CAVITY BEAM POSITION MONITOR IN MULTIPLE BUNCH OPERATION FOR THE ATF2 INTERACTION POINT REGION

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Abstract

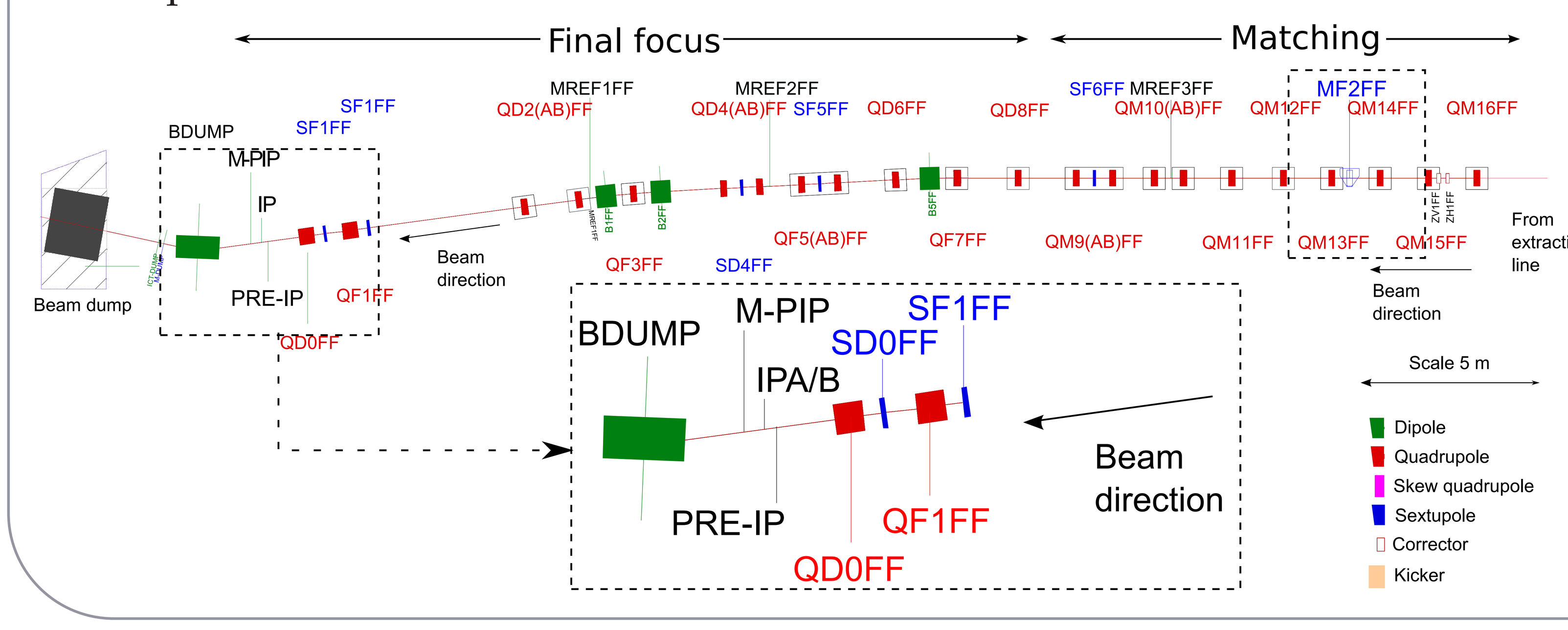
Ultra high position resolution cavity beam position monitors (BPMs) have been developed to measure the beam position and to be linked to control the beam position stability within a few nanometres in the vertical direction at the focus, Interaction Point (IP), of the Accelerator Test Facility 2 (ATF2). In addition, for feedback applications a lower-Q and hence faster decay time system is desirable. Specialised cavities which are called Interaction Point BPM (IPBPM) has been tested in the ATF2 extraction beam line. Using IPBPMs, a position resolution of less than 5 nm has been measured in single bunch operation. Multi bunch operation is also planned at ATF2 for the beam stabilisation. The nominal operation bunch spacing for the International Linear Collider (ILC) is 308 ns so the multi bunch operation bunch spacing is ILC like. IPBPM should be able to measure beam position within nanometre precision in multi bunch modes. Therefore the position resolution in multi bunch operation was also measured at ATF2 extraction line. The analysis method of cavity signals, calibration and results of multi bunch operation are discussed in this proceeding.

