Development of a Low-latency, High-precision, Intra-train Beam Feedback System Based on Cavity Beam Position Monitors

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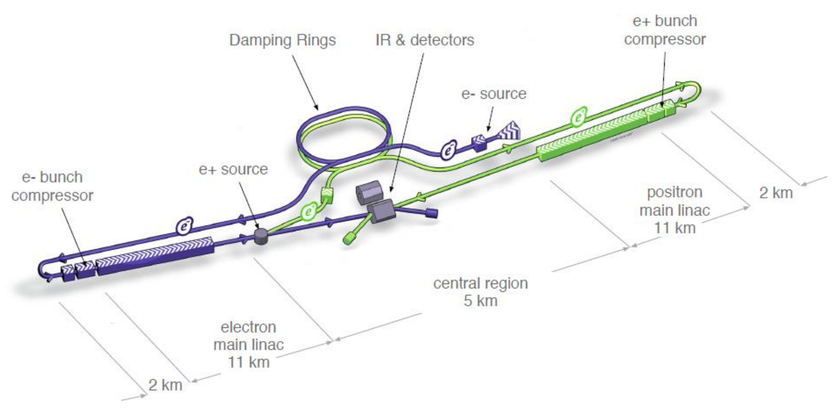
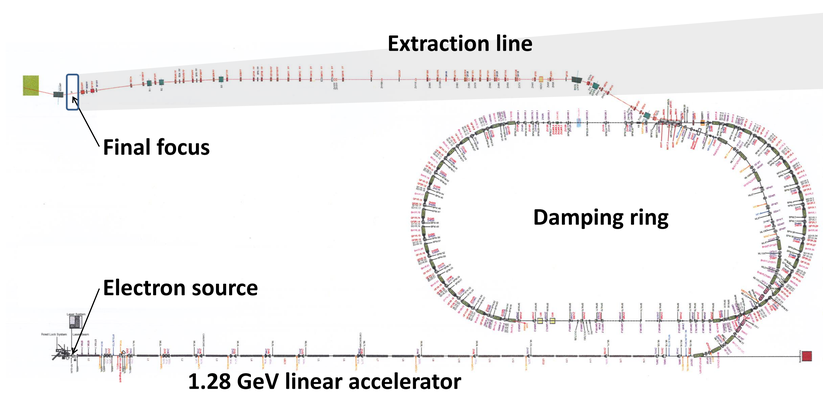
International Linear Collider



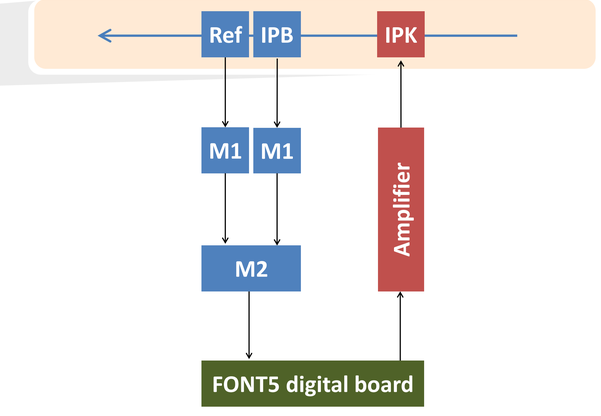
The International Linear Collider (ILC) is a proposed linear electron-positron collider with a centre-of-mass energy of 500 GeV [1]. The schematic above shows the 6.7 km circumference damping rings followed by the 11 km long superconducting main linacs. The ILC is designed to have a vertical beam size at the interaction point of 5.9 nm and a bunch separation of 554 ns.

Accelerator Test Facility



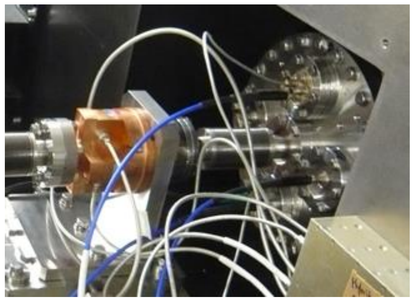
The Accelerator Test Facility (ATF) at KEK, Tsukuba, Japan is a test bed for the ILC. The ATF consists of a 1.28 GeV electron linac and a super-low emittance damping ring. ATF's current goal is to achieve a 37 nm beam size with nanometre beam stability as measured at the final focus [2].

