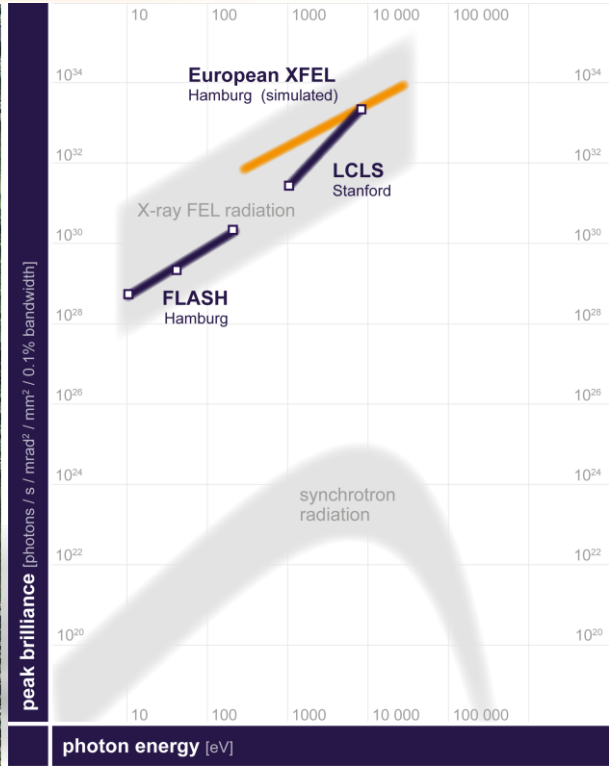
The European X-ray free-electron laser

will generate extremely intense X-ray flashes for a wide range of research uses

Gianluca Geloni, EU.XFEL

The European XFEL: a new lightsource of superlatives



- to investigate nanometer-scale structures, fast processes, and extreme states
- to take 3D images of viruses or proteins and film chemical reactions
- for applications in biology, chemistry, materials science, medicine, nanotechnology,…

SASE pulses, baseline mode of operation: poor longitudinal coherence

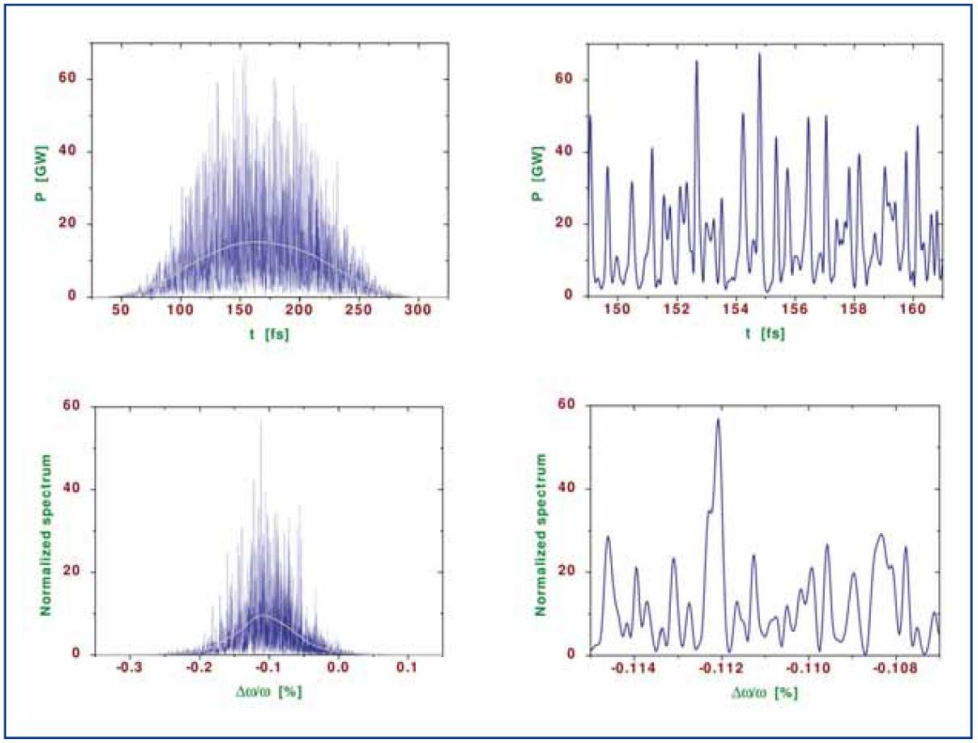


Figure 5.2.4 *Temporal (top) and spectral (bottom) structure for 12.4 keV XFEL radiation from SASE 1. Smooth lines indicate averaged profiles. Right side plots show enlarged view of the left plots. The magnetic undulator length is 130 m.*

