ORBIT RECONSTRUCTION, CORRECTION, STABILIZATION AND MONITORING IN THE ATF2 EXTRACTION LINE

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Abstract

The orbit in the ATF2 extraction line has to be accurately controlled to allow orbit and optics corrections to work well downstream. The Final Focus section contains points with large beta function values which amplify incoming beam jitter, and few correctors since the steering is performed using quadrupole movers, and so good orbit stability is required. It is also essential because some magnets are non-linear and can introduce position-dependent coupling of the motion between the two transverse planes. First experience monitoring the orbit in the extraction line during the ATF2 commissionning is described, along with a simulation of the planned steering algorithm.

INTRODUCTION

ATF2 is an Extraction line (EXT) and a Final Focus section (FF), scaled down in energy from ILC. Its goal is to produce a nanometer scale electron beam, the smallest ever observed, in a reproducible way [1]. It is being commissioned since January 2009, using the low emittance beam produced by the ATF damping ring. To achieve the nominal 37nm vertical beam size, the vertical emittance must be conserved to the Interaction Point (IP) and the β functions must be well matched.

In the old EXT, before reconfiguring for ATF2, emittance growth of variable magnitude was observed correlated with orbit displacements at injection[2]. Since few changes were made for ATF2, careful monitoring and control of the orbit in this region is expected to be very important to mitigate this effects. Once a *golden orbit* is found experimentally, an efficient steering algorithm will be needed to maintain conditions over time.

In this paper, orbit measurements using the 12 stripline Beam Position Monitors (BPMs) installed in the first part of the EXT are described in presence of intensity variations and after successive implementations of an initial Beam Based Alignment (BBA) procedure. The simulated performances of the steering algorithm which will be used is then presented before concluding and giving some prospects.

MONITORING OF THE STRIPLINE BPMS

Intensity Dependence

Initial monitoring of the orbits showed that the resolution of the majority of the 12 stripline BPMs installed in the EXT appears to be strongly affected by intensity dependent effects in their read-out electronics, see Fig. 1 were the intensity was varied on purpose for this study.

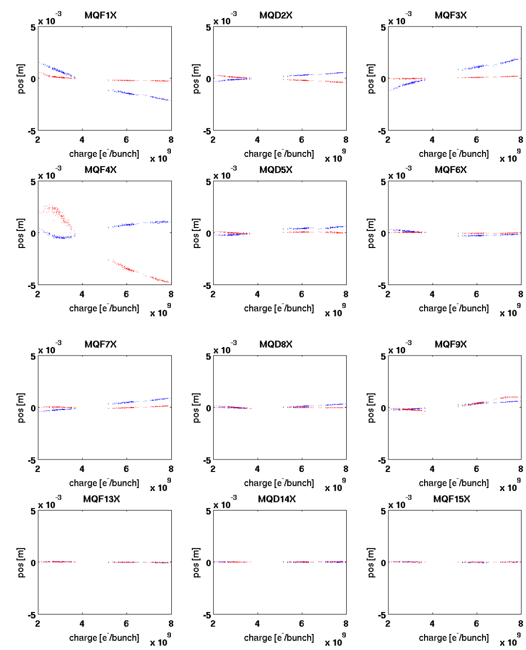

Figure 1: Horizontal (blue) and vertical (red) position readings as function of intensity (e^- per bunch) in the 12 striplines BPMs installed in the EXT.

There are 3 kinds of striplines, MQF1X to MQD5X are short (4 cm) and have a large aperture, MQF6X to MQD8X are short with a small aperture and MQF9X, MQF13X to MQF15X are long (12 cm) and have a small aperture. The large aperture BPMs are strongly correlated with the beam intensity, whereas the long ones have almost no dependence. The measurement spread at these last BPMs could be used to place upper bounds on any changes in beam position which were, taking into account the corresponding β functions and phase advances, well below the observed variations at the other BPMs. Energy changes could also be excluded as possible explanation using the sign of the dispersion function.

While the dependence is large and non-linear at low intensity ($I < 4.10^9 e^-$/bunch), for larger values, it becomes linear. However it doesn't seem stable from one week to the next, so any correction of this effect needs to be recalculated frequently. In the remaining of this paper, a linear correction is applied to improve the resolution. Before implementing such a correction, the resolution was in the 100 micron range for the BPMs with the largest non-linearity, corresponding to 5% intensity fluctuations, while after, it was improved by a factor of about two.

