SPARC operation in seeded and chirped mode

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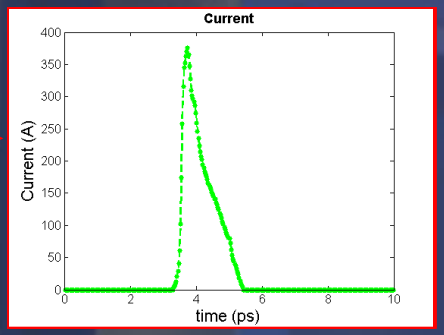
On behalf of the SPARC collaboration

Outline

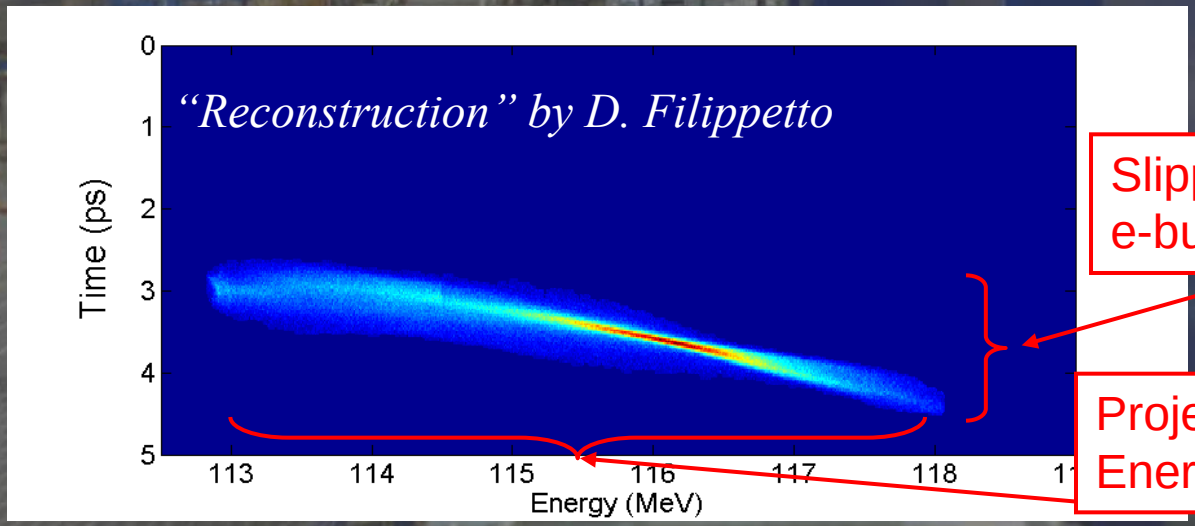
- SASE FEL operation with a chirped beam
  - Lasing with chirped beam combined with tapered undulator
- Seeded FEL operation
  - Seeded amplifier with the generation of high order harmonics
  - Cascaded FEL operating above saturation 400nm -> 200nm
  - Cascaded FEL seeded with harmonics generated in gas

