First Results From Beam Tests of the CLIC Drive Beam Phase Feedforward Prototype at CTF3

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Motivation

• In the CLIC two beam acceleration scheme the RF power that accelerates the main beam is extracted from a second “drive beam”. The phase (or time) synchronisation between the two beams must be maintained to within 0.2 degrees of 12 GHz (50 fs) to ensure the efficiency of this concept [1,2].

• A phase feedforward system with bandwidth above 17.5 MHz [3] is required to reduce the drive beam phase jitter to this level. A prototype of this system has been installed and the first tests completed at the CLIC test facility CTF3 at CERN to prove its feasibility.

CTF3 Phase Feedforward System

• The phase is corrected using two kickers placed prior to the first and last dipoles in the pre-existing chicane in the TL2 transfer line: bunches arriving late are deflected on to shorter paths and bunches arriving early on to longer paths through the chicane.

• Hardware: Three phase monitors and two strip line kickers (INFN/LNF Frascati) [4,5,7], kicker amplifiers and digital processor (JAI, Oxford University) [1,6].

• Latency of the system (including cable lengths) must be less than the 380 ns time of flight between the first monitor and the first kicker.

• Goal: 30 MHz bandwidth correction with 0.2 degrees of 12 GHz resolution.

Phase Feedforward Results

• The drive beam pulses in CLIC are 240 ns long. 100–200 ns pulses were used to test the functionality of the feedforward system at CTF3. As the amplifiers are upgraded during 2015 the increased power will allow tests to be conducted on the full CLIC pulse length.

• In the first feedforward tests the gain on the digital processor was varied, including both positive (acting to reduce the phase jitter) and negative (acting to increase the phase jitter) values, in order to determine the optimal gain setting and to verify the performance of the correction.

• The initial downstream phase jitter of 2° is reduced to 1.4° with a gain of +40, a reduction of 30%. Negative gain values or values above +40 result in the downstream phase being amplified or over-corrected.

• With the optimal gain of +40 the mean phase variation along the pulse is reduced from 7° to 3°. There is a remaining slope in the phase along the pulse as a result of the current limits in correlation and correction range.

Commissioning

• The complete PFF system became available in October 2014. Previous results from commissioning of the optics and phase monitors are presented in [8].

• The first prototype kicker amplifiers provide an output voltage of 340 V. They will be upgraded to 1.2 kV during 2015. Constant kick tests demonstrate a ±3.5° phase shift and >12 MHz bandwidth when applied to the kickers.

• The feedforward algorithm varies the drive signal to the amplifier based on the upstream phase to correct the downstream phase with 30 MHz bandwidth. Its performance was verified by comparing the position offset in a BPM after the correction chicane to the upstream phase whilst varying the correction.

Improving Performance

• An upstream-downstream phase correlation of 97% is required to reduce an initial phase jitter of 0.8° to the CLIC limit of 0.2°. The beam conditions at CTF3 are typically 2° phase jitter and 40% correlation.

• The dominant source of the low correlation between the upstream and downstream phase at CTF3 is energy jitter being converted to phase jitter via the transfer matrix coefficient R56. This was verified by comparing the phase to the beam position in a dispersive BPM.

• The residual R56 must be below 1 cm to achieve 97% phase correlation. R56 in the TL1 line can be varied to compensate for the non-zero R56 in TL2 and other sections. A factor 2 reduction in the phase jitter has already been demonstrated using this approach.

Conclusions

• Preliminary running of the prototype phase feedforward system at the CLIC test facility CTF3 has so far demonstrated a 30% reduction in the drive beam phase jitter by using kickers to vary the path length through a magnetic chicane.

• In order to achieve CLIC level phase stability at CLIC energy effects entering the phase via R56 must be removed in order to improve the correlation between the upstream and downstream phase from 40% to above 95%. Fine R56 tuning will be implemented in 2015 to achieve this.