A Versatile High Gain Storage Ring FEL Powered by a Distributed Optical Klystron

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Acknowledgments

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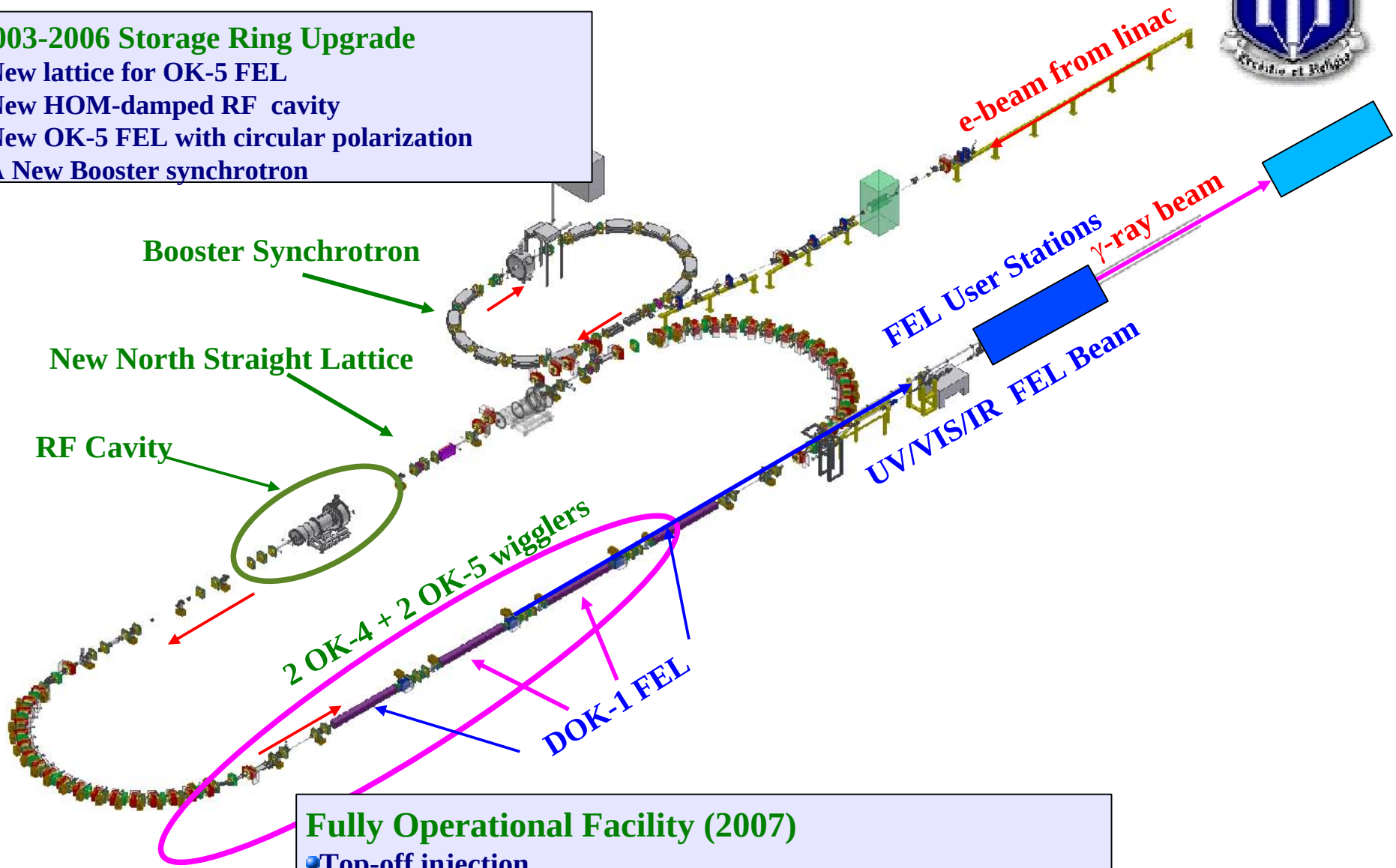
Outline

- FEL upgrade project at Duke University : 2003 – 2007
  - Two new FELs: OK-5 FEL and DOK-1 FEL
- DOK-1 FEL with two linear and two circular wigglers
  - High Gain Operation
  - Polarization Switch
- Versatile Light Source with DOK FELs

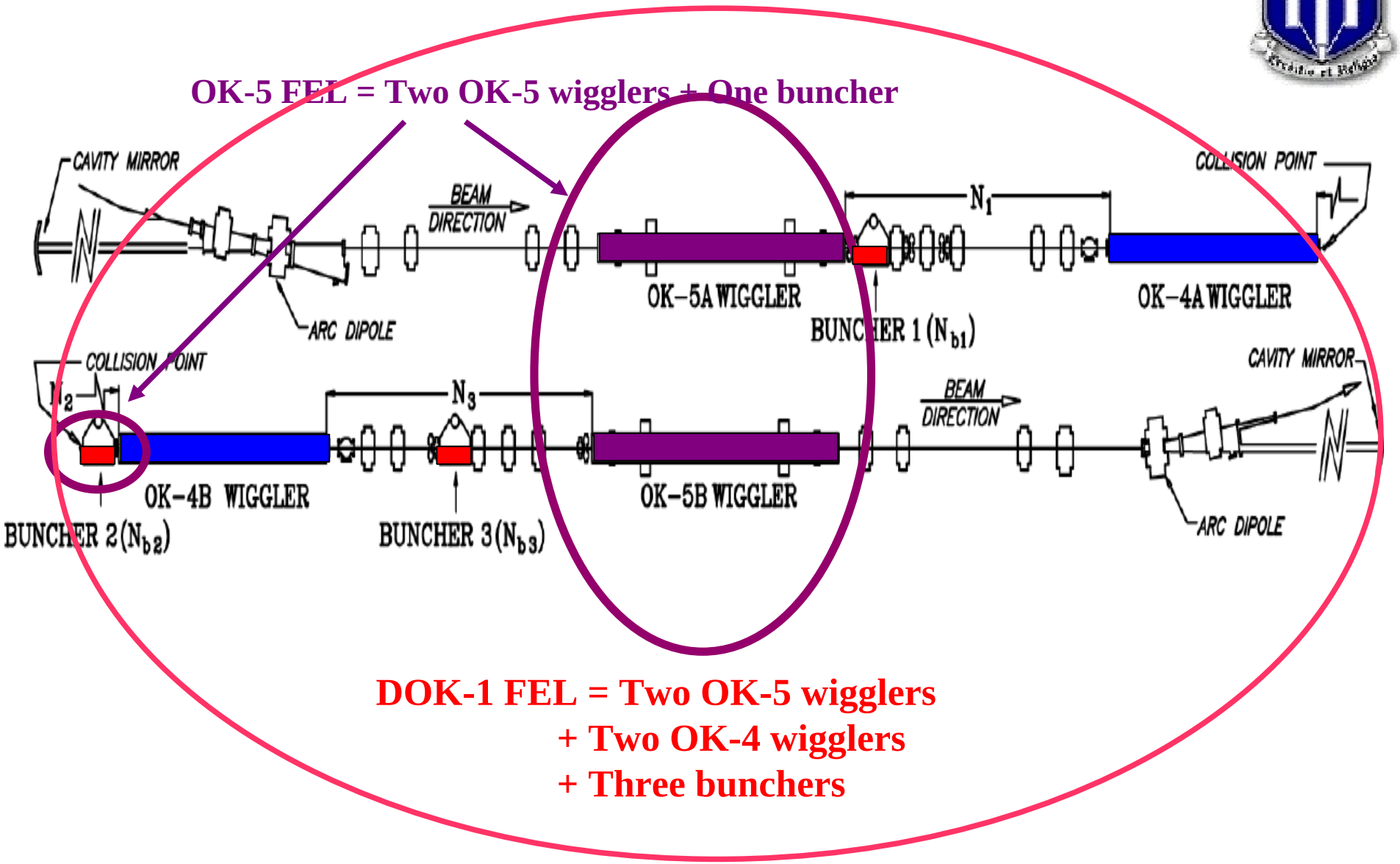
DFELL Facility after Full Upgrades in 2007

