll Errors

These measurements, especially $C_{i,j}$ and η_y, are influenced by BPM roll errors. For this reason the system of equations 1 is extended to include the BPM rolls $\vec{T}$ that are common parameters for all the measurements performed and thus can be identified:

$$\left(\begin{array}{c}(1-\alpha-\omega)\,\vec{y'}\\ \alpha\,\vec{\eta'}_y\\ \omega\,C'_{ij}]_{(N_i\times N_j)\times 1}\end{array}\right) = \mathcal{M}_v\left(\begin{array}{c}\vec{\theta}_V\\ \vec{K}\\ \vec{T}\end{array}\right) \qquad (2)$$

$$\left(\begin{array}{c}(1-\alpha-\omega)\,\vec{x'}\\ \alpha\,\vec{\eta'}_x\\ \omega\,B'_{ij}]_{(N_i\times N_j)\times 1}\end{array}\right) = \mathcal{M}_h\left(\begin{array}{c}\vec{\theta}_H\\ \vec{T}\end{array}\right)$$

where the prime denotes a measurement influenced by BPM roll errors. The rows added by the extention of matrices $\mathcal{M}_{v,h}$ contain elements to couple the horizontal and vertical plane. For example, the vertical dispersion at the i-th BPM is represented:

$$\eta'_{yi} = \eta_{yi}\cos(T_i) + \eta_{xi}\sin(T_i) \qquad (3)$$

LET AT SLS

LET has been applied in the past for various Machine Development (MD) shifts at the Diamond Light Source [6].

*The research leading to these results has received funding from the European Commission under the FP7-INFRASTRUCTURES-2010-1/INFRA-2010-2.2.11 project TIARA (CNI-PP). Grant agreement no 261905.

A vertical emittance of $\sim$1.7 $pm \cdot rad$ was achieved at the expense of an orbit excursion of $\sim$30 μm rms. For a complete relation of the measurements performed at DIAMOND, please refer to [4]. We present here the first results (3 MD shifts) obtained at the Swiss Light Source [7]. All measurements were performed in top-up mode (beam current of 350 or 400 mA) with open Insertion Device gaps and orbit feedback switched off.

LET Vertical Correction

In this measurement session, we aimed to reduce the vertical emittance introducing a vertical orbit. Orbit, dispersion and the vector $C_{i,1}$ before and after LET correction are shown in Figure 1. Three LET correction iterations were performed using only vertical correctors and the weights α and ω set to correct 94% orbit, 5% dispersion and 1% coupling with a cutoff at 1% of the highest eigen value. The initial vertical beam size of $\sigma_y = 16 \pm 0.5\ \mu m$, was reduced after correction to $\sigma_y = 7 \pm 0.5\ \mu m$. The residual rms orbit observed is 100 μm while the rms dispersion and $C_{i,1}$ have been reduced respectively to $\sim$63% and $\sim$44% of their initial values.

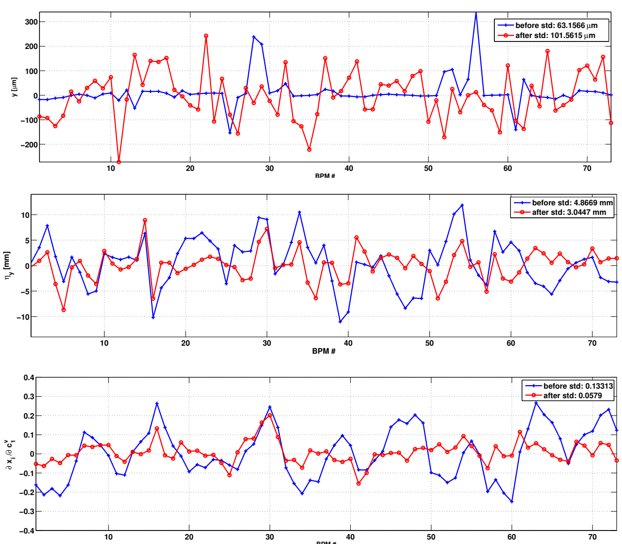

Figure 1: Orbit, dispersion and coupling before and after LET using vertical correctors.

