FEL WG: Summary

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Future Light Source WS 2010: FEL WG

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SLAC National Accelerator Lab

Menlo Park, CA

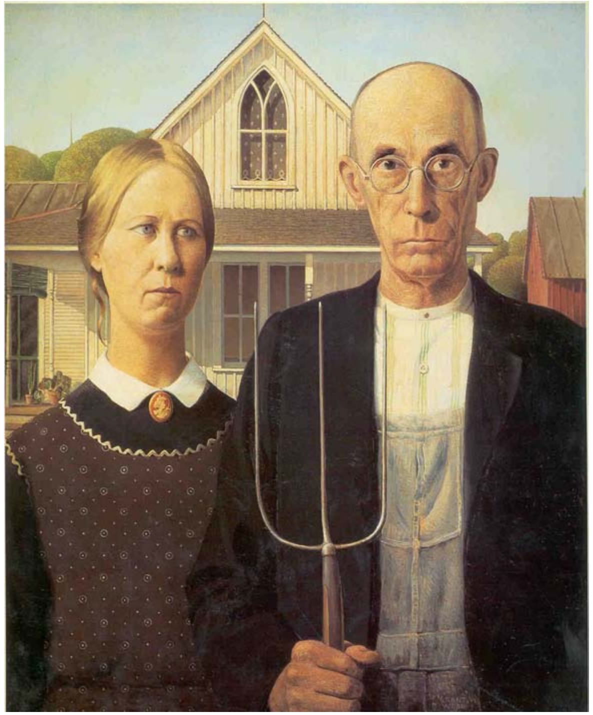
FEL I: Monday and Tuesday

- **XFELO**
  - **Intro (KJK), Physics & performance (Lindberg), X-ray cavity issues (Shvyd'ko), Simulation (Fawley), XFELO@ European XFEL (Zemella), Grazing incidence mirrors (Barty)**
- **Ultrafast SASE**
  - **Overview (Rosenzweig), 8-48 keV@LCLS (Wu), Coherent SASE @SDL (Wang)**
- **Soft x-ray oscillators and self seeding**
  - **SXO overview (Benson), Echo enhanced two O (Wurtele), Self Seeding (Wu), Optics for Self seeding (Feng)**
- **Science-FEL joint session**
  - **γ-in and γ-out HXS (Bergmann), SXS (Guo), Imaging (Jacobsen), Mössbauer (Cramer), PE (Parmigiani), What parameters? (Bisognano)**

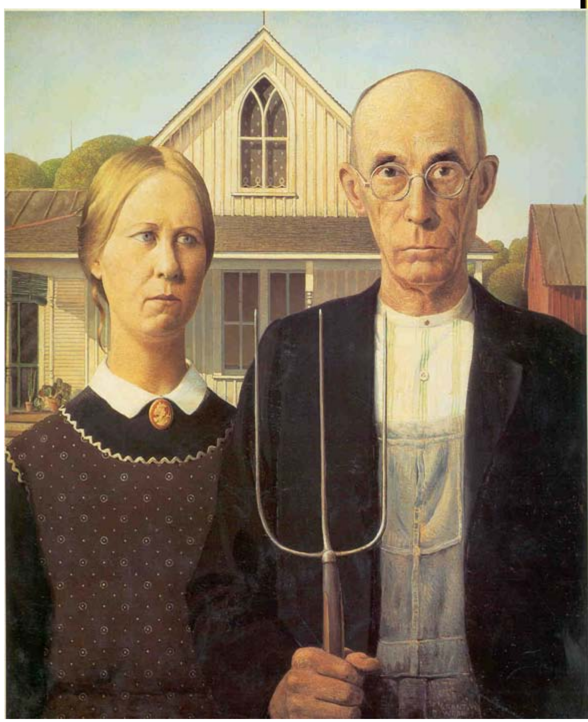
TheLCLS demonstrated that the FEL principles are valid for x-rays. In the future, multiple directions with complementary capabilities are foreseen:

- **Hard x-rays with E_e ~ 5-15 GeV**
  - **Intense pulses (♦10^{12})**
    - **Higher repetition rate (≏ 10 kHz with pulsed SCRF)**
    - **Improving coherence with self-seeding, etc**
  - **Gentle pulses (≏ 10^{9})**
    - **Ultrafast time-resolution (down to atto second) with single-spike SASE**
    - **Ultra-narrow spectral resolution (~ meV) with XFELO**
    - **Higher repetition rate up to MHz with CW SCRF**
- **Soft x-rays with E_e ~ 2 GeV**
  - **Various seeding techniques**
    - **HGHG, Echo-enhanced, self-seeding**
    - **Advance in laser techniques (high power, HHG,..)**
    - **Soft-x ray oscillators ?**

