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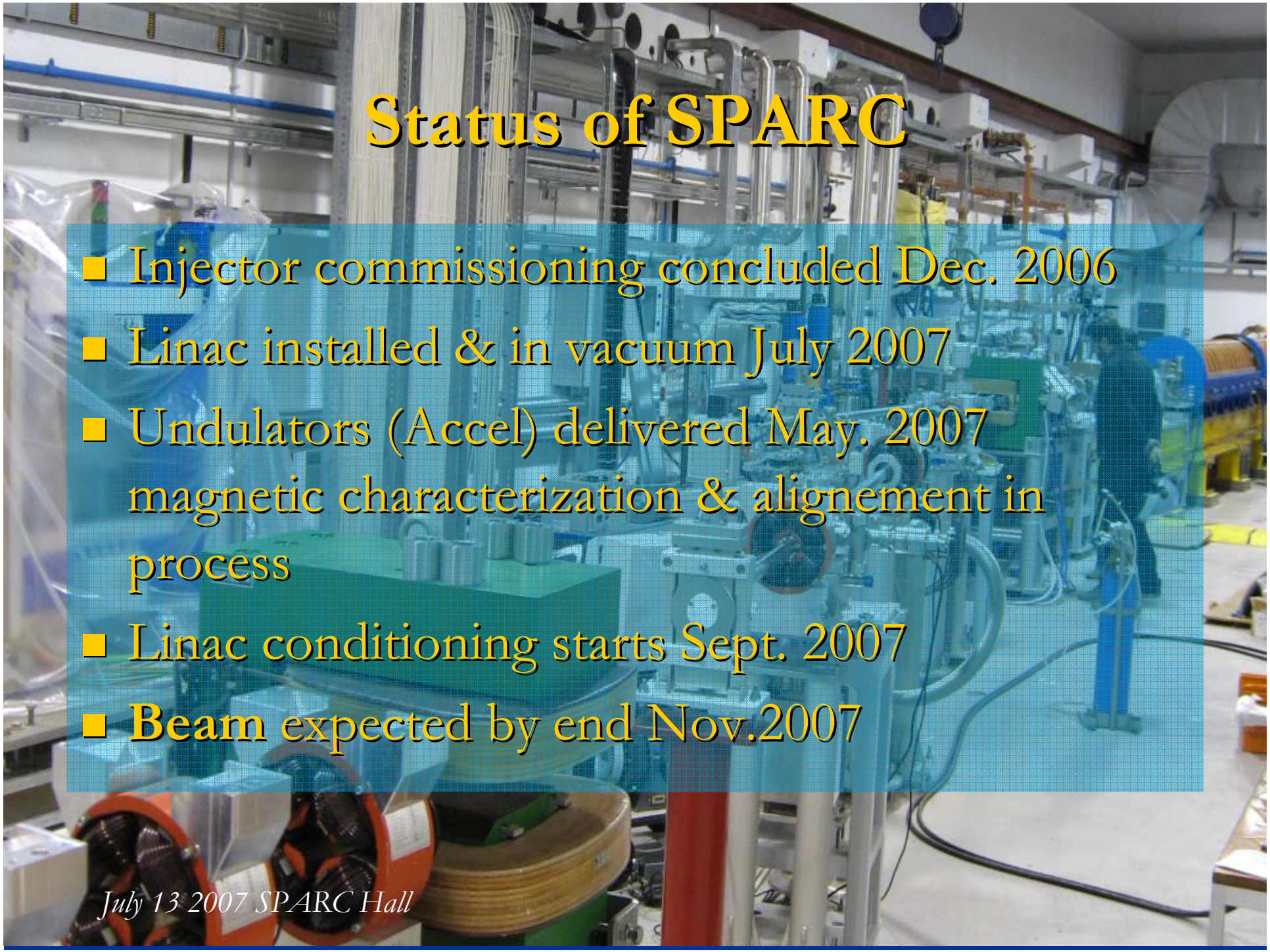
Elba, September 13 (2007)

Outline

- Overview of SPARC & seeding components installation
- Experiments planned
- Conclusions

SPARC main objectives

- **First MUR Contract (SPARC):**
  - **SASE FEL source** operating in the visible with an extended range of tunability down to the VUV (100nm) by the use of **non-linear harmonic generation & seeding**
  - Advanced **150 MeV photo-injector source,** aimed at producing state of the art, high brightness electron beams
  - R&D development of X-Ray optics – Monochromator / Table top X-ray sources
- **EUROFEL contract**
  - Pilot experiments to test High Harmonic generated in gas (HHG) seeding in an FEL amplifier
  - Bunch compression via "velocity bunching"
- **Second MUR Contract (SPARX)**
  - Extend seeding studies to FEL cascades
  - Study magnetic short period undulator



