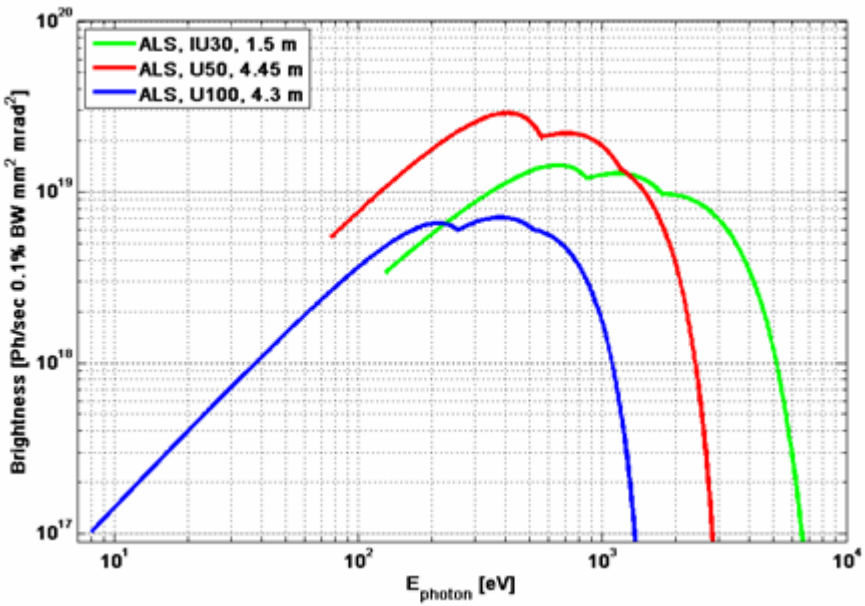
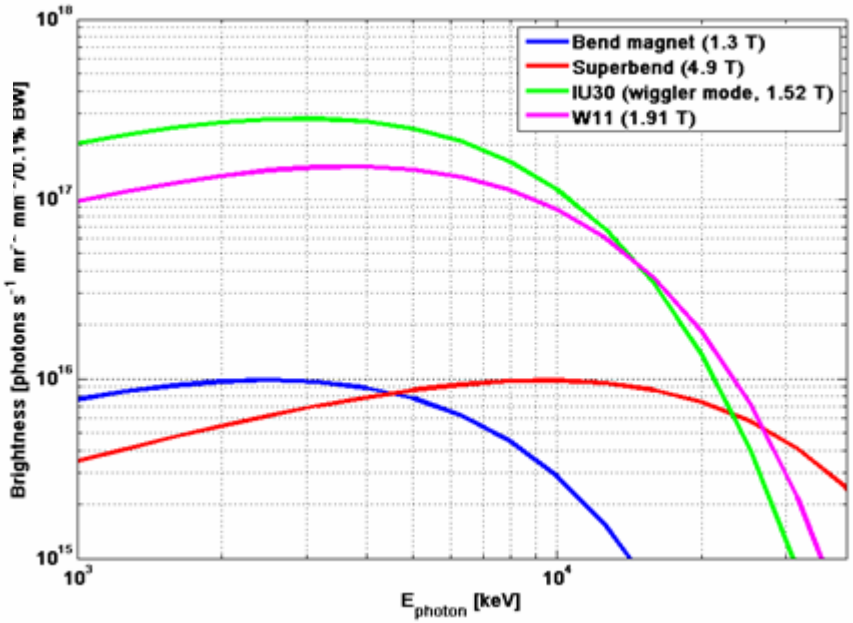
Exquisite Beam Control is Needed for X-Ray Sources

jc/ALSaerial/11-96

Top off upgrade is keeping ALS at the frontier





ALS lattice upgrade has big benefits

Brightness

- 3 times the brightness for central bend and Superbend beamlines

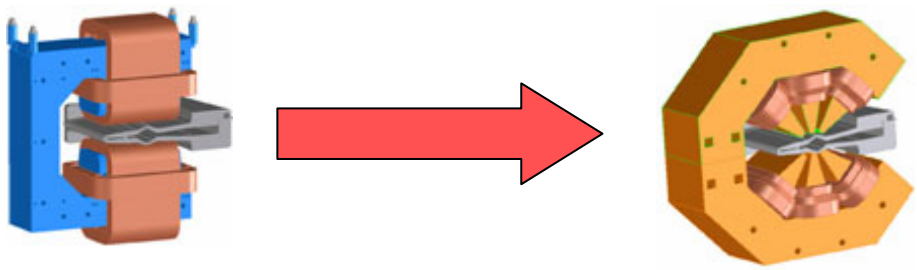
Up to 2 times the brightness for soft x-ray beamlines
(greater increases with more speculative lattices)

