Linear Accelerator Design for the LCLS-II FEL Facility

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ABSTRACT

The LCLS-II is an FEL facility proposed in response to the July 2013 BESAC advisory committee, which recommended the construction of a new FEL light source with a high-repetition rate and a broad photon energy range from 0.2 keV to at least 5 keV. A new CW 4-GeV electron linac is being designed to meet this need, using a superconducting (SC) L-band (1.3 GHz) linear accelerator capable of operating with a continuous bunch repetition rate up to 1 MHz at ~16 MW/m. This new 700-m linac is to be built at SLAC in the existing tunnel, making use of existing facilities and providing two separate FELs, preserving the operation of the existing FEL, which can be fed from either the existing copper or the new SC linac. We briefly describe the acceleration, bunch compression, beam transport, beam switching, and electron beam diagnostics. The high-power and low-level RF systems, and cryogenic systems are not covered here.

Figure 1: LCLS-II layout in existing SLAC tunnels (3.8 km).

Figure 2: Linac layout with RF and compression parameters. Most RF gradients are held at less than 16 MV/m, the HL section is a 3.9-GHz linac, and LH is the laser heater.

Figure 3: Focusing lattice from cathode to HXR dump. Large beta functions are in the existing, long-bypass line, while the HXR undulator is near the end of the line at 5 m.

Figure 4: Focusing lattice from cathode to SXR dump at 4 GeV. The SXR undulator is near the end of the line at 3.6 km. The two lines split (to HXR or SXR) at 3.7 km.

Figure 5: 3D tracking simulation using LiTrack and rms (Gaussian) stability tolerances of Table 3, confirming the final expected stability of (5(ε)E)max = 0.009%, (15(ε)E)max = 3.7%, and σmax = 20 fs rms. It also may be possible to do better.

Figure 6: Fast beam spreader system (plan view) with vertical “kicker” and two “2-hole septa” magnets which bend horizontally. This schematic shows the geometry rather than the complete optics (e.g., not all quads are shown here).

Figure 7: Full LCLS-II layout (plan view) with switching into the SXR undulator (top-right) and HXR undulator (lower-right) at up to 1-MHz switching rate using a fast “kicker”.

Figure 8: Elegant tracking results of longitudinal phase space (100 pC/bunch) including resistive-wall wakes and CSR in the bends. Space charge is only included in the ASTRA injector tracking. The energy chirp (middle) has been flattened by RW-wall wakefields.

Figure 9: Elegant tracking results showing slice emittance (left) and slice energy spread (right), both within FEL requirements (εmax < 0.45 μm and εmax/E < 0.015% rms in core).