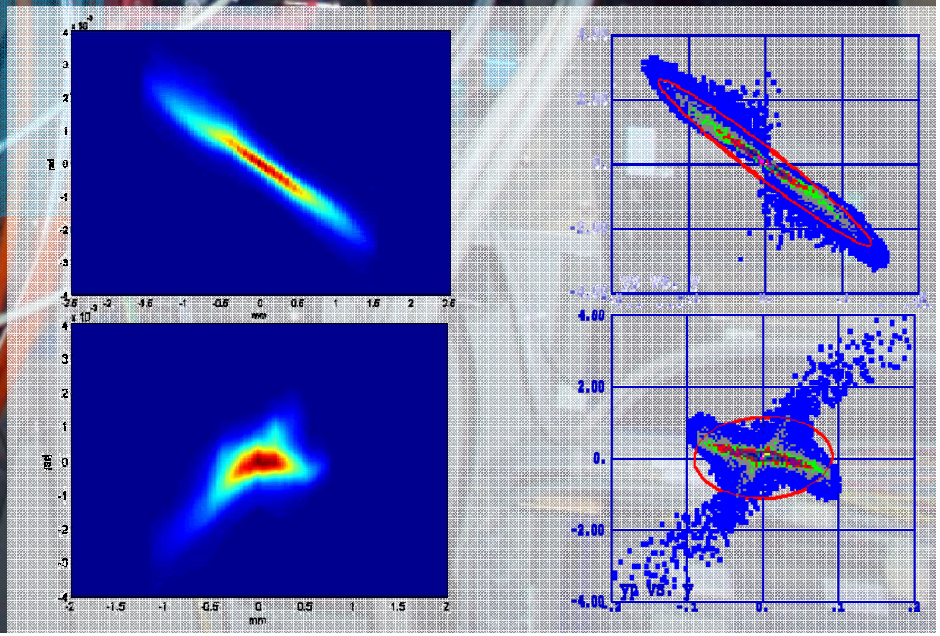
Status of SPARC

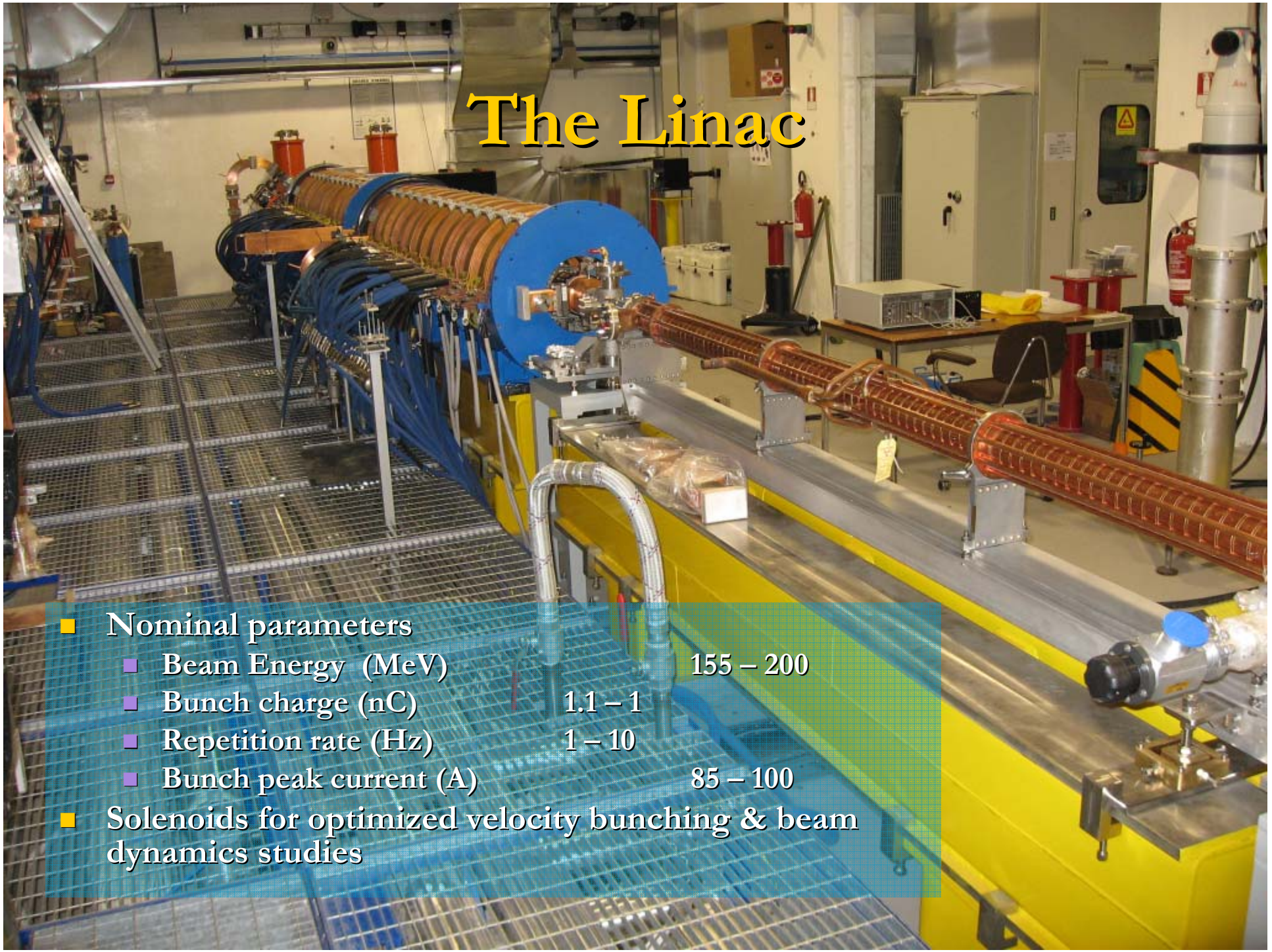
- Injector commissioning concluded Dec. 2006
- Linac installed & in vacuum July 2007
- Undulators (Accel) delivered May. 2007 magnetic characterization & alignement in process
- Linac conditioning starts Sept. 2007
- **Beam** expected by end Nov.2007

July 13 2007 SPARC Hall

The Injector

- BNL-SLAC-UCLA design 1.6 cells S-band rf-gun
- Realized @ UCLA Particle Beam Physics Laboratory
- Commissioning ended Dec. 2006
- Detailed beam characterization
  - 1.5 mm mrad @ 0.8 nC – 92 A
  - Gaussian vs. flat top comparison
  - Emittance meter – emittance vs.z & double minimum observed





The Linac

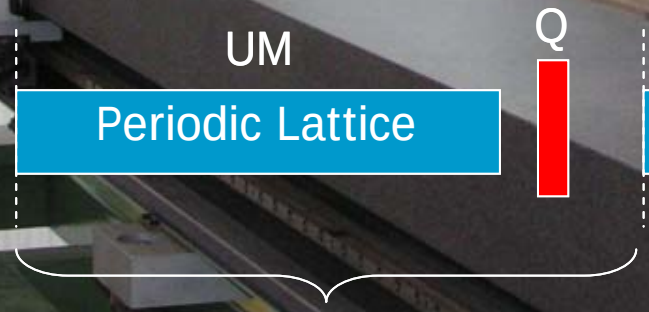
- Nominal parameters
  - Beam Energy (MeV) 155 – 200
  - Bunch charge (nC) 1.1 – 1
  - Repetition rate (Hz) 1 – 10
  - Bunch peak current (A) 85 – 100
- Solenoids for optimized velocity bunching & beam dynamics studies

The Undulator

ACCEL *(D. Doelling, P. Komorowksi)*

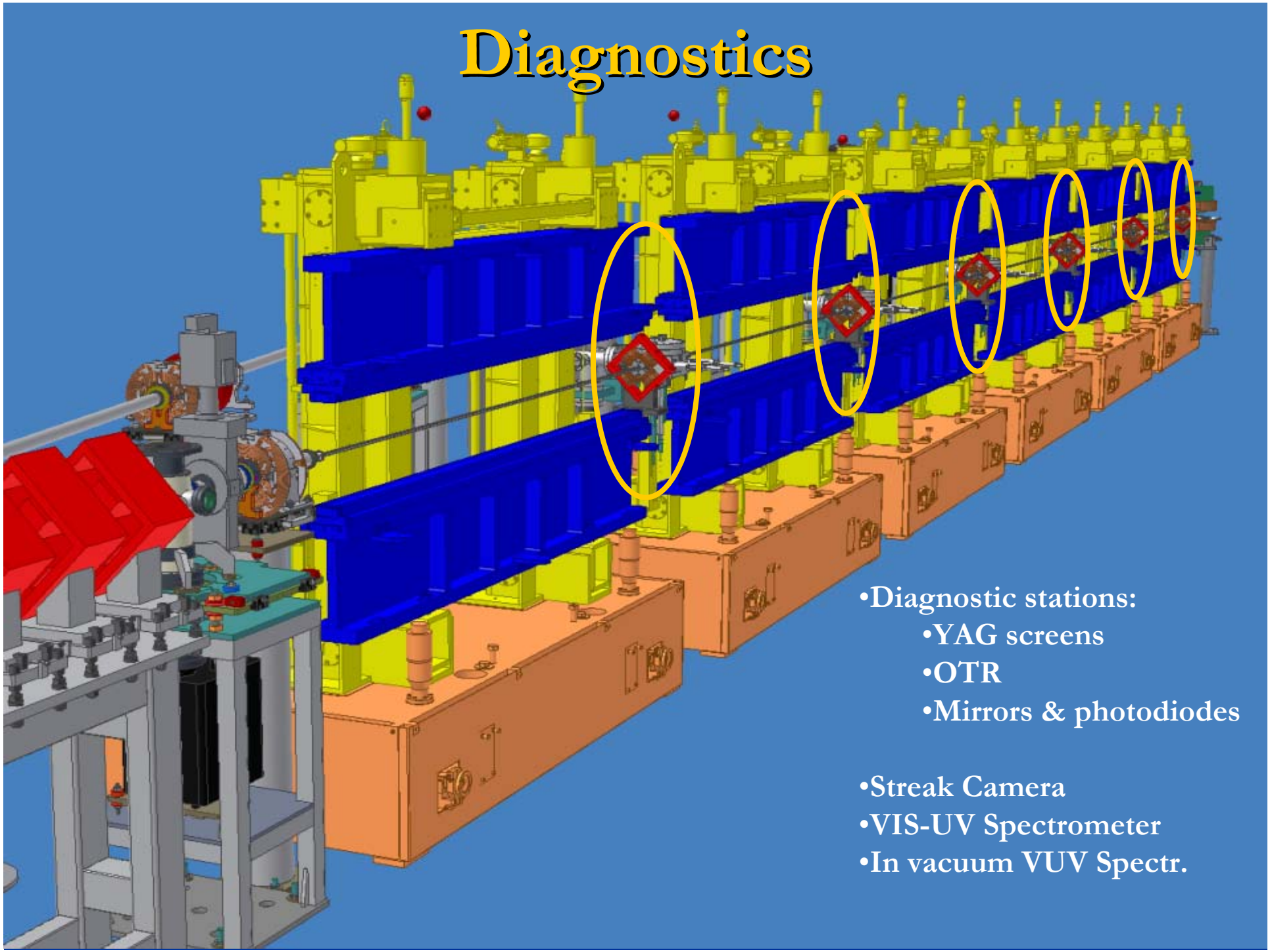
- PPM Halbach configuration, VARIABLE GAP
- Period 2.8 cm
- Sections 6
- Periods per section 75 (77 + phase shifter*)
- Section length 2.156 m
- Gap (nom./min/max, cm) 0.86 / 0.6 / 2.5
- K (nom./max) 2.145 / 3.2

