## SXR-FEL Performance when Driven by the Existing Copper Linac

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## Introduction

The baseline LCLS-II machine design includes the existing 15-GeV SLAC linac and a new 4-GeV SRF linac as well. Two new FEL undulators are also placed in the beam transfer hall (BTH), identified as the hard x-ray (HXR) and the soft x-ray (SXR) FELs. In this baseline plan, the HXR undulator can be fed with electrons either from the existing 2.5-15 GeV copper linac, or from the new 4-GeV high-rate linac. In contrast, the SXU undulator can be fed only from the SRF high-rate linac. That is, at present, there is no provision to transport the electrons accelerated in the existing 120-Hz copper linac into the SXR FEL. This fourth operating mode (copper-linac to SXR) can be arranged, although it is not yet included in the LCLS-II project's baseline plan. In any case, the required electron transport and the expected FEL performance for this possible fourth operational mode are described here.

## **A New Electron Transport Line**

The copper linac can be optionally made to feed the SXU undulator if a new electron transport line is built, as shown in Figure 1 (the brown dotted line extending from near the end of the copper linac, up to and through the SXU undulator). A "new kicker" magnet (also shown in Figure 1) can be used to steal electron bunches at up to 120 Hz (maximum copper linac beam rate) by kicking the beam into a two-holed magnetic septum. Since the beam rate from the copper linac is limited to 120 Hz, the kicker field needs to rise and fall cleanly within less than 8 ms (< 1/120 Hz). This kicker is then similar to the existing "BYKIK" magnet routinely used in LCLS-I to direct the 3-15 GeV beam into a tune-up dump. Note that the new kicker and septum magnet will be rolled by roughly 45 degrees in order to bend the beam both horizontally and vertically, eventually joining the SXU electron transport line through a "DC bend" merging magnet, also shown in Figure 1. Once injected into the SXU electron transport line, the SXR FEL will perform as discussed in the next section.



Figure 1: LCLS-II layout (plan view) where the possible new electron transport line from the copper-linac to the SXR FEL is shown as a brown dashed line.

## **SXR FEL Performance**

The SXR FEL performance depends on the electron beam parameters, which are listed in Table 1 below for the copper linac. Note that the upper-limit electron energy for transport into the SXR is chosen at 10 GeV. This energy is limited by the SXR electron transport line, which was designed to accept up to a 10 GeV beam; well above the 4-GeV nominal from the SRF linac. This 10-GeV limit can be extended up to 15 GeV with new magnet designs, but the science case for 15 GeV in the SXR FEL does not justify this extension and associated cost.

Parameter	Symbol	Value	Unit
Electron energy after the copper-linac	E	2.5-10	GeV
Hor. & vert. norm. initial emittance	$\gamma \mathcal{E}_{x,y}$	0.56	μm
Final energy spread (rms)	$\sigma_{\!E}$	1.9	MeV
Peak current	$I_{pk}$	4.0	kA
Bunch charge	$Q_b$	180	pC
Mean beta function	$\beta_{x,y}$	10-30	m
Photon pulse duration (rms)	$\sigma_t$	13	fs
Bunch repetition rate	$f_b$	≤ 120	Hz
SXU undulator period	$\lambda_{u}$	39	mm

Table 1: Electron beam parameters from the copper linac as they feed the SXR FEL.

The FEL performance using the 120-Hz copper linac beam is shown in Figure 2. The plot shows the FEL photon energy (keV) on the vertical axis and the electron energy (GeV) on the horizontal axis. The color-coding (legend at right) shows the FEL pulse energy in mJ. Note that the plot shows a wide performance band, not a single curve. This is because both the electron energy and the undulator *K* value (gap) can be independently adjusted. So for example, at a constant 7-GeV energy setting, the gap can be adjusted in order to set the photon energy anywhere from about 0.9 keV up to about 8 keV. In this case the FEL pulse energy will range from about 6 mJ (yellow/white) down to <0.1 mJ (black). The FEL photon energy can be set as low as 200 eV using a 2.5-GeV electron beam. The FEL power enhancement estimated from undulator field tapering is included here.



Figure 2: SXR FEL performance as driven by the copper linac. The screened-out sections of the plot reflect the 10-GeV maximum electron energy allowed in this Cu-linac-to-SXR operating mode.