Additional Benefits

Short pulses: 500 MHz picosecond pulses at reduced currents

Coherent Terahertz Radiation

Existing Correctors

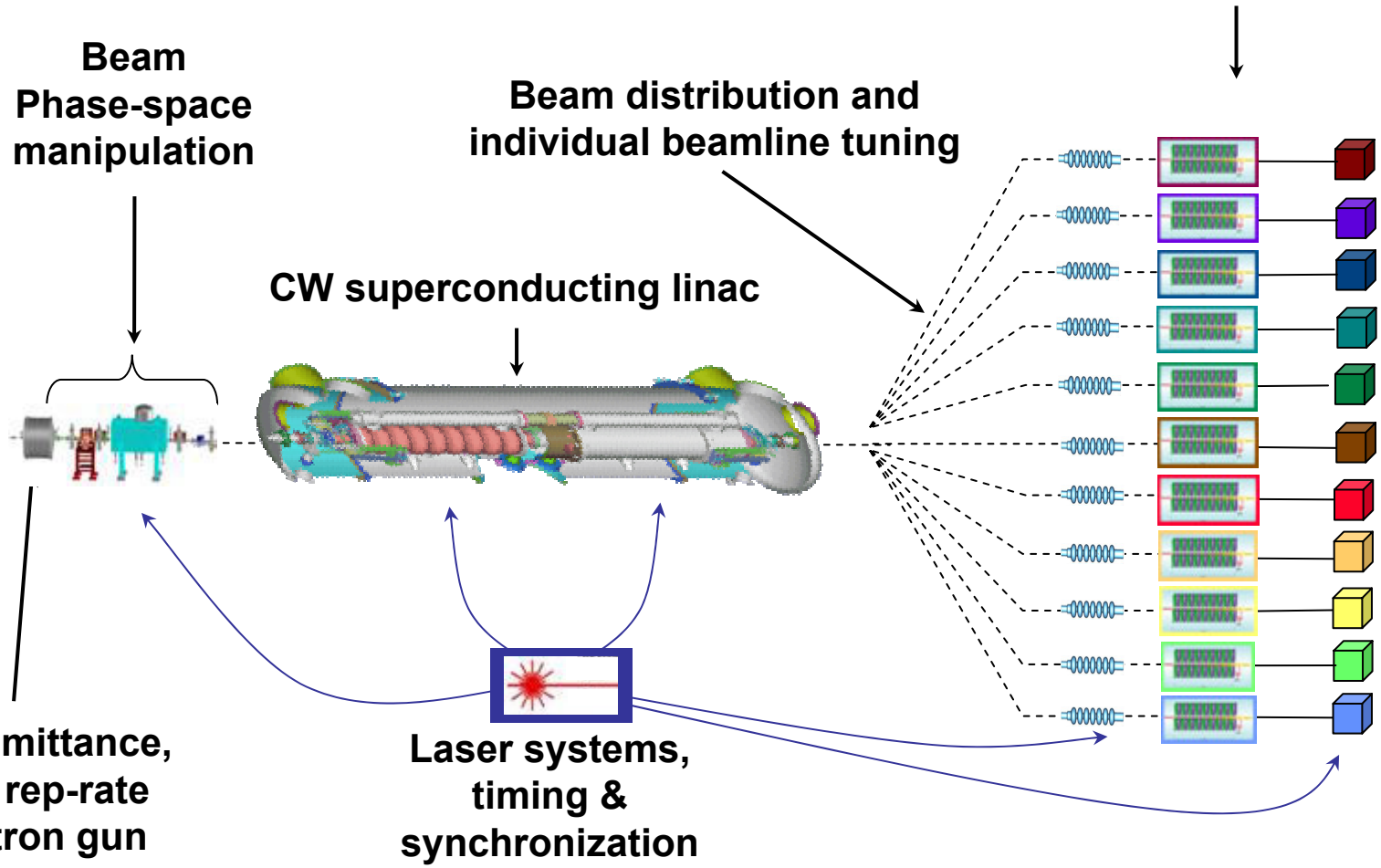


Sextupole/Corrector Multimagnet

A vision for a future light source facility

HIGH REP-RATE, SEEDED, VUV — SOFT X-RAY FEL ARRAY

- Independent array of configurable FELs
- Control of electrons: seeded, attosecond, ESASE
- Control of x-rays: wavelength, pulse duration, polarization



Performance goals of a SXR FEL

FELs WITH THREE MODES OF OPERATION

	Short-pulse beamlines	High-resolution beamlines	Sub-femtosecond beamlines
Wavelength range (nm)	~200 Š 1	~200 Š 1	~40 Š 1
Photon energy (eV)	6 Š 1240	6 Š 1240	30 Š 1240
Repetition rate (kHz)	100	100	1-100
Peak power (GW)	1	1	0.1 Š 0.3
Photons/pulse (@1 nm)	$5x10^{11}$ (in 100 fs)	$2.5x10^{12}$ (in 500 fs)	$1.5x10^{8}$ (in 100 as)
Timing stability (fs)	10	10	TBD
Pulse length (fs)	1 Š 100	100 Š 1000	0.1 - 1
Harmonics	² few%	² few%	² few%
Polarization	Variable, linear/circular	Variable, linear/circular	Variable, linear/circular