Source: The European XFEL TDR – DESY 2006-097 (2006)

$$\frac{\Delta\omega}{\omega} \sim 2\rho \sim 10^{-3}$$

$$\left(\frac{\Delta\omega}{\omega}\right)_{spike} \sim \frac{1}{\sigma_T \omega} \sim 10^{-5}$$

- Hundreds of longitudinal modes
- A lot of room for improvement
- Self-seeding schemes [Method historically introduced for soft x-rays in: J. Feldhaus et al., Optics Comm. 140, 341 (1997)] answer the call for increasing longitudinal coherence, but needed major baseline changes

EIROforum

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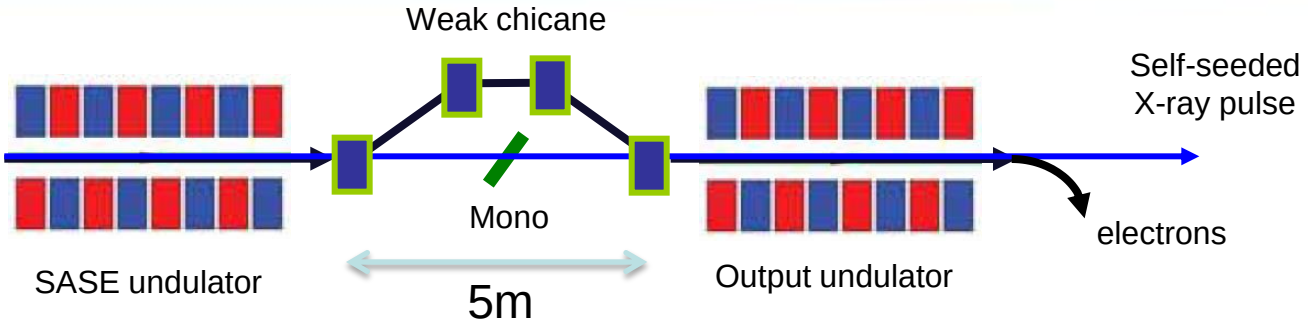
Hard X-ray Self-seeding with single-crystal monochromators: a path to single-mode X-ray Free-Electron Lasers

EIROForum Meeting
ILL, 15 November 2012

Gianluca Geloni, European XFEL,
Vitali kocharyan and Evgeni Saldin, DESY

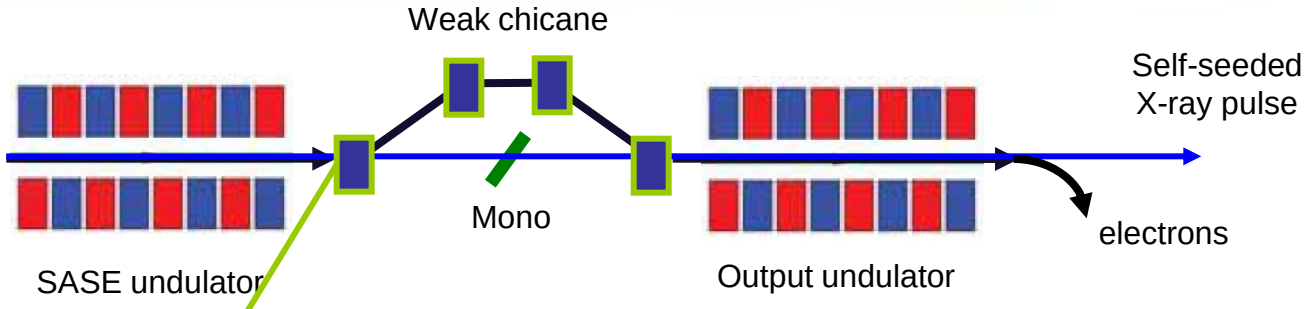
Self-seeding with single crystal monochromator

