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LCLS MULTI-BUNCH IMPROVEMENT PLAN: FIRST RESULTS

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Abstract

LCLS copper linac primarily operates in a single bunch mode with a repetition rate of 120 Hz. Presently, several in-house projects and LCLS user experiments require double- and multi-pulse trains of X-rays, with inter-pulse delay spanning between 0.35 and 220 ns. We discuss beam control improvements to the copper linac using ultra-fast stripline kicker, as well as additional photon diagnostics. We especially focus on a case of double-pulse mode, with 220 ns separation.

INTRODUCTION

LCLS has been offering ns-spaced hard x-ray (HXR) pulse trains to users for a several years [1]. The multi-bunch performance of the LCLS copper linac has been largely impaired by variations of RF phases in different klystrons, accelerating sections' misalignment [2], and, as a result, differences in the HXR undulator trajectories. Recently we have proposed to improve the performance of the LCLS multi-bunch mode by introducing ultra-fast e-beam TEM stripline kickers in the linac beamline. The choice of kicker technology was dictated by the minimum attainable pulse separation with the current state-of-the art electronics, and possible extension in the future to 8 or more pulses in a train. We designed and built two 0.3 m stripline structures, and installed them into the LCLS LI21-9 section. The details of the stripline design have been provided in [3]. The beamline installation model is presented in Fig. 1.

To energize the striplines, we designed and built a versatile system, with broadband high power solid-state amplifiers for the multi-bunch mode, and state-of-the-art solid state pulsers (based on drift step-recovery diodes (DSRD)) for the two-bunch mode. The amplifiers have been procured from the R&K company, and can output up to 1 kW of RF power in CW mode, and with 10 kHz - 300 MHz bandwidth. The feasibility and early design of the high-voltage pulsers based on DSRD technology has been presented in Ref. [4]. We have built two pulser units corresponding to the principal schematics in Fig. 2, D in Ref. [4], with the maximum attainable voltage of ± 5 kV.

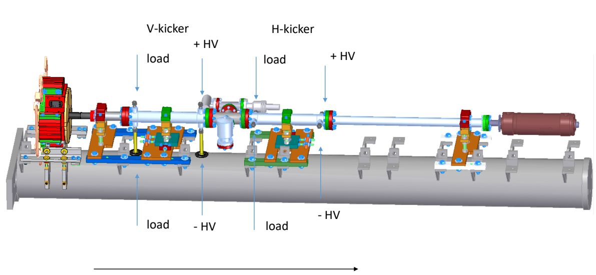

Figure 1: CAD model of the LCLS copper linac LI21-9 section installation.

FIRST EXPERIMENTAL RESULTS

We have commissioned the first two stripline kickers (X and Y) in LI21-9 section of the LCLS copper linac. The kickers were first energized with the strongest 7 kV pulse to verify no arcing or breakdown was occurring. We then proceeded with energizing the stripline structures together with the e-beam, and observing the corresponding trajectory responses.

Figure 2 shows e-beam X deflection as a function of time of arrival at the stripline structure, which has been powered with an RF waveform, generated with an arbitrary waveform generator (AWG) procured from Tabor Electronics and high power R&K amplifiers. The AWG clock was externally synchronized with a custom in-house built frequency multiplier which generated 1.428 GHz signal multiplying 119 MHz master oscillator clock by 12. We see that despite a quite "unconventional" application of the amplifiers in the pulsed mode, the e-beam transverse jitter remains the same across the waveform. Due to the full waveform tunability, we were later able to control pulse trains with the separations as small as 2 ns, and enhance x-ray intensity delivery in the multi-pulse user experiment.