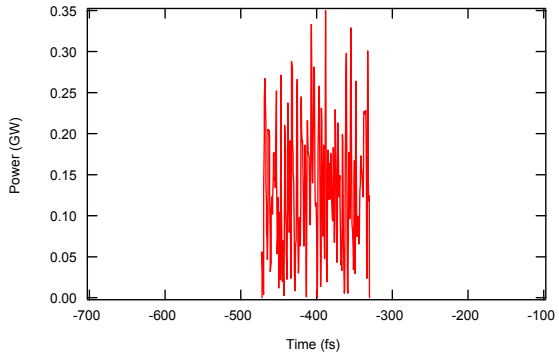
Lasers can control powerful electron accelerators

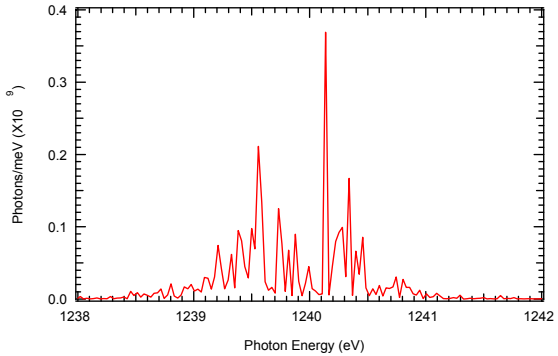
ENHANCED CAPABILITIES FOR CONTROL OF X-RAY PULSE

