Three Unique FEL Designs for the Next Generation Light Source

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NGLS
next generation light source

Next Generation Light Source

- Soft x-ray FEL facility
- High repetition rate – 1 MHz
- CW superconducting Linac to 2.4 GeV
- Multiple FEL beamlines using identical bunches
  - 3 distinct initial FELs for different science needs

- nominal bunch: 300 pC, 500 A, 0.6 μm emittance,
  150 keV energy spread, $\beta = 10$ m
- use idealized beam, include resistive wake fields

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Beamlines for different purposes

- **Self-seeded: high flux, harder x-rays** **0.2 – 1.2 keV**
  - Long pulses, large pulse energy, better BW than SASE
  - Highest repetition rate - MHz (no external laser)
  - Pulse duration and timing set by electron beam

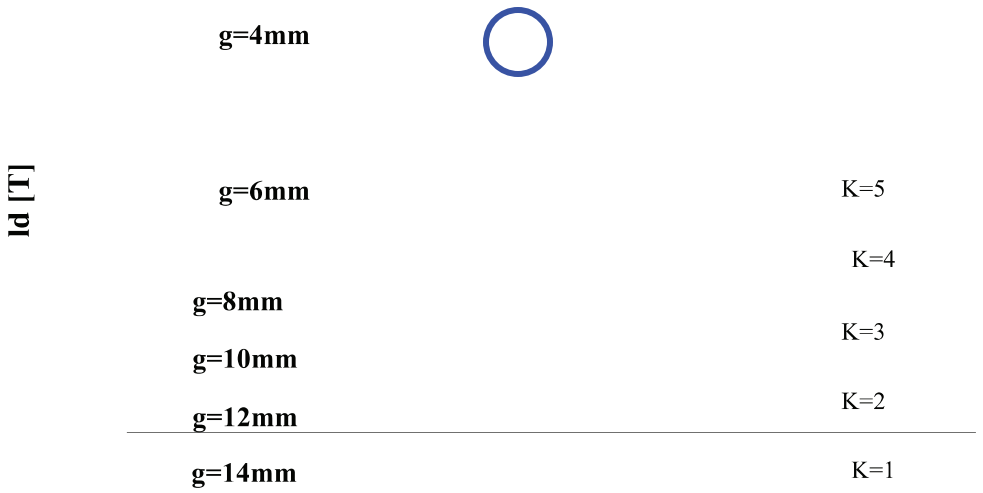
- **HGHG: stable, transform limited pulses, softer x-rays**
  - Close to transform limit **0.1 – 0.72 keV**
  - Adjustable pulse timing, duration and bandwidth
  - Lower photon energies

- **2-Color Chirp-Taper: pump-probe, short pulse** **0.2 – 1 keV**
  - Two short pulses ~2 fs, substantial frequency chirp
  - independent timing, photon energy, angle

Superconducting undulators for X-rays

- Nb_3Sn SC undulators, 6 mm magnetic gap
- shortest undulator period: λ_u=20 mm, max K = 5
  - allows 0.2 keV up to ~1.5 keV photons in fundamental
- HGHG beamline, λ_u=23 mm, K=6.8
  - allows 0.1 keV up to ~1 keV

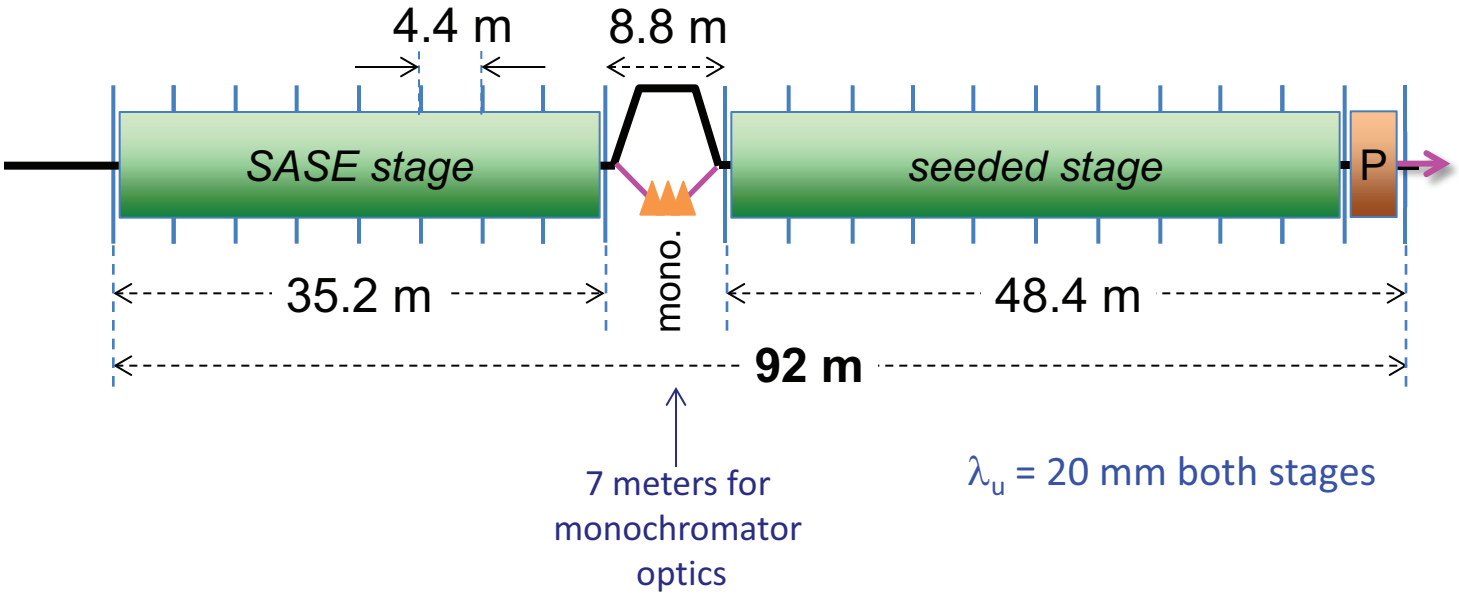
could use shorter undulator periods for dedicated beamlines at ~2.5 keV



