Effect of microbunching on seeding schemes for LCLS-II*

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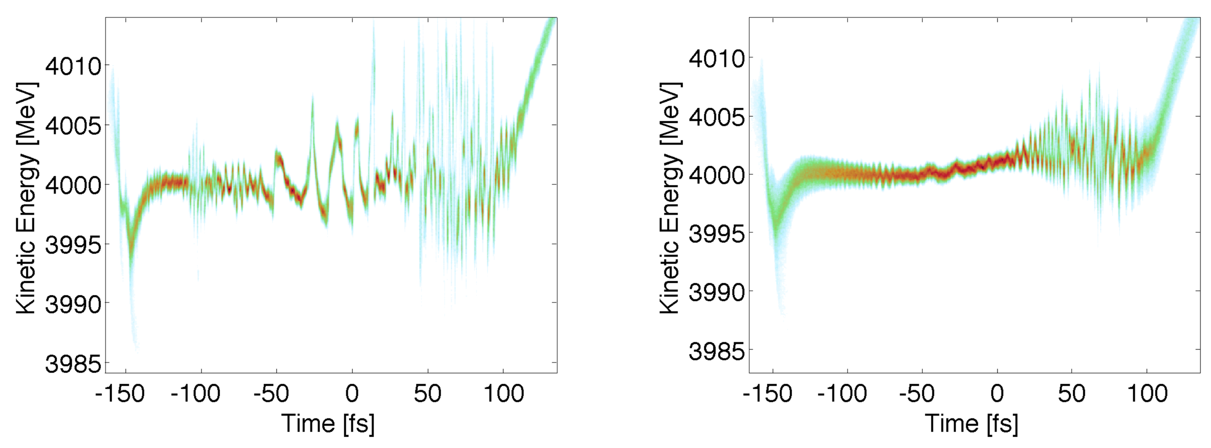
Abstract

External seeding and self-seeding schemes are particularly sensitive to distortions and fluctuations in the electron beam profile. Wakefields and the microbunching instability are important sources of such imperfections. Even at modest levels, their influence can degrade the spectrum and decrease the output brightness. These effects are evaluated for seeded FELs at the soft X-ray beam line of LCLS-II. FEL simulations are performed in GENESIS based on various realistic electron distributions obtained using the IMPACT tracking code. The sensitivity depends on both the seeding scheme and the output wavelength.

Beam distributions from S2E simulations

300 pC bunch
Initial bunch distribution calculated using IMPACT code
FEL simulations used GENESIS