Pulse profile

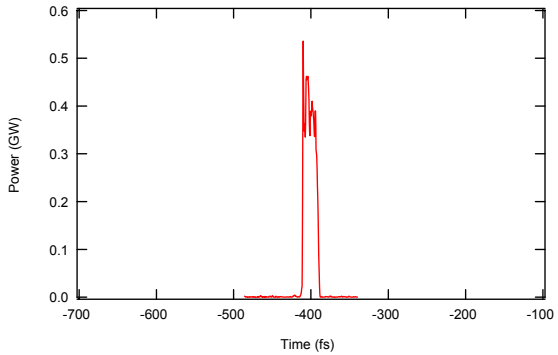
Spectrum

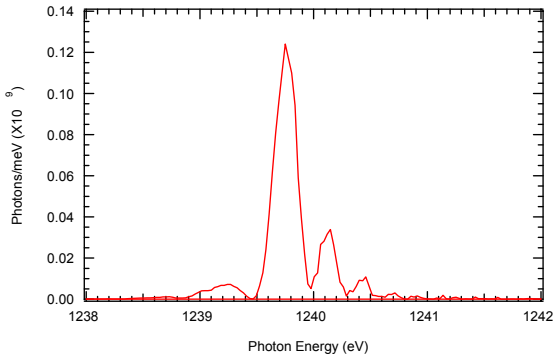
SASE



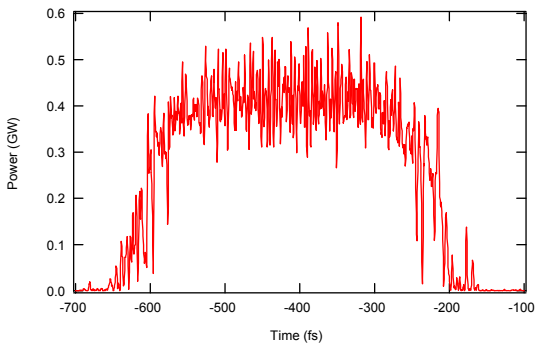


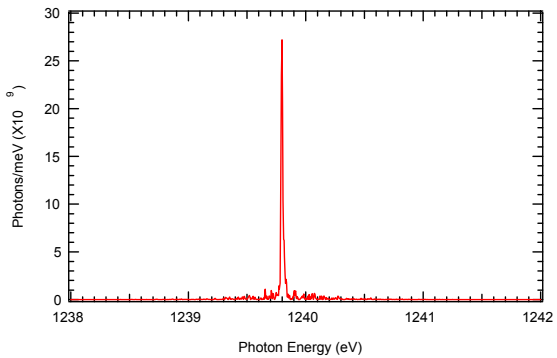
25 fs seed





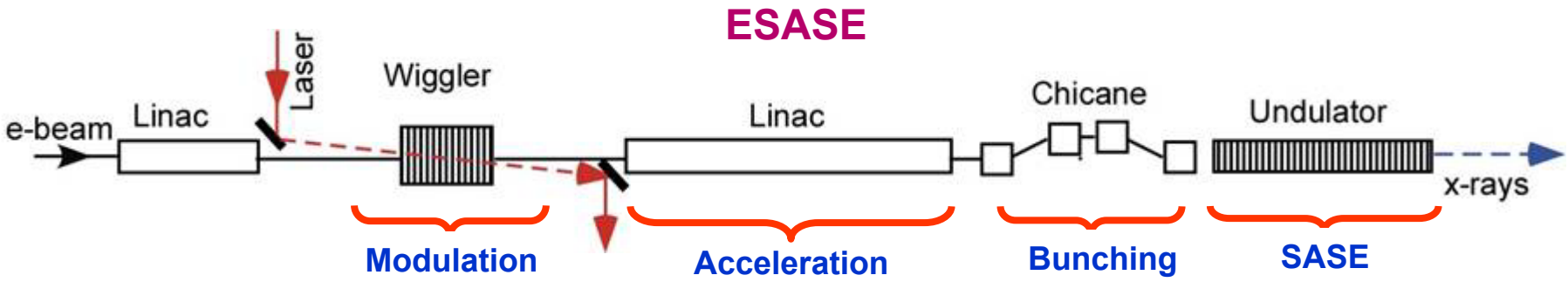
500 fs seed

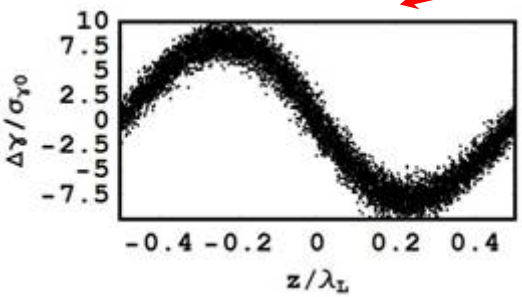


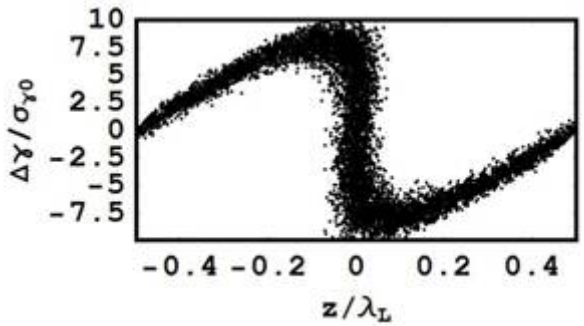


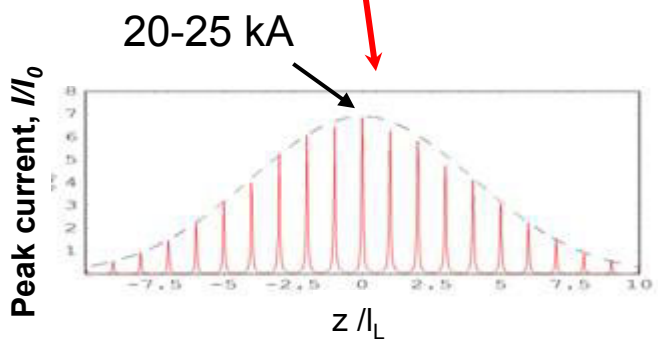
Electron beam is 1.5 GeV, energy spread 100 keV, 250 A current, 0.25 micron emittance; laser seed is 100 kW at 32 nm; undulator period 1 cm

Optical manipulations techniques (1)

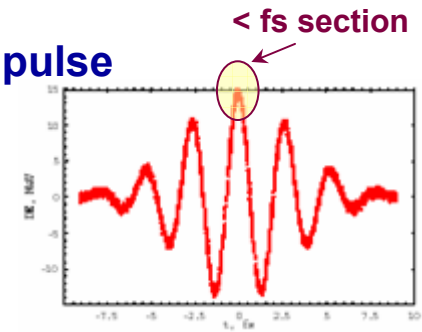








- Precise synchronization of the x-ray output with the modulating laser
- Variable output pulse train duration by adjusting the modulating laser pulse
- Increased peak current
- Shorter x-ray undulator length to achieve saturation
- Capability to produce a solitary ~100-attosecond duration x-ray pulse
- Other techniques can be used to produce controlled x-ray pulses



A. Zholents, Phys. Rev. ST Accel. Beams 8, 040701 (2005)

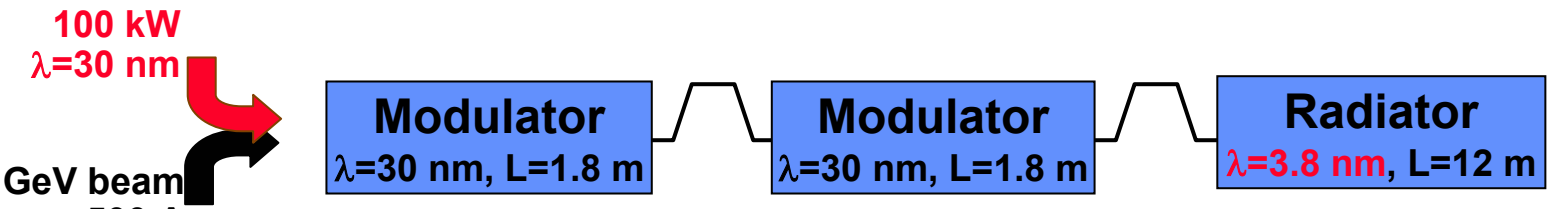
Optical manipulations techniques (2)