** G. Parisi et. Al., Proceedings Fel 2005*



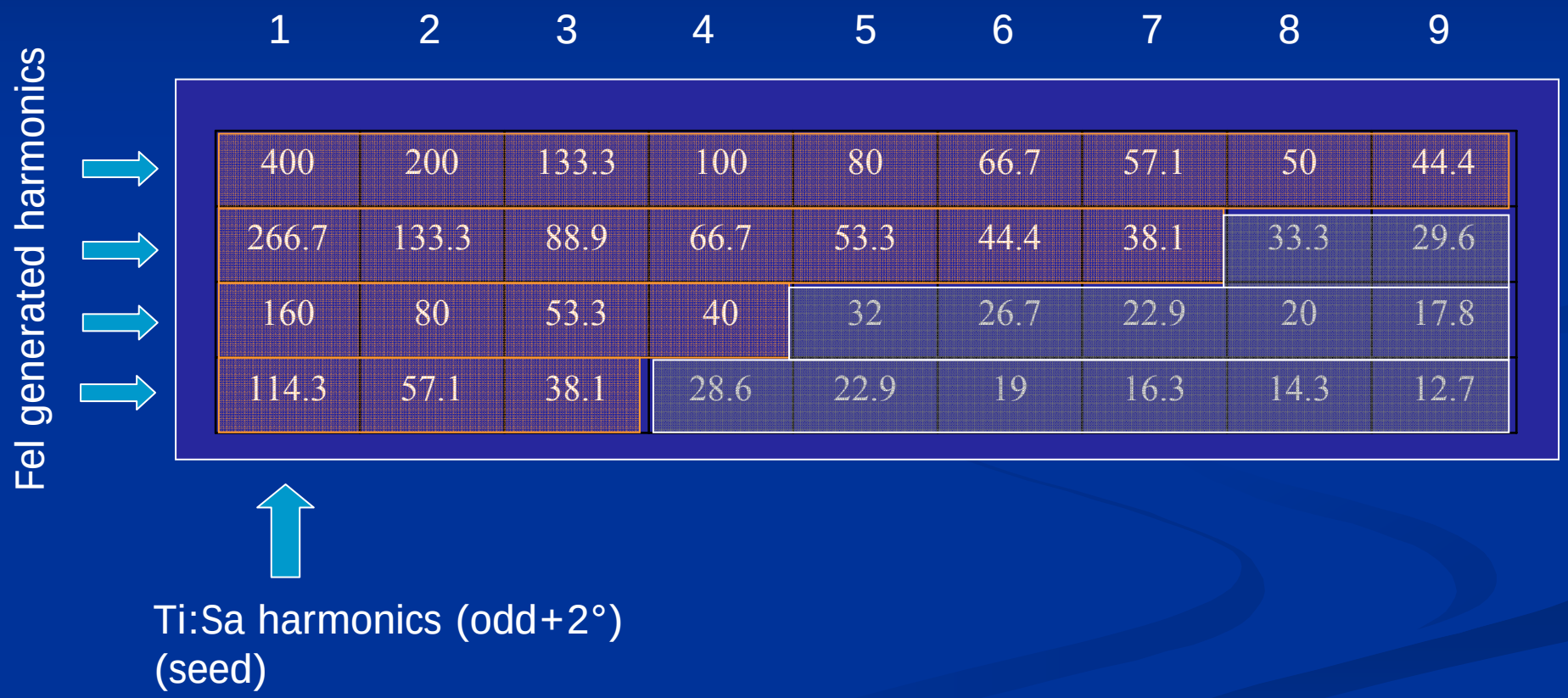
FODO (β 1.5 m – 2.2 m)

Diagnostics



- Diagnostic stations:
  - YAG screens
  - OTR
  - Mirrors & photodiodes
- Streak Camera
- VIS-UV Spectrometer
- In vacuum VUV Spectr.

OUTPUT wavelengths



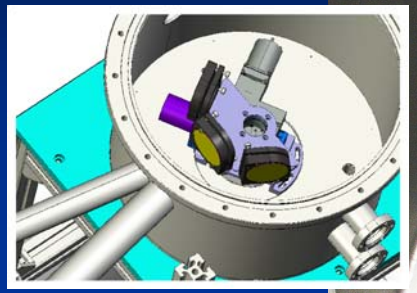
Laboratory for UV and X-ray Optical Research

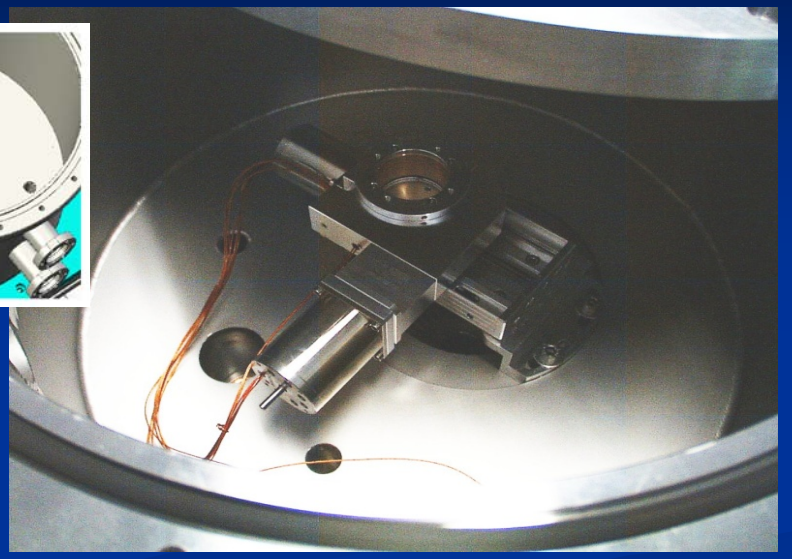
CNR-INFM

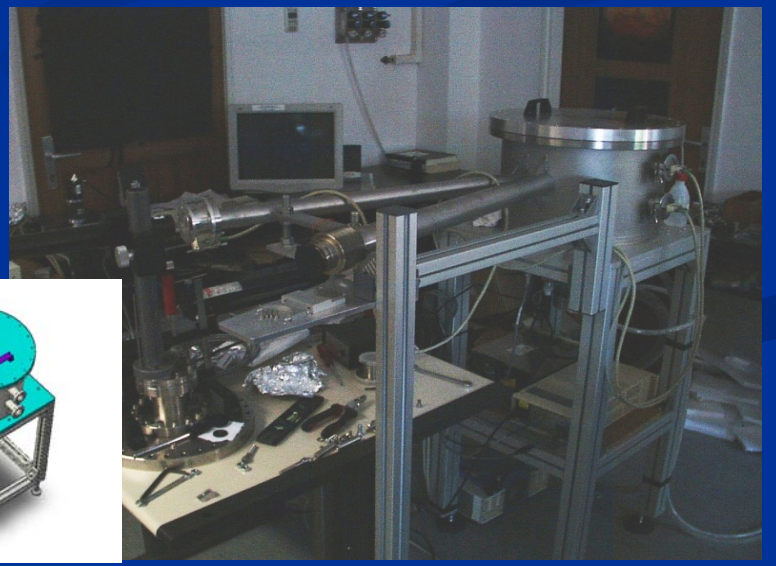
Courtesy of L. Poletto, F. Frassetto

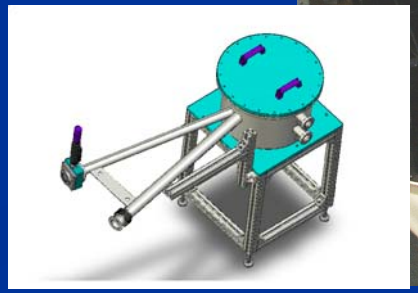
Installation 1w October

- Entrance slit:
  - minimum aperture 20 mm,
  - maximum aperture 2 mm
- Entrance/exit arms: ≈1 m
- Three gratings:
  - 600 gr/mm, 150-550 nm
  - 1200 gr/mm, 100-350 nm
  - 2400 gr/mm, 50-150 nm
- Acceptance
  - 25 mrad × 25 mrad (1.4 deg × 1.4 deg)
- CCD detector (Roper Scientific)
  - Thinned and back illuminated
  - Pixel size 20 mm
  - 1340 × 1340 pixel
- Resolving element
  - 0.034 nm/pixel (600 gr/mm)
  - 0.017 nm/pixel (1200 gr/mm)
  - 0.0084 nm/pixel (2400 gr/mm)



