LCLS Parameters – Update December 2017

Typical measured LCLS parameters with hard and soft x-rays. The values are general guidelines. Many parameters vary according to the exact energy, pulse length and band-with. Stability values (at bottom) are taken over a few minutes.

General SASE Parameters

Photon Beam Parameters	Symbol	Hard x-rays	Soft x-rays	Short Pulse soft	Short Pulse hard	Unit
Fundamental wavelength	λ_r	6.2-0.97	44.3-6.2	44.3-6.2	6.2-0.97	Å
Photon Energy	$\hbar\omega$	2000-12800	280-2000	280-2000	2000-12800	eV
Final linac e- energy	γmc^2	6.7-16.9	2.5-6.7	2.5-6.7	6.7-16.9	GeV
FEL 3-D gain length	L_G	1.5-5.4	1.0 – 2.6	0.6 – 1.6	1.0 – 2.9	m
Photons per pulse	$N\gamma$	0.57 – 16	10 – 55	1.1 – 11	0.17 – 2.6	10^{12}
Pulse Energy	U	5	4	0.51	0.5	mJ
Peak brightness	B_{pk}	0.083 – 1.4	0.0033 – 0.14	0.0054 – 0.21	0.14 – 1.5	10^{33} §
Average brightness (120Hz)	$\langle B \rangle$	1 – 19	0.051 – 2.8	0.0084 – 0.22	0.14 – 1.5	10^{21} §
SASE bandwidth (FWHM)	$\Delta\omega/\omega$	0.1-0.4	0.1-0.8	0.2 – 1.2	0.2 – 0.6	%
Final pulse duration (FWHM)	$\Delta\tau_f$	50-250	70-400	6.7 – 20	5.0 - 10	fs
Electron Beam Parameters						
Bunch Charge	Q	0.15 – 0.25	0.15 – 0.25	0.02	0.02	nC
Total Energy Spread	$\sigma E/E$	10^{-3}	10^{-3}	10^{-3}	10^{-3}	1
Inject. bunch length (rms)	σ_{z0}	650	650	230	230	μm
Undul. bunch length (rms)	σ_{zf}	4.3 – 22	6.1 – 35	0.6 – 1.7	0.4 – 0.9	μm
Final peak current	I_{pk}	1.0 – 3.0	0.63 – 2.1	1.0 – 3.0	2.0 – 4.0	kA
Proj. Emittance (injector)	$\gamma\varepsilon_{x,y}$	0.45	0.45	0.2	0.2	μm
Slice Emittance (injector)	$\gamma\varepsilon^{s}_{x,y}$	0.37 – 0.47	0.37 – 0.47	0.17	0.17	μm
Proj. Emittance (Undulator)	$\gamma\varepsilon^{u}_{x,y}$	0.5-1.6	0.5-1.6	0.3-1.0	0.3-1.0	μm
Single Bunch Rep. Rate	F	120	120	120	120	Hz
UV laser energy on cath.	u_l	15	15	~2	~2	μJ
UV laser beam diam. on cath.	$2R$	1.2	1.2	0.6	0.6	mm
e- energy stability (rms)	$\Delta E/E$	0.02	0.07	0.1	?	%
e- x,y stability (rms)	x/σ_x	15,10	25,20	?,?	?,?	%
e- timing stability (rms)	Δt	50-100	50-100	?	?	fs
Peak current stability (rms)	$\Delta I/I$	10	6	8	?	%
Charge Stability (rms)	$\Delta Q/Q$	2.5	2.5	?	?	%
FEL pulse energy stability	$\Delta N/N$	<10	<10	<15	?	%

§Brightness units are photons/sec/mm²/mrad²/0.1%-BW

Seeded x-ray beam parameters

Mode	Energy Range	Bandwidth	Pulse Energy	Pulse Length
HXRSS	> 4.5 keV	0.35-1.5 eV	~ 1 mJ	Up to 40 fs
SXRSS	0.4-1.2 keV	~ 100 meV @ 400 eV ~ 150 meV @ 530 eV ~ 200 meV @ 800 eV	< 50 – 100 μJ @ 20 fs Up to ~ 0.5 mJ with pedestal	20 – 120 fs

Polarized Beam Parameters

Standard LCLS configurations deliver linearly polarized x-ray beams. Upon request, circularly polarized beams with adjustable helicity can be provided. The parameters for polarized beams are summarized in the following table:

Parameter	Value	Unit
Energy range	500 – 1200	eV
Pulse Energy	200	μJ
Polarization	99	% circularly

