Future Performance of the LCLS

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Outline

• Recent performance
• Near-term improvements
• LCLS 2 ... and Beyond
Reliable

- First LCLS lasing April, 2009
- First User run Oct-Dec.

Available 92.9%
Flexible

• Rep Rate: Single shot, 10, 30 Hz

• Pulse Length: (70 - 300 fs FWHM), easily changed in 1 minute

• FEL Power: (0 - 40 GW) set by pulse length

• Photon Energy: 800 - 8000 eV, changed in 5-30 minutes.

• Ultra-Short Pulse: (<10? fs fwhm), requires 1-2 hours to establish and only runs with low charge 20 pC.
Stable

- Energy: RMS 3.6%
- X-ray position jitter <10% of beam spot size, (20% for overcompressed bunches)
- Wavelength jitter: 0.1% - 0.2%, (2x electron energy jitter)
Bright

- Derived from K-monochromator, averaging many shots
- Double hump spectrum common
- Brightness \( \approx 1 \times 10^{33} \) ph/(s mm\(^2\) mrad\(^2\) 0.1\%BW)

250 pC, 8 keV x-rays
Near -Term Improvements

- Conversion of 8 of the 33 undulator segments to 2nd harmonic afterburners (SHAB)
- Diagnostic Skew quad in BC1
- Photon energy range: 800 - 8000 eV -> 530 to 10,000 eV (tested Dec 18, J. Frisch)
- Rep rate to 60 Hz, 120 Hz later this year.
- Pulse stealing for bunch length measurements (Loos).
0.75 Å FEL Production

Second Harmonic Afterburner

1.5 Å, $K = 3.5$

0.75 Å, $K = 2.26$

existing LCLS undulator

“2nd Harmonic Afterburner”

- Replace Shims
- Beam Tested Dec. 09, Nuhn

Smaller $\beta$ function in afterburner helps

8 undulators

power (GW)

$<\beta>$=15m
$<\beta>$=30m

Small structure in afterburner helps
Diagnostic Skew Quad

First Measurements on Dec. 15, 2009 (250 pC)
(K. Bertsche, P. Emma, O. Shevchenko, PAC09)

OTR in BC1

$\otimes y' = x/f$

Skew quad generates $y'$ from $x$:

$\Delta y' = x/f$

1.3% rms relative chirped energy spread at 250 MeV and 230 mm horizontal dispersion

$I_{pk} = 250$ A (after BC1)
**Measured vs Elegant on OTR12 (250 pC, X-band RF Off)**

**Preliminary**

\[ \Pi_{L1S} = 32^\circ \]

**Measured**

BC1 skew quad ON

\[ \Pi_{L1S} = 34^\circ \]

**Elegant**

**Elegant**

rms = 1.49 %

\[ E_0 = 0.249 \text{ GeV} \]

rms = 0.0739 mm
Measured vs Elegant on OTR12 (250 pC, X-band RF Off)

PRELIMINARY

Profile Monitor OTRS:L121:291 15—Dec

$\Pi_{L1S} = 34^\circ$

$\Pi_{L1S} = 36^\circ$

Elegant vs Measured on OTR12 (250 pC, X-band RF Off)

BC1 skew quad ON
Measured vs Elegant on OTR12 (250 pC, X-band RF Off)

PRELIMINARY

Measured

Elegant

BC1 skew quad ON
LCLS 2

• Goals
• Injector
• FEL
• Xray lines
Goals

• Increase user access through simultaneous delivery to multiple experiments

• Extend physics reach

spectral range, polarization, pulse length, seeding, pump-probe beams, THz beams...

• Increase repetition rate

• Provide continuous and rapidly tunable x-ray energy
• A second injector provides for two simultaneous FEL beams with independently adjustable parameters
• Two independent e- beams allows x-ray pump, x-ray probe with decoupled wavelength, pulse width, energy and timing constraints
FEL Concept

- Baseline: One hard xray beam and one two-color, two-pulse, variable delay beam; e-beam lases twice.