2003-2006 Storage Ring Upgrade
- New lattice for OK-5 FEL
- New HOM-damped RF cavity
- New OK-5 FEL with circular polarization
- A New Booster synchrotron



Fully Operational Facility (2007)
- Top-off injection
- High single-bunch current operation (50 to 95 mA)

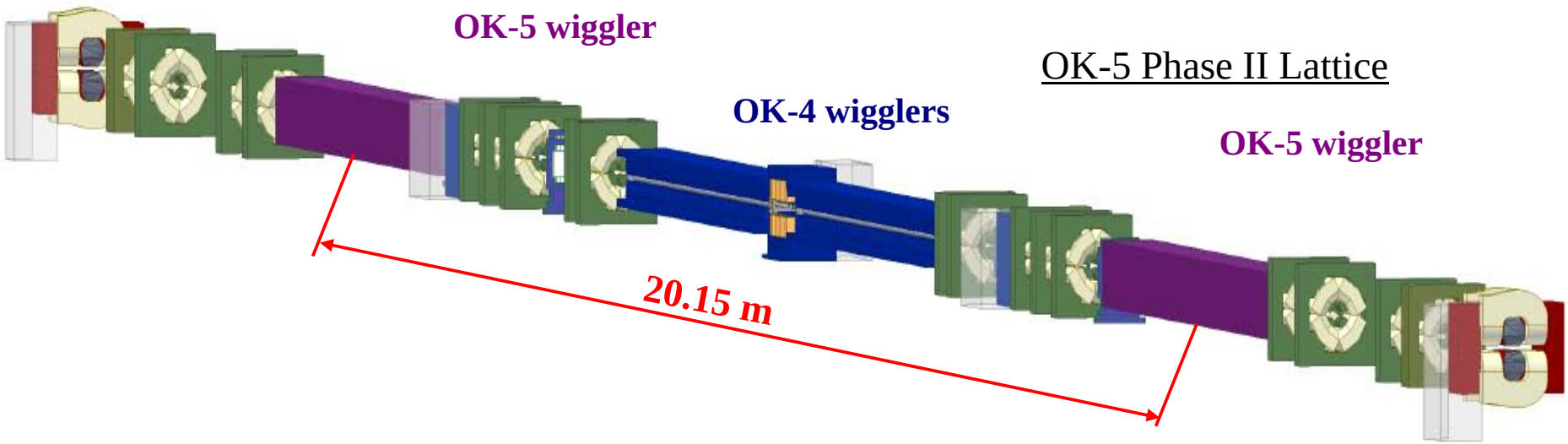
OK-5 FEL and DOK-1 FEL Layout



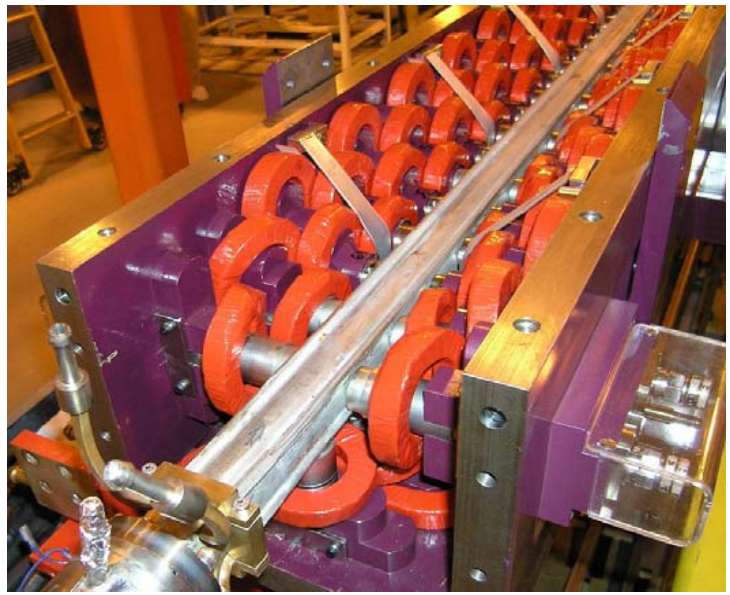
DOK-1 FEL = Two OK-5 wigglers
+ Two OK-4 wigglers
+ Three bunchers

OK-5 Phase II Lattice Upgrade (2004-2005)

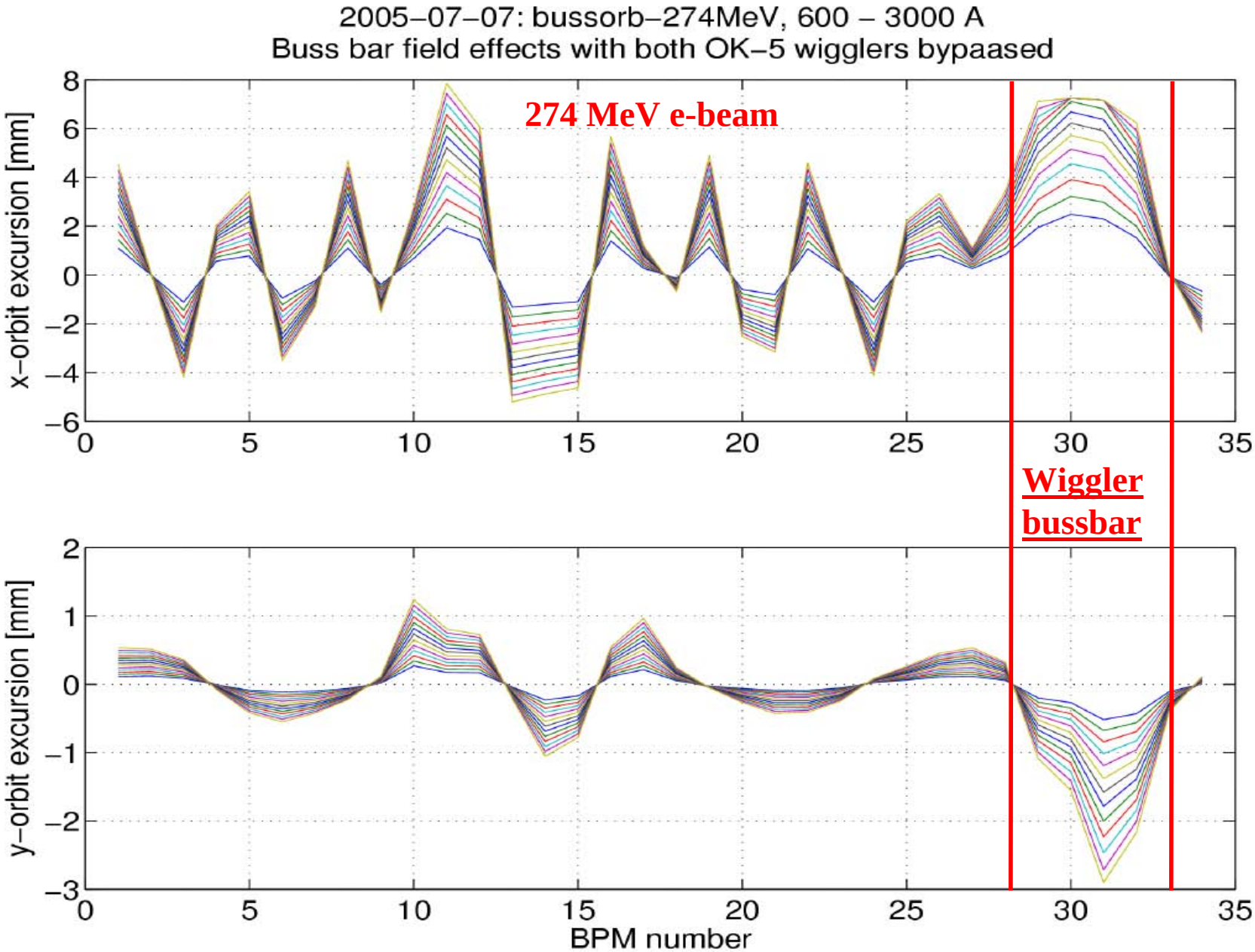
- Study dynamics impacts of OK-5 wigglers
- Retain OK-4 FEL as the user light source
- Commission main part of OK-5 magnetic optics
- Commission the OK-5 FEL with two wigglers
- Study operation of OK-4 and OK-5 together