SASE with chirped & compressed beam

- Compression with “Velocity Bunching”
  - **High peak current (up to 380A)**



Strong chirp / energy spread in the longitudinal phase space

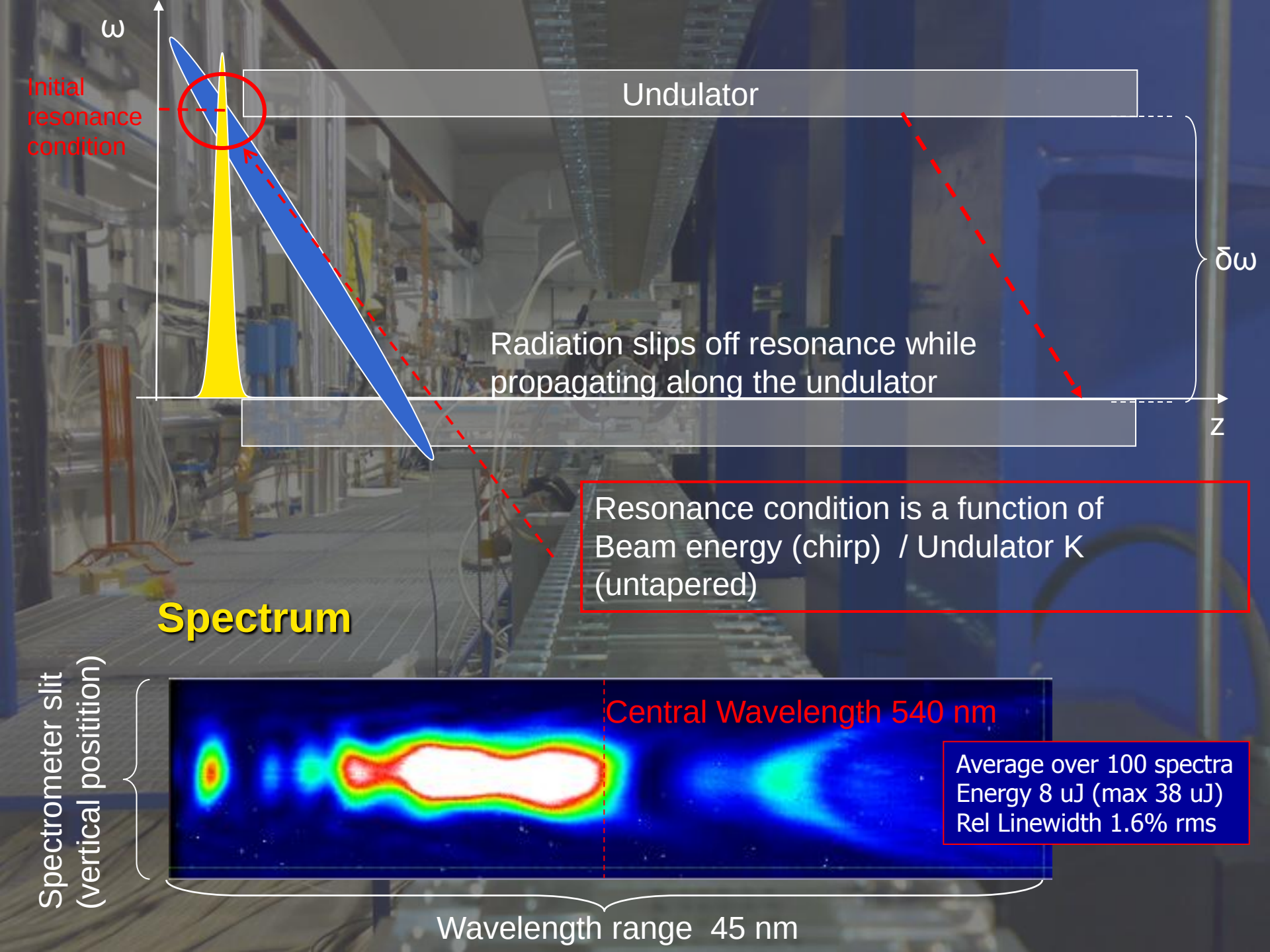


Slippage length ~ e-bunch length

Projected r.m.s. Energy spread ~ 1%

Compensation of the chirp with UM Taper

E. L. Saldin, E. A. Schneidmiller, and M.V. Yurkov, Self-amplified spontaneous emission FEL with energy-chirped electron beam and its application for generation of attosecond x-ray pulses, PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS 9, 050702 (2006)


ω
Initial resonance condition
Undulator
δω
Radiation slips off resonance while propagating along the undulator
z
Resonance condition is a function of Beam energy (chirp) / Undulator K (untapered)
Spectrum
Spectrometer slit (vertical positition)
Central Wavelength 540 nm
Average over 100 spectra
Energy 8 uJ (max 38 uJ)
Rel Linewidth 1.6% rms
Wavelength range 45 nm

Compensation with Undulator taper

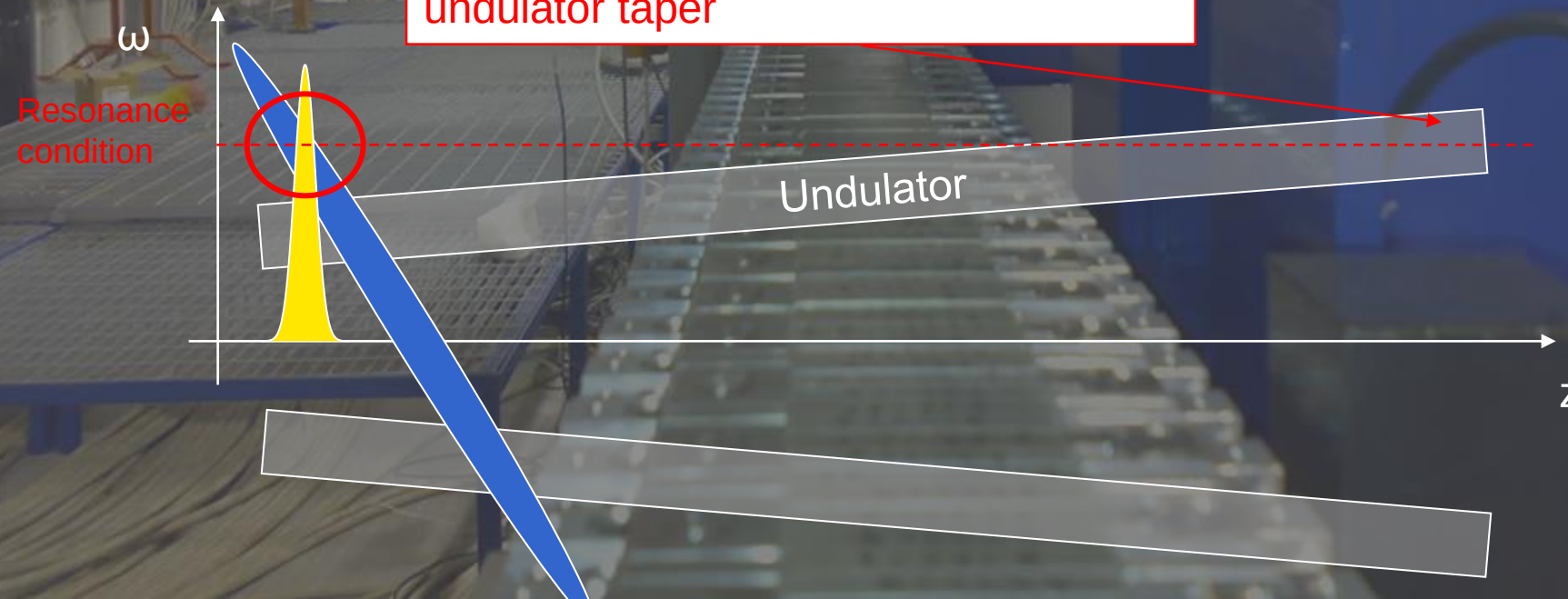
$$\omega_r = \frac{2\gamma^2}{1+\frac{K^2}{2}}\omega_u$$