S. Prestemon et al., PAC 2003, MPPG010

Self-seeded Beamline

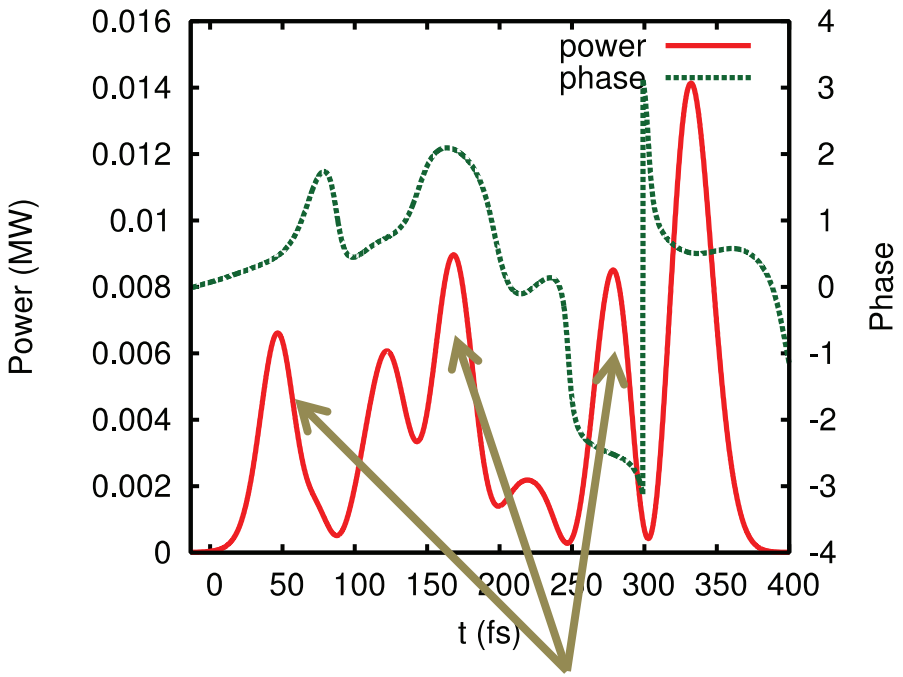
- tuning range 0.2 – 1.2 keV self-seeded
  - 1.2 keV to 1.5 keV, SASE only
- MHz repetition rate
- aim for 2% efficiency with resolving power 20,000