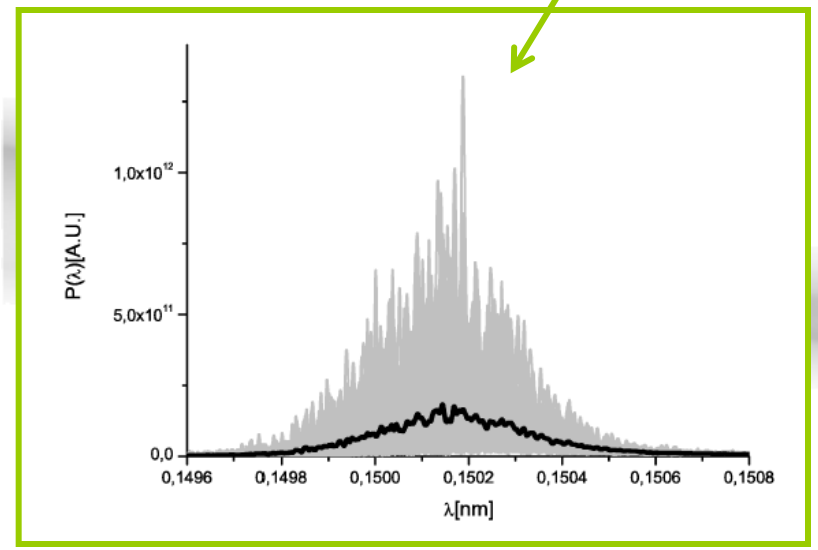


- First part: usual SASE FEL process
- Weak chicane (among other functions) acts as a tunable delay line
- The photon pulse from SASE goes through the monochromator
- Photon and electron pulses are recombined

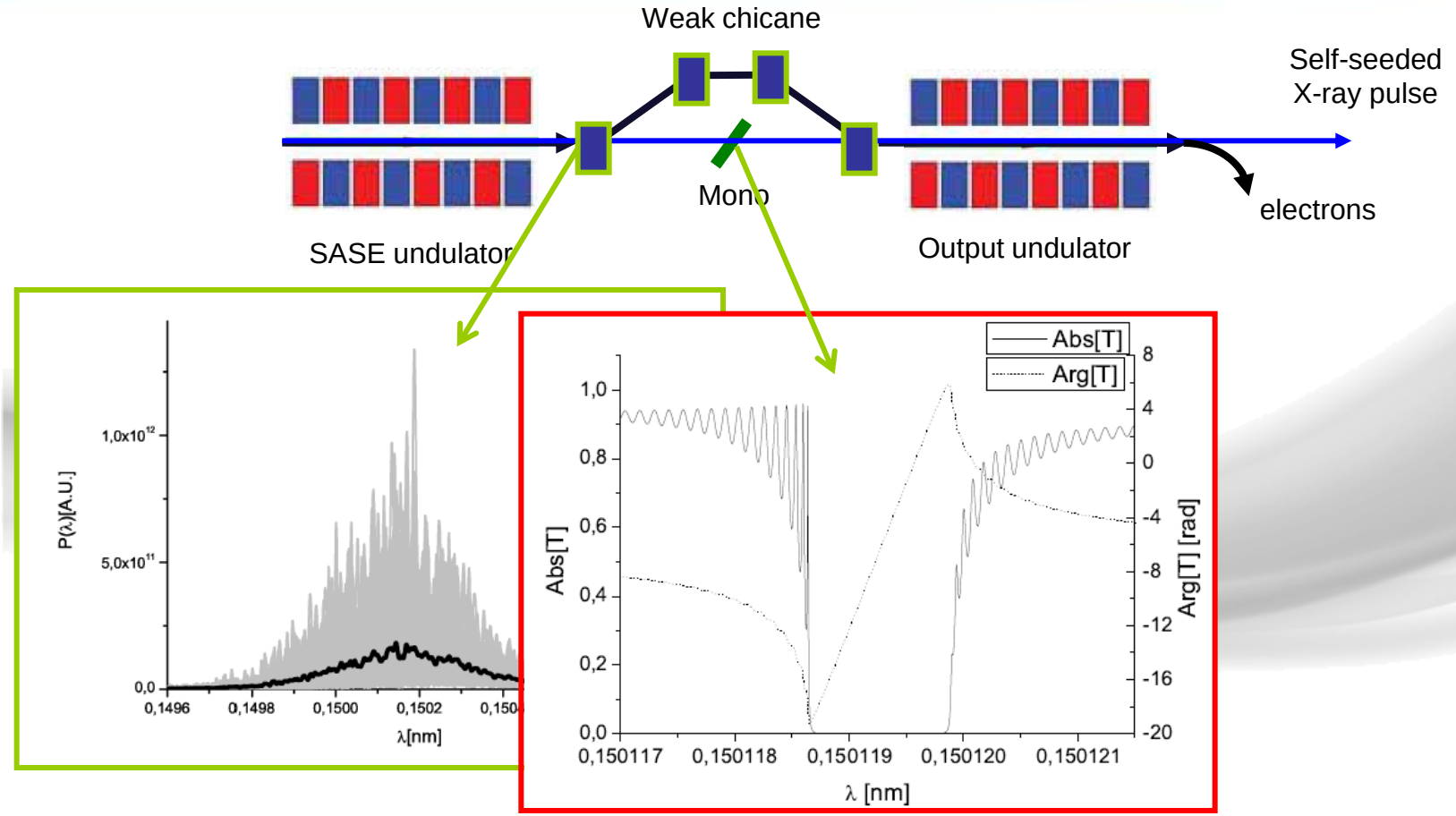
G. Geloni, V. Kocharyan and E. Saldin, J. of Modern Optics 58, 1391 (2011).