LET Skew Quadrupoles, Vertical Correction and BPM Roll Errors

The correction performed with skew quadrupoles within the LET tool is basically identical to the VRM [8] correction currently in use at SLS, the only differences are the use of a smaller set of correctors in the evaluation of the off diagonal response matrix and the use of a standard SVD algorithm (instead of a 2D-SVD) that simultaneously constraints dispersion and coupling (or linear optics in the horizontal correction). The application of the LET correction could realize vertical beam sizes slightly worst respect to the ones obtained using the VRM technique. We iterated the skew quadrupole correction (alternating dispersive and non dispersive skew quadrupoles) constraining dispersion and 15 vectors ($N_j = 15$) of the off diagonal response matrix ($C_{i,1:15}$). The vertical beam size was reduced to $4.7 \pm 0.2(stat) \pm 0.5(syst)\ \mu m$. The correction has been performed with 80% weight on dispersion and the residual to correct the off diagonal elements of the response matrix. The eigenvalue cut was set at 10% of the highest eigenvalue in the SVD fit.

Various test have been performed trying to improve this result, using horizontal correctors, vertical correctors, simultaneous correction with skew quadrupoles and vertical correctors, and increasing the number of eigenvalues (up to all), but none of them could improve the previous minimum vertical beam size. However, evaluating vertical corrector strengths including possible BPM roll errors, gave an improvement in the correction. The four iterations performed with this extra condition, constraining orbit at 80%, dispersion at 10% and coupling at 10%, using all the available eigenvalues, reduced the vertical beam size to $4.4 \pm 0.4(stat) \pm 0.5(syst)\ \mu m$, corresponding to the vertical emittance of $\sim$1.3 $pm \cdot rad$. Figure 2 shows the final change in orbit, dispersion and $C_{i,1}$ (as an example), before and after the various corrections.

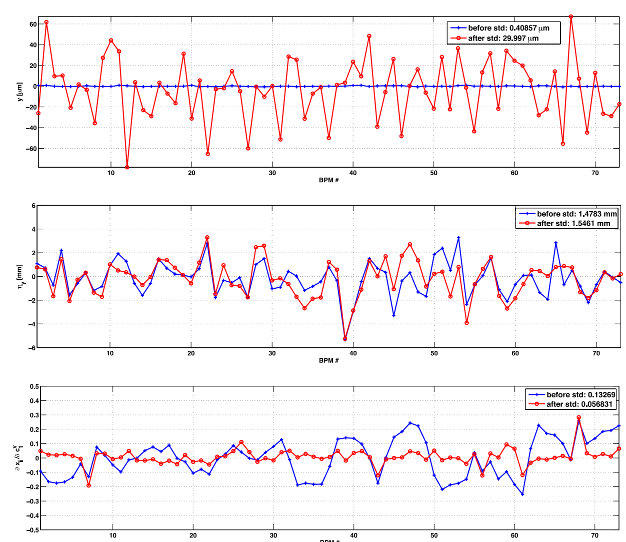

Figure 2: Residual orbit, dispersion and $C_{i,1}$ before (blue) and after (red) correction with skew quadrupoles followed by vertical correction+bpm roll estimations.

The averages of the BPM roll errors estimated at each measurement are shown in Fig. 3.

During the MD some artifacts (large spikes) appeared in the beam size measurement due to an issue with the RF coupler (therefore the beam current was 350 mA during this MD). Although clear spikes are removed when the average beam size is computed, the statistical error is still larger than the usual value (0.1 μm).

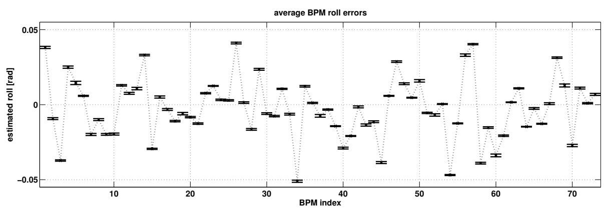

Figure 3: Average BPM roll errors.