Monochromator selects bandwidth

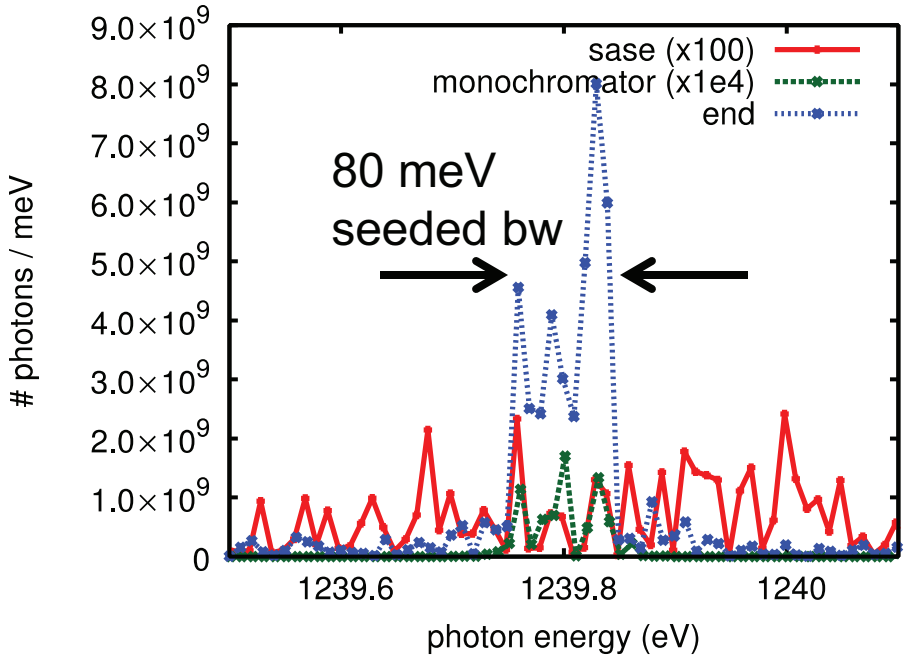
- bandwidth unchanged through seeded stage unless beam has energy chirps

typical pulse after monochromator



independent peaks,
~ 25 fs width each

constant bandwidth in seeded stage



~ 1 eV
SASE bw

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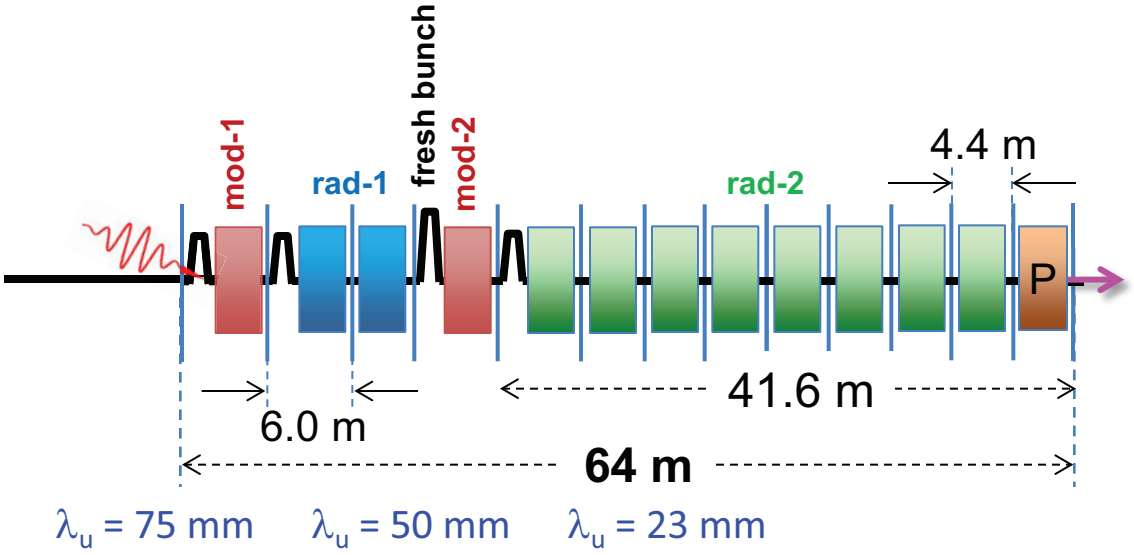
HGHG Beamline



- tuning range 0.1 – 0.72 keV
- 2 stages of HGHG with fresh bunch delay
  - similar to FEL-2 of FERMI@Elettra
- input laser 215 – 260 nm
  - 100 kHz repetition rate
  - 200 MW peak power (more for short pulses)

