CAVITY BEAM POSITION MONITOR AT THE INTERACTION POINT REGION OF ACCELERATOR TEST FACILITY 2

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Abstract

Nanometre resolution cavity beam position monitors (BPMs) have been developed to measure the beam position and to be linked to control the beam position stability within a few nanometres in the vertical direction at the focus, or Interaction Point (IP), of the Accelerator Test Facility 2 (ATF2). In addition, for feedback applications a lower-Q and hence faster decay time system is desirable. Two cavity so-called IP BPMs have been installed inside the IP chamber at the ATF2 focus area. To measure the resolution of IPBPMs two additional C-band cavity BPMs have been installed one upstream and one downstream of the IP. One cavity BPM has been installed at an upstream vertical image point of the IP. The performance of the BPMs is discussed and the correlation between the IP and image point positions is presented along with a discussion of using these BPMs for position stabilisation at the IP.

INTRODUCTION

The Accelerator Test Facility 2 (ATF2) [3] is a test beam line for Linear Collider (LC) final focus systems (FFS) which was constructed to extend the extraction line at ATF, located at KEK, Japan.

Accelerator Test Facility 2

ATF2 has two goals: firstly to demonstrate focusing using local chromatic correction [2] down to 37 nm vertical beam size, secondly to achieve a few nanometer level beam orbit stability at the focus point in the vertical plane [3].

The ATF2 collaboration has recently tentatively achieved its first goal of a vertical beam size of < 100 nm [4], as measured using an interference pattern Compton scattering beam size diagnostic (Shintake monitor) although only at relatively low bunch charges of $\sim 0.1 \times 10^{10}$ electrons per bunch. A beam line schematic of the ATF2 is shown in Figure 3 and in terms of optical functions in Figure 1 and Figure 2.

This paper is mainly related to the second goal which is to keep the focus location stable. As there is no opposing beam to collide with, the IP point must be instrumented with a beam size diagnostic to confirm the ATF2 optics. This only leaves the up- (or down-) stream beam line available for IPBPMs. The IPBPMs are required to monitor the

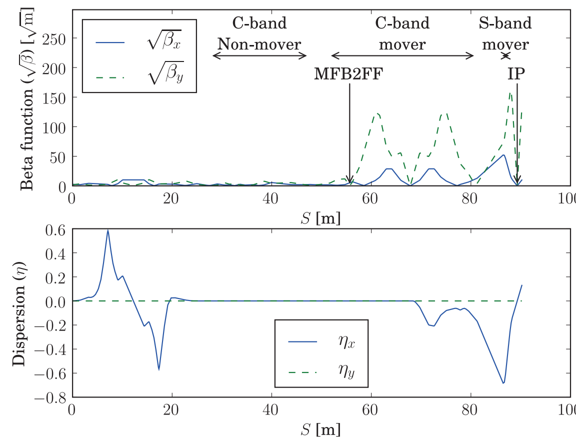

Figure 1: ATF2 beta (β) and dispersion (η) as function of distance along the beam line s from the first extraction kicker, calculated using MAD version 8 [1].

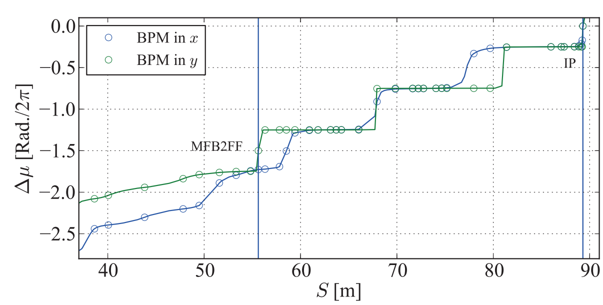

Figure 2: ATF2 horizontal and vertical betatron phase μ compared to the IP phase.

beam orbit at the interaction point beam size monitor and also provide a proxy measurement of beam size as beam jitter should scale linearly with beam size. MFB2FF is the only location at the same IP betatron phase with waist small σ_y 400 nm beam size. It is critical for FFS feedback [6].