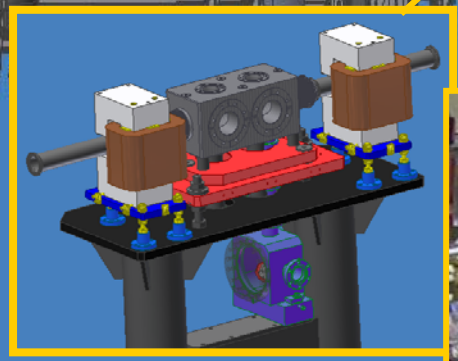






EUROFEL

Ti:Sa Regenerative amplifier
800 nm - 2.5 mJ – 1 kHz
+
High order harmonics
400 & 266 nm
+
High order armonics in gas:
266, 160, 114 nm
High Energy
Short duration
Spatial and temporal Coherence



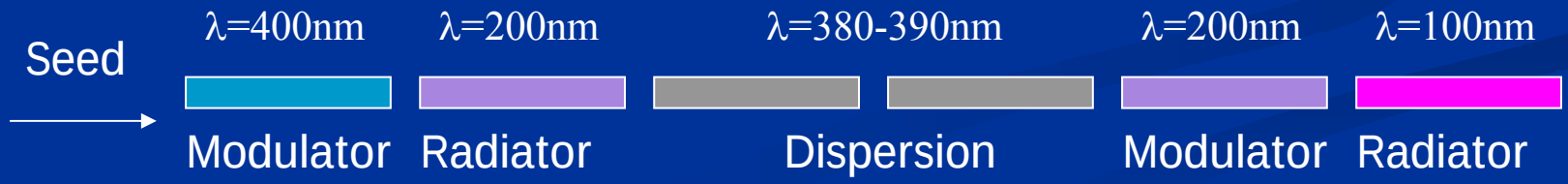
Seeding Configurations

FEL Amplifier

FEL Harmonic Generation

FEL Harmonic Cascade

Fresh Bunch injection technique



Harmonic Cascaded FEL

Resonant at λ_1

UM1

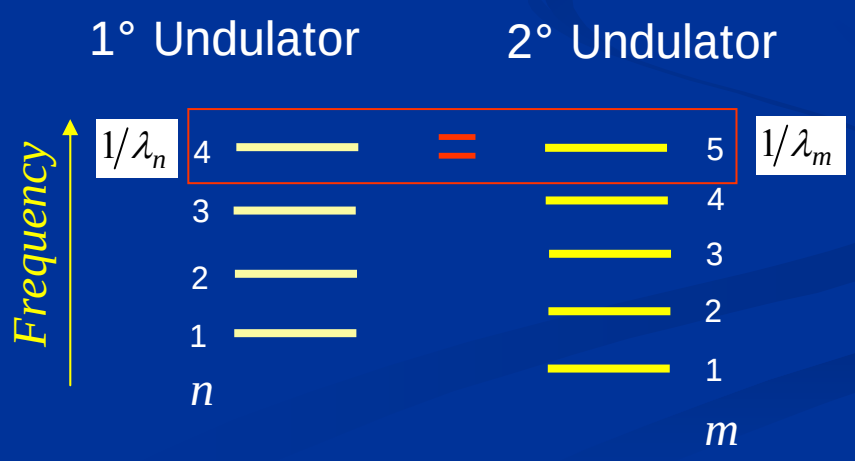
Bunching at $\lambda_n = \frac{\lambda_1}{n}$

Resonant at $\lambda_2 = \frac{m}{n}\lambda_1, \quad m \neq n$

UM2

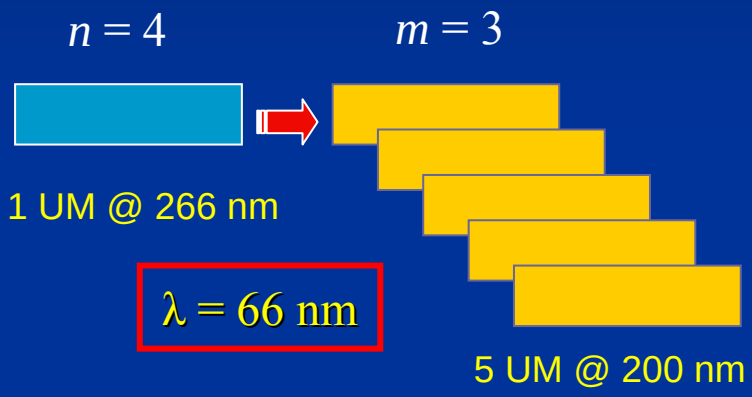
Emitted wavelength: $\lambda_m = \frac{\lambda_2}{m} = \lambda_n$

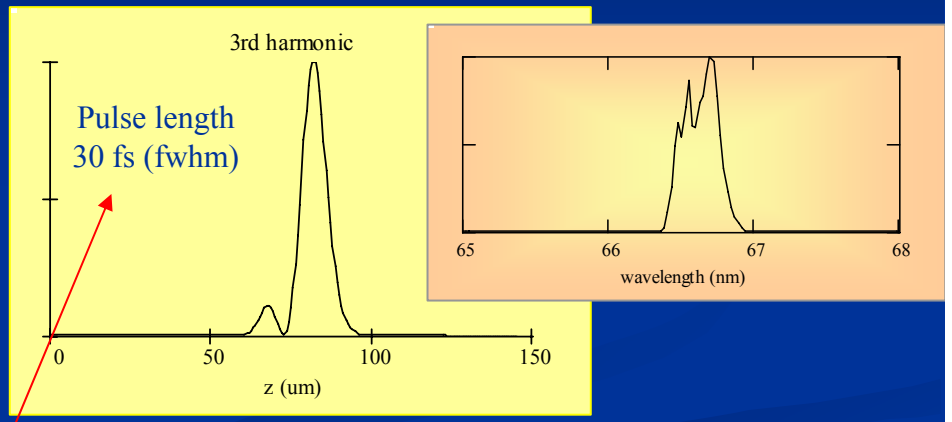
Harmonics Spectrum of the two undulators