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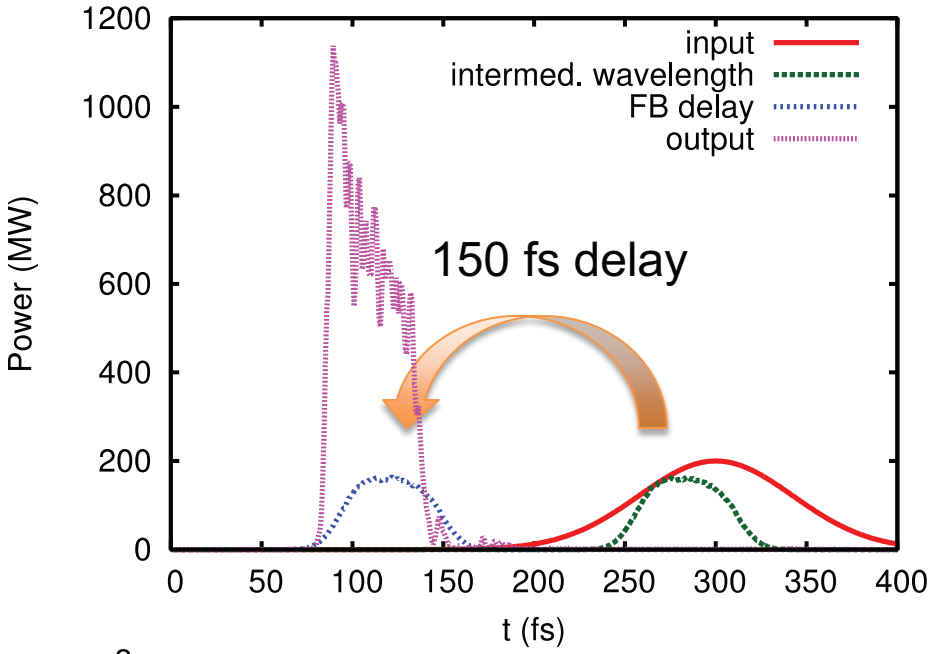
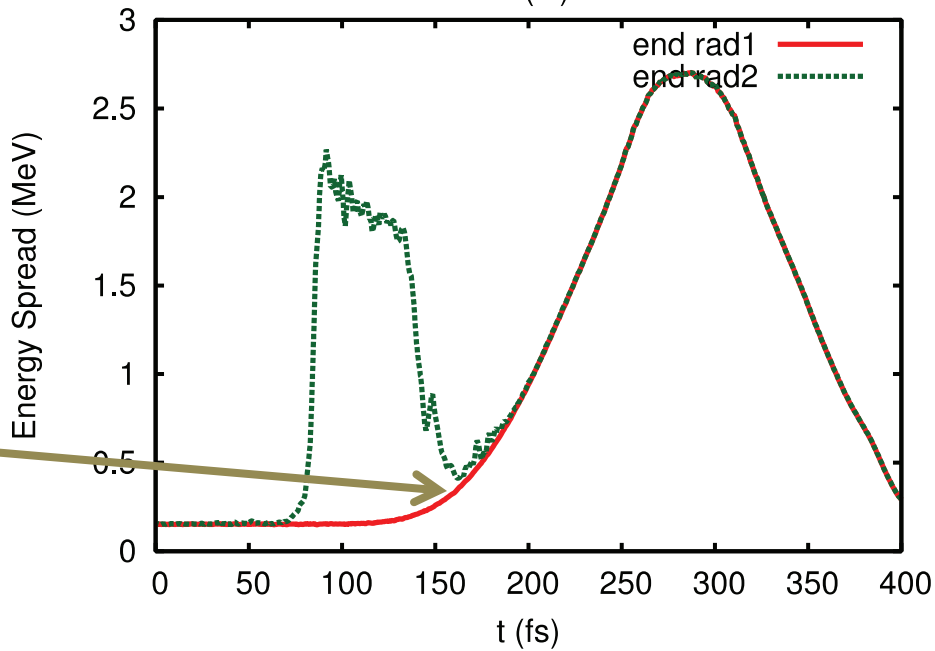
Relies on fresh bunch delay

- fresh bunch needed for high photon energies
- input laser at 100 fs FWHM almost overlaps second round of HGHG
  - ~ 50 fs output duration