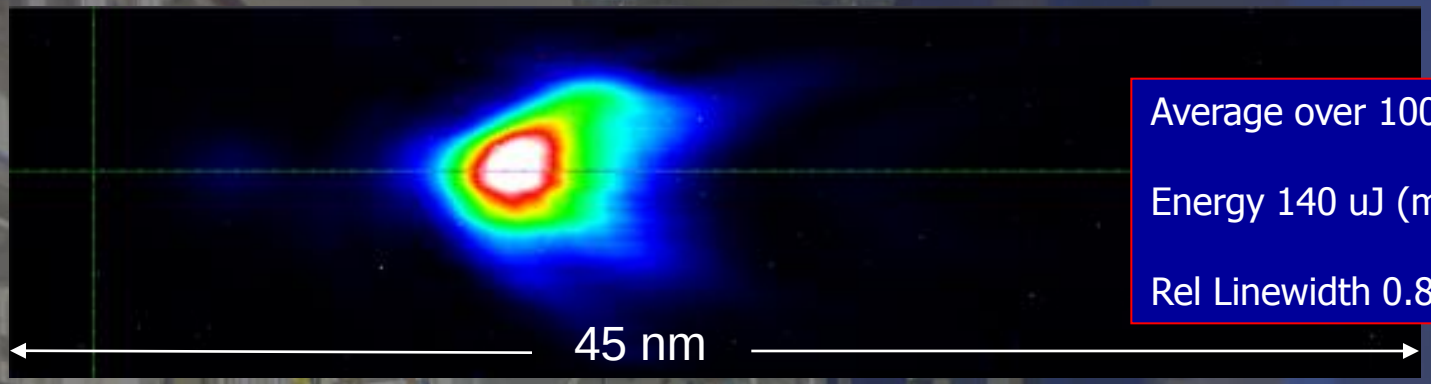
$$\omega_u = \frac{2\pi c}{\lambda_u}$$

Chirp $\bar{\gamma} = \bar{\gamma}(s) = \gamma_0 + \alpha(s - s_0)$

Taper $K = K(z) = K_0 + \alpha_k(z - z_0)$

Resonance is maintained by tuning the undulator taper





Average over 100 spectra:

Energy 140 uJ (max 380 uJ)

Rel Linewidth 0.8% rms

Single cooperation length observed in many spectra (as the one shown above)

Average energy per pulse 18 times higher !!!