Example with *Sparc* undulator/beam parameters

1D *Perseo* simulation *(http://www.perseo.enea.it)*

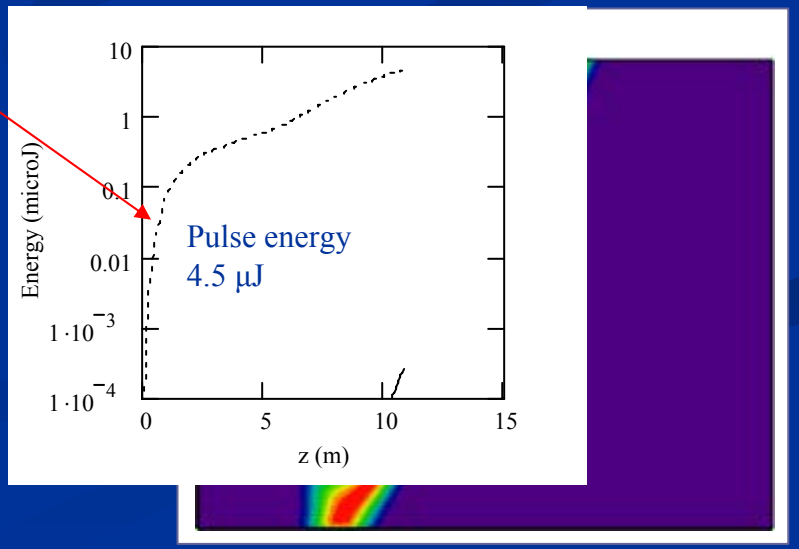




Main parameters

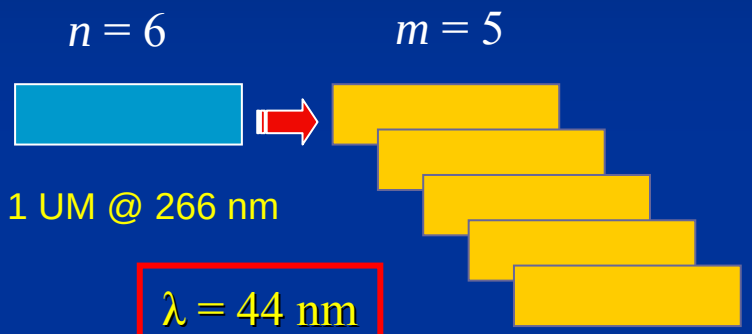
Undulator period	2.8 cm
Undulator K (UM1/UM2)	1.95 / 1.53
Number of periods	77 / 77*5
Beam energy	200 MeV
Res. wavelength (nm)	266 / 200
E-beam current	110 Amp
Energy spread	10^{-4}
Emittance	1 mm-mrad
Input Laser power	2 MW
Input pulse length (fwhm)	100 fs

