Interaction Point Feedback System R&D

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The status of R&D on hardware components of fast beam-based feedback systems is described. The main developments are being pursued by the Feedback On Nanosecond Timescales (FONT) and Feedback at High Energy Requirements (FEATHER) groups based in the UK/SLAC and in Japan, respectively. The FONT2 and FONT3 experimental results are summarised, and plans are outlined for FONT4.

1. INTRODUCTION

In the ILC interaction Region (IR) a very fast feedback system, operating on 100-nanosecond timescales within each bunchtrain, is required to compensate for residual ground-motion and facilities-induced position jitter on the beams by steering them into collision. A pulse-to-pulse feedback system is also envisaged for optimising the luminosity on timescales corresponding to the collider repetition rate of 5Hz. Slower feedbacks, operating in the 0.1 - 1 Hz range, will control the beam orbit through the linacs and Beam Delivery System.

The key components of each such system are beam position monitors (BPMs) for registering the beam orbit; fast signal processors to translate the raw BPM pickoff signals into a normalised position output; feedback circuits, including delay loop function, for applying gain and taking account of system latency; amplifiers to provide the required output drive signals; and kickers for applying the position (or angle) correction to the beam.

2. FONT2

Feedback On Nanosecond Timescales FONT [1] is a collaboration between UK academic groups (QMUL, Oxford, Daresbury) and the ILC Group at SLAC with the purpose of prototyping and testing Interaction Point (IP) intra-train feedback components. Two rounds of beam tests, FONT1 [2] and FONT2 [3], have taken place at the NLC Test Accelerator (NLCTA) at SLAC and the latest system, FONT3, is in development at the Accelerator Test Facility (ATF) at KEK.

At NLCTA an upstream dipole magnet was used to steer the beam so as to introduce a controllable vertical position offset in a downstream BPM. A signal processor and a feedback circuit provided a correction signal to drive upstream kickers so as to steer the beam back into nominal vertical position. The bunchtrain was 170 ns long; the bunch spacing was c. 87 ps (X-band frequency); the beam energy was typically 65 MeV. The vertical beam size was typically around 1 mm, and the vertical position jitter was at the level of 50-100 microns. Data runs were taken in the summer of 2002 (FONT1) and the winter of 2003 (FONT2).

In FONT2 the BPM signals were mixed from X-band to baseband in a two-stage down-mixing process with an intermediate frequency stage of 400 MHz. Normalisation by the beam charge was performed in real-time by taking the difference between the top and bottom pickoff signals using logarithmic amplifers. The correction signal was fed to two solid state amplifiers (maximum power roughly 800 W each) which drove the two kickers.

Results from the FONT2 run in January 2004 are shown in Figure 1. The system was able to make a 14:1 correction in beam position within a latency period of 53 ns, of which 37 ns is from the speed of the electronics and 16 ns due to time-of-flight of the beam and return signal propagation delay.

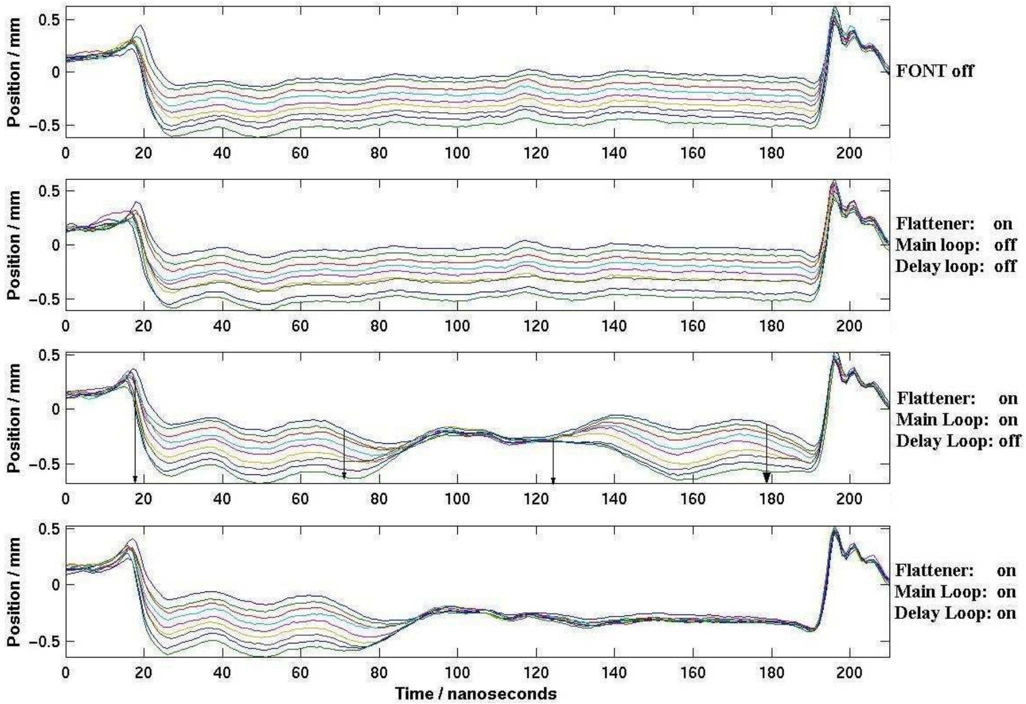

Figure 1: Results from FONT2. Top: beam starting positions. Upper middle: action of the 'beam flattener' to remove slowly-varying components in the bunch position structure within the train. Lower middle: effect of the feedback without delay loop. The arrows show the boundaries between the latency periods during the system operation; 3.2 latency periods are apparent. Bottom: full system including delay-loop feedback.