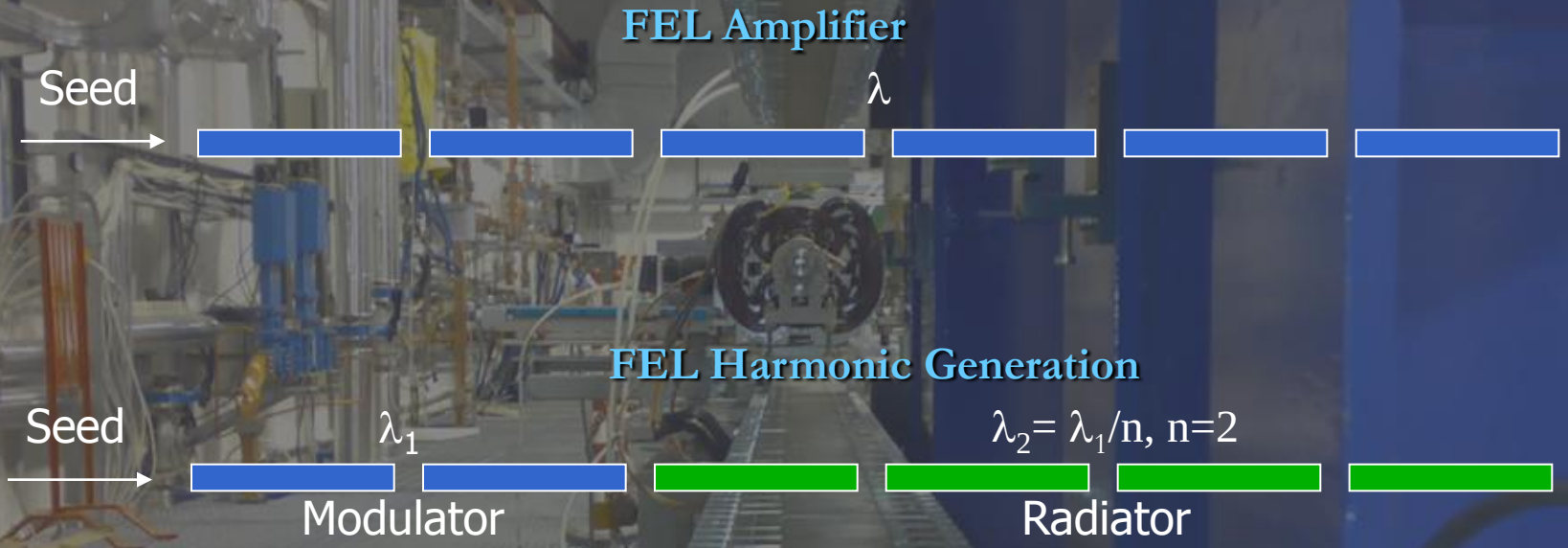
… in a narrower bandwidth (~1/2)

To see more: Poster sessions

ID: 1491 - TUPB18 FEL Experiments at SPARC

ID: 1642 - MOPB16 Energy Phase Correlation and FEL Efficiency

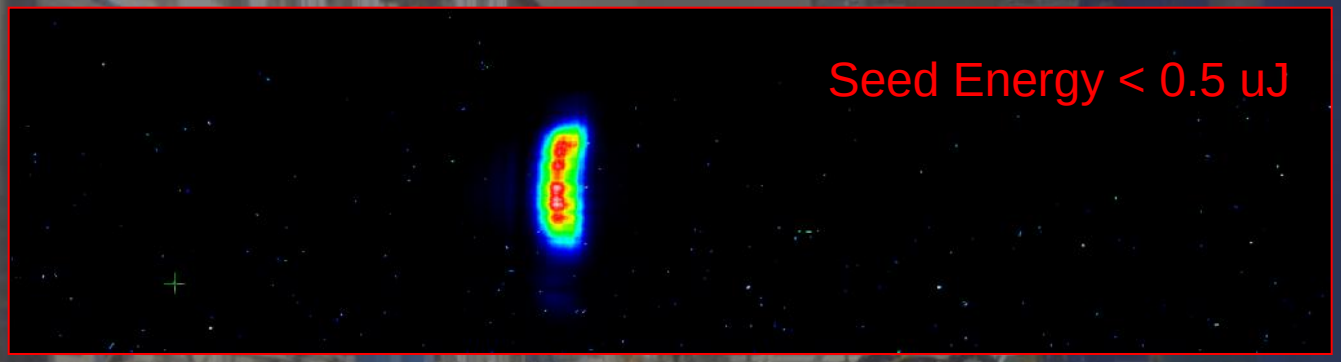
Seeded Operation



- Seed Sources:
  - 266 nm & 160 nm generated in gas
  - 400 nm in BBO crystal (high seed energy)