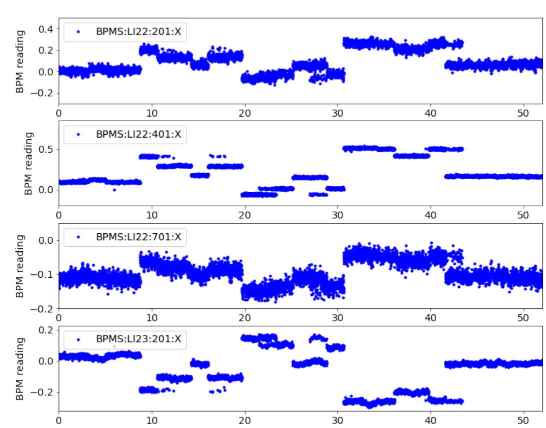

Figure 2: Scanning e-beam time of arrival through an arbitrary waveform generated by a pair of two solid-state amplifiers.

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DEMONSTRATION OF CBXFEL-LIKE LASING

We then proceeded with testing high voltage pulsers. It was previously determined that a substantial orbit correction is needed for large, several tens of ns, pulse separations; see Ref. [2]. This regime is envisioned for the Cavity-based XFEL (CBXFEL) project. CBXFEL is aimed to build first hard x-ray regenerative amplifier, using LCLS HXR undulator line. In the initial phase, CBXFEL will operate with two LCLS bunches spaced by 218 ns. Previous attempts to generate this configuration in the LCLS copper linac have been largely unsuccessful, due to significant differences in beam compression and undulator trajectories. While our kicker system does not address the issues of e-beam compression, we demonstrated that with two kickers and quadrupole tuning we can obtain CBXFEL-like lasing configuration.

In the experiment, we first set up a two-bunch configuration, with two UV laser pulses impinging on the LCLS photocathode, 218 ns apart, and providing two IR pulses for the laser heating downstream. We then obtained two electron bunches with similar longitudinal phase-space (LPS) in the HXR undulator line.

The two-pulse orbit had a residual 270 μm trajectory difference in the undulator line in X-plane, which was corrected via corresponding kick in the X-stripline, acting on the second bunch. A raw waveform of the HXR gas intensity monitor was used as a diagnostics, showing a fairly equal XFEL intensity in both pulses, of up to 200 μJ (Fig. 3). We note, that due to the ultra-fast kickers currently available only in one location, the full (x, x', y, y') correction is not yet possible. It is, however, possible to readjust phase advance of the machine lattice, and rematch the e-beam into the HXR undulator, under the assumption that both bunches have identical Twiss parameters. We will continue to investigate the best re-matching procedures, before the next pair of kickers is installed.

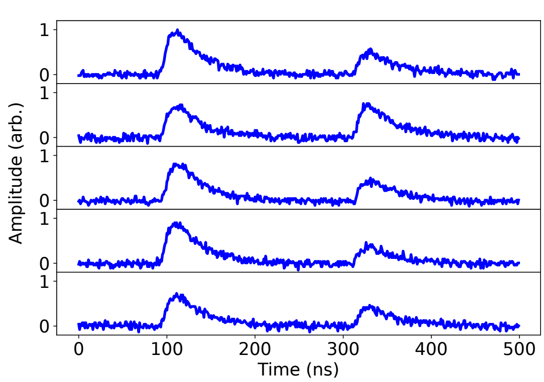

Figure 3: Gas intensity monitor waveform, demonstrating the LCLS two-pulse train with 218 ns separation, as required by the CBXFEL project. Up to 200 μJ in each pulse were generated.

NEXT STEPS

With the first two kickers successfully installed and commissioned, we will move to the next phase of the project which includes two more kickers to be installed in LI22-9 section, roughly 70 deg. away in phase advance. This will allow us to control full trajectory, without readjusting the phase advance via quadrupole tuning. After that, the photoinjector laser infrastructure will be upgraded, in order to support larger pulse separations and increased number of pulses [5].

SUMMARY

We presented first experimental results as well as a comprehensive plan towards more robust multi-bunch operation of LCLS. When enabled, multi-bunch mode will allow for many new in-house and user experiments. It will also serve as test source for future ultra-high repetition rate XFELs.

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