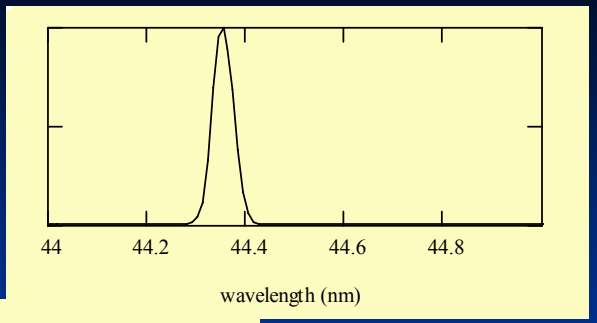
Peak power ≈ 130 MW

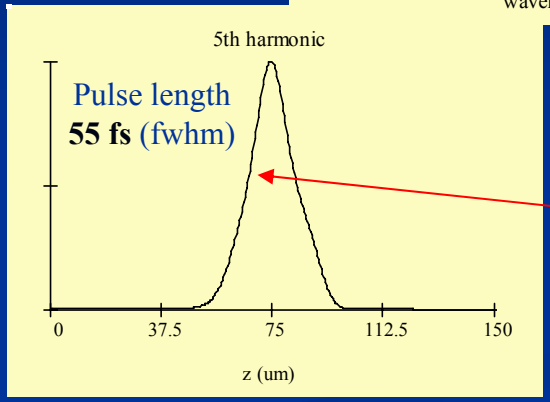


SPARC

$n = 6$ and $m = 5$



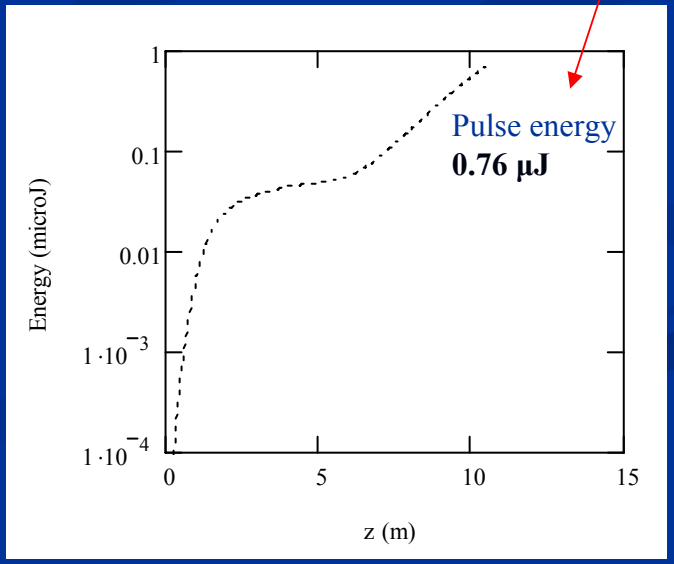




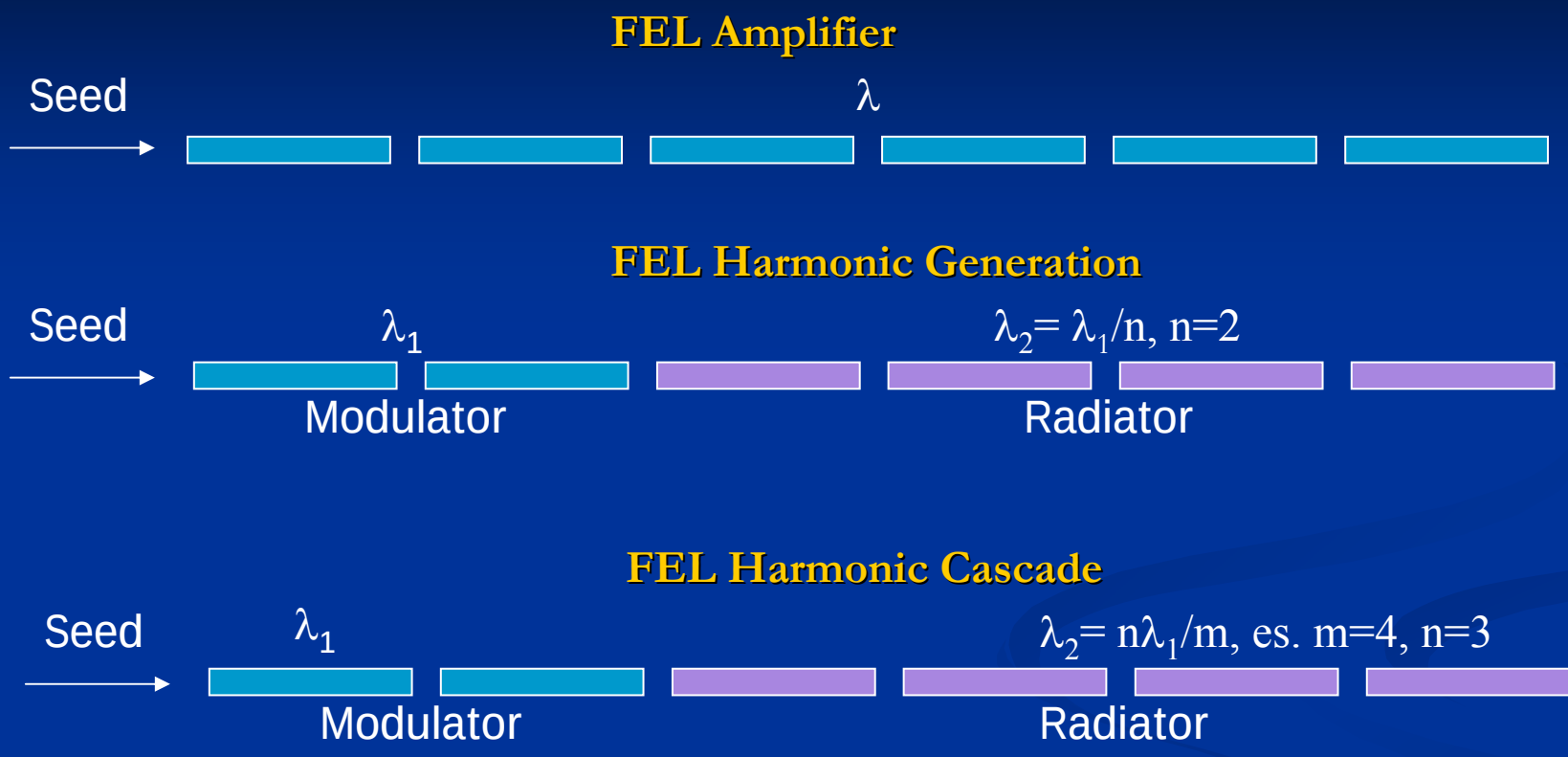
Peak power ≈ 12 MW

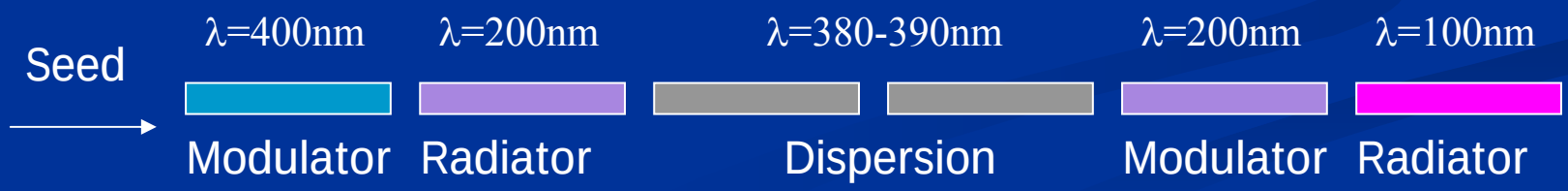
Main parameters

Undulator period	2.8 cm
Undulator K (UM1/UM2)	1.95 / 1.69
Number of periods	77 / 77*5
Beam energy	200 MeV
Res. wavelength (nm)	266 / 222
E-beam current	110 Amp
Energy spread	10^{-4}
Emittance	1 mm-mrad
Input pulse length (fwhm)	100 fs



Seeding Configurations



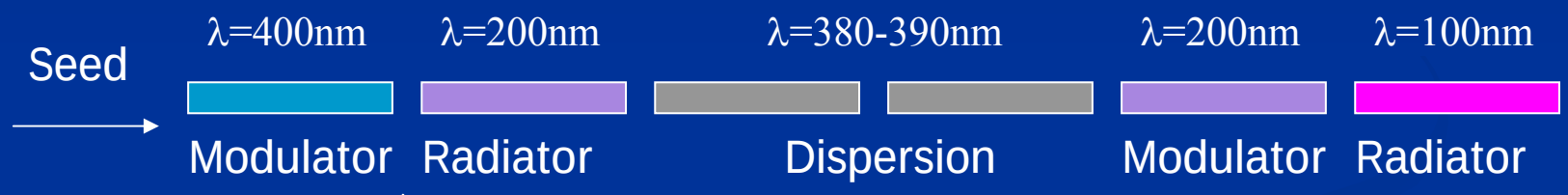


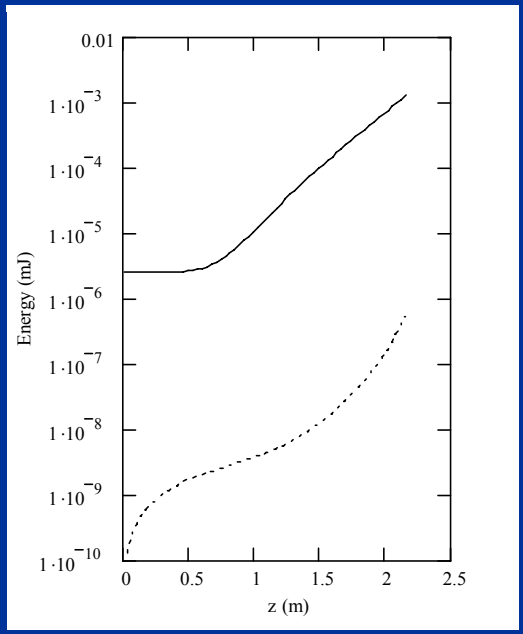
Yu, Ben-Zvi NIM A 393 (1997) 96

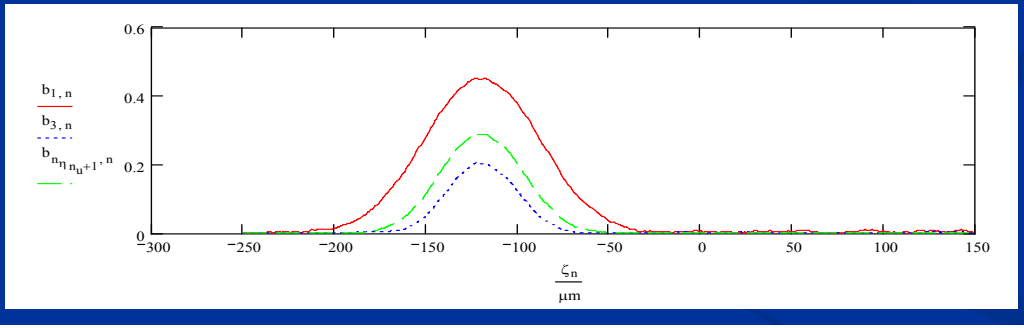
Double stage FEL cascade

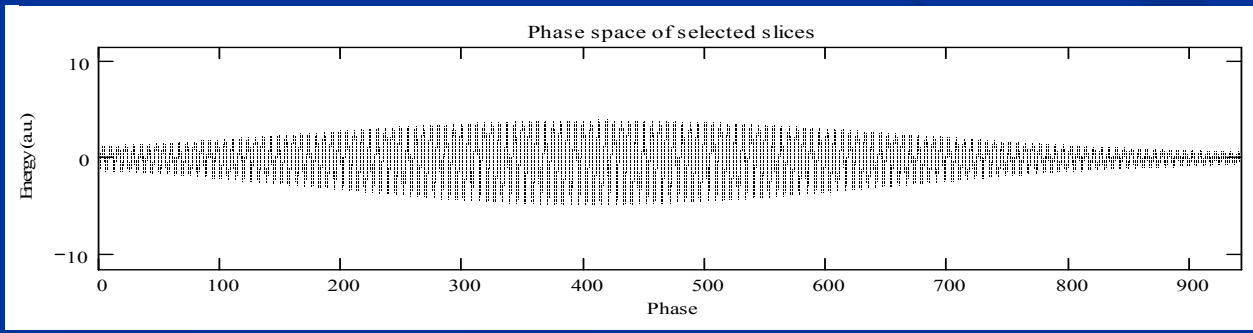
Beam energy	175 MeV
Peak current	100 A
Input seed	20 kW
Pulse length (rms)	100 fs