Self-seeding with single crystal monochromator

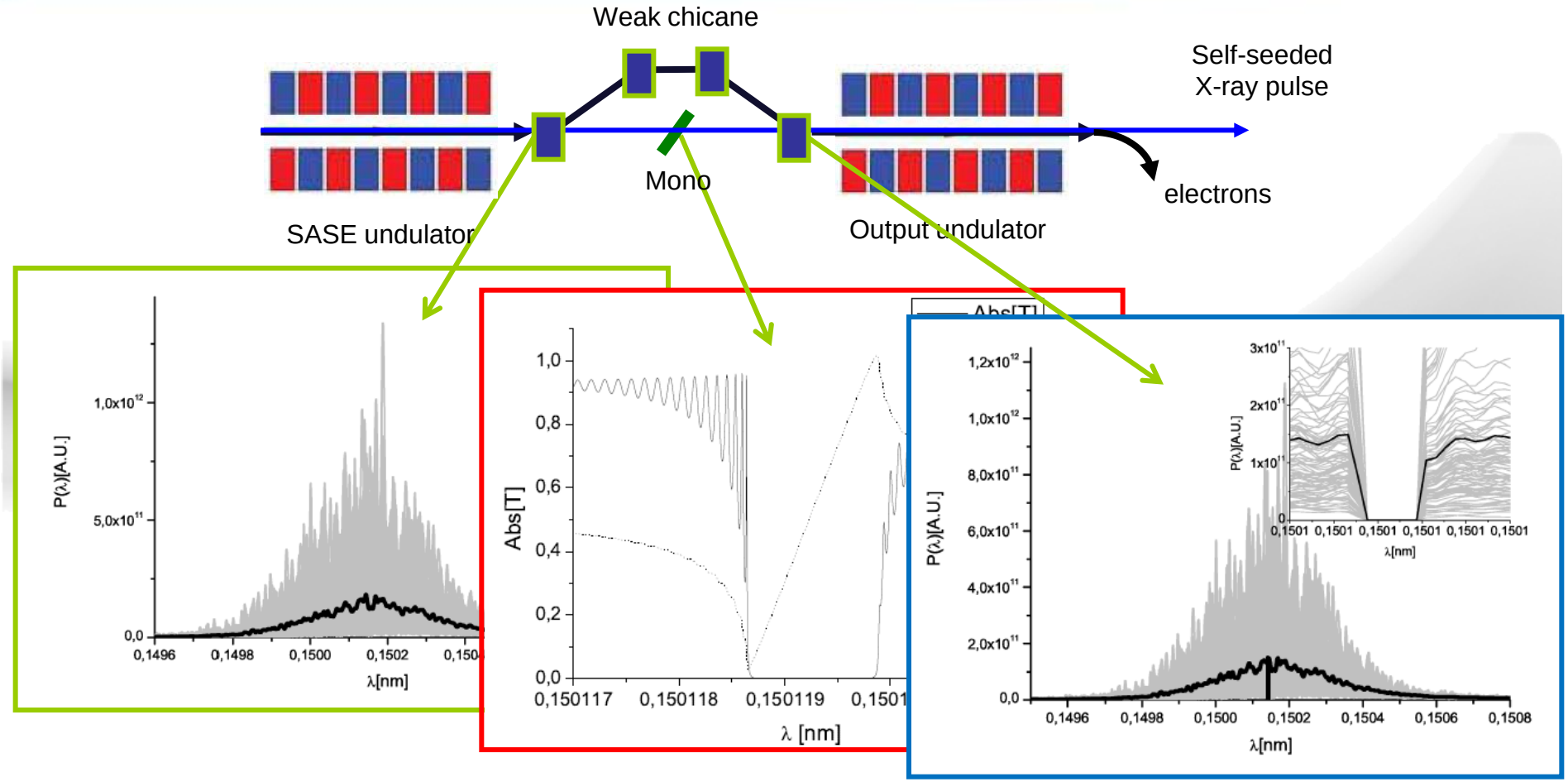




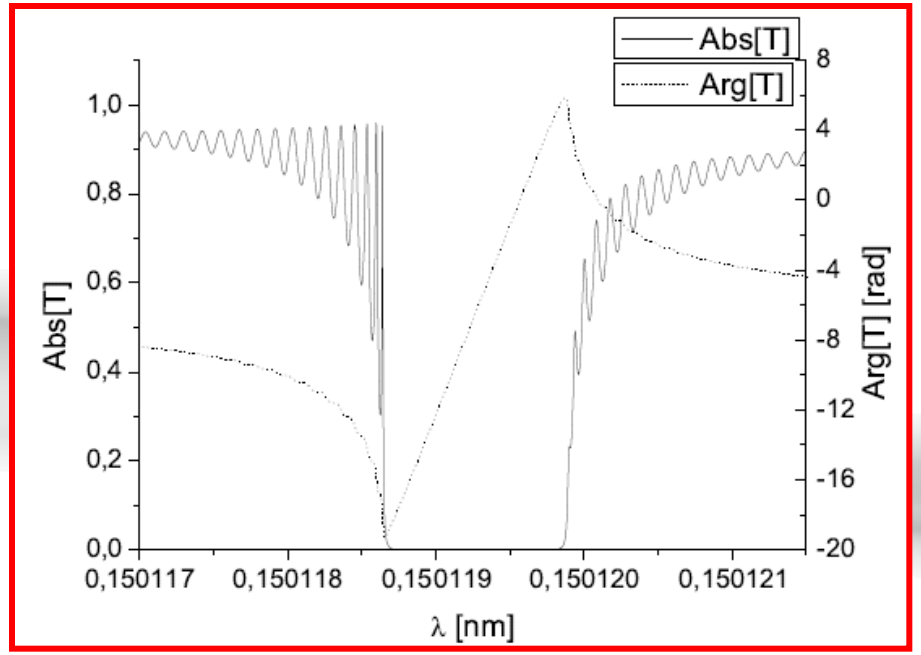
Self-seeding with single crystal monochromator