Accelerator Test Facility 2 and Cavity Beam Position Monitor System

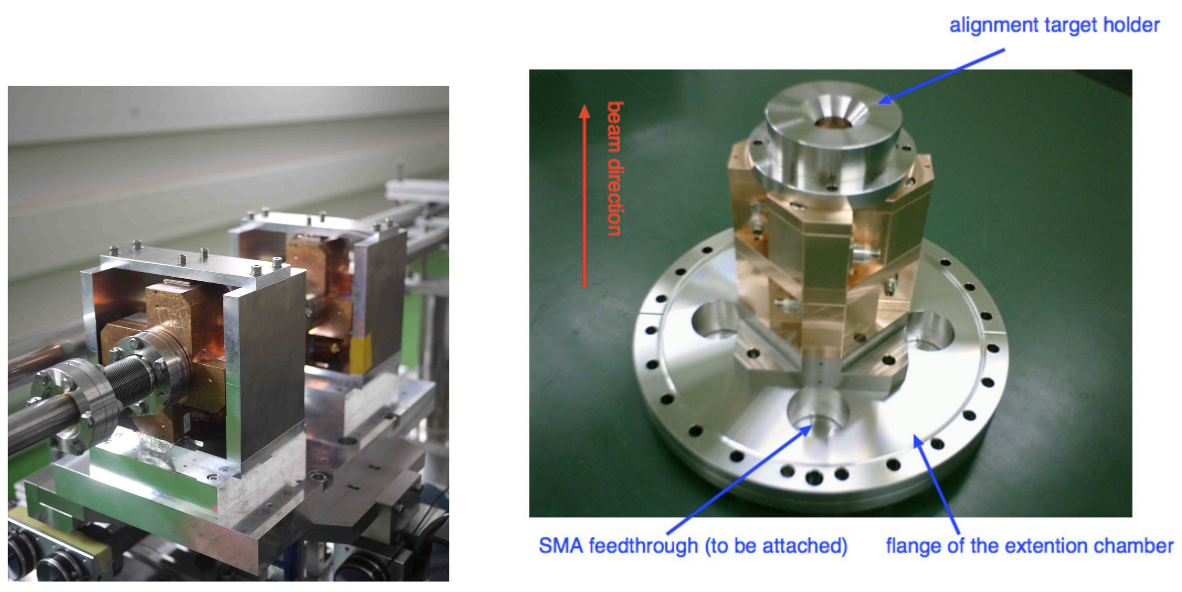
Accelerator Test Facility 2 (ATF2) : A test beam line for Linear Collider (LC) final focus systems (FFS), located at KEK, Japan

Accelerator Test Facility 2

- To demonstrate focusing using local chromatic correction down to vertical beam size
- Recently tentatively achieved its first goal of a vertical beam size of < 100 nm only at relatively low bunch charges of $\sim 0.1 \times 10^{10}$ electrons per bunch
- To achieve a few nanometer level beam orbit stability at the focus point in the vertical plane



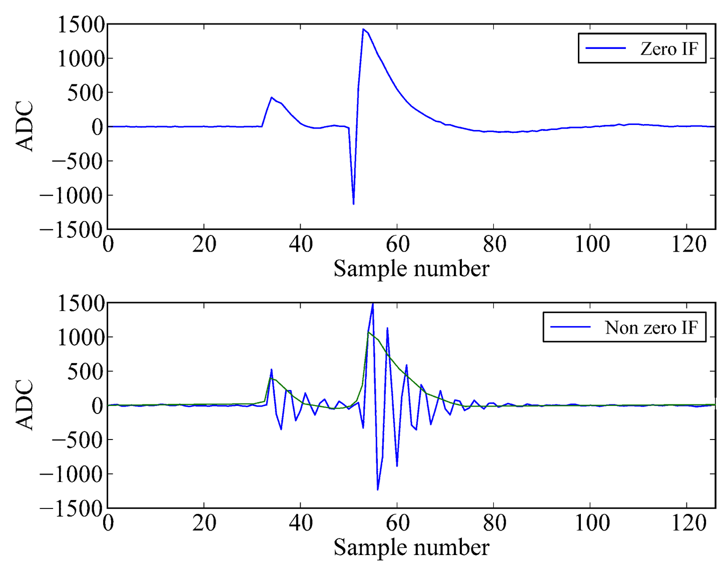
Interaction Point region cavity beam position monitor