Cavity beam position monitor system

There are a total of 39 position sensitive dipole cavities: 35 normal C-band cavities installed at the ATF2, 2 S-band cavities used in the final focusing doublet (where a

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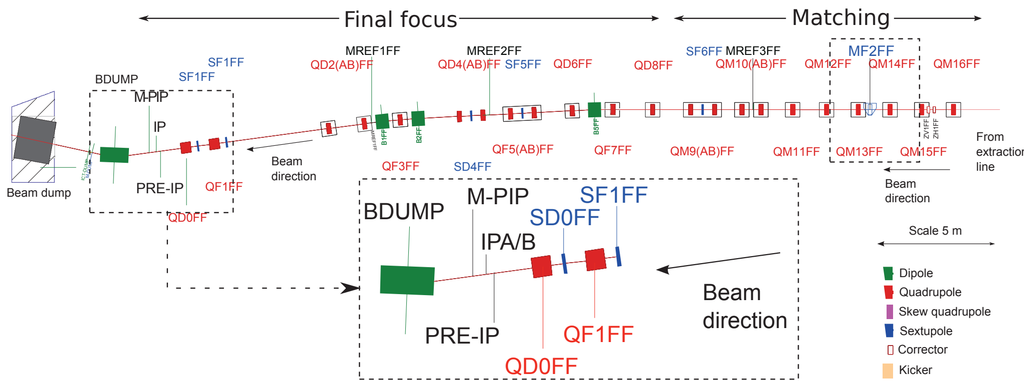

Figure 3: Layout of the ATF2 from the β matching section onwards to the IP and dump. The IP region is zoomed [5].

larger aperture is required due to the large beam size there) and 2 IPBPMs. The C and S-band BPMs are each located in quadrupoles: the first 10 BPMs are mounted in fixed quadrupoles, whilst the next 27 are mounted in quadrupoles which are moved by three axis mover magnet movers and the 4 IP region BPMs (2 normal C-band and 2 IPBPMs) are installed without movers and are not in magnets. The BPM system has a resolution of 200 nm for BPMs with 20 dB attenuators and 30 nm for BPMs without attenuation [5].

Another experiment requiring small vertical beam size, the laserwire (LW) [8], was moved to the MFB2FF location (Figure 4). MFB2FF is mounted directly on the LW

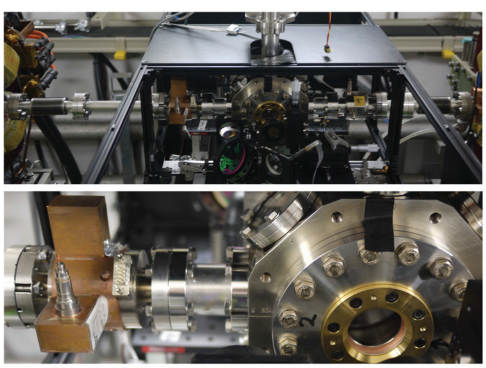

Figure 4: Top : Photo of MFB2FF region, showing the laserwire system from the surrounding quadrupoles (QM14FF and QM13FF). Bottom : Zoom of the laserwire interaction chamber and down-stream BPM, MFB2FF.

chamber and is moved by moving the entire assembly both vertically and horizontally with a total range of ± 2.5 mm and 50 nm optical encoder position read out. The IP region BPMs are calibrated by moving the final focusing quadrupole (QD0FF). The electronics and digital readout are exactly the same as the regular C-band systems.

MEASUREMENTS

During recent ATF2 operation in December 2013 and April 2013, complete orbit data were taken and used to calculate beam position jitters, BPM resolutions and the correlations between different BPMs.

MFB2FF resolution

The resolution was measured as the root mean square (RMS) residual between the measurement provided by MFB2FF and the prediction made by spectator BPMs. Matrix inversion on measured data using singular value decomposition (SVD) provided correlation coefficients for the prediction. Figure 5 shows the residuals between measured and predicted positions. The RMS of the residuals is 33 nm at 0.2 $\times 10^{10}$ electrons per bunch beam intensity. The beam size at MFB2FF is smaller than 400 nm accord-

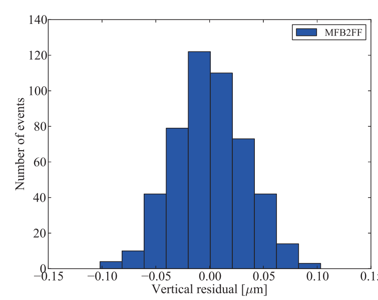

Figure 5: MFB2FF vertical position residual histogram for 500 ATF2 machine pulses.

ing to simulation. The MFB2FF resolution was measured to be continuously less than 50 nm over a period of a few days. At that time jitter at MFB2FF was below 200 nm. Figure 6 shows the vertical jitter at ATF2 during December 2012. The IPBPMs were not calibrated at that time so the scales for IPA and IPB are not correct, 140 nm jitter was measured at MFB2FF.