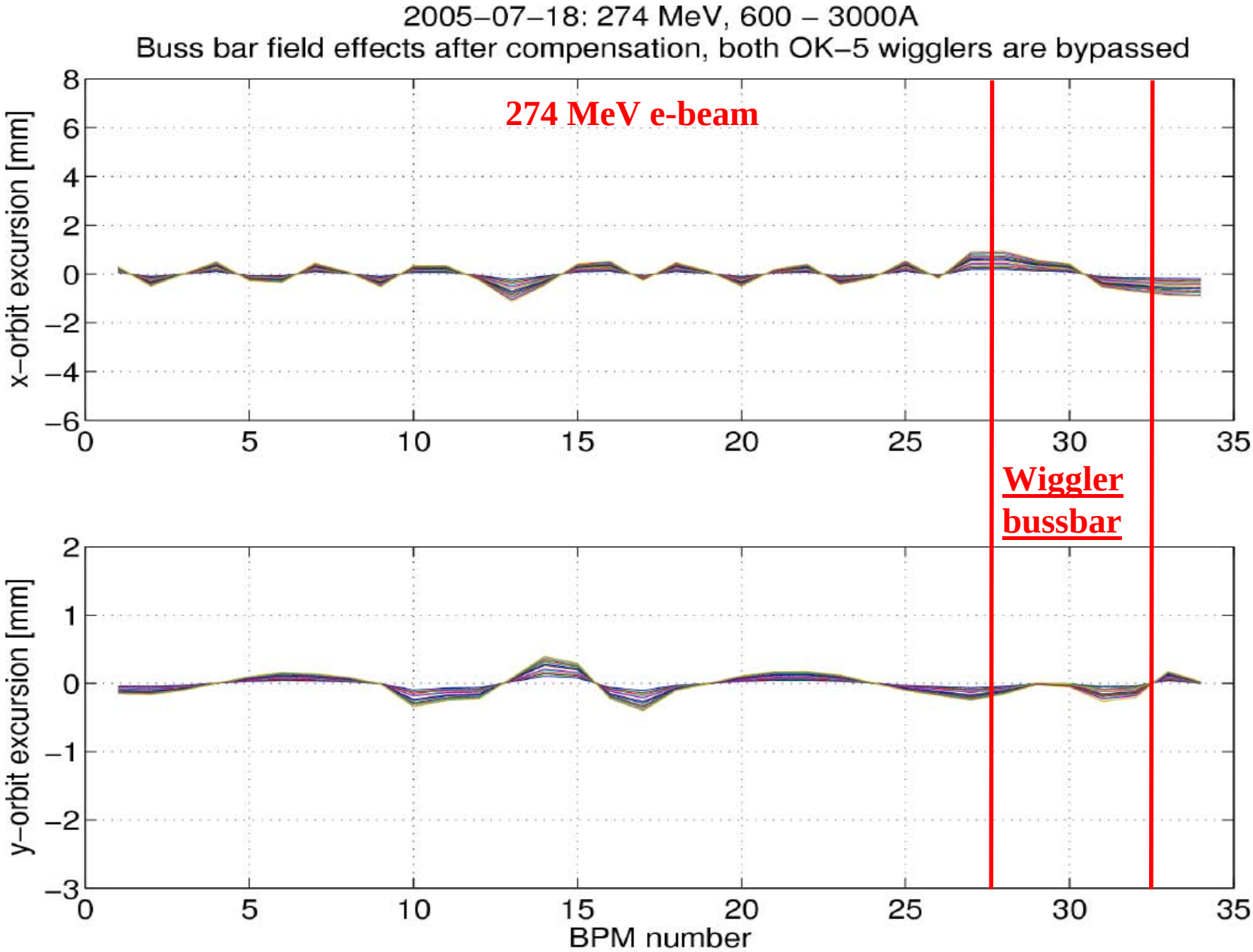
OK-5 Wiggler Installation



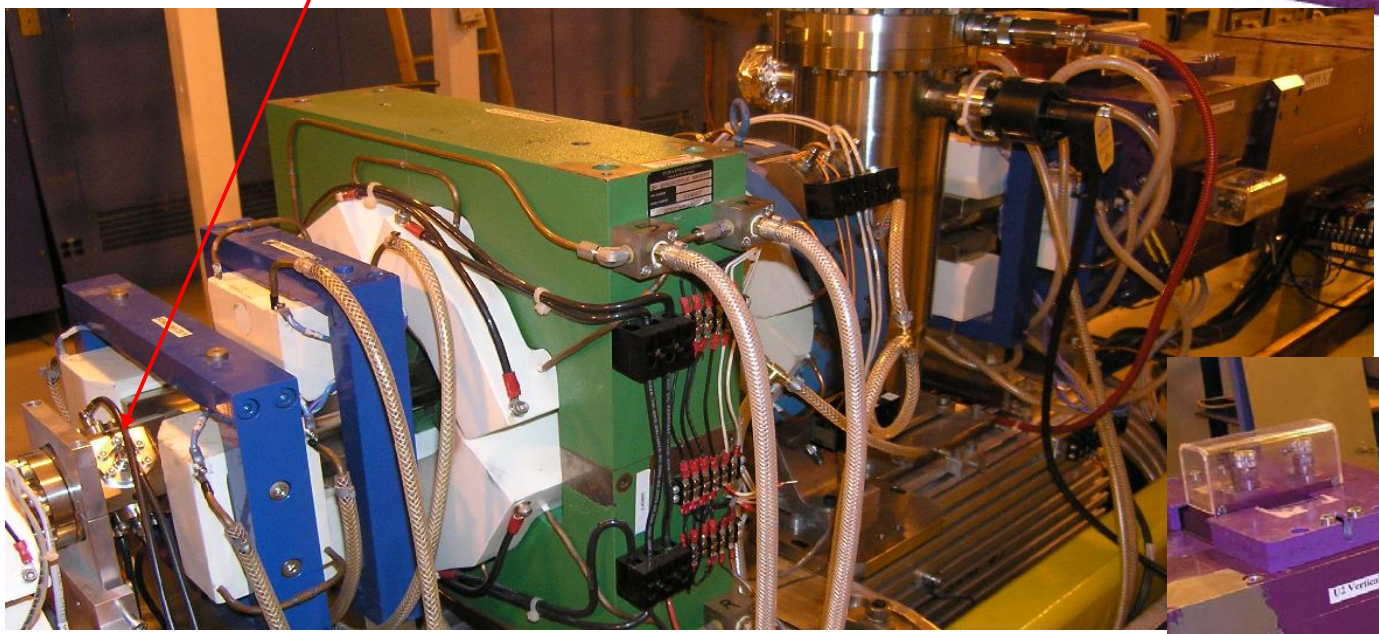
Bassbar Impact on Beam Orbit

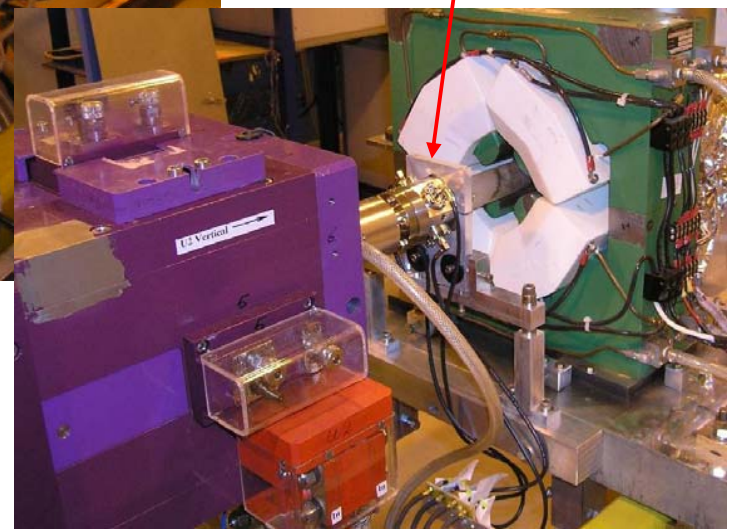


Bassbar Impact on Beam Orbit