FEL 1



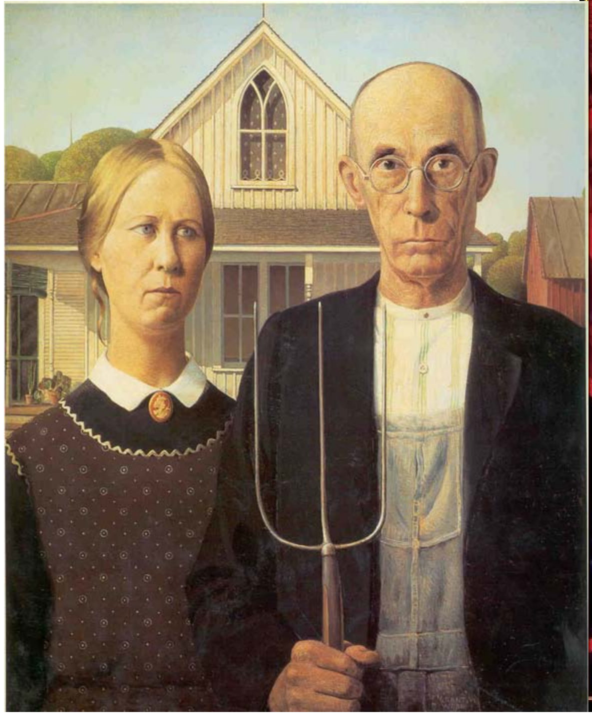
FEL 1



FEL 2

Different FELs have complementary characteristics and applications!