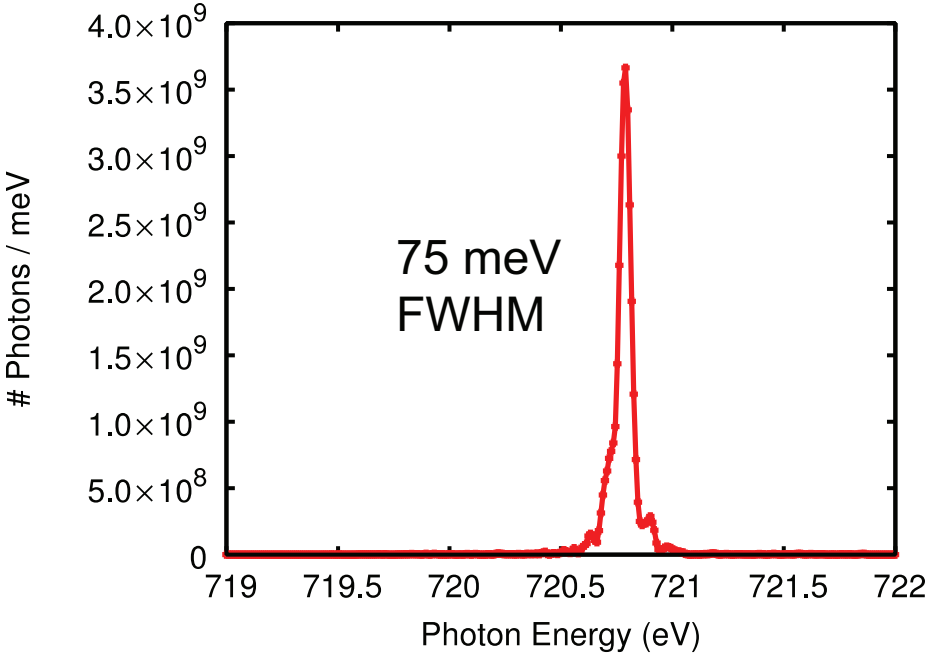


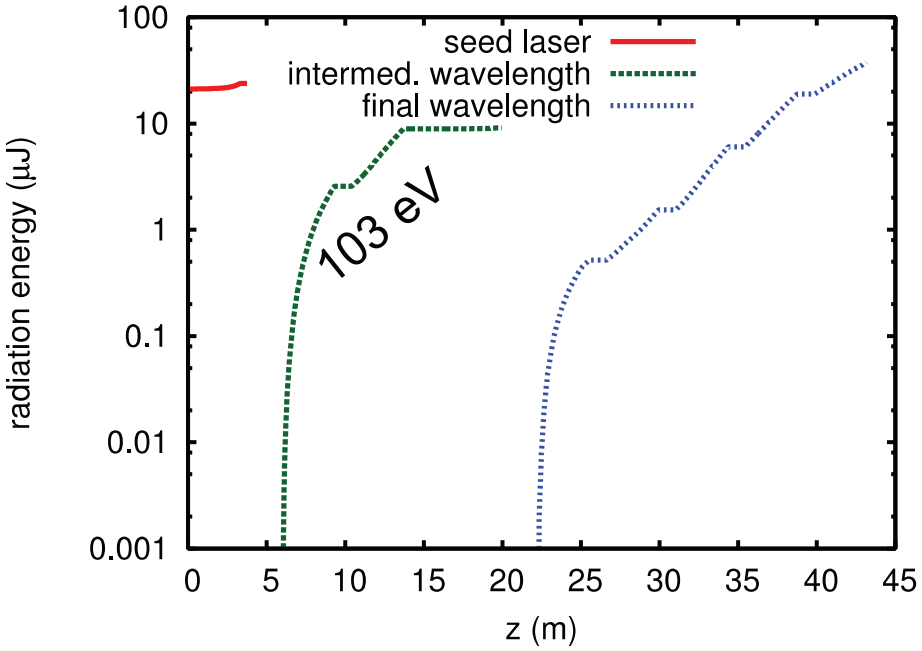


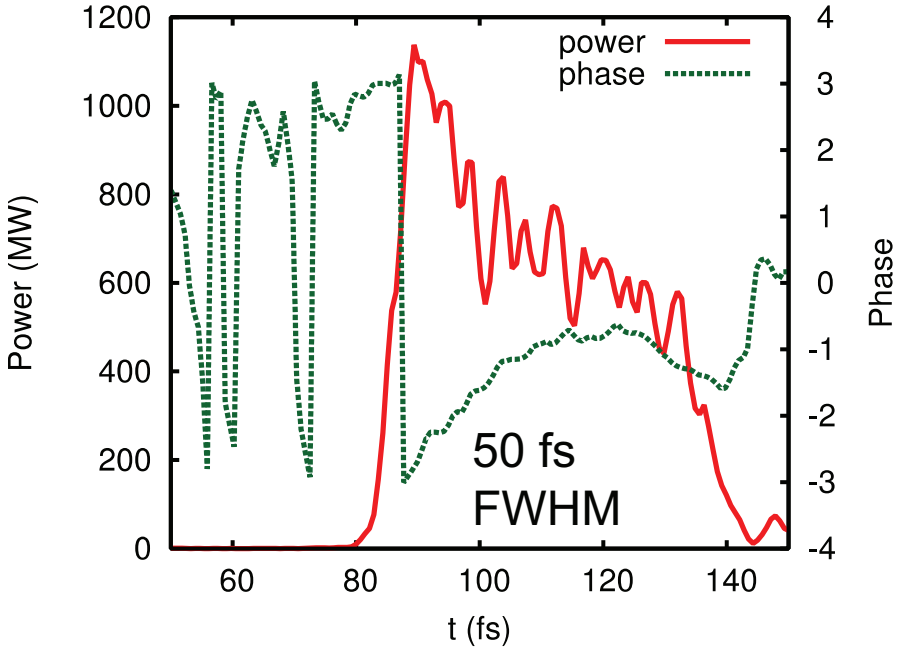
increased energy spread hurts performance

Results at 720 eV

- ideal beam
- total harmonic, 126
- 100 fs input laser
  - 50 fs output pulse
  - 2.1 × transform limit