Feedback on Nanosecond Timescales



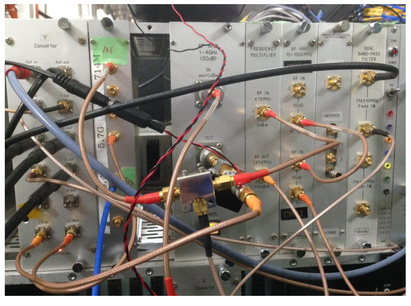
The Feedback on Nanosecond Timescales (FONT) [3] project works towards ATF's high stability goal by performing intra-train beam-based feedback. Operating with 2-bunch trains at a bunch separation of ~150 ns, the FONT system monitors the path taken by the first bunch to correct the path of the second bunch using the set-up shown above.

Ref **IPB** Cavities



IPB is a C-band cavity beam position monitor (BPM) with a 6.4 GHz dipole mode for the y signal. The reference cavity has a 6.4 GHz monopole mode and is used for phase detection and charge normalisation [4].

M1 **M1** First stage mixer

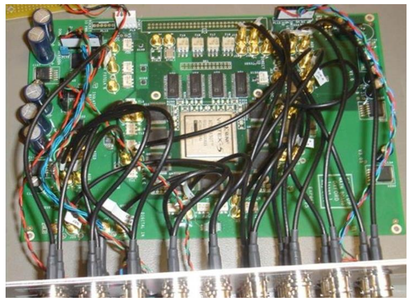


The first stage downmixer takes the 6.4 GHz reference and IPB signals and mixes each with an external common 5.7 GHz local oscillator (LO) to produce downmixed outputs at 714 MHz [5].

M2 Second stage mixer

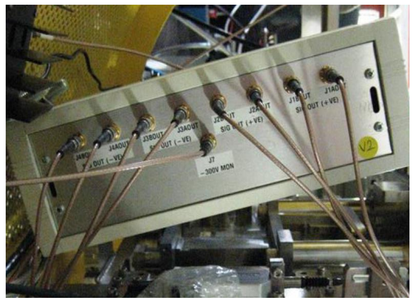
The second stage downmixer mixes the 714 MHz IPB signal using the 714 MHz reference as the LO [5], giving two baseband signals: I (IPB and reference mixed in phase) and Q (IPB and reference mixed in quadrature).

FONT5 digital board



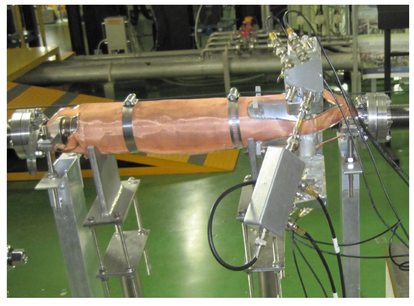
The FONT5 digital board contains a Virtex-5 Field Programmable Gate Array (FPGA) [6]. The I, Q and charge signals are digitised at 357 MHz and used to compute the beam position and generate the kick signal.

Amplifier



The kick signal from the FONT5 board is amplified by a purpose-built amplifier manufactured by TMD technologies [7]. The amplifier provides ±30 A of drive current and takes 35 ns to reach 90 % of peak.

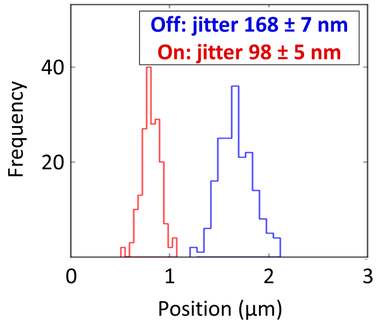
IPK Kicker

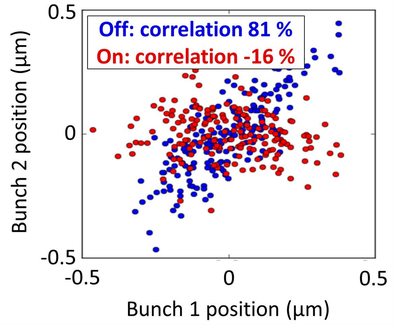


The stripline kicker consists of a pair of top and bottom electrodes connected to the corresponding amplifier at its downstream end and shorted together at its upstream end, forming a transmission line [8].

Results

The histogram on the right shows the distribution of vertical bunch positions for bunch 2 as measured at IPB. Feedback is interleaved between feedback off (blue) and feedback on (red). The feedback reduces the standard deviation of the position distribution from 168 ± 7 nm to 98 ± 5 nm. It also shifts the average vertical position from 1.68 ± 0.01 µm to 0.81 ± 0.01 µm. The performance is consistent with a BPM resolution of somewhat better than 100 nm [9]. For best feedback performance, a high incoming bunch-to-bunch position correlation is required. This was measured to be 81 % with feedback off. The scatter plot on the right shows the bunch-to-bunch position correlation for both feedback off and feedback on. The feedback removes the correlated component of the bunch-to-bunch position jitter and thus reduces the correlation to -16 %. The feedback system latency is 212 ns.





References

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