- Cascaded FEL tested with both seed configurations

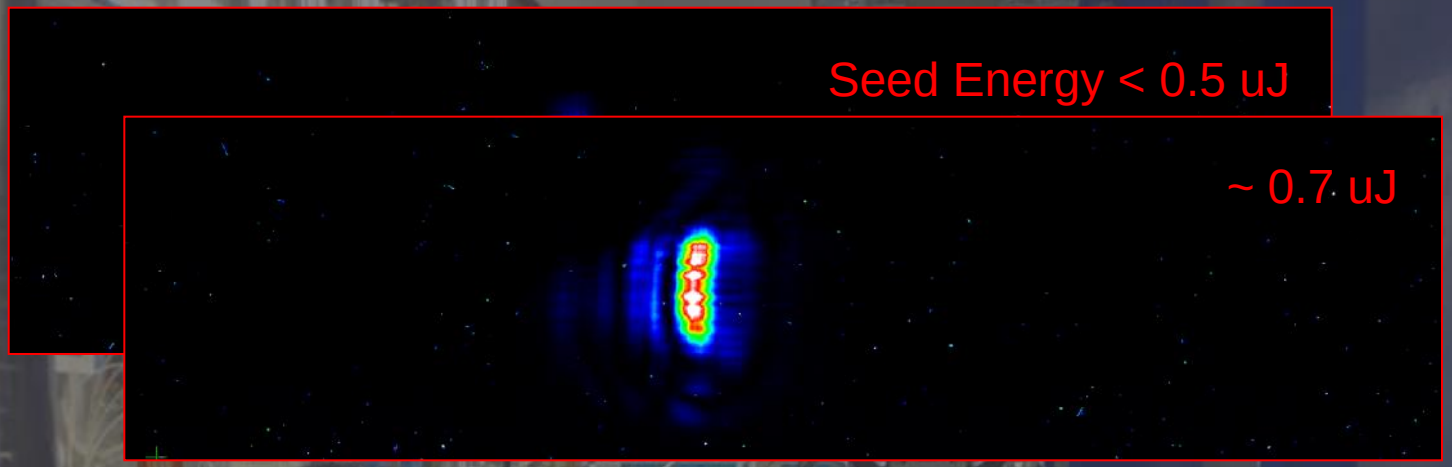
Direct seeding above saturation



Expected very efficient generation of high order harmonics

L. Giannessi, P. Musumeci, S. Spampinati, J. Appl. Phys. 98, 043110 (2005)

Direct seeding above saturation



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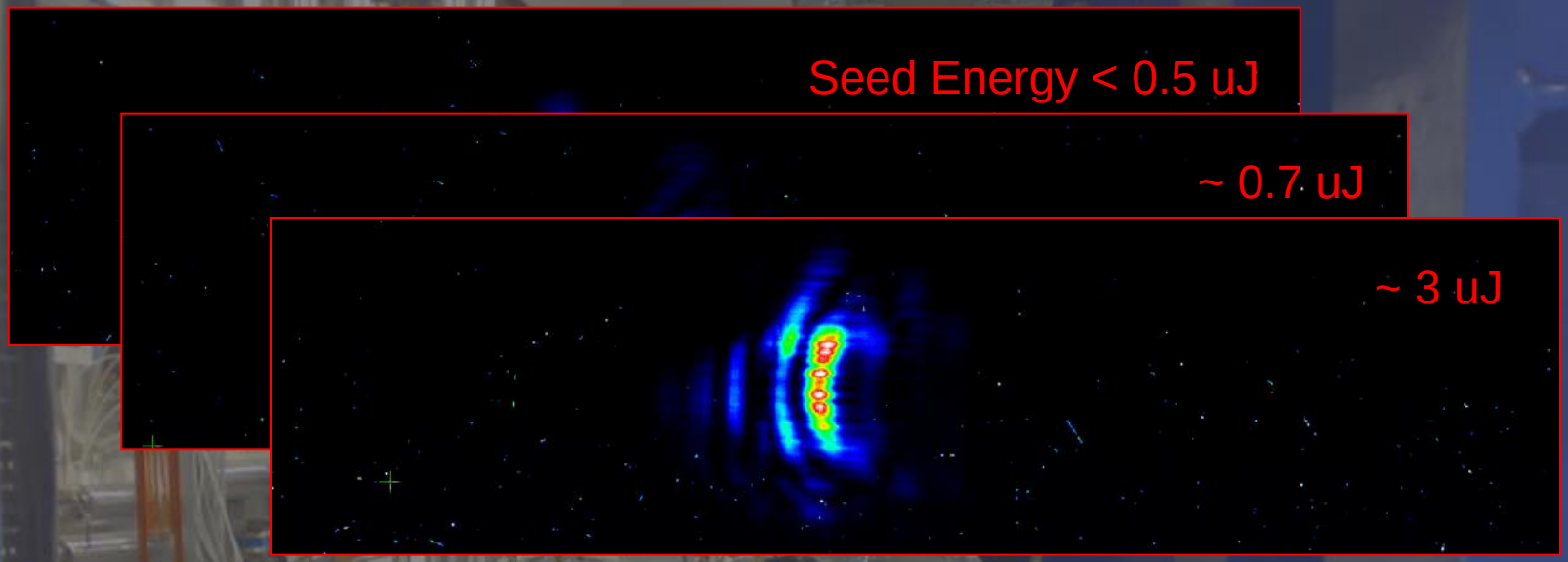

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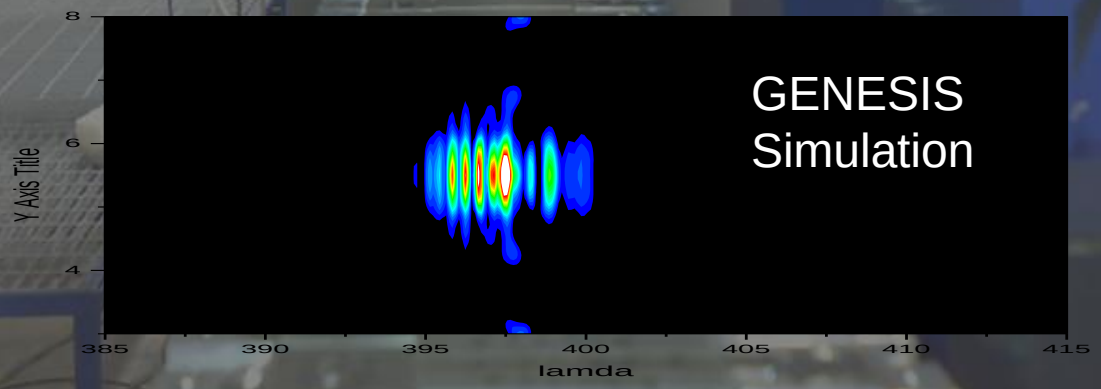
Direct seeding above saturation