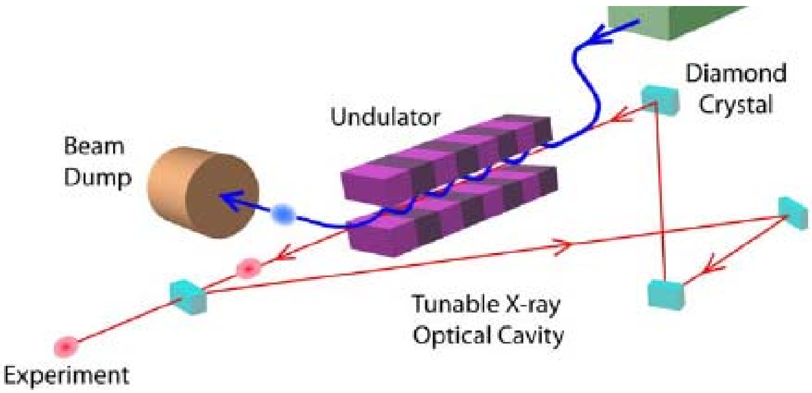
FEL 1

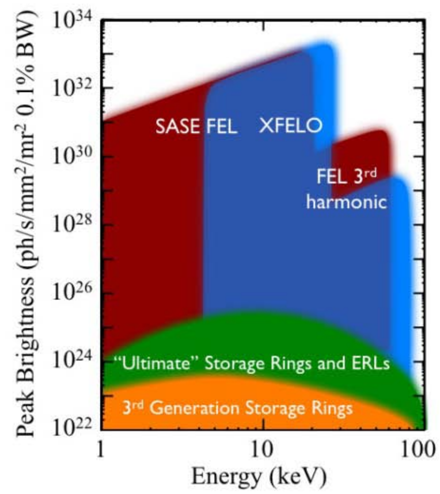


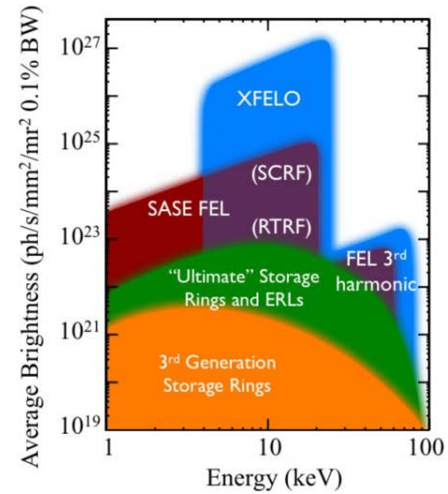
FEL 2

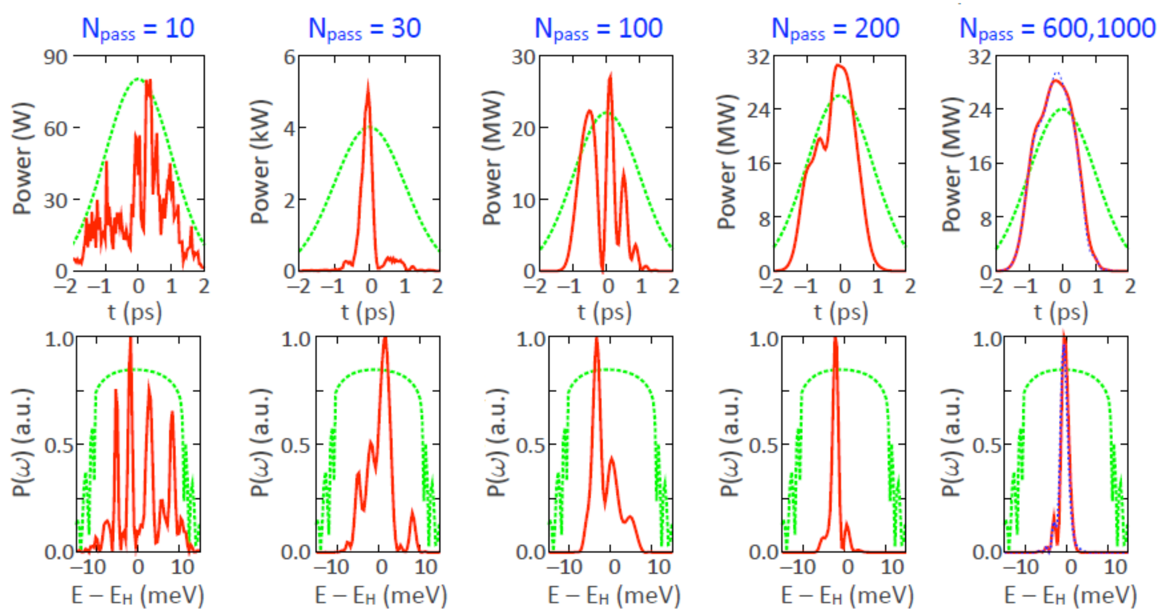
FEL 3

Hard X-Ray FEL Oscillator

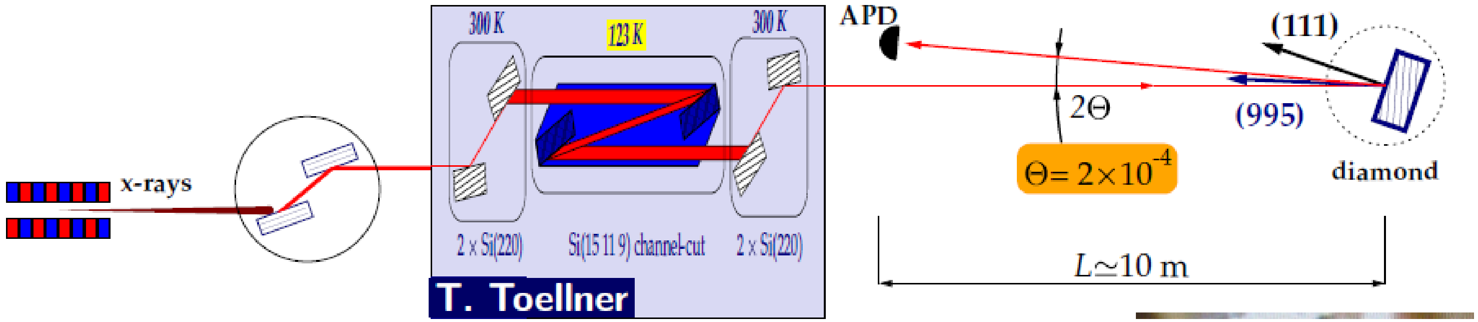


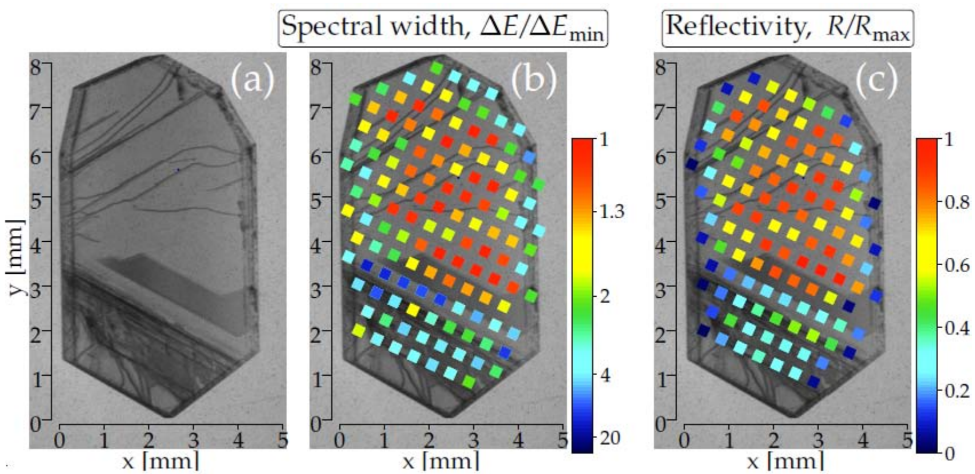






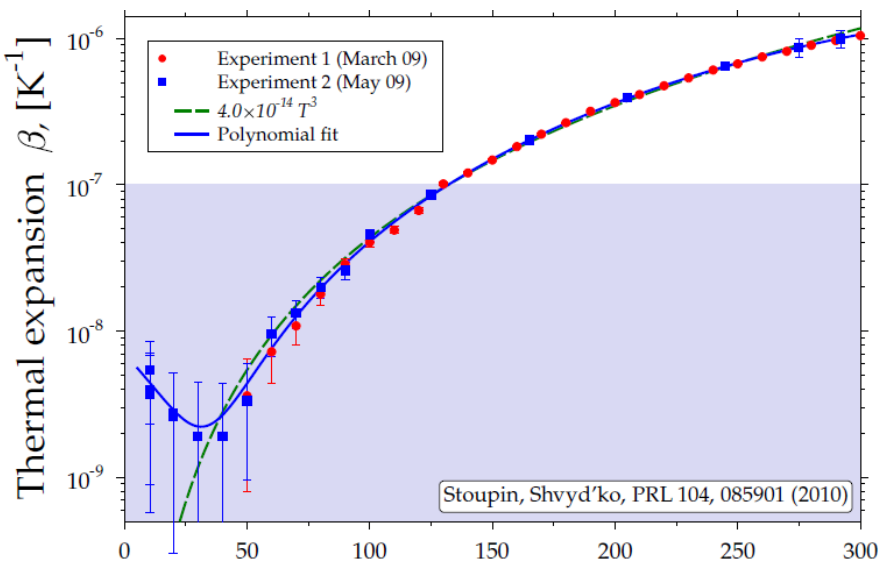
APS Experiments on Synthetic Diamonds





Regions of near-perfect crystal structures

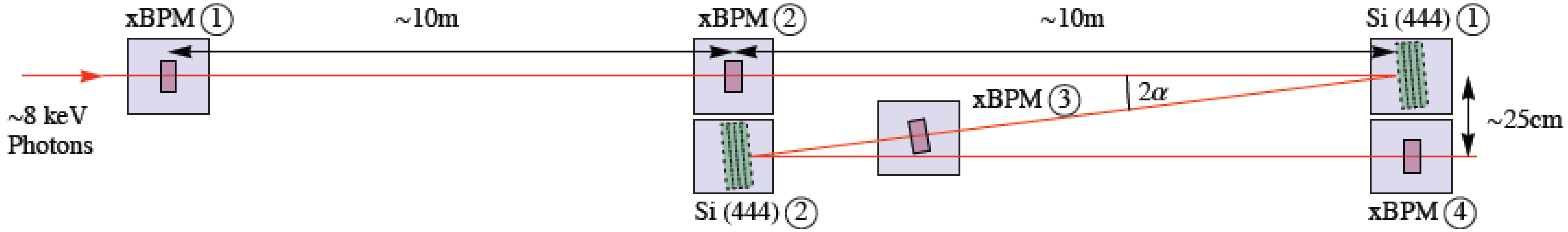
Thermal exp. coeff β ~ 2 10^{-8} K^{-1}@ T=50 K



KJK KEK Dec 21, 2009

XFELO Optical Cavity

- **Technical issues**
  - Diamond crystal
    - Is theoretical reflectivity achievable?
    - Heat load problem: ΔE_γ spread < 1 meV ?
    - Radiation damage
  - Grazing incidence, focusing mirror for an XFELO ($\Delta\phi$=1 μr to 0.25 μr):
    - Specs tighter than LCLS mirrors
  - Stability of optical elements
    - $\Delta\theta$ < 10 nr ?
- **Test set-up to verify angular tolerance at European XFEL**