J. Wu, Self Seeding
H.D. Nuhn, Undulator parameters
Crossed Undulator Polarization

- Horizontal + vertical undulators, or two helical undulators
- Polarization controlled by phase shifter, fast switch possible with pulsed dipoles at ~100 Hz
- Circular polarization requires $L_2 \sim$ one gain length
- 80% polarization near SASE saturation - more for seeded FELs

2. Y. Ding & Z. Huang, PRST-AB 11, 030702 (2008)
6-nm Self-Seeded FEL


1st undulator

chicane

grazing mirrors

slit

2nd undulator

SASE FEL

Seeded FEL

electron

can

grazing mirrors

slit

electron dump

FEL spectrum at ~26 m in 2nd undulator for seed of 0.1 MW (black) and 0.01 MW (red)

J. Wu

Need 1000 times more power on grating

FEL spectrum at ~26 m in 2nd undulator for seed of 0.1 MW (black) and 0.01 MW (red)

FWHM $3.1 \times 10^{-4}$

J. Wu

6 nm

1st undulator

2nd undulator

10 MW

0.1 MW

0.01 MW

P (W)

$10^{10}$

$10^{9}$

$10^{8}$

$10^{7}$

$10^{6}$

$10^{5}$

$10^{4}$

$10^{3}$

$10^{2}$

$10^{1}$

$10^{0}$

$10^{-1}$

$10^{-2}$

$10^{-3}$

$10^{-4}$

$10^{-5}$

$10^{-6}$

$10^{-7}$

$10^{-8}$

$10^{-9}$

$10^{-10}$

z (m)

0 5 10 15 20 25 30 35

10 MW

0.1 MW

0.01 MW

P (W)

$10^{10}$

$10^{9}$

$10^{8}$

$10^{7}$

$10^{6}$

$10^{5}$

$10^{4}$

$10^{3}$

$10^{2}$

$10^{1}$

$10^{0}$

$10^{-1}$

$10^{-2}$

$10^{-3}$

$10^{-4}$

$10^{-5}$

$10^{-6}$

$10^{-7}$

$10^{-8}$

$10^{-9}$

$10^{-10}$

z (m)

0 5 10 15 20 25 30

FWHM $3.1 \times 10^{-4}$
Xray Lines

- Mirrors can provide four possible LCLS-2 beamlines. One active at a time.
- Beamlines can reach multiple experiments
- Mirrors in Hutch 2 can send LCLS-2 beam to Far Hall
Option: Beam Doubler

- If e- bunch can be made to lase twice
- Result: two spatially separated xray beams of somewhat independent wavelength to supply two experiments simultaneously

Variant of scheme suggested by Phil Heimann
Beam Doubler Layout

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**Undulator Hall**

- SXR1
- SXR2

- ~0.1 mrad

**FEE**

- ~19 mm

- Insertable mirrors pairs for 0 or 60 mrad deflection
- Four possible beamlines, two active at any time

**LCLS undulator cross-section**

- ~6 mm

**SXR2 segments would mechanically move to be able to return to two-color mode**
If bunch doesn’t lase twice...

- One xray beam from one e-bunch using fast correctors ~100 Hz.
- Two xray pulses from two e-bunches (many ns apart) is possible with fast kickers.

R. Brinkman, J. Frisch
More options

• Higher Rep rate: 360 Hz for soft x-ray line at full energy (7 GeV) without SLED.

• Higher energy option: two linacs work together as one (up to 22 GeV)

• Future expansion: first 1/3 of SLAC linac still unused
LCLS 2 Issues for Workshop

• Lasing twice with same e- beam. Limitations and practicalities.

• Multiplying the xray beams to serve more users simultaneously.

• Distributing hard and soft xray beams in pump probe arrangements

• Self-seeding and echo

• Prioritizing or weighting factors for Future Needs: wavelength range, polarization, bandwidth/brightness, pump-probe beams, tHz radiation, and importance of independent beam controls for each user.

The End