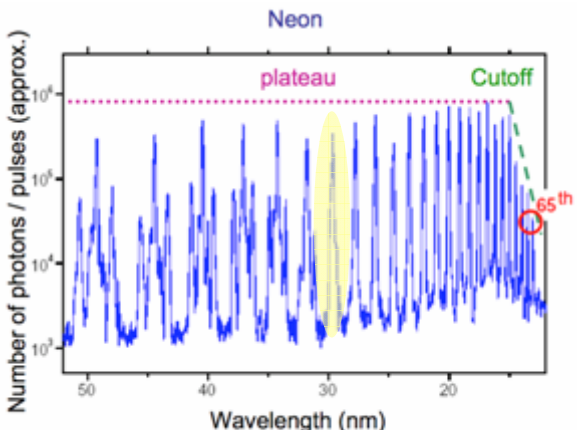
HHG LASER SEED

Example with seed at 30 nm, radiating in the water window

First stage amplifies low-power seed with "optical klystron"

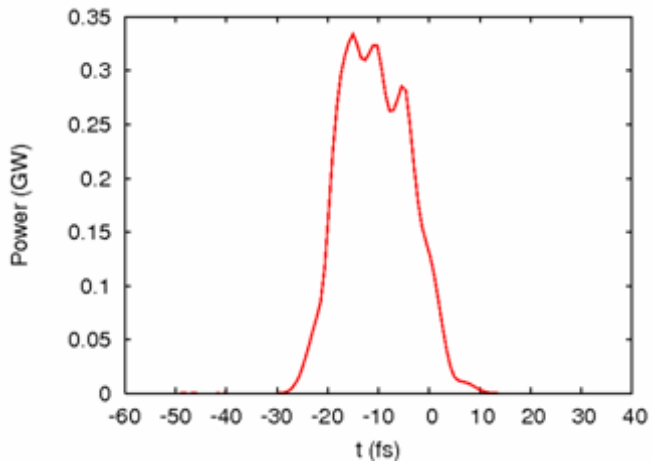
- More initial bunching than could be practically achieved with a single modulator
- Output at 3.8 nm (8th harmonic)





Lambert et al., FEL04

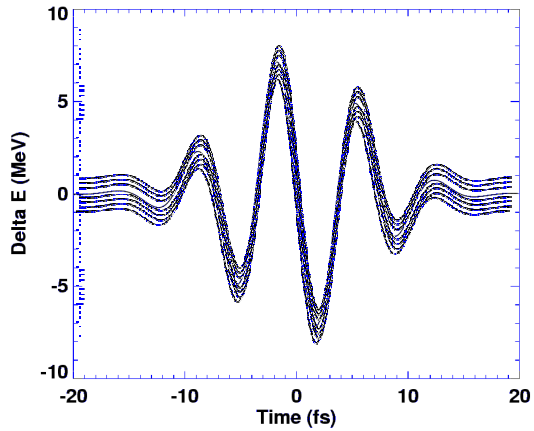
300 MW output at 3.8 nm (8th harmonic) from a 25 fs FWHM seed