3. FONT3/FEATHER

A group at KEK and Tokyo Metropolitan University has designed a system that is conceptually similar to FONT, called FEATHER [4]. The hardware includes an adjustable-gap kicker which is deployed in the ATF extraction line. The performance of the kicker has been tested with beam and agrees with the design parameters [5]. Up to 20 bunches can be extracted from the ATF ring with a bunch spacing of 2.8 ns, equivalent to 357 MHz frequency. The ATF offers the advantage of transporting a very small emittance beam down the extraction line, and the vertical pulse-to-pulse position jitter in multi-bunch mode is at the level of 10 microns.

The aim of FONT3 is to perform intra-train feedback within the 56ns-long bunchtrain. In order to see delay-loop operation the system latency must be less than 28ns. For this reason the system was designed to have a latency of c. 20ns, corresponding to 2.8 latency periods during the bunchtrain. This design latency comprises a goal of 5ns for the BPM processor, 5ns for the FB and amplifier, and 10ns for beam time-of-flight and return signal propagation delay.

Components of the FONT3 system have been deployed and tested in the ATF extraction line. A string of three stripline BPMs was instrumented with 'superfast' analogue processors. Figure 2 shows a measurement of the processor latency, which is 4.3 ns and meets the design goal. Figure 3 shows the BPM response to position, which is linear over variation of order one millimetre. Figure 4 shows the resolution of one BPM, which is around 5 microns.

Closed-loop beam tests with the complete system, including a new custom solid-state amplifier, are planned for May/June 2005.

4. FONT4

Following the choice of superconducting Nb technology for the ILC main linacs, the ILC bunch structure will comprise c. 3000 bunches with 337ns inter-bunch separation. Extremely fast, nanosecond-scale response is hence

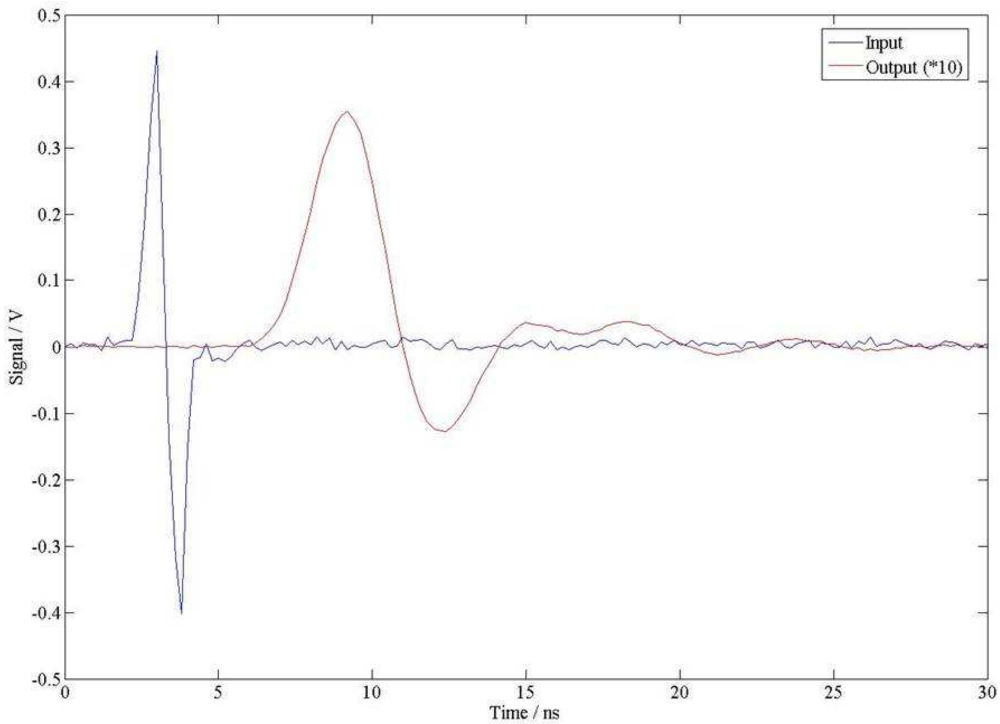

Figure 2: Latency measurement of FONT3 BPM processor The latency is characterised by the time difference between the raw input signal (left) and the processed output (right).

no longer required of the intra-train feedback system performance. Rather, the system should be designed with a latency of c. 100ns, and for a long train of 3000 bunches. This allows a digital approach to the signal processing and a new emphasis on algorithms and robust performance. Such a system is currently being designed for deployment at ATF in 2006, and it will form a critical component of the beam stabilisation system for the proposed ATF2 final focus.