LET AT DAΦNE

The LET tuning technique, is currently being tested also at the DAΦNE e^+e^- collider in Frascati. The application of the LET tuning in DAΦNE is of crucial importance for SuperB, since it allows to test the technique in presence of collisions (beam-beam), at high currents and with short lifetimes. Care is to be taken also for the interaction region that needs to be excluded from the correction, not to modify the collision point as it is true for IDs at synchrotron light sources. Since not all of this requirements have been fulfilled by the LET at this time and there is not yet a full implementation of the tool in the control system, currently only preliminary tests were performed using the available skew quadrupoles.

Beam Based Alignment at DAΦNE

Beam based alignment has been performed for DAΦNE recently in order to survey the relative positions of quadrupoles and beam position monitors. The following relations [9] have been used to determine the quadrupole misalignments:

$$y_{q,m} = y_{q,\Delta H}\, k_q \Delta H + y_{q,\Delta V}\, t_q \Delta V \tag{4}$$

$$x_{q,m} = x_{q,\Delta H}\, k_q \Delta H + x_{q,\Delta V}\, t_q \Delta V \tag{5}$$

where $y(x)_m$ are the orbit excursions measured powering the q^{th} quadrupole $\pm 1A$, $y(x)_{\Delta H(V)}$ are the simulated orbit due to a misalignment of $\Delta H(V)$ and k, t are the fit parameters that determine the misalignment of the quadrupole in the vertical and horizontal planes. Figure 4 shows the misalignments estimations for the e^- beam, before (left) and after (right) the realignment of quadrupoles and the absolute orbits at the time of measurement, to evidence the influence of the off axis orbit respect to the effective quadrupole misalignment. The large vertical misalignments are due to a fixed bump of 10 cm at the second IP. After the first measurements quadrupole QUAPL203 has been realigned in the vertical plane and the orbit bump at injection has been revised.

CONCLUSIONS

LET has been tested at the SLS obtaining very promising results, especially showing the influence of the roll estimations in the LET correction. First measurements and preparations for the analysis have also been performed at DAΦNE.

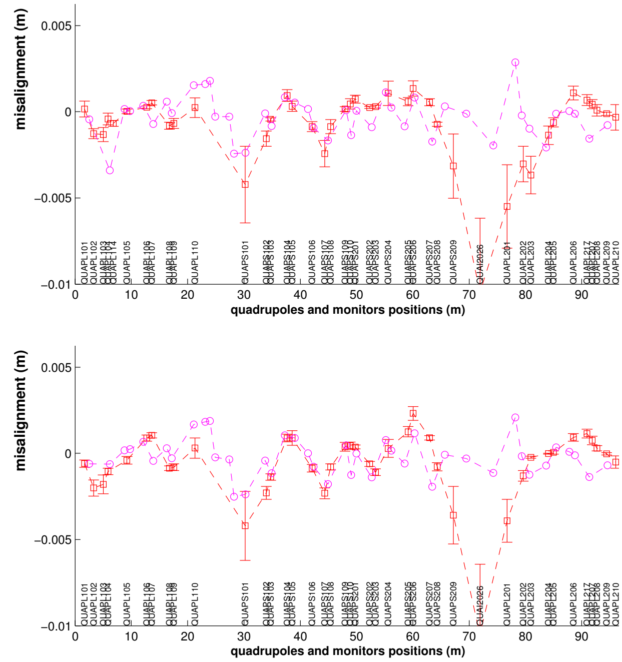

Figure 4: Before (left) and after (right) realignment. In purple is the vertical absolute orbits and in red the vertical estimated misalignments ($\Delta V = 300\mu m$).

REFERENCES

[1] Biagini M.E., et al, Overview of Super B Factories, this conf.

[2] TIARA, `http://www.eu-tiara.eu`.

[3] C. Milardi et al.,THPZ004, IPAC 2011.

[4] S.M. Liuzzo, WEPC013, IPAC 2011.

[5] R. Assmann et al, 10.1103/PhysRevSTAB.3.121001.

[6] R.P Walker, APAC, pg 66, (2007).

[7] M. Böge et al., "The SLS Accelerator Complex: An Overview", EPAC'98, Stockholm 1998.

[8] M. Böge et al., SLS Vertical Emittance Tuning, IPAC-2011.

[9] M. Wodley et al. LBNL-55728.