LCLS-II Technical Note

Instrumentation and methods for LCLS2 Key Performance Parameter (KPP) measurement

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For each KPP parameter, at least one method/instrument has been prepared or existing for the characterization purpose. All the methods have been widely used during the LCLS-1 operations, such as electron beam energy is measured by a bending magnet together with BPMs in a downstream dispersive region, the bunch charge is measured by Faraday Cup, turbo-ICT and BPM, the photon quantity is measured by electron beam loss scan (E-loss scan) method and gas monitor, the photon energy is measured by spectrometer and material edge absorption scan, and the photon bandwidth is measured by spectrometer.

We add details of the characterization methods and instrumentation for each KPP item in the following table.

Performance Measure	Threshold	Objective	Characterization
Variable gap undulators	2 (soft and hard x-ray)	2 (soft and hard x-ray)	
SC linac-based FEL system			
SC linac electron beam energy	3.5 GeV	≥ 4 GeV	Bending magnet + BPM in the DOG dispersive region for energy measurement. The bending magnet dipole field rms stability is ~0.01%, and the BPM position tolerance (alignment, drift, electrical probe offset) is about 1mm. The BPM tolerance dominates the measurement accuracy. With dispersion at the DOG about ~0.25/0.4 (x/y) m, this gives an energy measurement accuracy better than 0.5%.
Electron bunch repetition rate	93 kHz	929 kHz	Set by controls and read from BPM.
SC linac charge per bunch	0.02 nC	0.1 nC	The bunch charge/current can be measured by Faraday cup, Integrated Current Transformer (Turbo-ICT) and BPM. The accuracy of Faraday cup and ICT is ~5%; BPM charge resolution is about pC after calibration.
Photon beam energy range	250–3,800 eV	200–5,000 eV	HXR will use existing spectrometer and material edge absorption scan; SXR will use carbon edge absorption scanning method. For the x-ray absorption scans, the accuracy is about 5 eV for soft x-ray, and about 25 eV for hard x-ray.
High rate capable end stations	≥ 1	≥ 2	
FEL photon quantity (10^{-3} BW)	5×10^{8} @ 2.5 keV (10x P_{spon})	> 10^{11} @ 3.8 keV	E-beam loss scan measurement and Gas monitor. The E-loss scan gives an absolute x-ray pulse energy, which will be used to calibrate the gas monitor. An accuracy from E-loss scan would be ~5%. The gas monitor resolution is about 1%. The bandwidth will be measured a spectrometer.

NC linac-based system			
NC linac electron beam energy	13.6 GeV	15 GeV	Bending magnet + BPM in the DL2 dispersive region for energy measurement. The bending magnet dipole field rms stability is ~0.01%, and the BPM position tolerance (alignment, drift, electrical probe offset) is about 1mm. The BPM tolerance dominates the measurement accuracy. With dispersion at the DL2 about ~0.125m, this gives an energy measurement accuracy better than 1%.
Electron bunch repetition rate	120 Hz	120 Hz	Set by controls and measured by BPMs.
NC linac charge per bunch	0.1 nC	0.25 nC	The bunch charge/current can be measured by Faraday cup, Integrated Current Transformer (Turbo-ICT) and BPM. The accuracy of Faraday cup and ICT is ~5%; BPM charge resolution is about pC after calibration.
Photon beam energy range	1,000–15,000 eV	1,000–25,000 eV	HXR will use existing spectrometer and material edge absorption scan; SXR will use material edge absorption scan method. For the x-ray absorption scans, the accuracy is about 5 eV for soft x-ray, and about 25 eV for hard x-ray.
Low rate capable end stations	≥ 2	≥ 3	
FEL photon quantity (10^{-3} BW)	10^{10} @ 15 keV (lasing)	> 10^{12} @ 15 keV	E-beam loss scan measurement and Gas monitor. The E-loss scan gives an absolute x-ray pulse energy, which will be used to calibrate the gas monitor. An accuracy from E-loss scan would be ~5%. The gas monitor resolution is about 1%. The bandwidth will be measured a spectrometer.