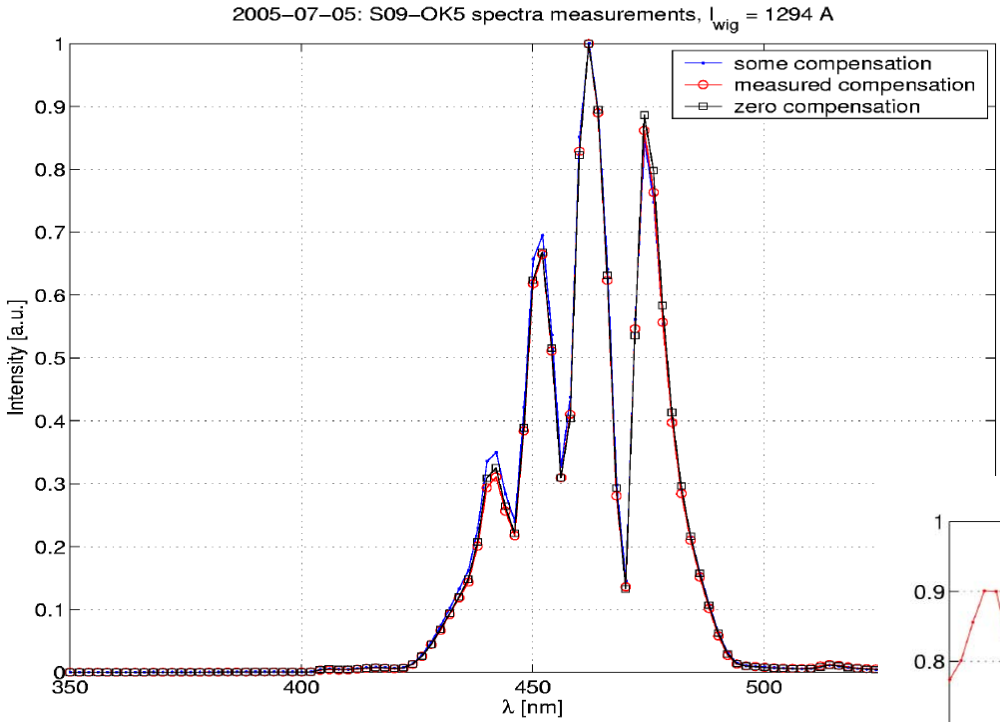


Limited Beam Diagnostics Capabilities



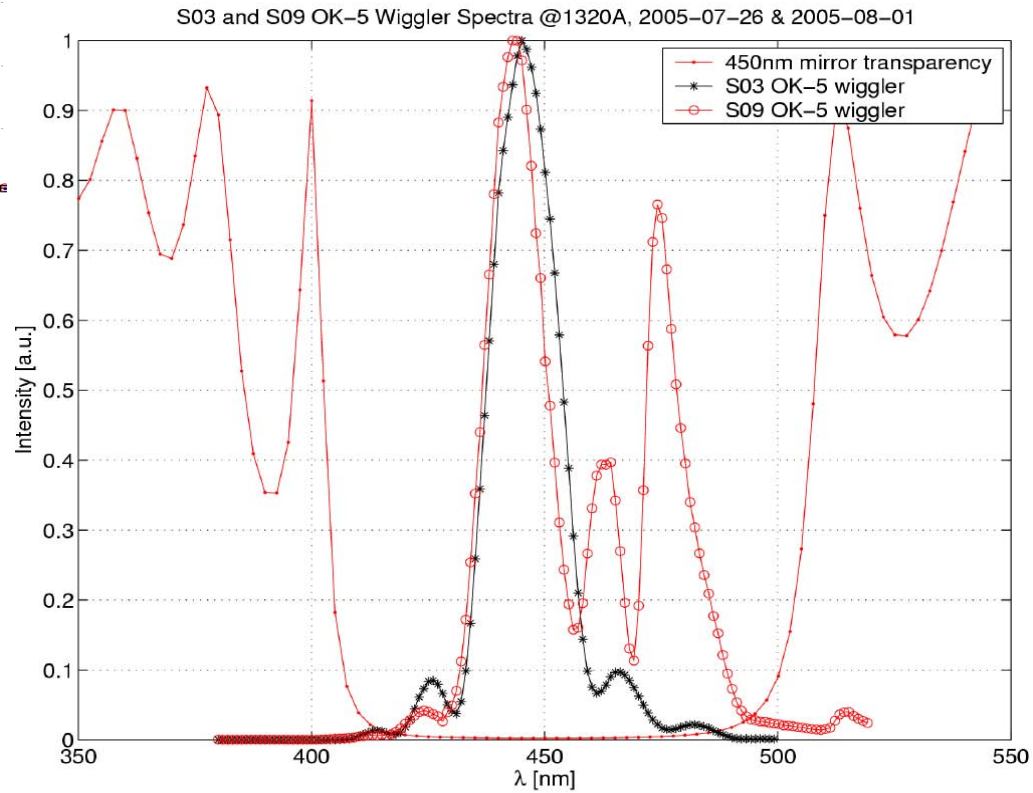


Spectra Improvement for OK-5 Wigglers (Horizontal Polarization)