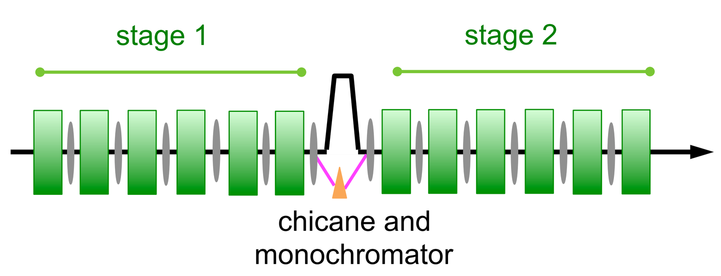
Low laser heater **High laser heater**

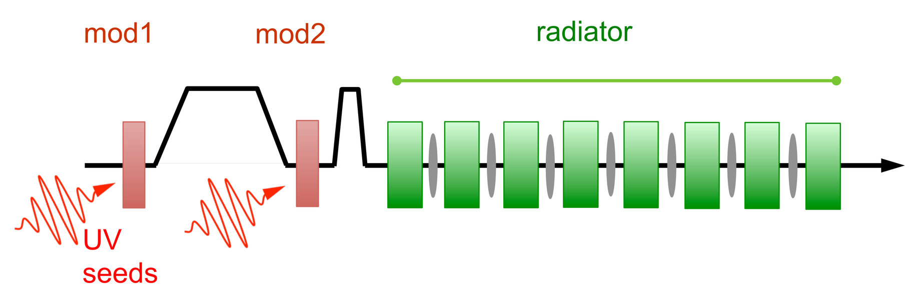


Self-seeding

EEHG

Beamline Schematics

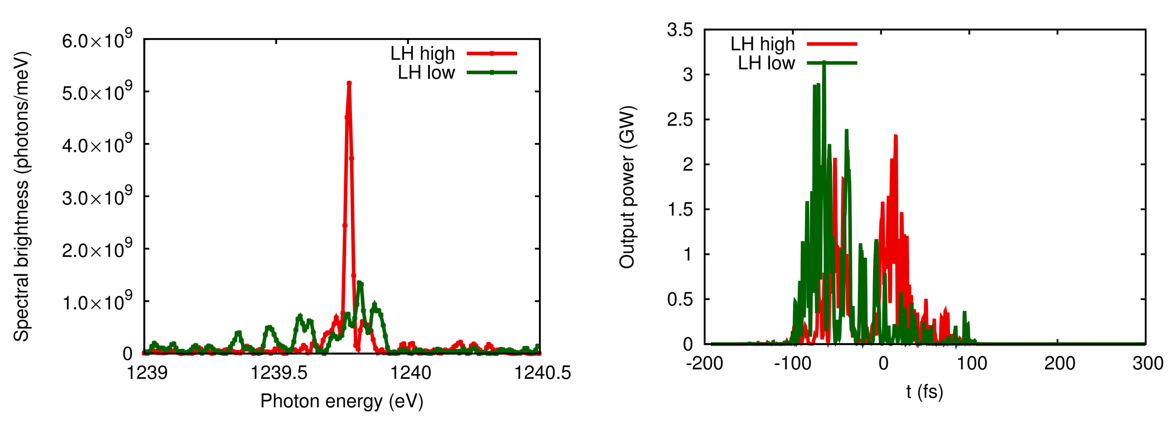


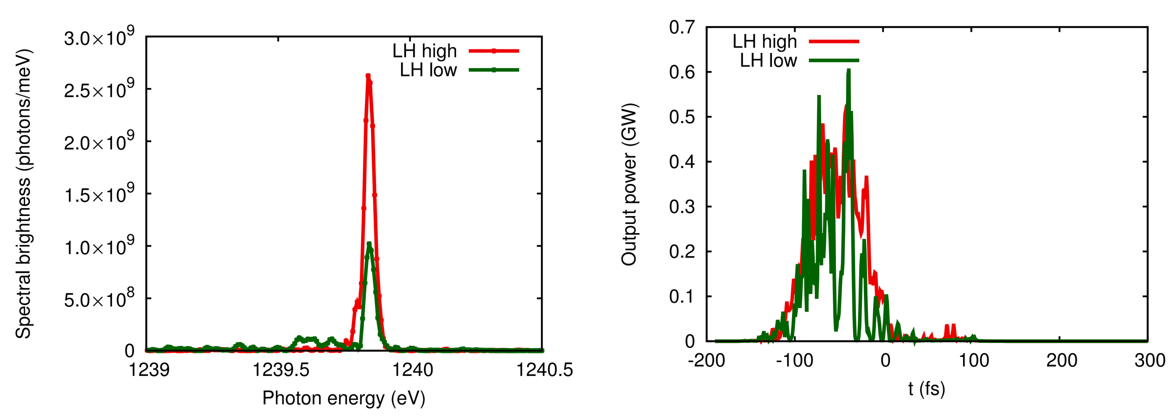


1.24 keV photons

For self-seeding, only 19 nJ of radiation is transmitted through the monochromator.

For EEHG, energy spread is increased to up to 3 MeV by the seeding process.