Seed Energy < 0.5 uJ

~ 0.7 uJ

~ 3 uJ

~ 9 uJ



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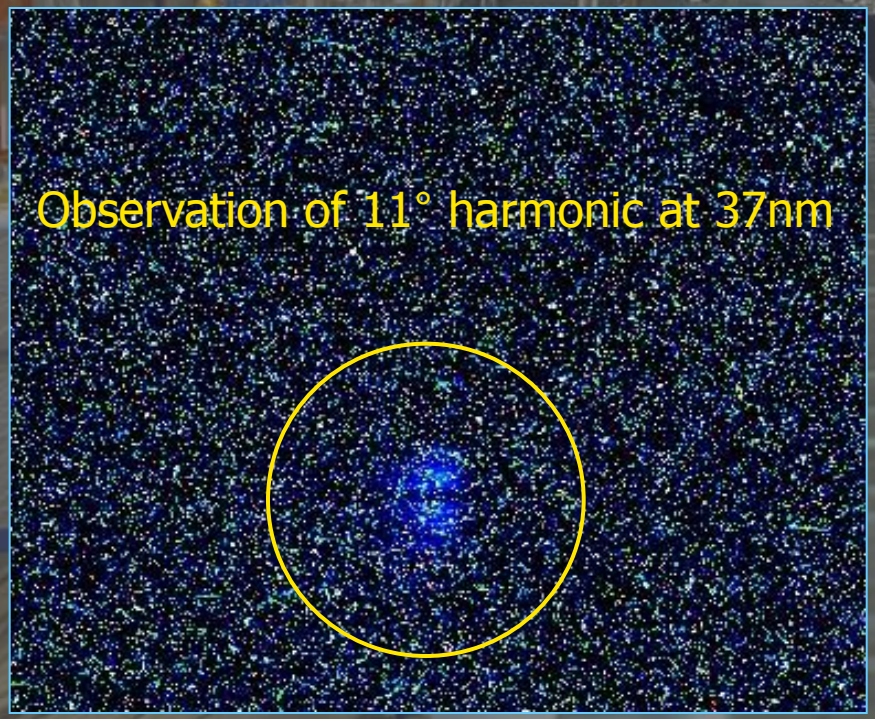
L. Giannessi, P. Musumeci, S. Spampinati, J. Appl. Phys. 98, 043110 (2005)

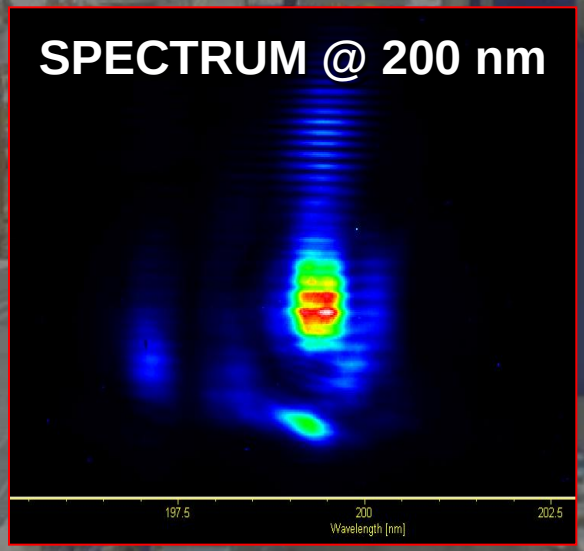
Harmonics down to 37 nm



Measured energy per pulse, spot size & and bandwidth of the first 11° harmonics

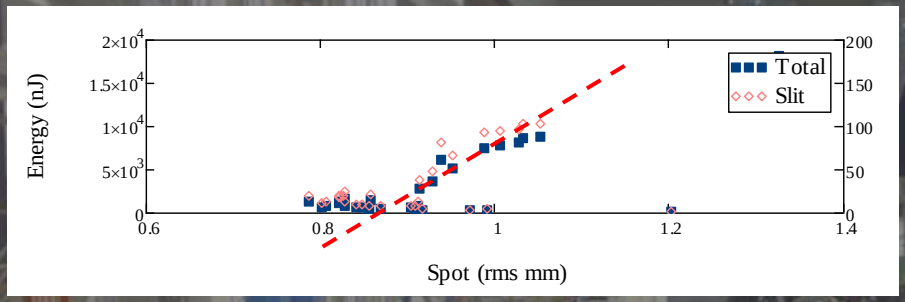
To see more:
Poster session ID: 1491 - TUPB18
FEL Experiments at SPARC