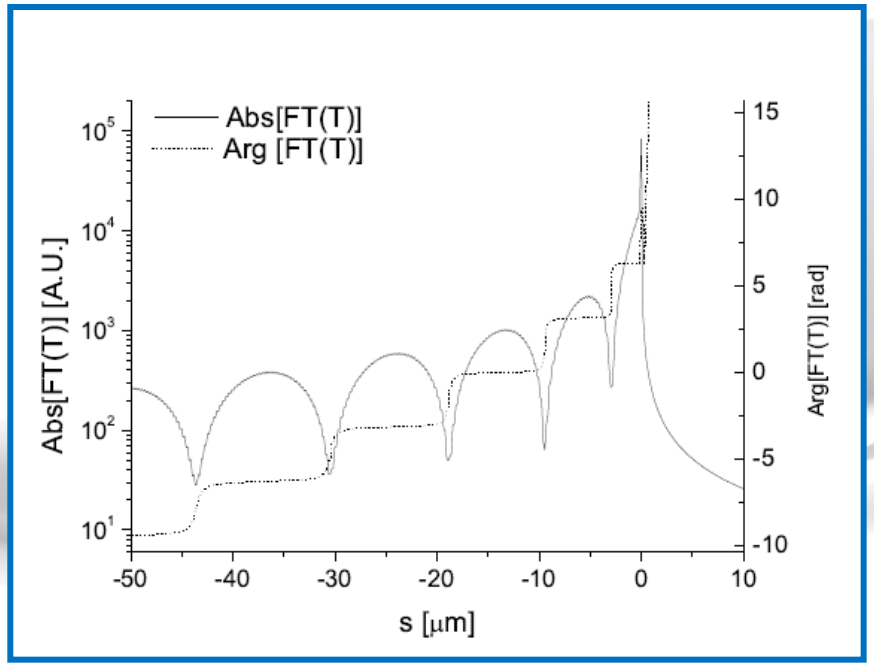


Self-seeding with single crystal monochromator



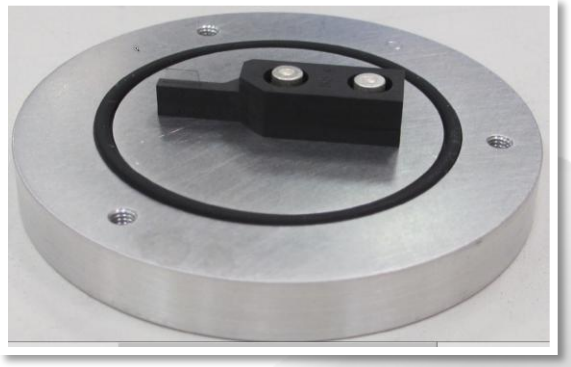
Self-seeding with single crystal monochromator

