Development of a Beam-based Phase Feedforward Demonstration at the CLIC Test Facility (CTF3).

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Abstract

The Compact Linear Collider (CLIC) is a proposal for a future linear electron–positron collider that could achieve collision energies of up to 3 TeV. In the CLIC concept the main high energy beam is accelerated using RF power extracted from a high intensity drive beam, achieving an accelerating gradient of 100 MV/m. This scheme places strict tolerances on the drive beam phase stability, which must be better than 0.2° at 12 GHz. To achieve the required phase stability CLIC proposes a high bandwidth (>17.5 MHz), low latency drive beam "phase feedforward" (PFF) system. In this system electromagnetic kickers, powered by 500 kW amplifiers, are installed in a chicane and used to correct the phase by deflecting the beam on to longer or shorter trajectories. A prototype PFF system has been installed at the CLIC Test Facility, CTF3; the design, operation and commissioning of which is the focus of this work.

Two kickers have been installed in the pre-existing chicane in the TL2 transfer line at CTF3 for the prototype. New optics have been created for the line to take these changes in to account, incorporating new constraints to obtain the desired phase shifting behaviour. Three new phase monitors have also been installed, one for the PFF input and two to verify the system performance. The resolution of these monitors must be significantly better than 0.2° to achieve CLIC-level phase stability. A point by point resolution as low as 0.13° has been achieved after a series of measurements and improvements to the phase monitor electronics.

The performance of the PFF system depends on the correlation between the beam phase as measured at the input to the PFF system, and the downstream phase, measured after the correction chicane. Preliminary measurements found only 40% correlation. The source of the low correlation was determined to be energy dependent phase jitter, which has been mitigated after extensive efforts to measure, model and adjust the machine optics. A final correlation of 93% was achieved, improving the theoretical reduction in jitter using the PFF system from a factor 1.1 to a factor 2.7.

The performance and commissioning of the kicker amplifiers and PFF controller are also discussed. Beam based measurements are used to determine the optimal correction timing. With a maximum output of around 650 V the amplifiers provide a correction range of $\pm 5.5 \pm 0.3°$. Finally, results from operation of the complete system are presented. A mean phase jitter of $0.28 \pm 0.02°$ is achieved, in agreement with the theoretical prediction of $0.27 \pm 0.02°$ for an optimal system with the given beam conditions. The current limitations of the PFF system, and possible future improvements to the setup, are also discussed.