Cascaded configurations – Seed@400nm

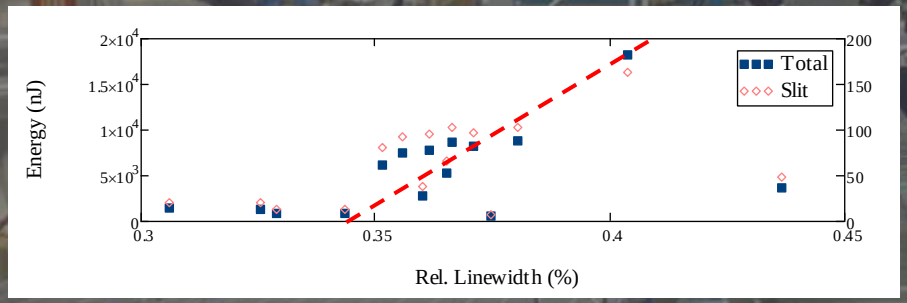


Indication of saturation @200 nm

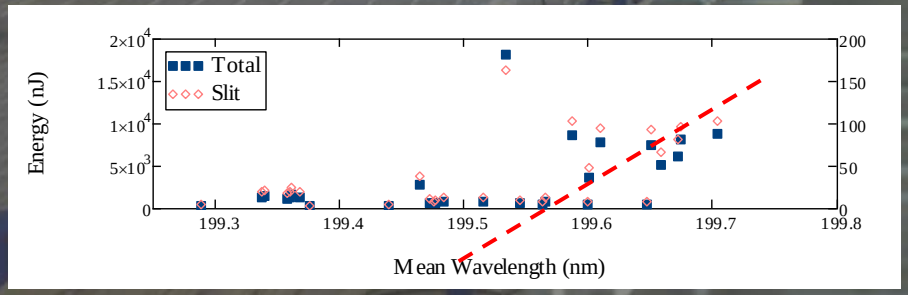
Indication of saturation at 200nm



Correlation Energy – Spot size

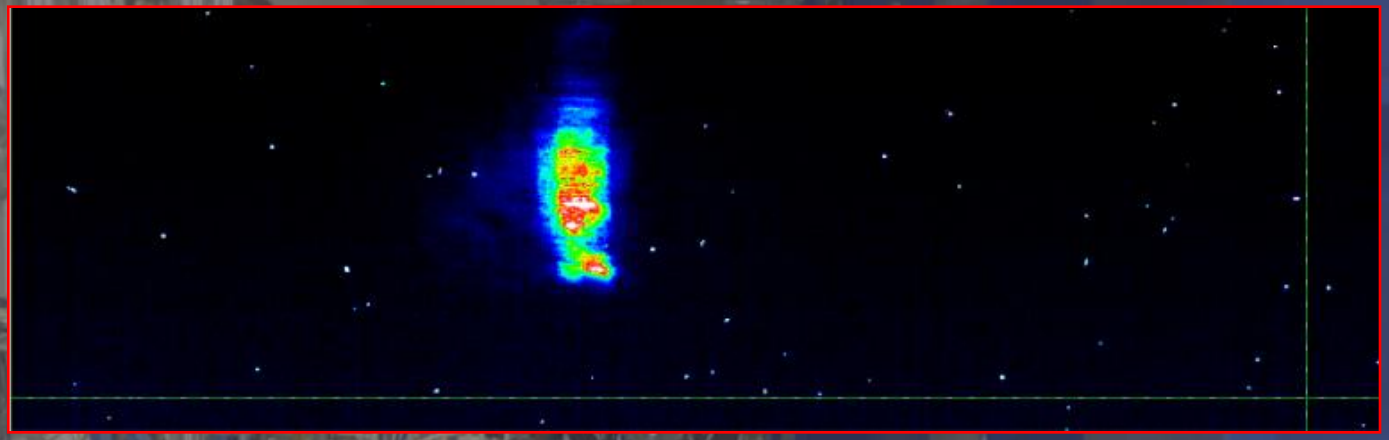


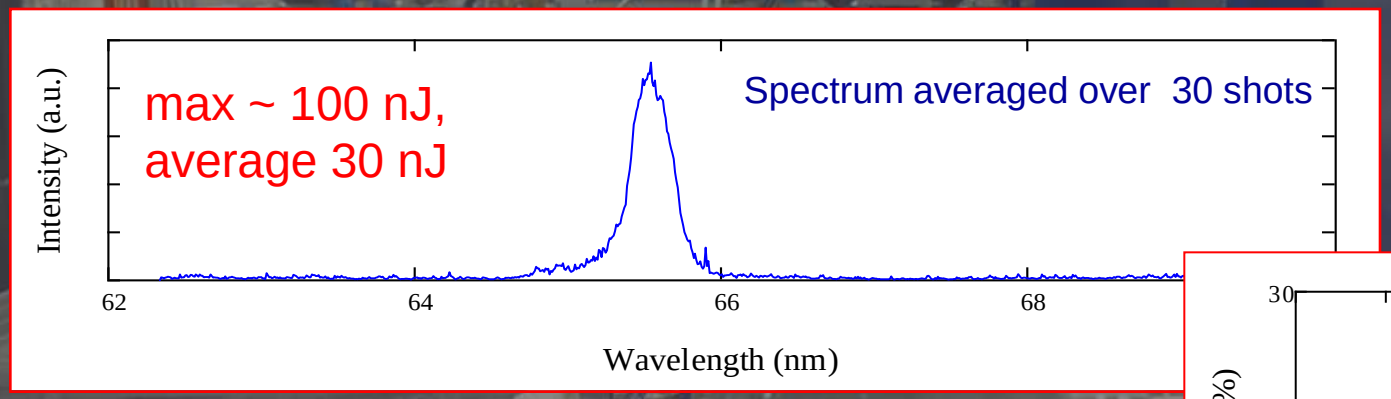
Correlation Energy – Linewidth

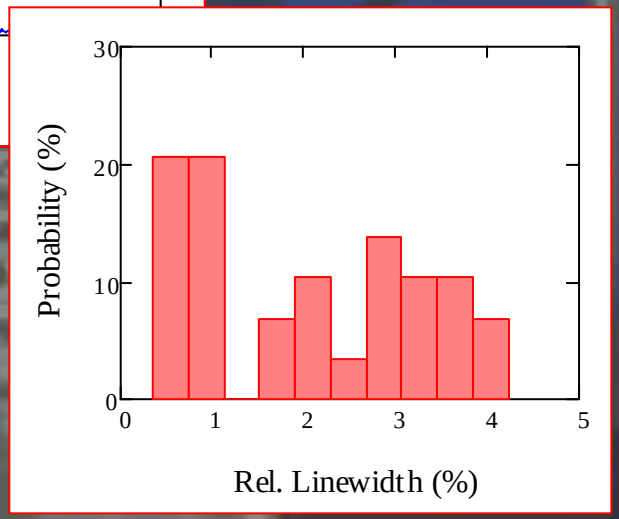


Redshift

3° harmonic of the radiator