Dual Bunch & Dual Energy Parameters

Multi-color Pulse Mode Table

SOFT X-RAYS

Technique	Pulse Separation	Min Pulse Duration	Energy Separation	Max Energy/Pulse	Mode	Setup Time	Comments
Fresh Slice							Modes with the dechirper + orbit control.
Two SASE Pulses	~-15 to +850 fs	~5-8 fs	+/-2.5%	200 - 500 uJ (20 fs duraton)	SASE		Probe intensity is higher if the max delay req'd is 35 fs. Pump pulse intensity is higher if the min delay req'd is +15 fs or more (no zero delay).
Linear SASE + Polarization Controlled SASE	~-15 - +850 fs	~5-8 fs	+/-2.5%	300 uJ	SASE		Only pump polarization can be controlled. See also comments re: Fresh-slice, Two SASE Pulses.
One Pulse Self-Seeded, One SASE	0 - 50 fs	~15-20 fs	+/-2.5%	100 uJ seeded, 200 uJ SASE	SASE SEEDED		Only probe polarization can be controlled. See also comments re: Fresh-slice, Two SASE Pulses. Requires longer setup.
Three SASE Pulses	0 - 900 fs (1st to 2nd), 0 - 50 fs (2nd to 3rd)	~5-8 fs	2.5% range for all	100 uJ	SASE		Second pulse has lowest intensity, weak if E > 700 eV.
Split Undulator SASE	0 - 50 fs	40 fs	+/-2.0%	30 uJ	SASE		Minimally invasive, easy to maintain.
Double Slotted Foil	15 - 70 fs	~ 10 fs	+/-1.5%	100-300 uJ	SASE		Minimally invasive, easy to maintain. Delay and energy separation are not independent, minor tuning needed between changes.
Two bucket (ns spacing)	350 ps increments, +/- 120 ns	40 fs	+/-2%	0.5-2 mJ (100 fs duration SASE)	SASE SEEDED		Under development
Twin Bunches (fs spacing)	-	-	-	-	-		Intensity performance comparable to Fresh-slice. Max time separation shorter and tuning more invasive. Recommend Fresh Slice going forward.

HARD X-RAYS

Technique	Pulse Separation	Min Pulse Duration	Energy Separation	Max Energy/Pulse	Mode		Comments
Twin Bunches							Requires long setup (laser stacker/injector tune).
Two SASE Pulses	0 - 125 fs	~ 10 fs	0.2-3%	2 mJ (30 fs duration)	SASE		1st/probe pulse always higher photon energy
Twin bunches + V slotted foil	+/- 50 fs	~5-10 fs	~3%	50 uJ	SASE		
Twin bunches + HXR Self-Seeding	0-100 fs	~ 10 fs	~1 %	150 uJ per pulse	SEEDED		Both colors or a single color can be seeded. Requires longer setup time (hours).
Double Slotted Foil	7-20 fs	~ 10 fs	+/-1.5%	100-300 uJ	SASE		Minimally invasive, faster setup than twin bunches. Delay/energy separation not independent, minor tuning needed between changes.
Two bucket (ns spacing)	350 ps increments, +/- 120 ns	20 fs	~ 2%	1-2 mJ (40 fs duration SASE)	SASE SEEDED		Under development
Fresh Slice / Split Undulator	-	-	-	-	-		Do not apply for hard X-rays (insufficient FEL gain length).

For detailed information and trade-off decisions, contact the Instrument Scientist!

Attosecond Pulses

Important Note: The delivery of attosecond pulses is currently under development and not yet fully transitioned to routine operation. For further information regarding availability, required setup time, risks and trade-offs, please discuss details with your LCLS Point Of Contact.

HXR

Two methods have been demonstrated at the LCLS for generating sub-fs pulses in the hard x-ray domain. Both methods used 20 pC bunch charges. One is based on a nonlinear compression scheme where the harmonic linearizer is running at a lower voltage level 12-15 MV; the other method used a new version of the slotted foil with optimized beam optics.

Measurements based on spectrometer show about half of the shots containing single-spike spectra, while other shots have a few spectral spikes. The estimated pulse duration for the single-spike pulse is about 200 - 400 as. Spectra data show that the nonlinear compression scheme gives a bit wider bandwidth. For example, at the 5.6 keV, nonlinear method measured bandwidth about 11 eV, while the slotted foil measured bandwidth about 4.5 eV. These two schemes should work in all the hard x-ray range about 5 - 10 keV.

SXR

For softy x-rays, the XLEAP system is under development. It uses the interaction of a laser beam with the electrons to modulate the beam energy across the beam pulse. Subsequent compression using an undulator and chicane generates sub-femtosecond pulses of up to 50 μJ.

Energy Range	Parameter	Value	Unit
HXR	Pulse Energy	5-10	μJ
	Pulse Duration	200 – 400	as
	Photon Energy	5 – 10	keV
	Bandwidth [FWHM]	4 – 11	eV
SXR	Pulse Energy	20	μJ
	Pulse Duration	500	as
	Photon Energy	500 - 1000	keV
	Bandwidth [FWHM]	5	eV