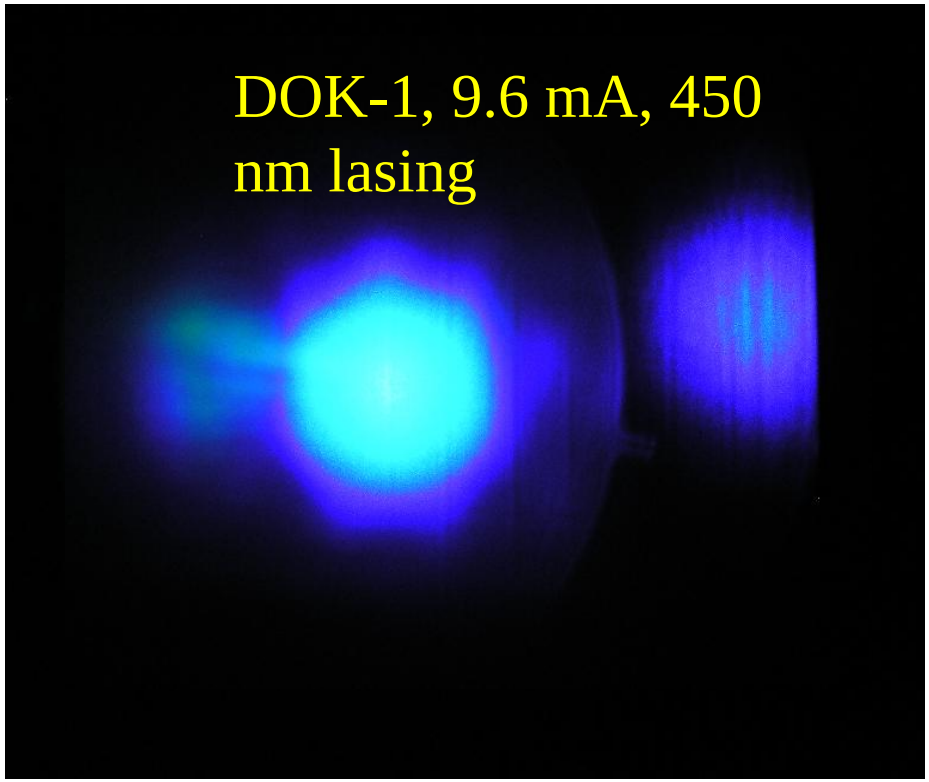


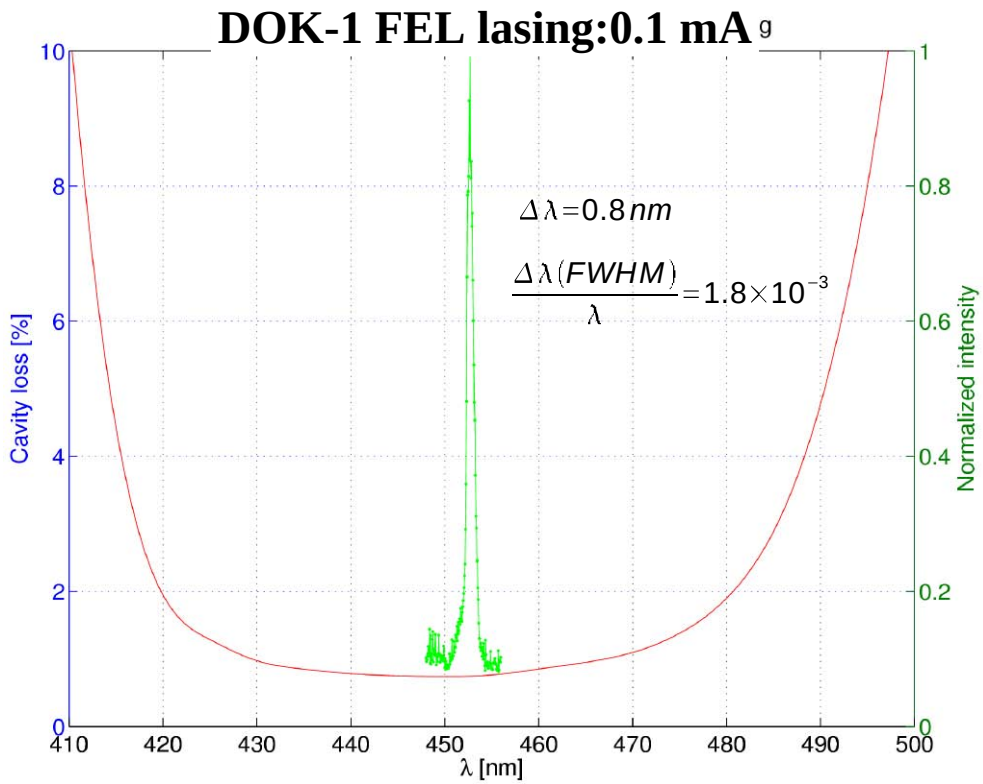
Before orbit correction:
Two wigglers together

After orbit correction:
individual wigglers



DOK-1: No Lasing vs Lasing (450 MeV)





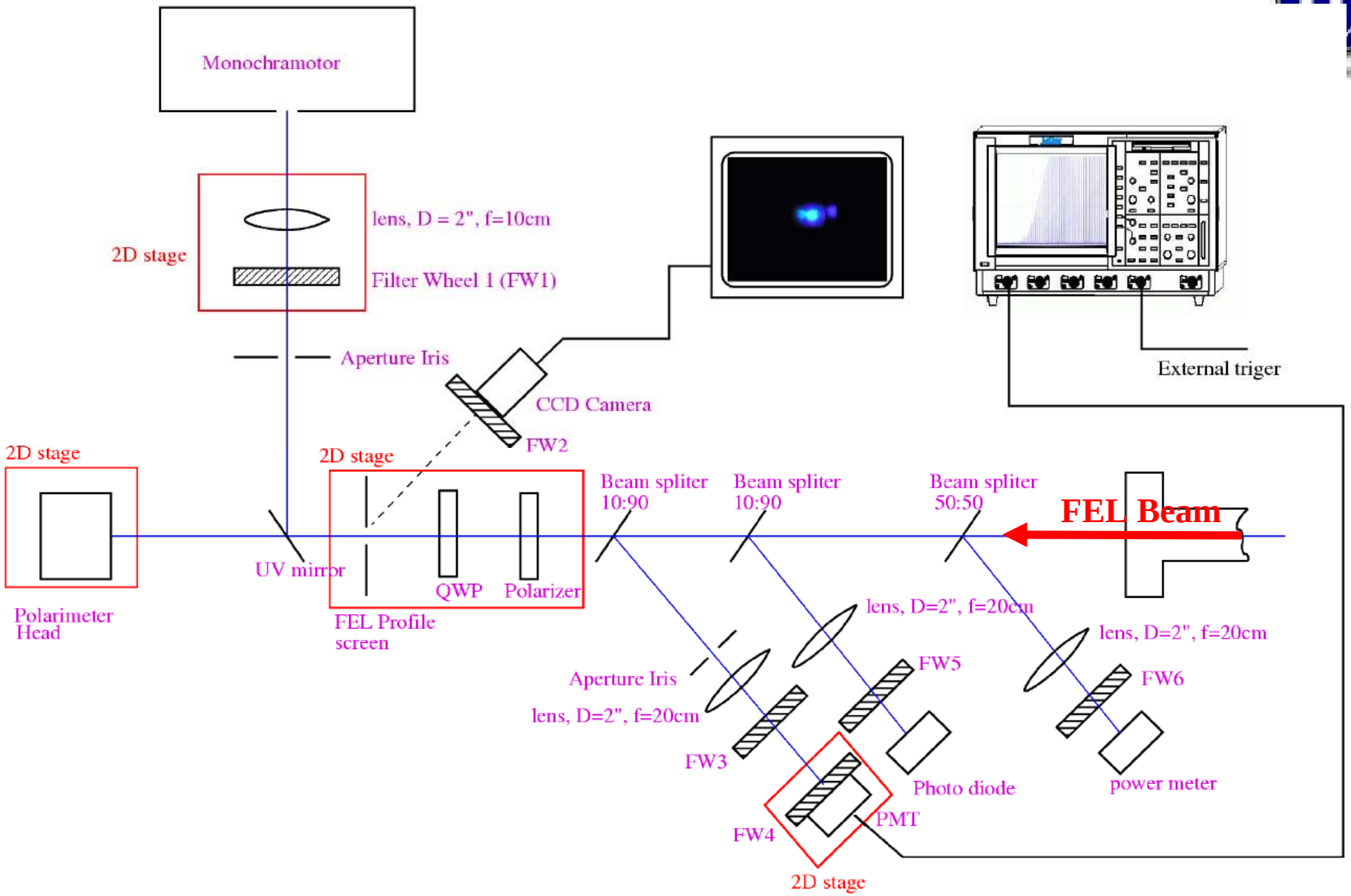
DOK-1 FEL (Mixed Polarization):