Fresh Bunch injection technique





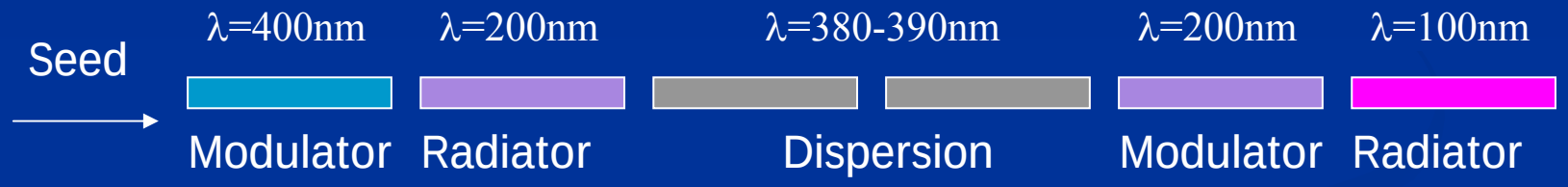


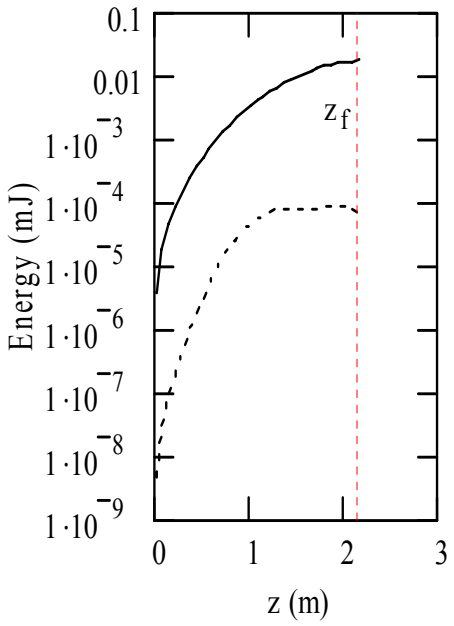


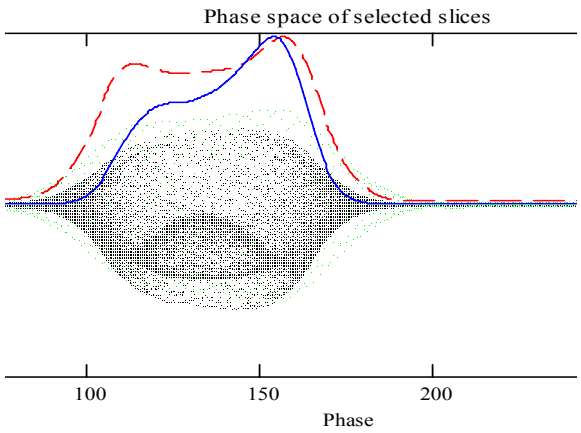
Double stage cascade

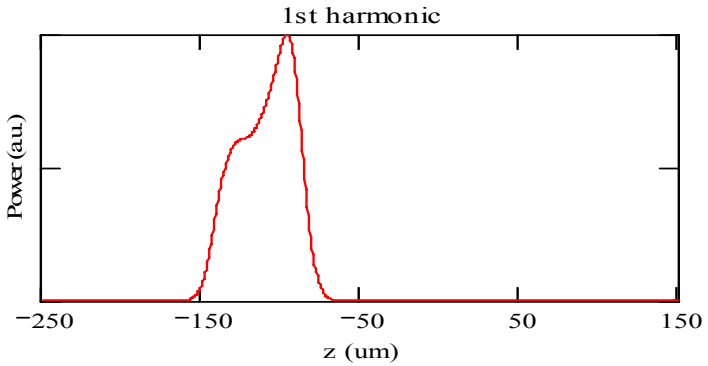
AFTER THE FIRST RADIATOR

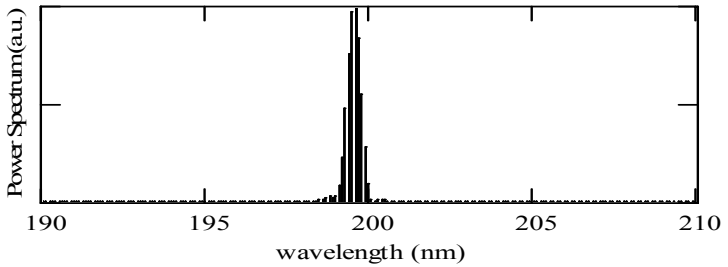
Fresh Bunch injection technique







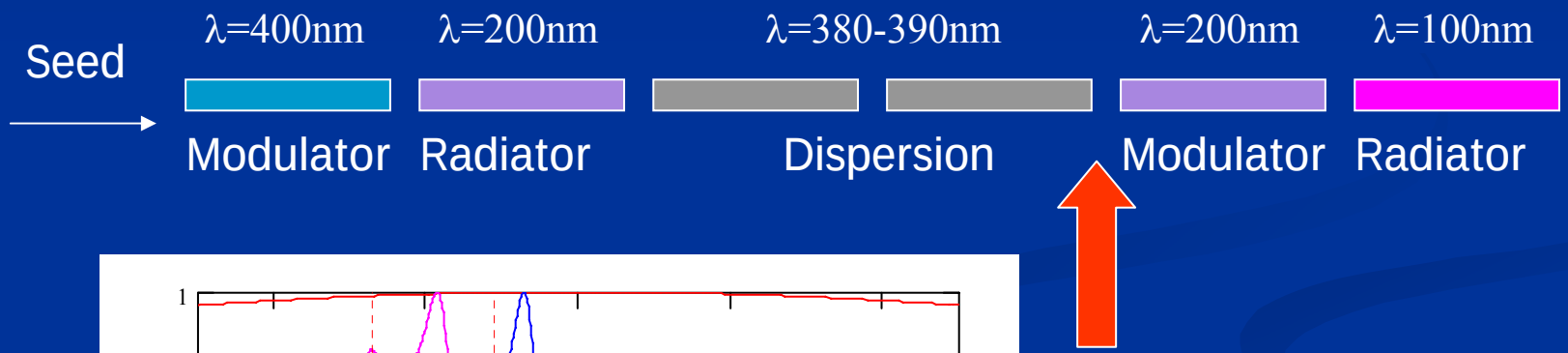


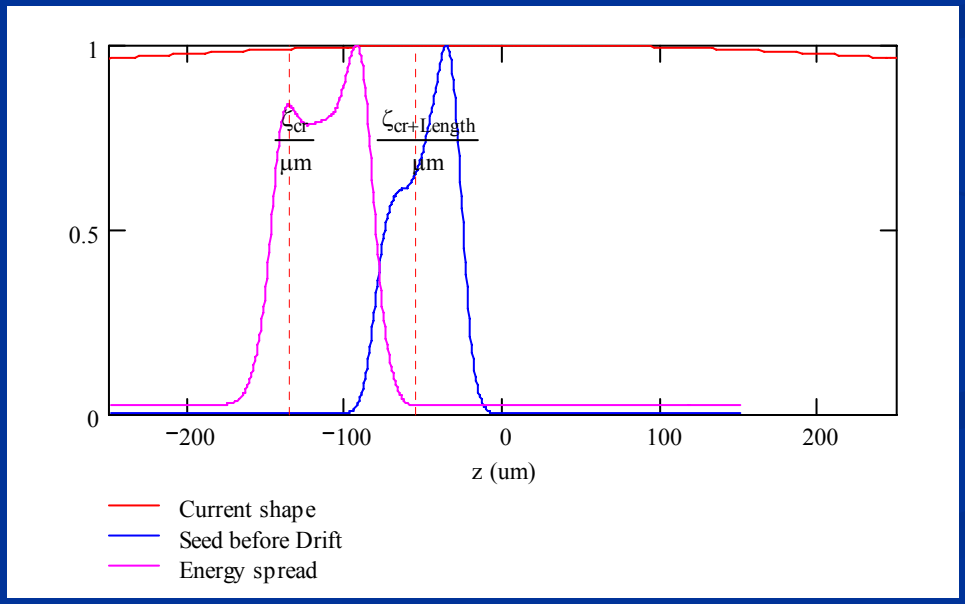


Double stage cascade

AFTER THE DISPERSIVE SECTION

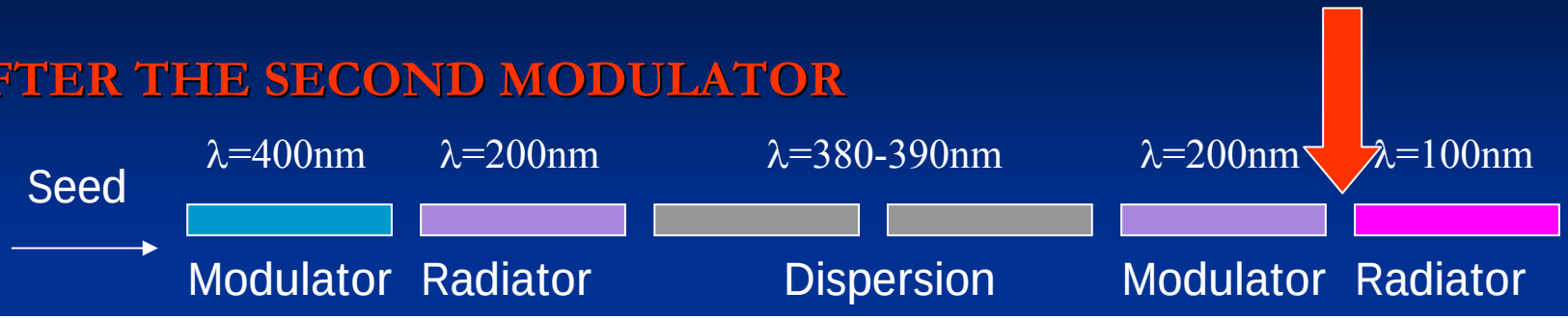
Fresh Bunch injection technique

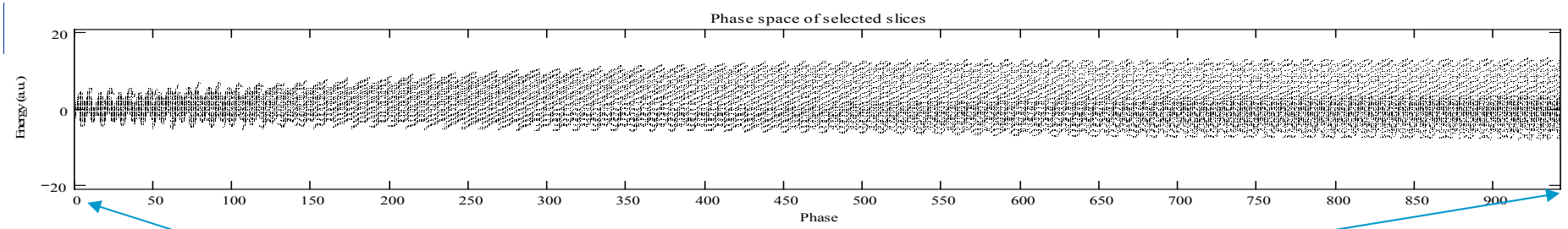




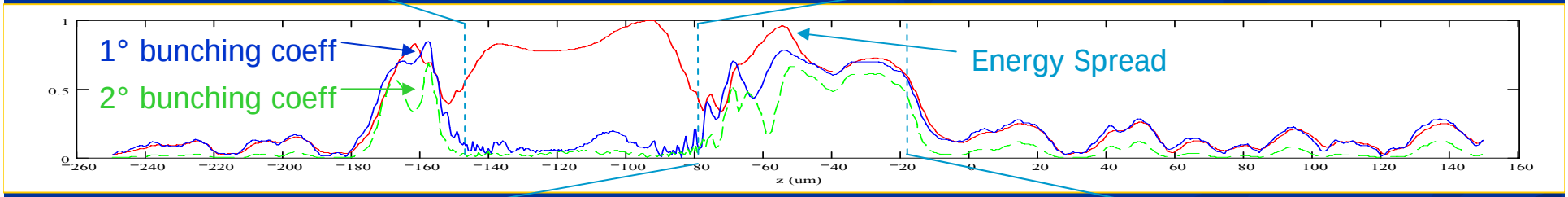
Double stage cascade

AFTER THE SECOND MODULATOR