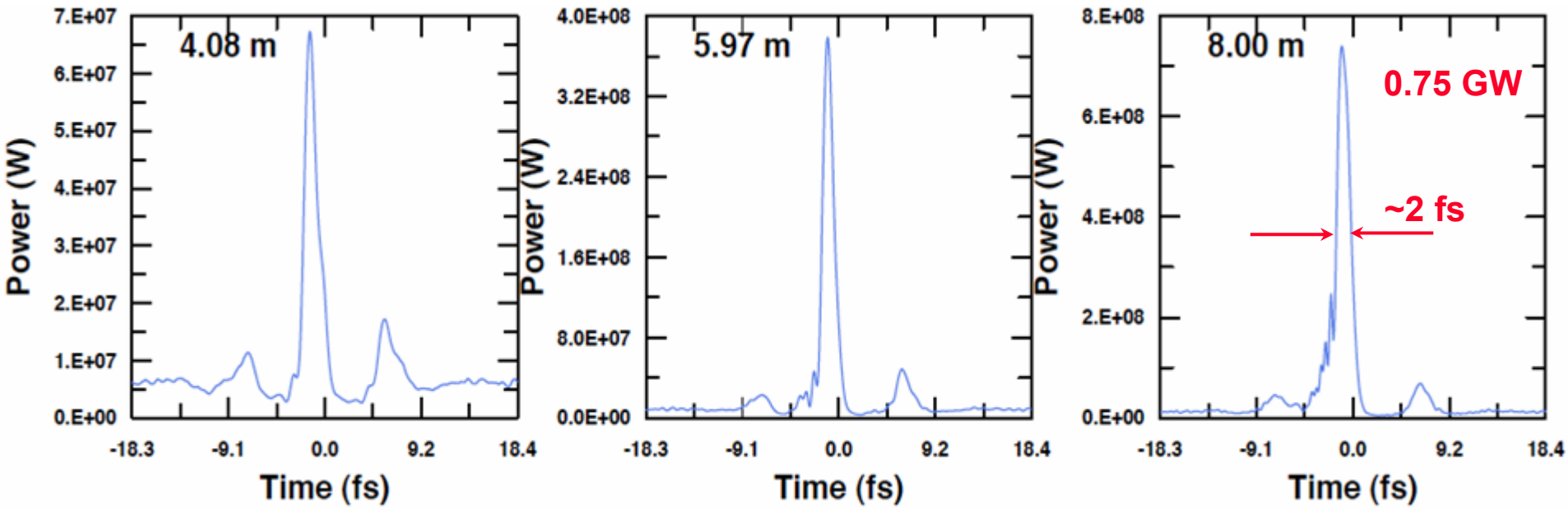
Optical manipulations techniques (3)

ULTRAFAST SASE PULSES IN VUV-SXR

- Again, a few-cycle optical pulse modulates electron beam
  - Modulating laser is possibly 1 - 2 μm wavelength
  - This time there is no compression following the modulation
  - Take advantage of the energy chirp in the bunch
  - Tapered FEL keeps the small section of appropriately chirped beam in resonance



Evolution of an 8 nm wavelength pulse along undulator



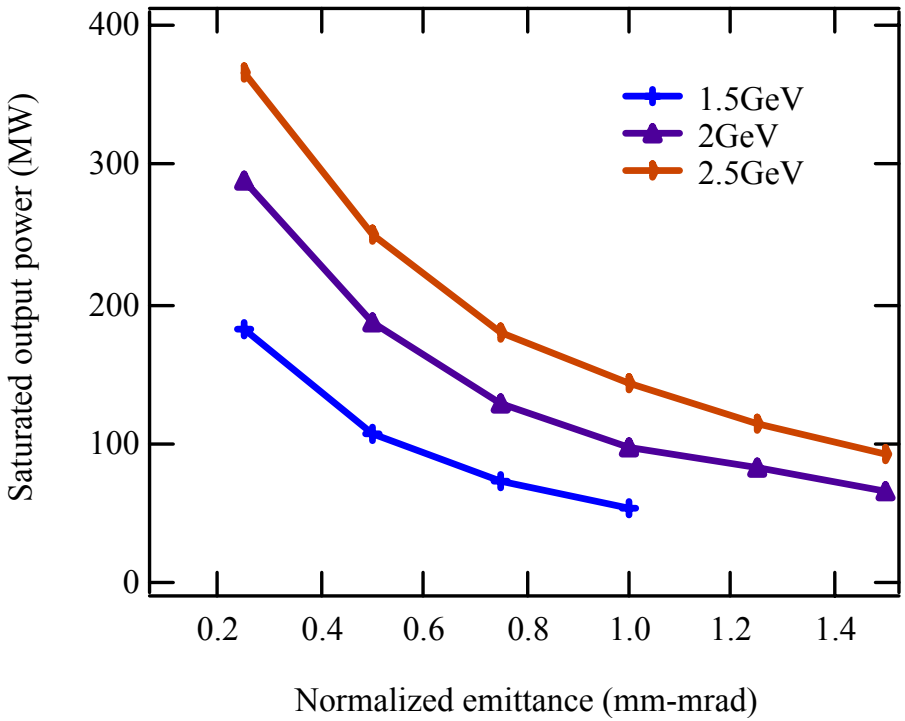
E.L. Saldin, E.A. Schneidmiller, and M.V. Yurkov, PRSTAB 9, 050702 (2006)