two circular (OK-5) wigglers

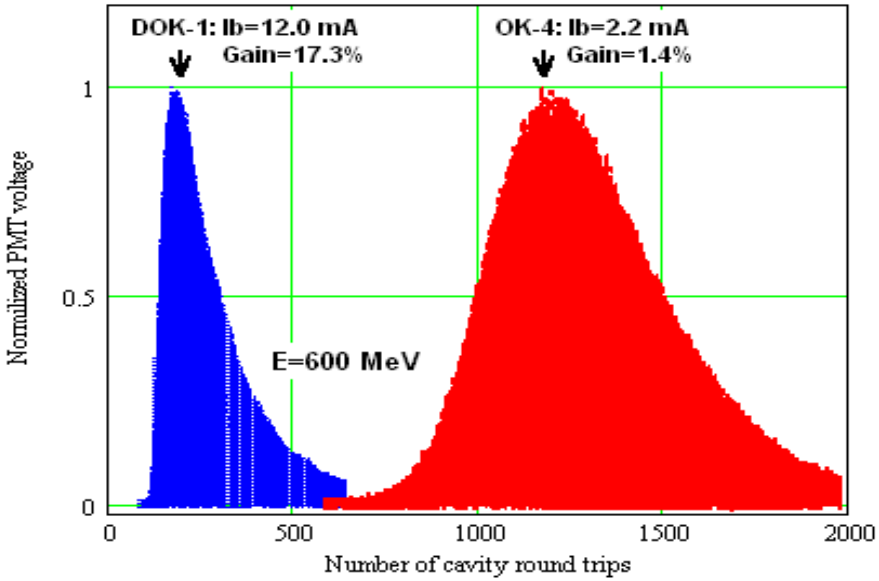
+

two horizontal (OK-4) wigglers

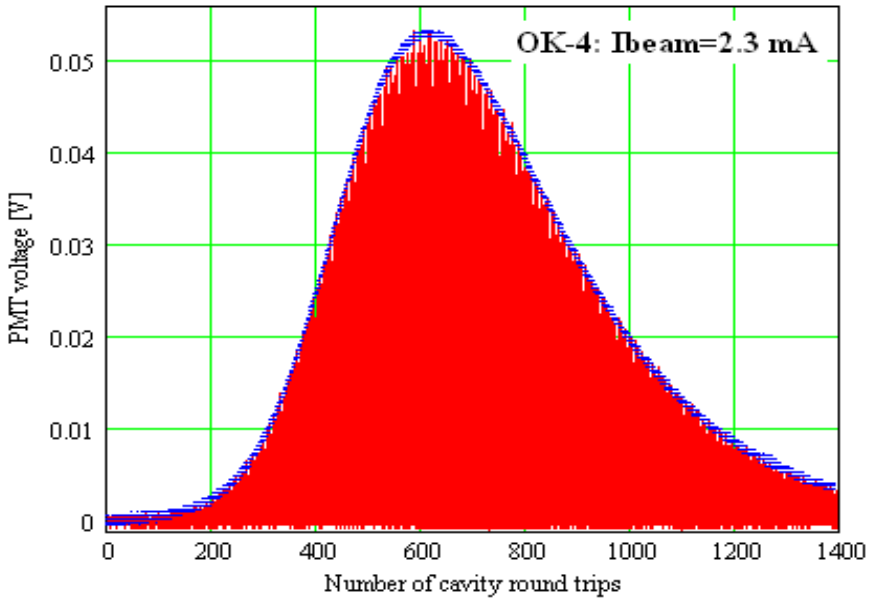
FEL Measurement Setup

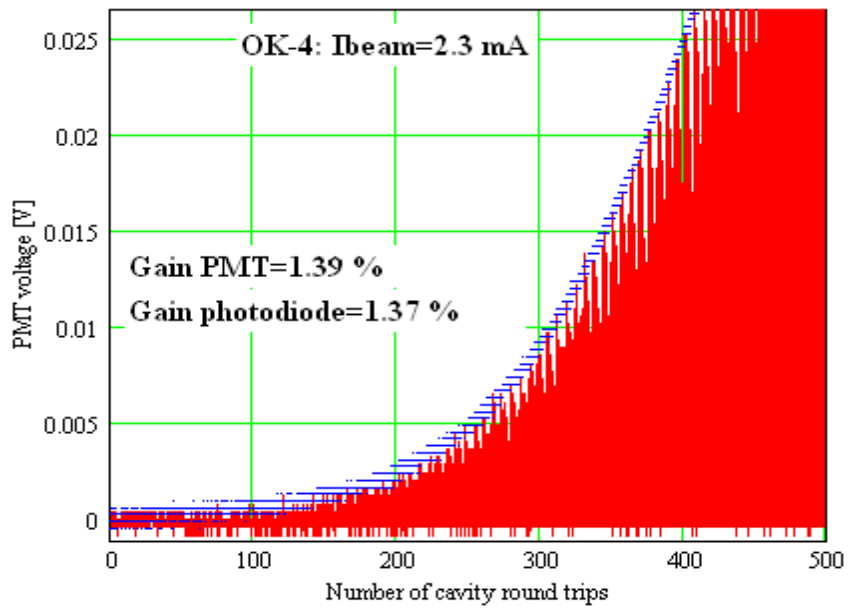


Giant Pulse Operation (G-Switch Operation)