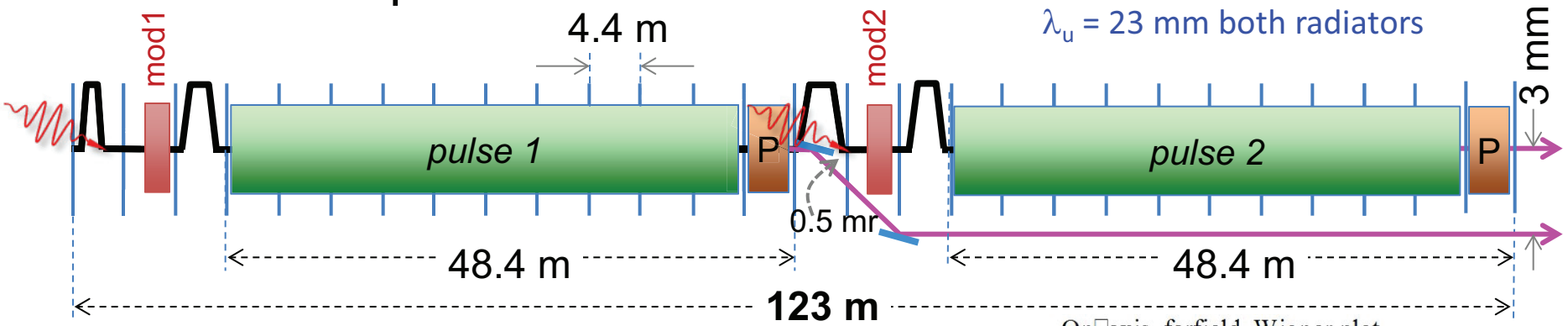


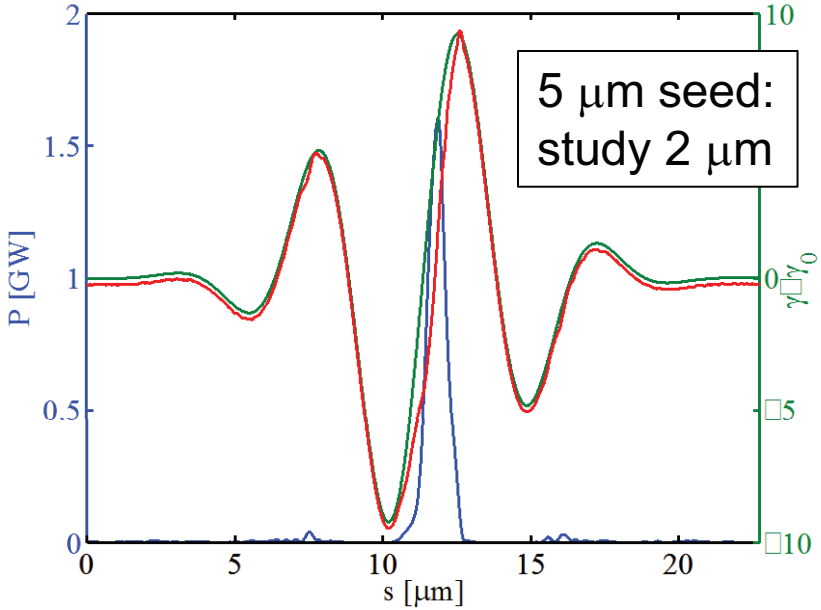


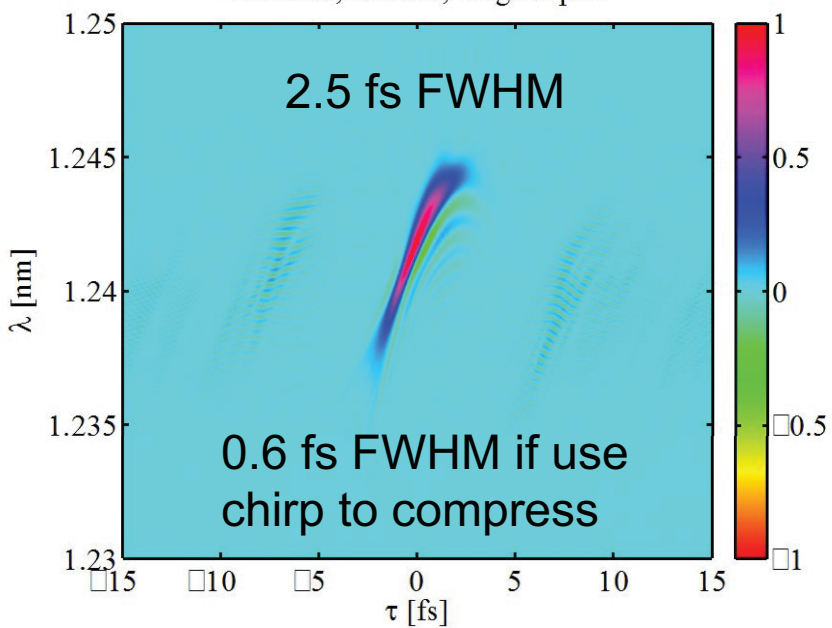


2-Color Chirp-taper beamline

- 2 pulses with one electron bunch, from 0.2 keV to 1 keV
- 100 kHz repetition rate