Acknowledgments

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References

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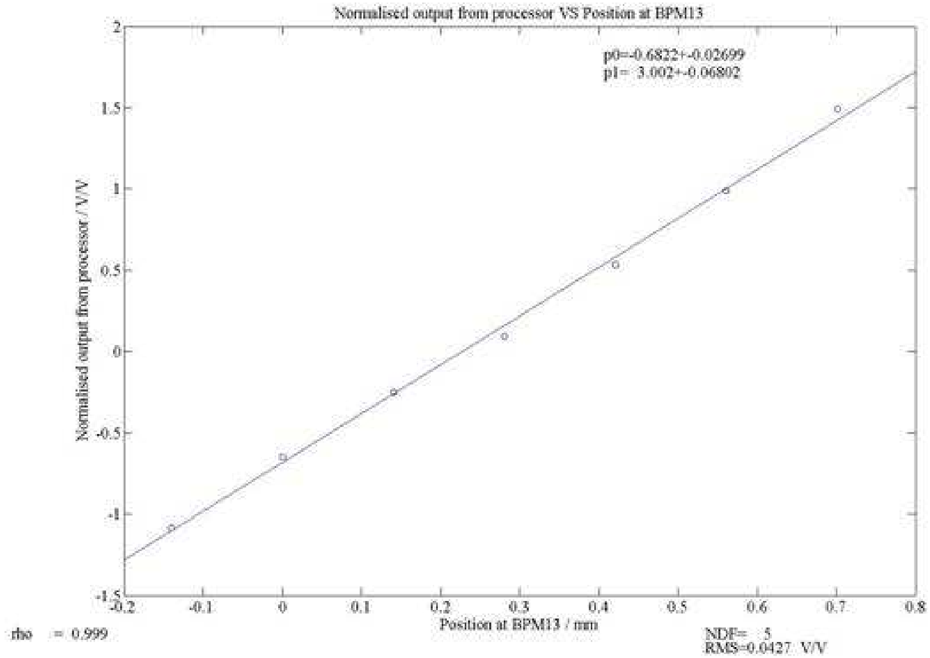

Figure 3: Response of FONT3 BPM processor for position variations up to c. 1mm.

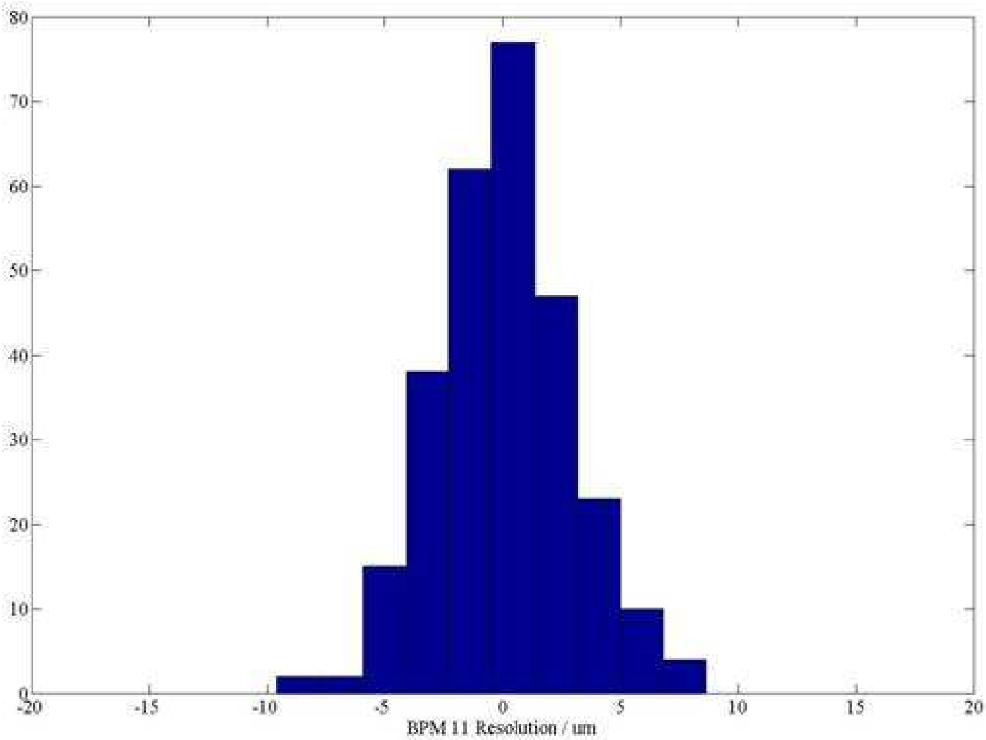

Figure 4: Vertical position resolution (microns) of FONT3 BPM processor.