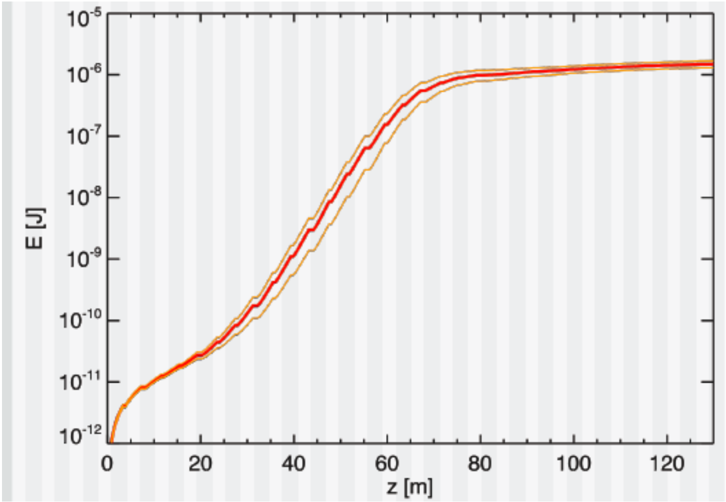
LCLS Mirror Specs (KB)

	Spatial Frequency Range	Spatial Wavelength Range	Specification	LLNL Measurement Vendor 1 Si substrate	LLNL Measurement Vendor 2 Si substrate
HSFR	$0.5\ \mu m^{-1}$ - $50\ \mu m^{-1}$	20 nm - 2 μm	≤ 0.4 nm rms	(nm rms) Loc. 1 = 0. 15 Loc. 2 = 0. 16	(nm rms) Loc. 1 = 0.36
MSFR	$10^{-3}\ \mu m^{-1}$ - $0.5\ \mu m^{-1}$	2 μm - 1 mm	≤ 0.25 nm rms	(nm rms) Loc. 1 = 0. 20 Loc. 2 = 0. 18	(nm rms) Loc. 1 = 0.20 Loc. 2 = 0.18
Figure	$(\text{mirror size})^{-1}$ - $10^{-3}\ \mu m^{-1}$	mirror size – 1 mm	≤ 0.25 μrad rms 2 nm rms	< 0.16 μrad rms 24 mm – 1 mm	< 0.3 μrad rms 62 mm – 1 mm

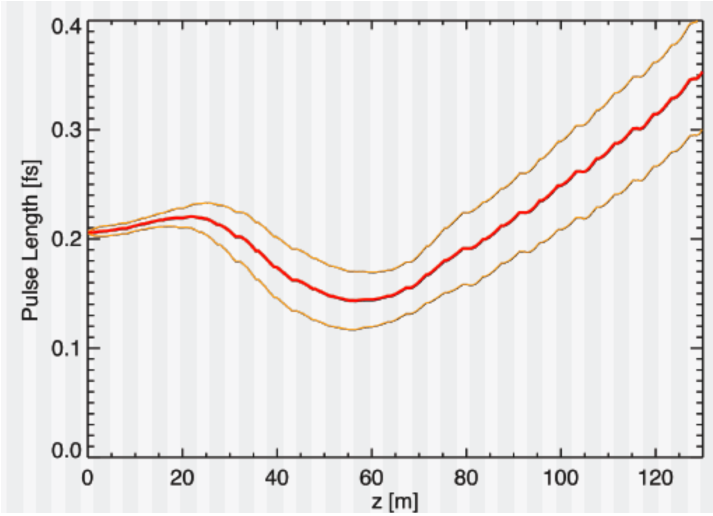
Ultrafast SASE

- Emittance scaling→ low emittance ε_x ~ 0.1 mm-mr with Q < 1 pC → compression to τ < 1 fs → SASE producing single spike
- Investigate at atomic electron spatio-temporal scale
- Low charge (10 pC) option at LCLS for 1.5-40 keV
- Can be compact and cheap
- Issues:
  – Inherent or accelerator stability
  – Atto-second timing and diagnostics