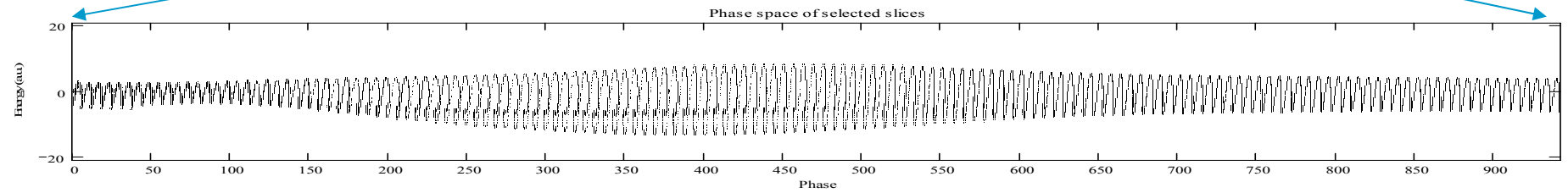




Modulated in the first stage

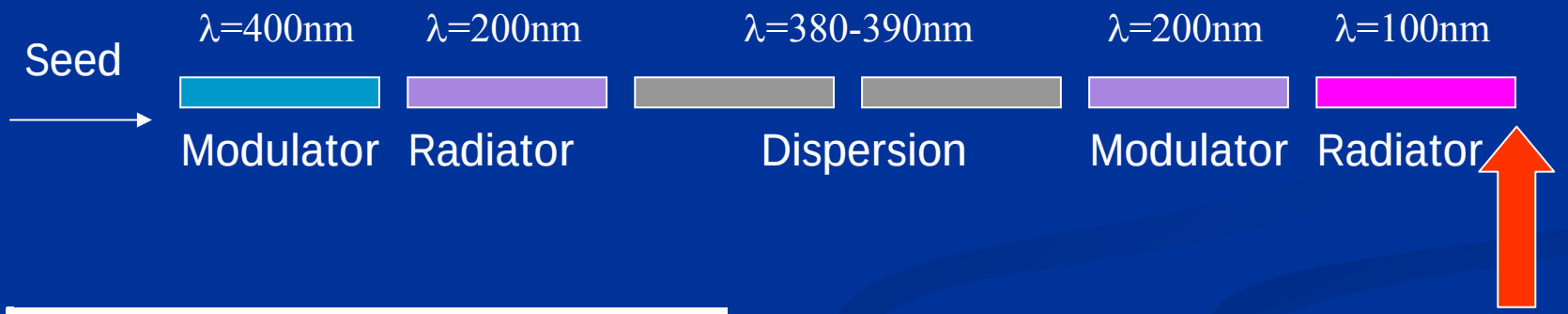


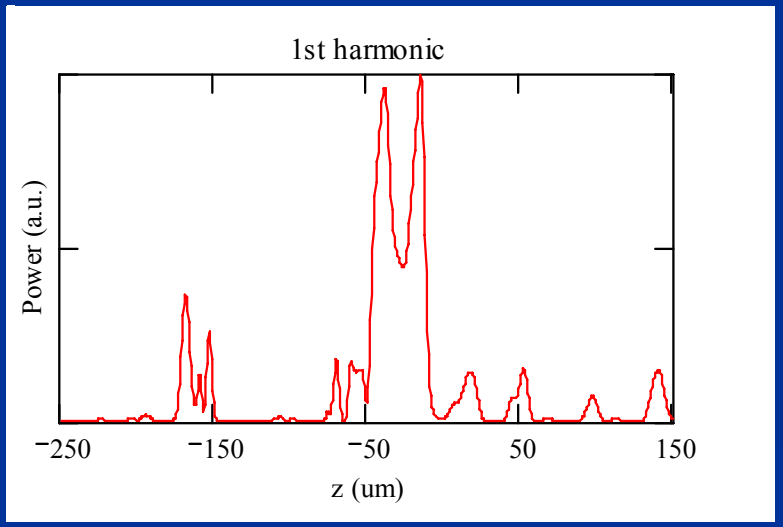
Modulated in second stage

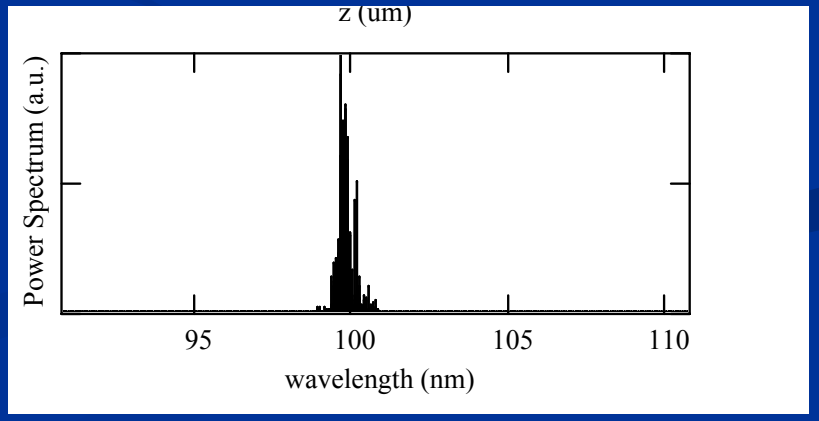


Double stage cascade

Fresh Bunch injection technique







Conclusions

- SPARC is an ideal test bench for single pass & cascaded FEL physics
  - Compatibility of Ti:Sa Harmonics generated in gas with FEL gain filtering & cascades
  - Codes/theory validation
  - Fresh Bunch Injection Technique (full double stage cascade)
  - Further studies on superradiance and superradiant cascade
  - Test of harmonic cascade concept
  - Short pulse operation
  - Many other ideas …