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Fast Intra Bunch Train Charge Feedback for FELs based on Photo Injector Laser Pulse Modulation

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Bunch charge variations in Free Electron Lasers such as the Free Electron Lasers at Hamburg (FLASH) or the European X-Ray Free Electron Laser (E-XFEL) impacts the longitudinal phase space distribution of the electrons resulting in different bunch peak currents, pulse duration and pulse shapes. The electron bunches are generated by short ultraviolet laser pulses impinging onto a photocathode inside a radio frequency (RF) accelerating cavity. At FLASH, bursts of bunches up to 800 pulses with an intra train repetition rate of 1 MHz are used and even higher repetition rates for the E-XFEL (up to 4.5 MHz) are planned. Charge variations along these bunch-trains can be caused by variations of the laser pulse energies, instabilities of the accelerating field in the RF cavity and time dependent effects in the photoemission process. To improve the intra bunch-train charge flatness and to compensate train-to-train fluctuations a dedicated digital control system, based on the Micro Telecommunication Architecture (MicroTCA.4) standard, was designed and implemented at the FLASH. The system consists of a bunch charge detection module which analyzes data from toroid system and provides input signal for the controller which drives a fast UV-Pocket cell installed in the optical path of the photo-cathode laser. The Pockels cell alters the laser polarization and thus the transmission through a polarizer. The modulation of UV laser pulse energy with an iterative learning feed-forward minimizing repetitive errors from bunch-train to bunch-train and a fast feedback algorithm implemented in a Field Programmable Gate Array (FPGA) allows for fast tuning of bunch charge inside the bunch-train. In this paper a detailed description of the system and first measurements results is presented.

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