- Resonant frequency of dipole mode f_0 for x and y: 5.7086/6.4336 [GHz]
- Coupling strength β for x and y: 1.578/3.154
- Q_L for x and y: 2070/1207
- Q_0 for x and y: 5337/5015
- Q_{ext} for x and y: 3382/1590
- decay time τ: 58/30 [ns]

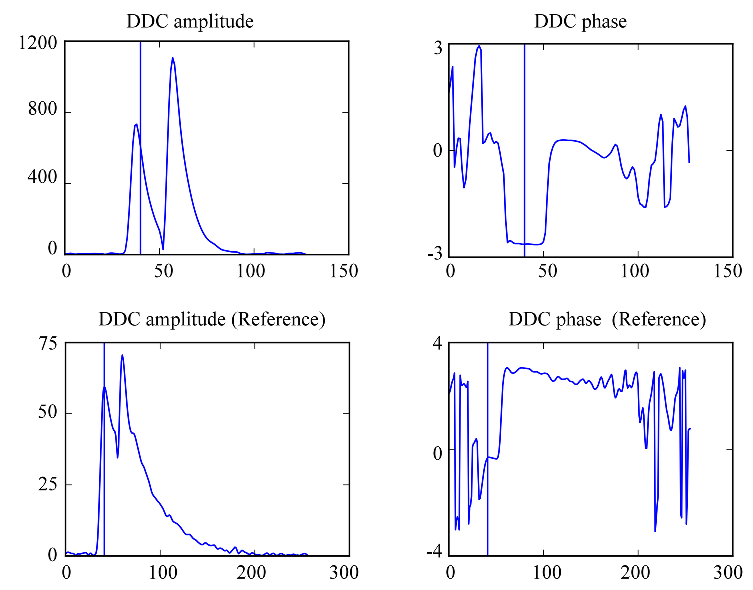
Signal processing

Cavity BPM signal processing



- Two main methods used for cavity BPM signal processing: zero intermediate frequency (IF) and nonzero IF
- Zero IF: good for feedback as additional signal processing is not required
- Same signal processing method is used for multi bunch data
- Strong peak at the beginning of second bunch signal of zero IF, possible transients
- It is not clear to see on nonzero IF signals
- Green trace is DDC amplitude
- The bunch spacing is longer than the cavity decay time τ = 30 ns in y direction so their signal overlapping is smaller than regular C-band cavity BPMs

Digital down-conversion (DDC)