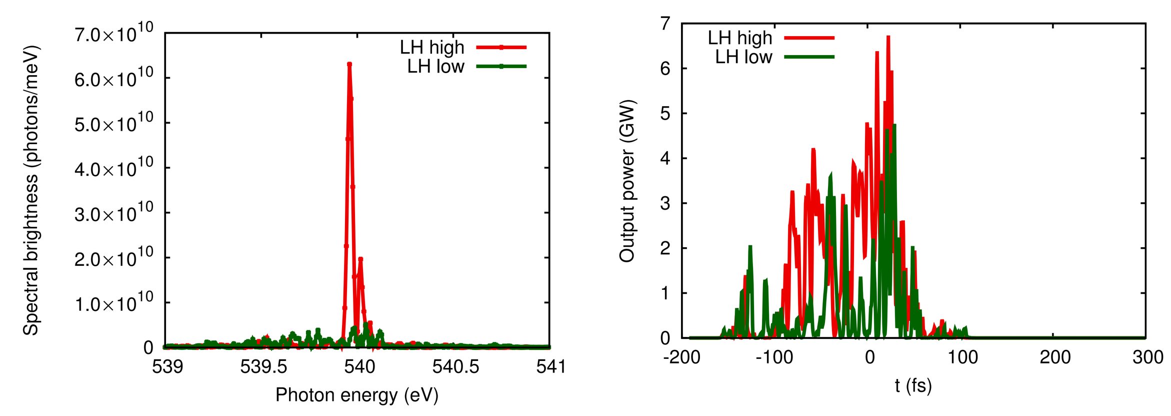


Shown for 400 fs fwhm input laser pulses

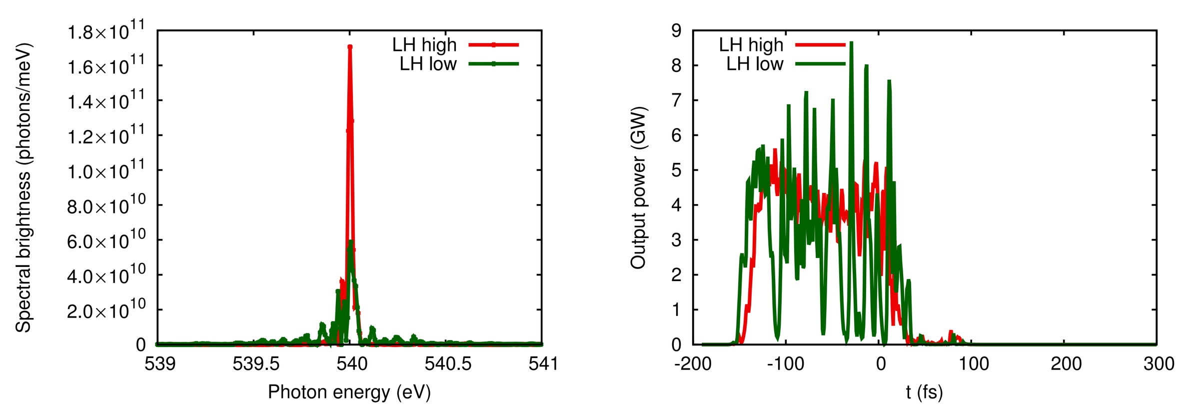
540 eV photons

For self-seeding, only 12 nJ of radiation is transmitted through the monochromator.

For EEHG, energy spread is increased to up to 1.6 MeV by the seeding process.



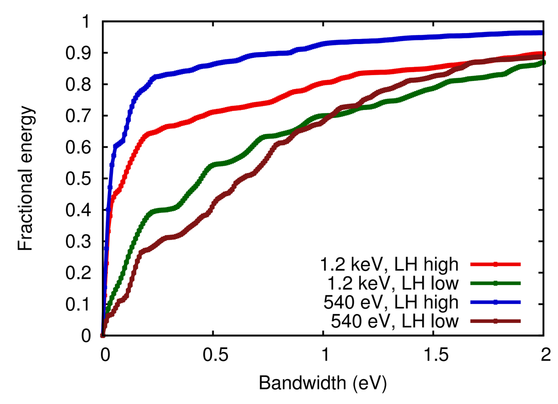
Self-seeding at 540 eV shows the greatest sensitivity to microbunching

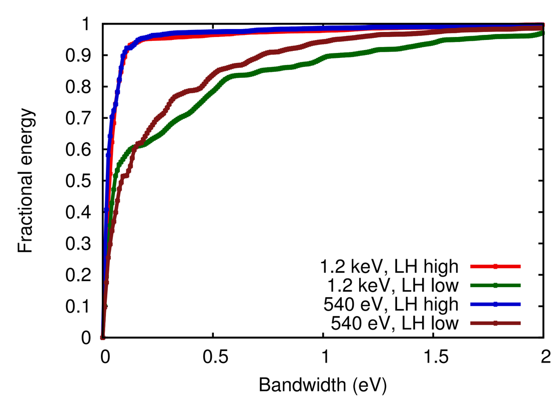


Shown for 400 fs fwhm input laser pulses.
Large power fluctuations but still fairly coherent.

Summary

Plots of cumulative fraction of energy which occupies a given bandwidth range.





Nominal Parameters

Electron Bunch Parameters:

- 300 pC
- 4 GeV energy
- 0.43 μm normalized emittance
- 1 kA current
- 500 keV slice energy spread
- 15 m beta function

Seed Lasers:

- 260 nm wavelength, up to 1 GW peak power

Undulator Parameters:

- final x-rays: 39 mm period
- laser seeding: 0.1 m or 0.4 m period (EEHG)

Monochromator

- R=15000, efficiency = 2%

Tolerances to energy modulations

Self-seeding:
For a given level of relative energy deviations, η, coherence requires

$N_u < 0.1/\eta$

N_u is the number of undulator periods after the monochromator
Requires $\eta < 0.1$ * FEL parameter if seed at low power

EEHG:
Three main contributions to phase noise

1) bunching distortions due to energy deviations
   requires first energy modulation > η
2) wake fields within EEHG stage
   requires second energy modulation > $\Delta\eta_{wake} \underbrace{\lambda_2 / \lambda_X}_{\text{big factor}}$
3) propagation after bunching is produced
   for ~ 2% bunching, requires $\eta < 0.3$ * FEL parameter

SASE in the current spikes can also add a pedestal to the spectrum

Selected References

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