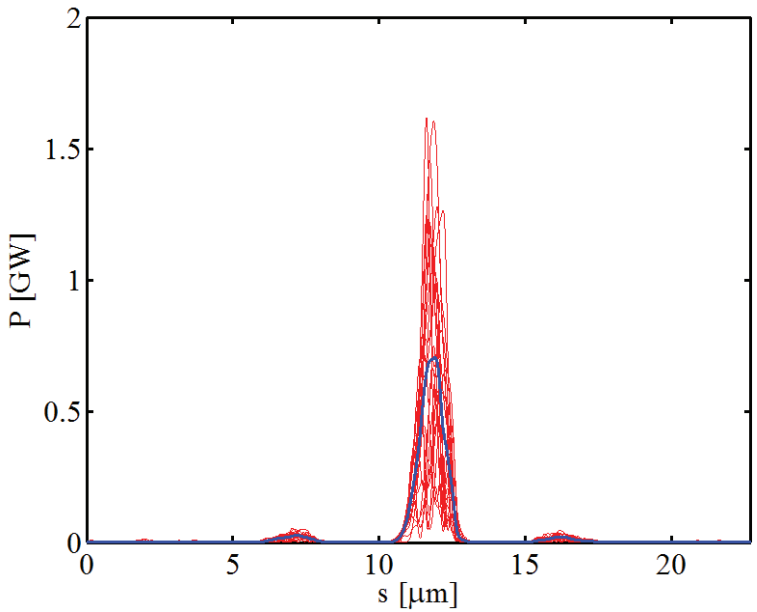


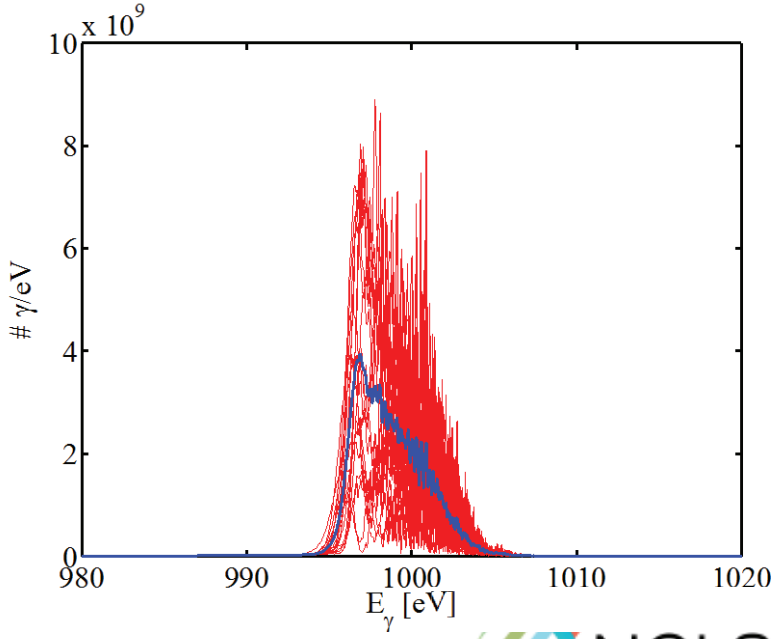


Statistical fluctuations

- good transverse mode quality, low background
- starts from noise so fluctuates shot to shot
  - varies mostly in pulse energy
  - timing, photon energy and chirp very stable