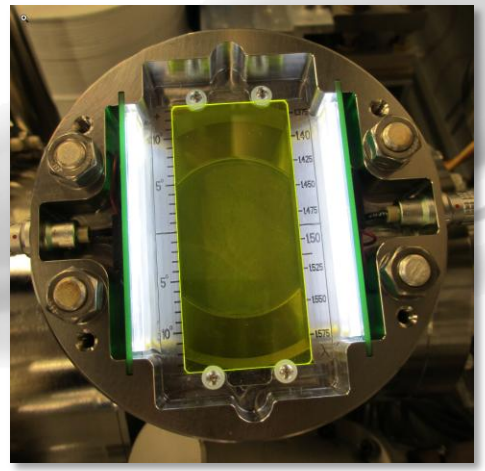




Experimental verification at the LCLS (January 2012)

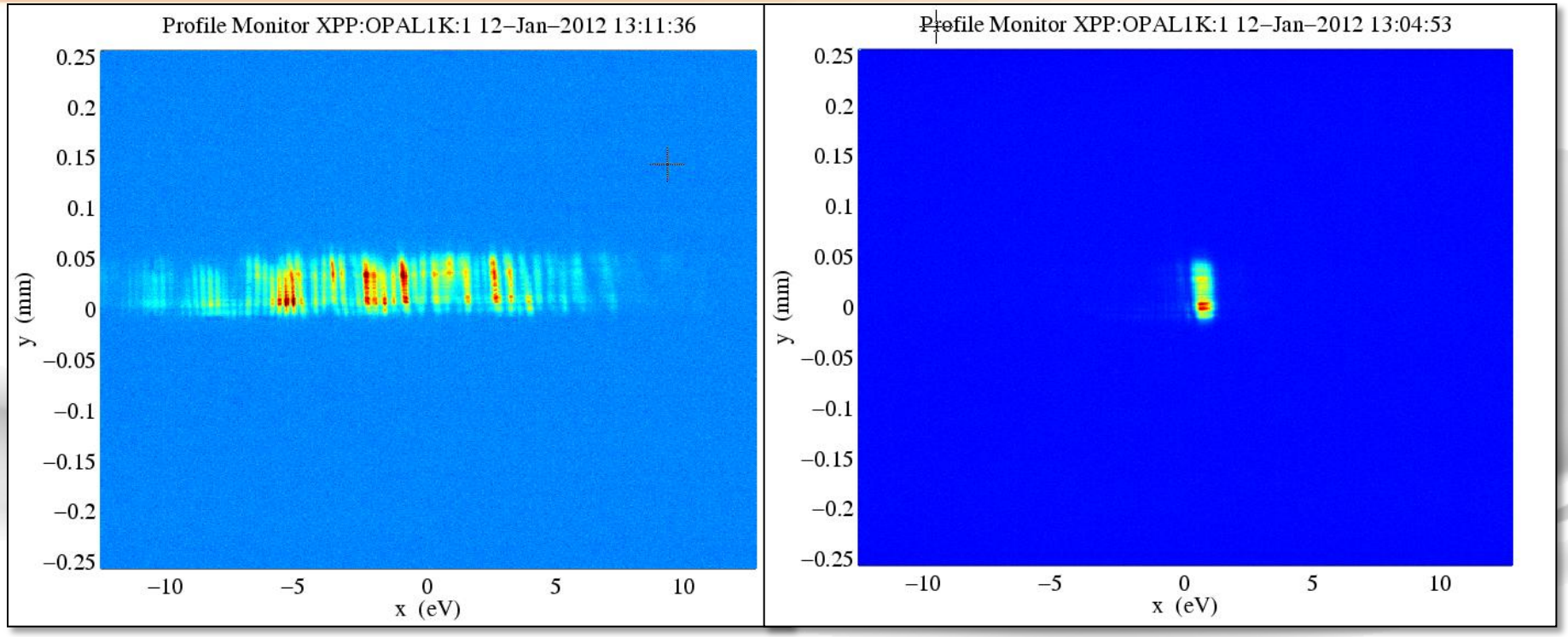
Chicane and Monochromator at Undulator #16 (of 33)