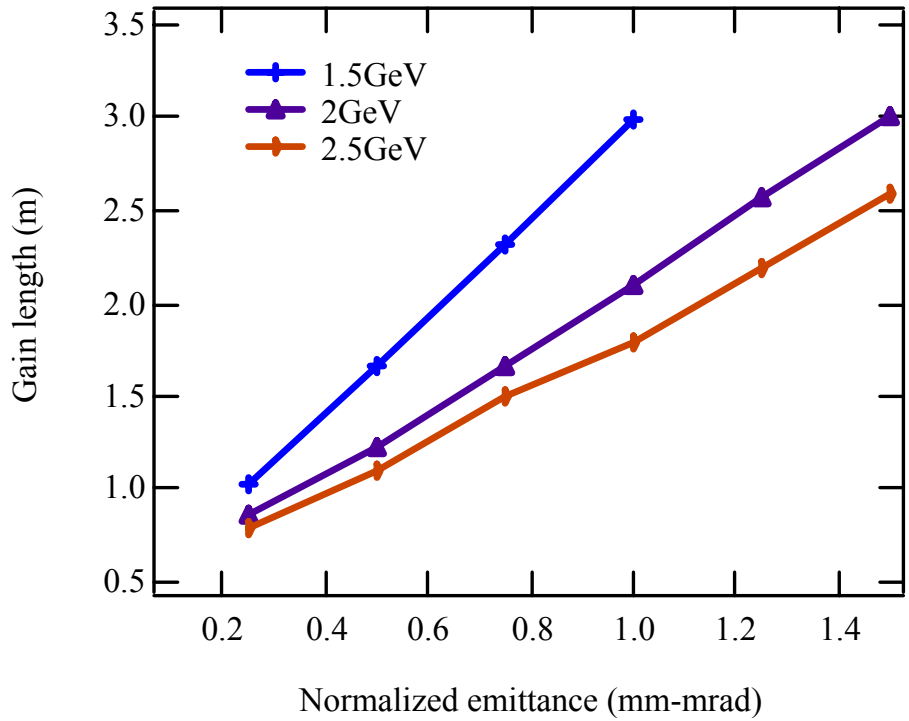
Emittance sensitivity is great for new FELs

COST EFFECTIVE TO USE LOW EMITTANCE BEAMS

Lower emittance

- **For a given x-ray wavelength**
  - **⇒Lower energy linac**
  - **⇒Shorter undulator**
- **For a given beam energy**
  - **⇒Shorter x-ray wavelength (within constraints of undulators)**

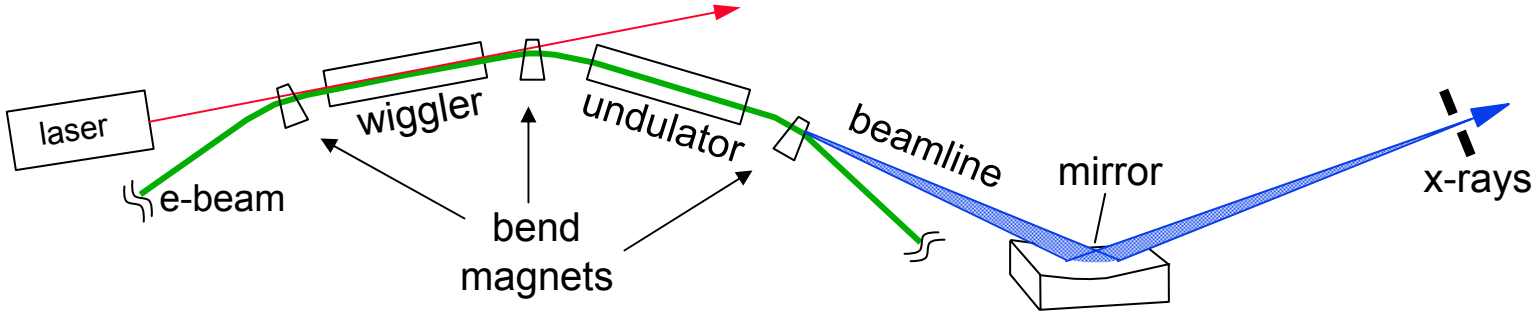


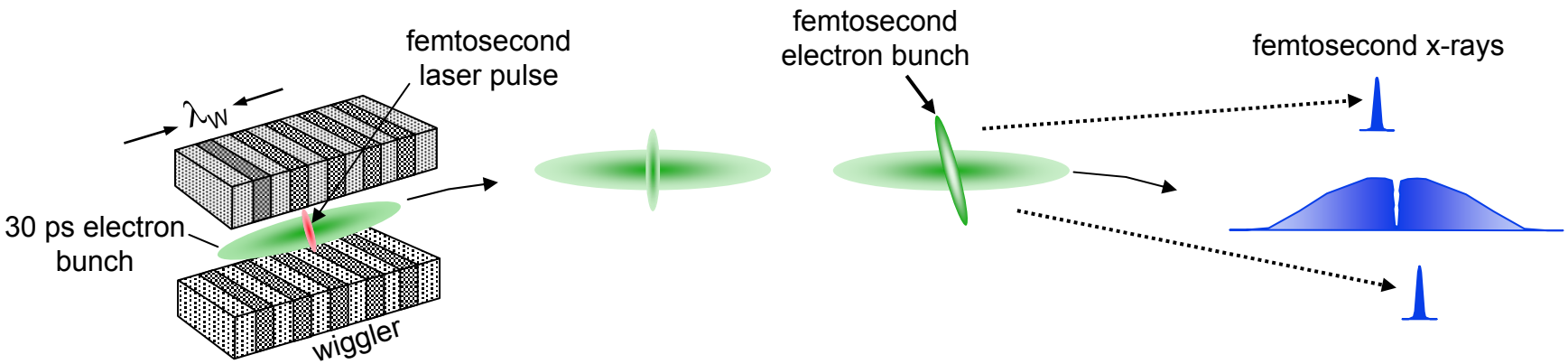


λ_x=1 nm, I_{peak}=250 A, σ_E=100 keV

W. Fawley

Laser-sliced x-ray pulses from synchrotrons (ALS, BESSY, SLS) are used now as tunable soft and hard x-ray probes