IP area

Measurement of the BPM resolution in the IP area is complicated by the large angular divergence of the focusing beam. It is not easy to reconstruct the beam orbit using other BPMs in the IP area. To put an upper limit on the resolution of the IPBPMs the vertical focus of ATF2 was

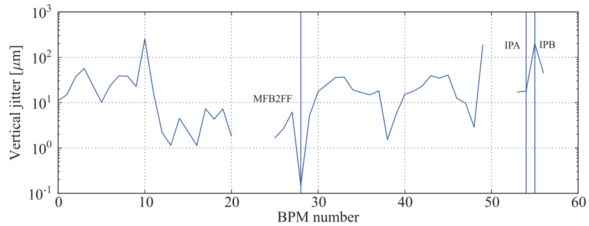

Figure 6: Vertical beam position RMS for the BPMs on the ATF2.

shifted by varying the strength of QD0FF. The focus was shifted in turn to both IPA and IPB locations and the vertical beam position jitter measured. Figure 7 shows one such scan the focus around IPB.

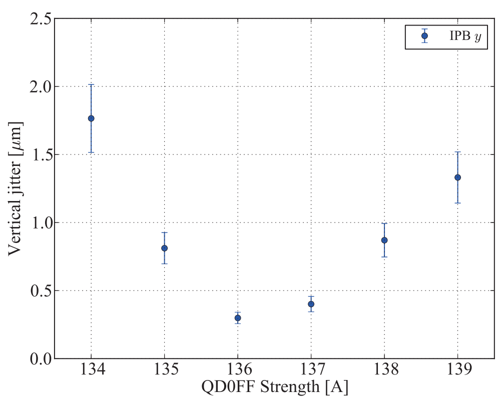

Figure 7: IP waist position scan, around IPB, using QD0FF current.

Correlations

The beam was kicked using the upstream kicker K1 which is normally used as part of the Feedback On Nanosecond Timescales (FONT) [7] feedback system. ATF2 orbit data was taken with all the ATF2 strip-line and cavity BPMs. The correlation in the vertical direction between MFB2FF and IP(A/B) is shown in Figure 8. In Figure 8 the correlation between MFB2FF and the IPBPMs is high , although it decreases somewhat if only the data for a single kick setting is considered. For the data presented in Figure 8 the correlation coefficient is 99.9%, whilst for just un-kicked data the correlation is approximately 70%.

CONCLUSIONS AND DISCUSSION

Using BPMs for feedback and position stabilisation at the ATF2 is an important goal for the ATF2 project. The typical resolution of MFB2FF at a virtual IP point is 30 nanometres, whilst the resolution of IPA and B is below 200 nm. Determining the resolution of the IP region BPMs is complicated due to the large angular divergence around the IP and the lack of high resolution, large dynamic range

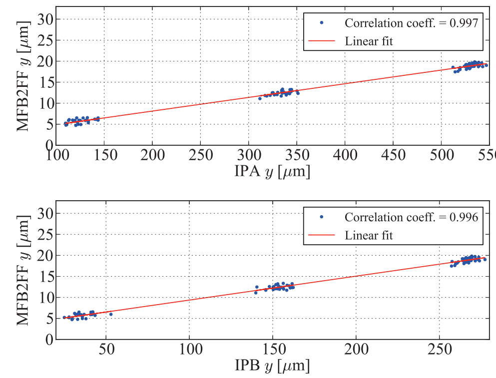

Figure 8: Vertical position correlation between MFB2FF and IPA (top) and IPB (bottom).

BPMs in this location. A first attempt at correlating the position measurements between these two locations has been performed. The correlation in vertical position between MFB2FF and IP(A/B) is very high when the beam is kicked although this correlation is not so strong over shorter scales. This could be due to resolution effects or beam optics effects which destroy the position correlation. Ultimately using a location like MFB2FF and matching the measurements there to an IP might provide a quicker way of initially tuning the ATF2. Simulations are ongoing with MAD8 and PLACET [9] to simulate the resolution and correlation of the BPMs discussed in this paper.

For trying to understand the relationship between MFB2FF and the IPBPMs special recalculated optics with the focus located at IPA or B could be used. This will avoid the problem of the large angular divergence and allow better resolution measurement. Ultimately the highest resolution and smallest dynamic range BPMs are located only in the IP area.

ACKNOWLEDGMENTS

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