Monitoring of the Orbit

Whereas the vertical emittance in the ring was about 15 pm during April runs, it was measured between 20 and 60 pm in the EXT after dispersion and coupling corrections. The orbits were monitored during these runs to try to find correlations with these observed changes. In the setup procedure, a manual BBA procedure was usually applied before these corrections.

This BBA adjusts the orbit to the magnetic centers of the quadrupoles by trying to cancel beam displacements at a screen downstream when its strength is changed. It is carefully done at the beginning and the end of each straight section (QF2X, QD5X and QD8X), and just checked at the others quadrupoles [3].

Figure 2 shows the readings of the striplines BPMs after successive implementations of this BBA during the April runs. The error bars are the estimated accuracies considering a resolution of 3 pixels ($\sim$100 μm) at the screen for the carefully BBA-ed quadrupoles and 9 pixels ($\sim$300 μm) for the ones which were only checked. MQF4X, which had very large readings, indicating possible hardware problems, is ignored in the following.

The most significant differences between the orbits giving a good emittance (blue line) and the others are:

- the horizontal position after the septum magnets (in QF1X to QF3X)
- the vertical position before the 2^{nd} kicker (in QF7X and QD8X)

At these two locations, differences of at least a millimeter were seen, much larger than the predicted accuracy of the BBA. Since the vacuum chambers in the septum magnets and in the 2^{nd} kicker have small apertures, precise beam centering may be essential to avoid emittance growth, if optical or other effects in these elements are the reasons for the observed variations. During the running in May, it is planned to investigate more systematically the influence

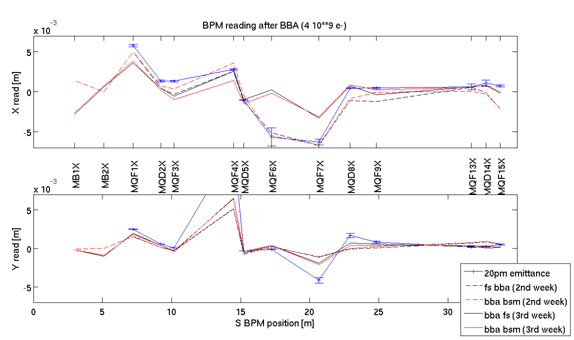

Figure 2: Monitoring beam position readings after BBA.

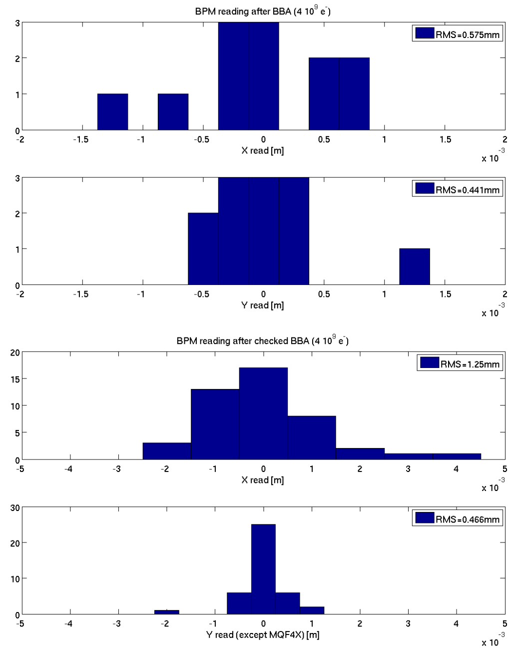

Figure 3: Spread of BPM readings after successive BBAs around mean values, for BPMs where careful BBA was done (upper two plots) and where it was only checked (lower two plots).

which the beam position at these two locations may have on the emittance measured downstream.

The reproducibility of the measurements is not the one expected as the spread of the measurements is larger than the computed accuracy, both at the BPMs where careful BBA was done and at the other ones (see Fig. 3). Improved automated BBA using the newly commissioned and very precise cavity BPMs, rather than the screen, should help to determine if the present manual method or drifts in the stripline measurements are responsible for this spread.