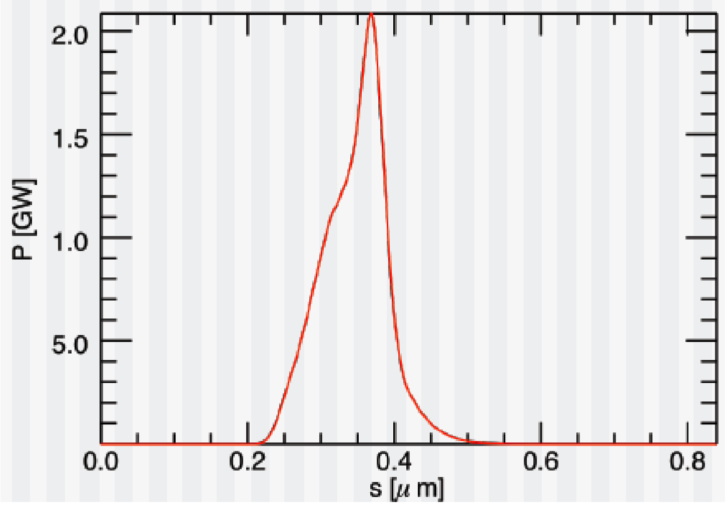
LCLS with Q=0.25 pC, ε_x=0.033 μ (Genesis)



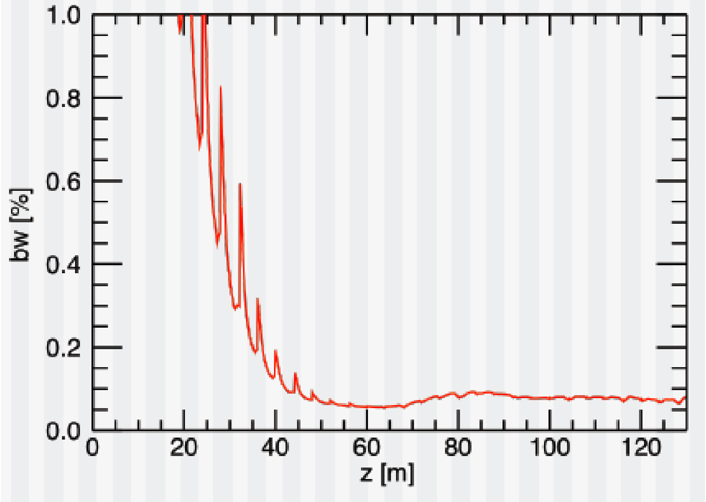
Deep saturation achieved



Minimum rms pulse: 150 attosec



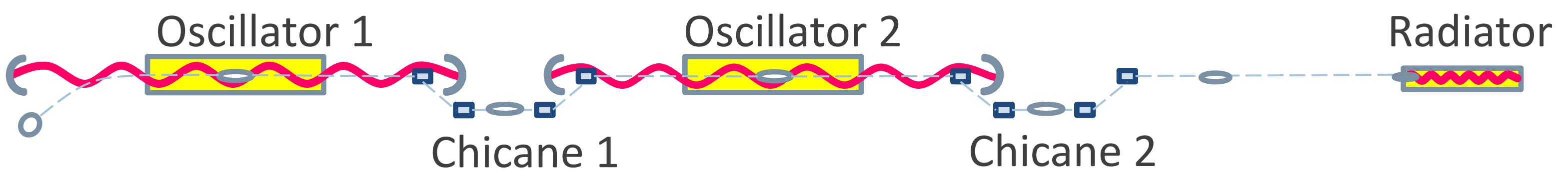
Quasi-single spike, 2 GW



$\sigma_\omega \sigma_t \cong 1.1$

Soft X-ray FEL schemes

- Seeded HG (HG cascade or Echo-enhanced)
  - NLS, NGLS
- Oscillator
  - Challenging in mirror reflectivity, tolerance, and transmission→ regenerative amplifier
  - An option for JLAMP ?
- Self-seeding scheme for LCLS upgrade
  - 6 nm to 6 Å
  - Variable line-width grating
- An echo-enabled, tunable, two-oscillator scheme
  - Full coherence without seed laser
  - Inherent tunability and photon energy reach of EEHG



Science Drivers for FELs

- What parameters are worth fighting for?
- What photons enable edgiest science?
  - 900eV vs 1 keV vs 1.2 keV, 12 keV,…etc
  - Polarization
- What pulse lengths…?
  - 1 ps, 100 fs, 10 fs, 1 fs, 100 as,…
- What bandwidth?
- What rep rate…?
  - 1 kHz, 10 kHz, 100 kHz, 1 MHz,…, 1 GHz
- What photon numbers/pulse are useful/tolerable?
- Fluence (joules/area)?
- How important is coherence
  - transverse, longitudinal, degeneracy
- See this as a multidimensional matrix, with some elements highlighted