shot to shot fluctuations, and averaged profile





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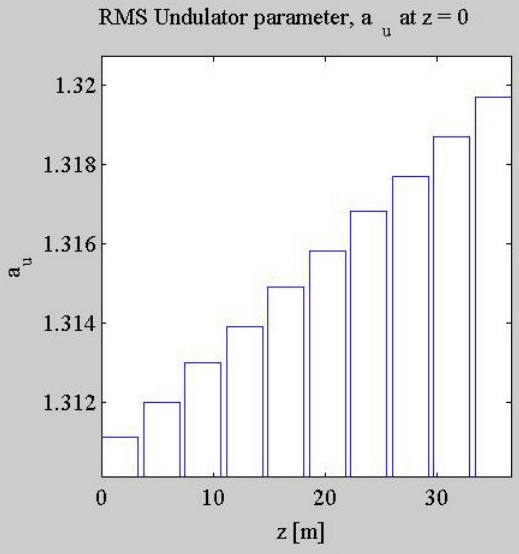
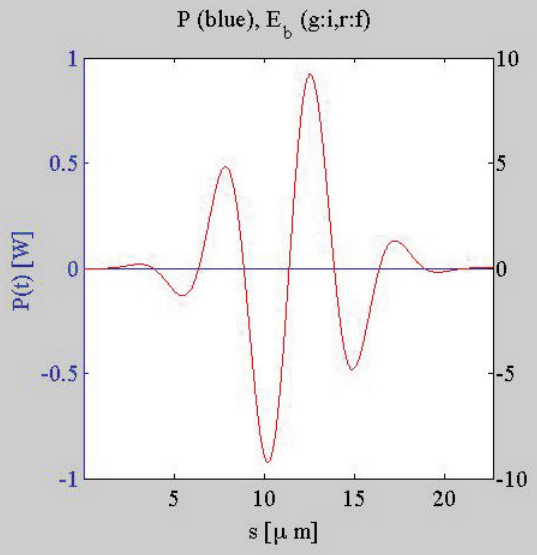
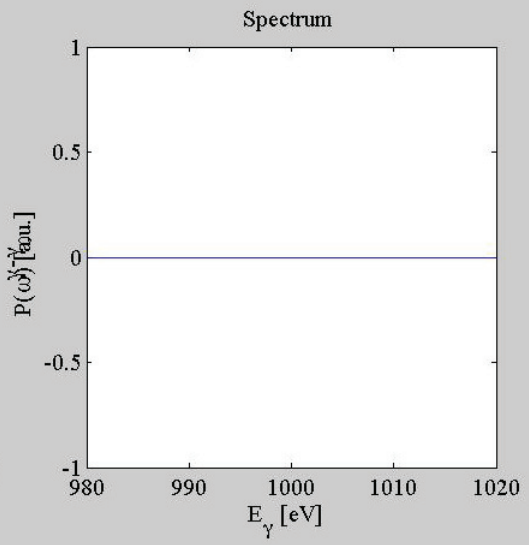
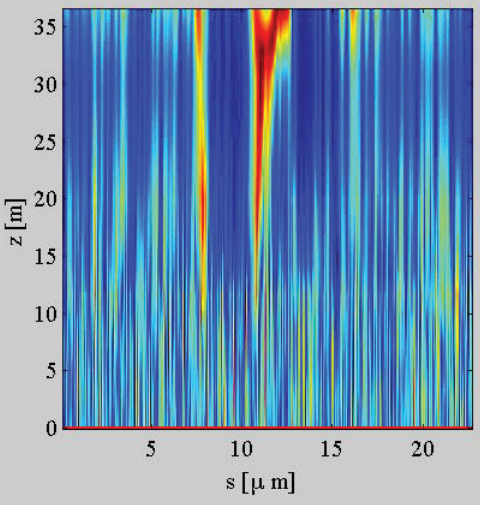
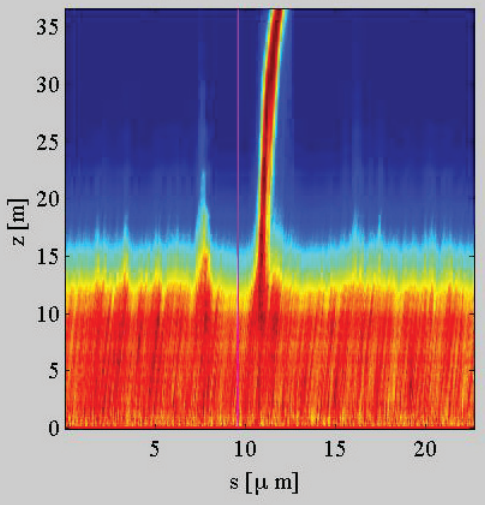
Evolution of Pulse

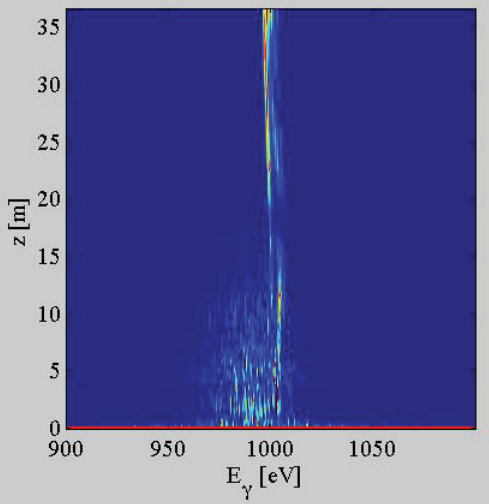












Each beamline serves a role

Self-seeded

- can use full 1 MHz repetition rate
- highest brightness and photon energy

HGHG

- near transform limit
- adjustable parameters, stability from seed laser

Two-color chirp-taper

- pump-probe at 100 kHz
- can scan in time delay, photon energy, orientation