RESULTS OF STEERING IN SIMULATION

Description of the Algorithm

A steering algorithm has been implemented using correctors (steering dipoles for the EXT and quadrupole movers for the FF). It corrects the orbit in one iteration, minimizing the root mean square of the difference between averaged BPM readings at all quadrupoles and a predetermined reference orbit.

The algorithm handles maximum strengths by recomputing solutions after setting successive correctors to their largest allowed values. The interface allows convenient exclusion of specific BPMs and correctors in the whole system.

Simulation Results

Figure 4 and Fig. 5 show the results of simulated steering corrections in the EXT with the nominally expected errors.

Table 1 sums up the steering results in the EXT and FF for two different error levels and optical configurations, as described below.

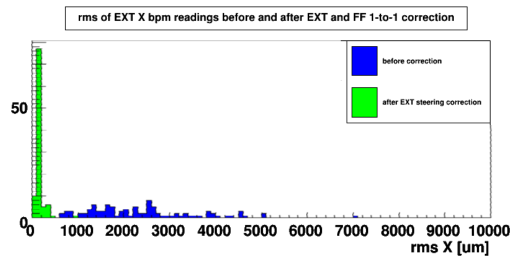

Figure 4: RMS of horizontal BPM readings in EXT before and after correction.

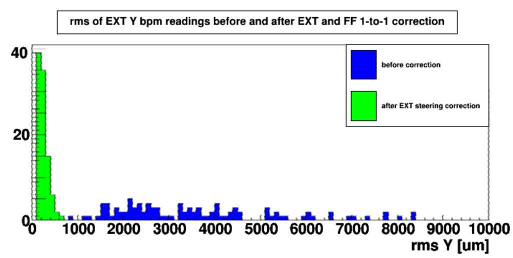

Figure 5: RMS of vertical BPM readings in EXT before and after correction.

Table 1: Results of the Steering Algorithm in the EXT and FFS for Different Error Levels and Optical Configurations

optical config.	error level	RMS [mm]			
		EXT X	EXT Y	FF X	FF Y
nominal	nominal	0.2	0.3	0.2	0.2
	large	0.2	0.3	0.2	0.2
high β	large	0.5	0.5	0.2	0.2

The nominal optics is the one which achieves a 37nm vertical beam size. The high β optics was used for the initial commissioning of the hardware in March ($20 \times \beta_{x\ nominal}$ and $800 \times \beta_{y\ nominal}$). The nominal errors are a set which was agreed in the collaboration for simulations. The most important ones for the present study are:

- 200 μm magnet displacements in x/y/z
- 300 μrad roll
- 10 μm BPM/magnet alignment (post-BBA) in x/y
- 0.1 % magnetic field strength errors (dB/B)
- 100 nm C/S - band BPMs nominal resolution in x/y
- 10 μm stripline BPMs nominal resolution in x/y
- 30 μm FF's mover step size

The large errors are the same as the nominal ones except for the errors on the BPMs and on the magnetic fields which were multiplied by a factor 50.

The simulation shows that this algorithm is precise (less than 500 μm RMS error in all cases) and very tolerant to errors. In the EXT, it was shown to be limited mainly by the number of correctors. The resolution of the BPMs begins to matter only above 200 μm. The cavity BPMs are so precise that increasing $50\times$ their errors has no effect.

Even though the algorithm relies heavily on the modeling of the optics, it converges successfully even with 5% field errors. For the nominal errors, the optimal solution is found at the first iteration. For the large errors 5 iterations are needed to obtain the same level of accuracy. However this is still much quicker than an experimental determination of the transfer matrices.

CONCLUSION AND PROSPECTS

Before being able to establish a reference orbit and implement automatic orbit steering, the magnetic centers of the BPMs must be determined, and their behavior (intensity dependence, long term stability) must be well understood. It is expected that this will be important to improve the reproducibility of the orbit in the region of the EXT where emittance growth is observed. It will also enable systematic studies to understand the origin of the corresponding variations.

Two additional button type BPMs in the immediate vicinity of the septum magnets were recently upgraded to allow additional monitoring of the injection parameters. A few of the stripline BPMs show large variations which need to be investigated. For these, and for the cases where drifts of the measured offsets have been observed, more studies are needed to determine if the electronics is the cause and can be improved.

ACKNOWLEDGEMENT

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