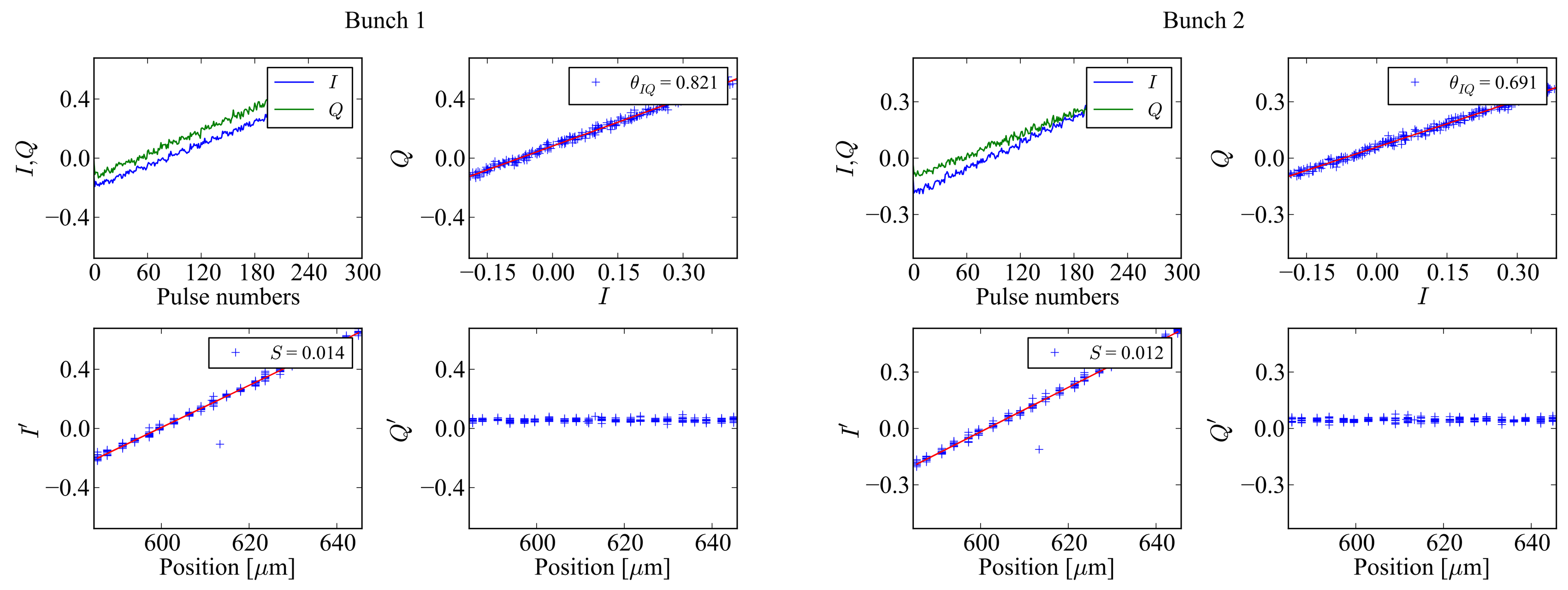


- IPBPM has a lower Q than regular C band cavity BPM at ATF2 so a wider filter width is chosen
- The filter width for two bunches data analysis is set the same as the single bunch data analysis
- As reference cavity has higher Q the signal overlapping is larger than IPBPM so sample point should be chosen carefully

Calibration

First bunch calibration

Second bunch calibration



- Calibration is needed to convert electronics output signals and waveforms information into the beam position
- Top left and right : I and Q as a function of pulse number, I verses Q
- Bottom left and right : I' as a function of beam position, Q' as a function of beam position
- Phase advance with respect to each other bunch, 0.13 rad.
- Expected phase advance : $2\pi\times$ 100 KHz $\times$ 274 ns = 0.17 rad.

Resolution

- BPM resolution : Root-mean-square (RMS) of the residual between the position measured in the BPM in question and the position predicted in this BPM by other BPMs
- The residual was calculated using the singular value decomposition (SVD) method
- Calibration was done with attenuation due to narrow dynamic range and large beam jitter
- The calibration constants were extrapolated from the calibration results with attenuations to unattenuated
- Resolution without attenuation : 14 nm (first bunch) and 24 nm (second bunch)
- Resolution with 30 dB attenuation : 432 nm (first bunch) and 718 nm (second bunch)
- The vertical focus of the ATF2 was shifted by varying the strength of QD0FF magnet current
- The minimum measured jitter on IPBPMs at IP area is below 100 nm

Conclusions and Suggestions

- Using BPMs for feedback and position stabilisation at the ATF2 is an important goal for the ATF2 project
- IPBPMs were installed at upstream and IP area for high resolution and IP feedback studies
- The decay time τ of the IPBPM is 30 ns and bunch spacing is 274 for two bunches operation signal overlapping is small
- The resolution of IPBPM at upstream is 14 nm and 24 nm for the first and second bunch, respectively
- Determining the resolution of the IP region BPMs is complicated due to large angular divergence around the IP
- The signal subtraction can be applied to improve the precision for multibunch operation
- Low Q reference cavity can be improve the signal processing