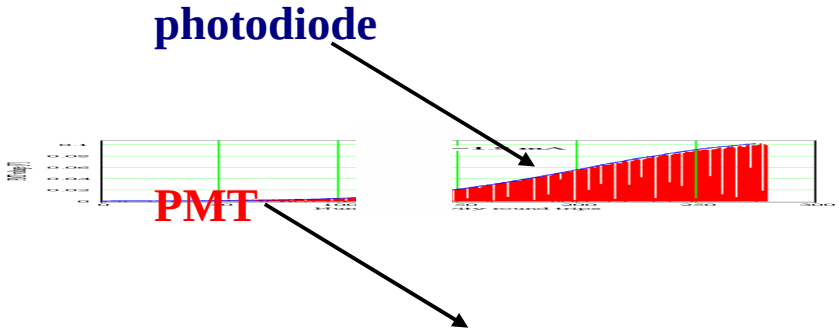


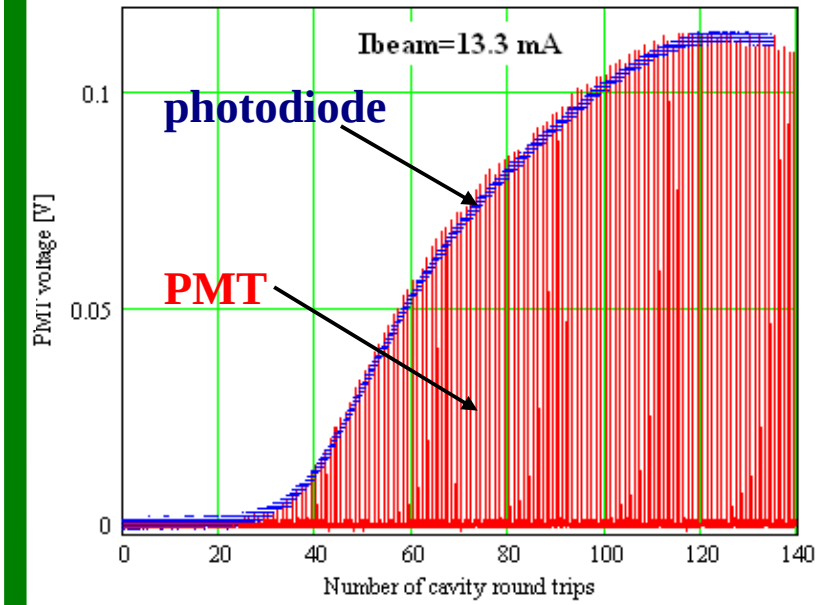
T= 0.36 μs

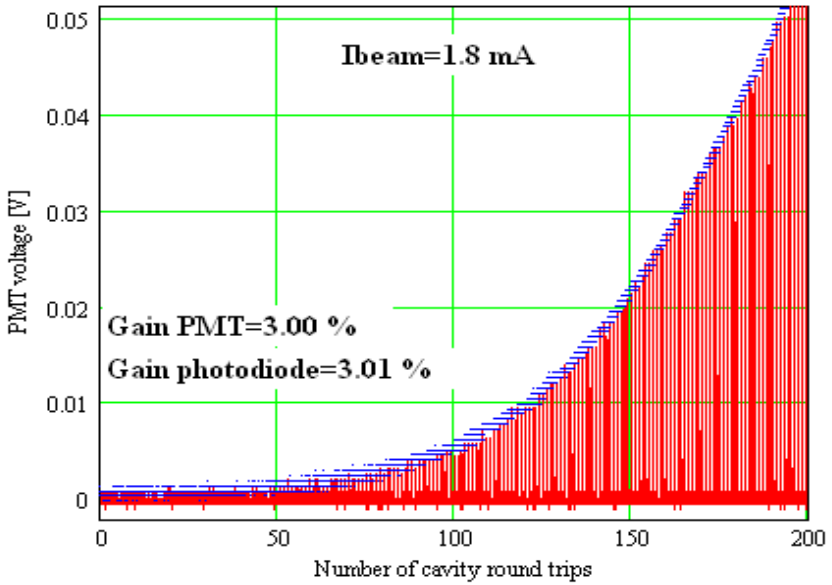


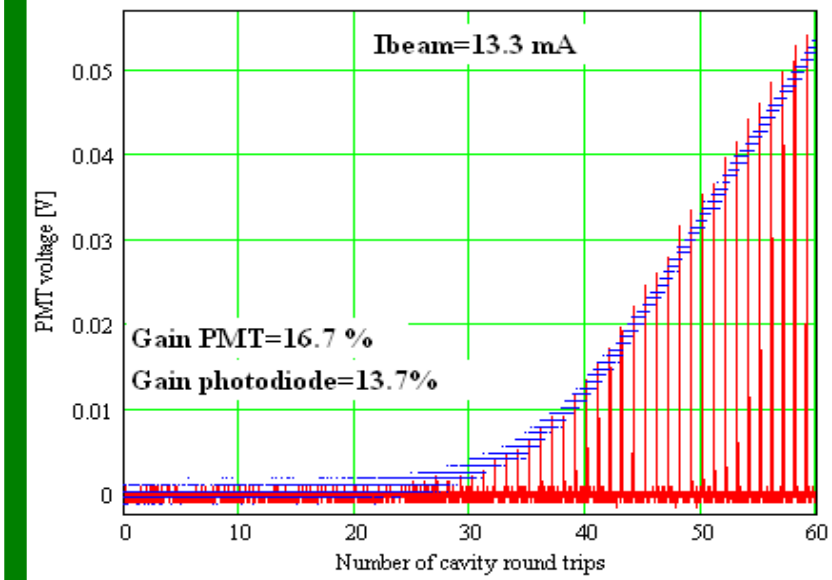


PMT vs Photo-diode



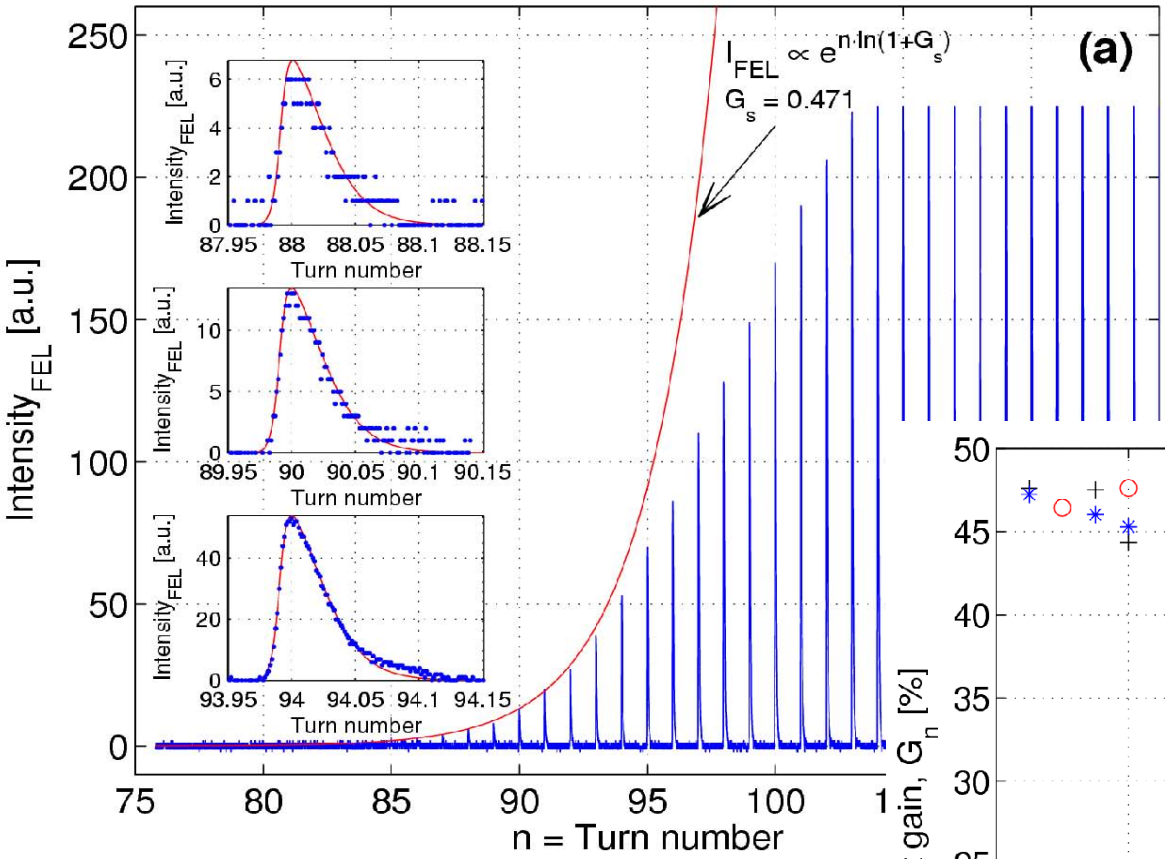




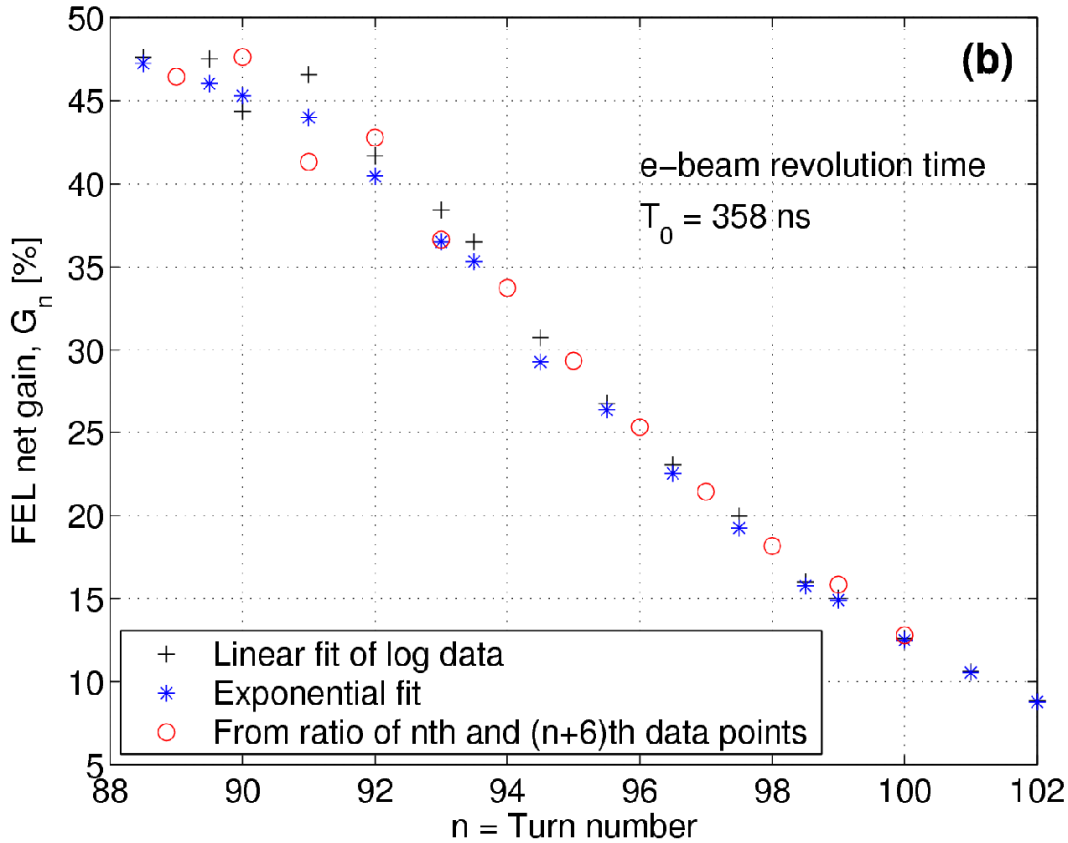


