Shorter-wavelength options Ling Huang Hard X-Ray Upgrade Workshop July 29, 2009



Outline

2nd harmonic afterburner
For polarization control
For sub-Angstrom radiation

Open gap of the existing undulator
0.75 Å and 0.5 Å FEL at 14 GeV
cover longer wavelengths by electron energy and/or gap change

Energy upgrade option
Double linac energy to reach 0.38 A

Second harmonic afterburner

- When SASE FEL reaches saturation, significant harmonic bunching appears
 - $b_1 > b_2 > b_3$
 - LCLS third harmonic power ~ a fraction of % of fundamental level, very little second harmonic power



Add a 2nd harmonic afterburner gives simultaneous 1st, 2nd, 3rd harmonics

2nd harmonic afterburner undulator obtainable by opening existing undulator gap

Open LCLS undulator gap for 2nd harmonic afterburner

- 5 to 10 sections of the LCLS undulators, K ~ 2.27 with taper
- Smaller beta function in afterburner undulator helps



Open LCLS undulator gap to access shorter λ

LCLS undulator is fixed gap

- no gap control
- change wavelength by electron energy
- no phase shifters between sections (fixed phases)

Without phase shifter, LCLS undulator gap may be opened to second and third harmonic of present undulator setting

Wavelength (Å)	K	Gap (mm)	L _{sat} (m)
1.5	3.5	6.8	60
0.75	2.27	10	90
0.5	1.62	13	120

Example: 0.5 Å FEL at 14 GeV



0.75 Å FEL saturates at ~ 90 m with ~10 GW power

The gap change will affect LCLS wavelength coverage from 5 Å (at 4.3 GeV) to 0.5 Å (14 GeV) unless gap is variable



Energy upgrade options

- New injector at Sector 10 or Sector 0
- New BC1, BC2 and LTU



- Pump-probe capabilities with soft-hard, hard-hard x-ray FELs
- THz pump, soft/hard x-ray probe

28 GeV hard x-ray FEL

- Use the same LCLS undulator, we may reach 0.375 Å (33 keV photon) by doubling LCLS energy
- At such a high energy, 4 times more spontaneous radiation is generated (~0.3% energy loss)
- Energy spread is increased in undulator due to random emission process







- Parameters not optimized, beam brightness requirement close to what LCLS generated
- Higher peak current desirable (ESASE?)
- Low charge, low emittance should help too

Summary

- LCLS has reached FEL saturation at 1.5 Å well within the designed undulator length
- Afterburner can provide 2nd harmonic at a few hundred MW to ~ GW power level
- Open undulator gap allows access fundamental radiation at 2nd and 3rd harmonics with ~10 GW power
- Double the electron energy allows access fundamental radiation at 4th harmonic of 1.5 Å (spontaneous energy spread is an issue)

Thanks for your attention!

Thank useful discussions with

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