Courtesy of Paul Emma

Experimental verification at the LCLS (January 2012)

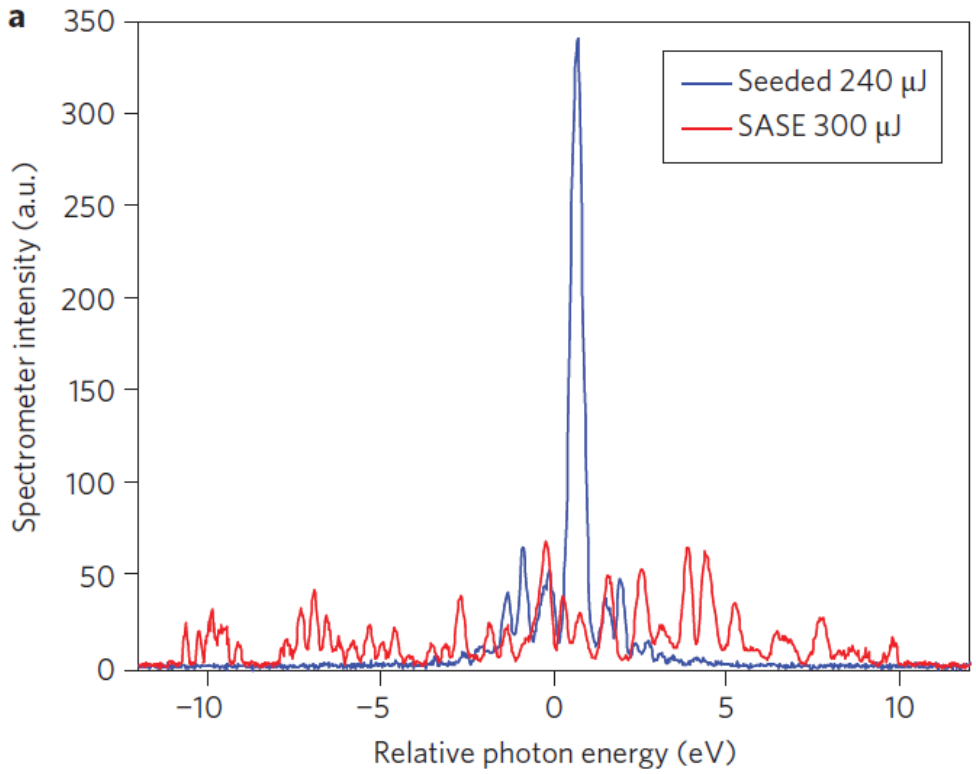


150 pC, 3 kA, diamond OUT **150 pC, 3 kA, diamond IN**

E = 8 keV (0.15 nm wavelength)

Courtesy of Paul Emma

Experimental verification at the LCLS (January 2012)



Single-shot X-ray SASE spectrum compared with single-shot seeded spectrum at 0.15 nm for a 40pC electron bunch

SASE spectrum is with all 28 undulators in

The seeding increases the spectral density of the FEL pulse.

J. Amann et al., Demonstration of self-seeding in a hard-X-ray free-electron laser, NATURE PHOTONICS DOI: 10.1038/NPHOTON.2012.180 (2012)

Conclusions and Outlook

- Self-seeding is an active-filtering, state-of-the-art technique for the generation of Fourier-limited FEL pulses
- Self-seeding in the hard X-ray region can be easily implemented with a single crystal monochromator setup
- HXRSS with a single crystal monochromator is a reality: nearly Fourier limited XFEL pulses are produced routinely at the LCLS
- Combination of Self-Seeding with tapering promises TW-class pulses of narrow-band X-ray radiation at the European XFEL

Thank You for your attention!