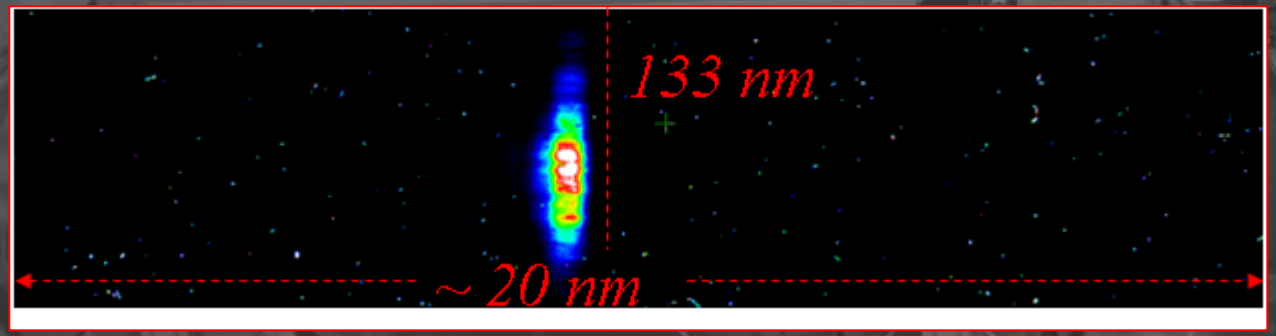


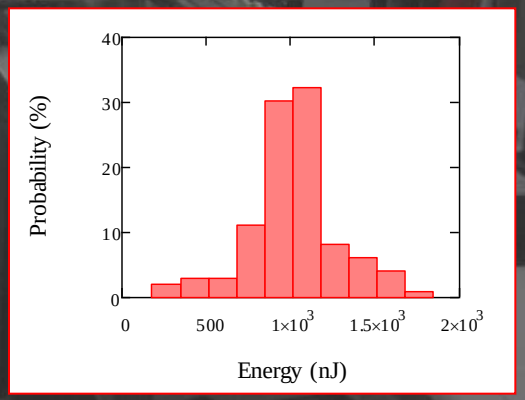




FEL seeded with harmonics generated in gas

Seed @ 266 nm → 133 nm





Studied the cascade changing the number of modulators/radiators

50 nJ 5-4-3 UM tuned @ 266 nm – 1-2-3 UM tuned @133 nm

Direct seeding @ 160 nm


Thank you !!!
Poster sessions
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ID: 1642 - MOPB16 Energy Phase Correlation and FEL Efficiency