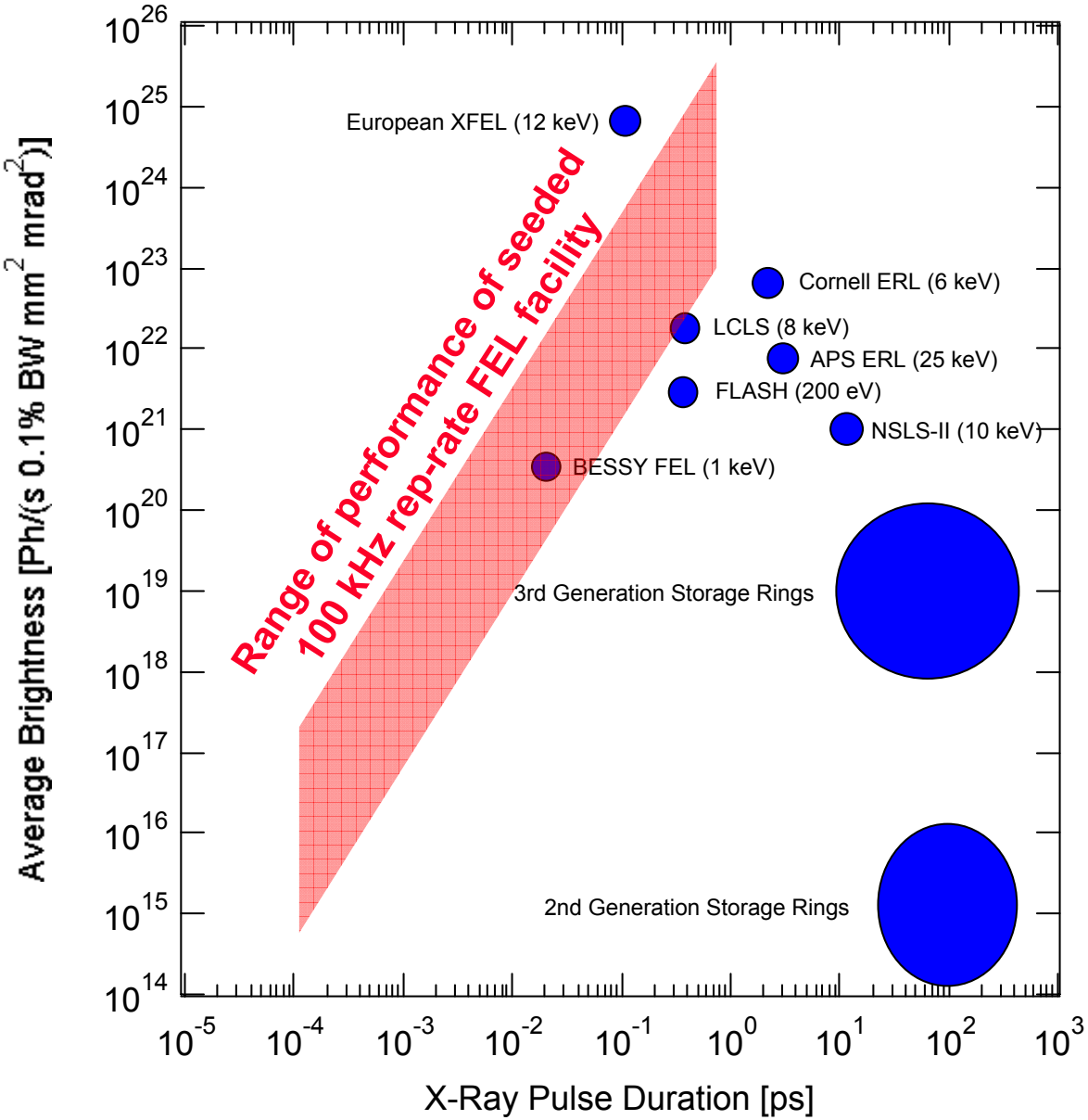
electron-photon interaction in wiggler

spatial separation dispersive bend

bend magnet beamline

Zholents and Zolotorev, Phys. Rev. Lett., 76, 916,1996

A range of new accelerator-based light sources is being built and planned



LCLS Accelerator Schematic