Note: zeroth round-trip time is arbitrary and different in two sets of plots

DOK-1 FEL Gain Measurement



V. N. Litvinenko, *High gain distributed optical klystron*, NIMA 304, 1991

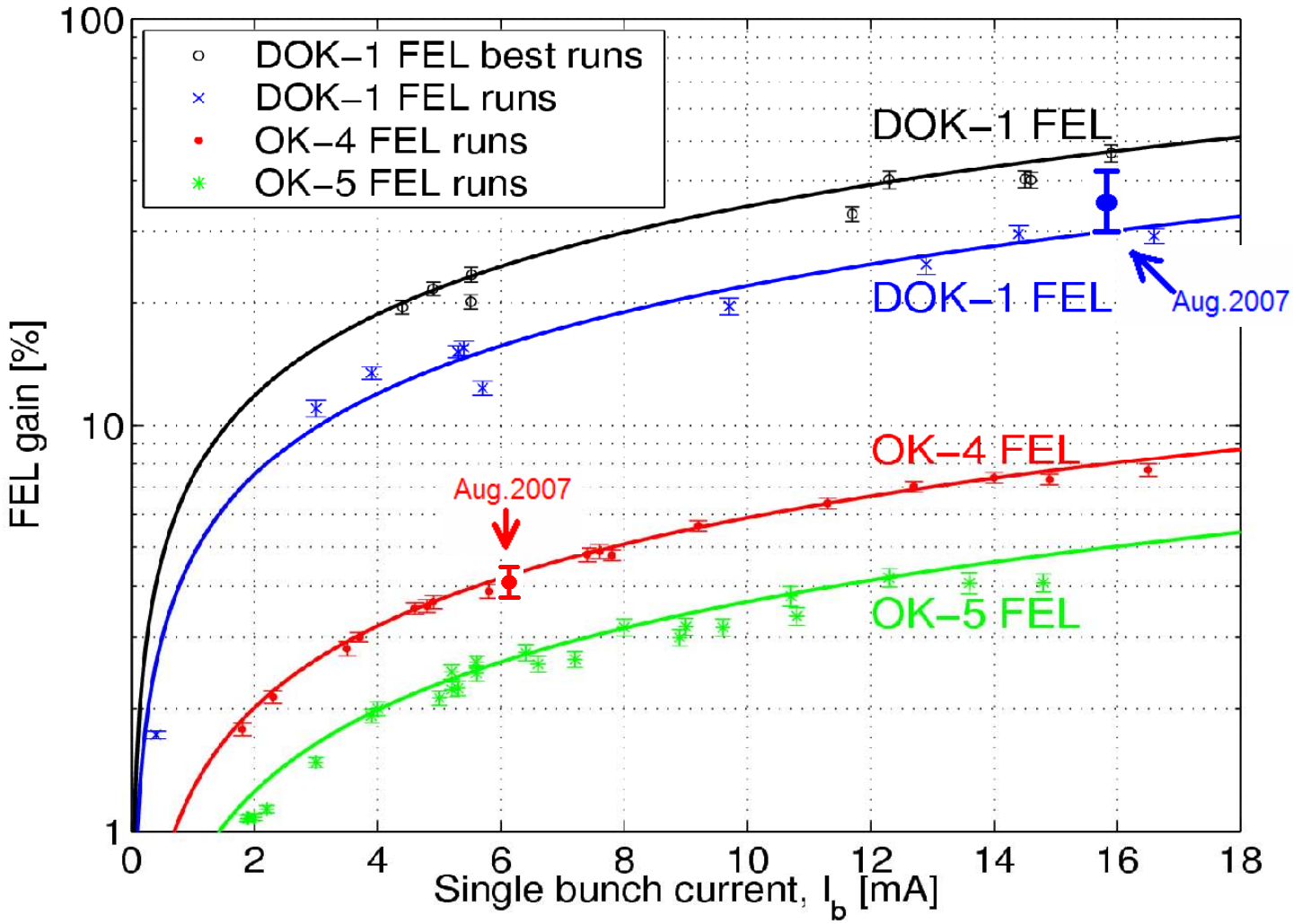


Max differential gain: 47.8% (+/-2.7%) with 16 mA of bunch current

Peak current: ~29 A

Energy spread (σ_E/E): ~1.4e-3

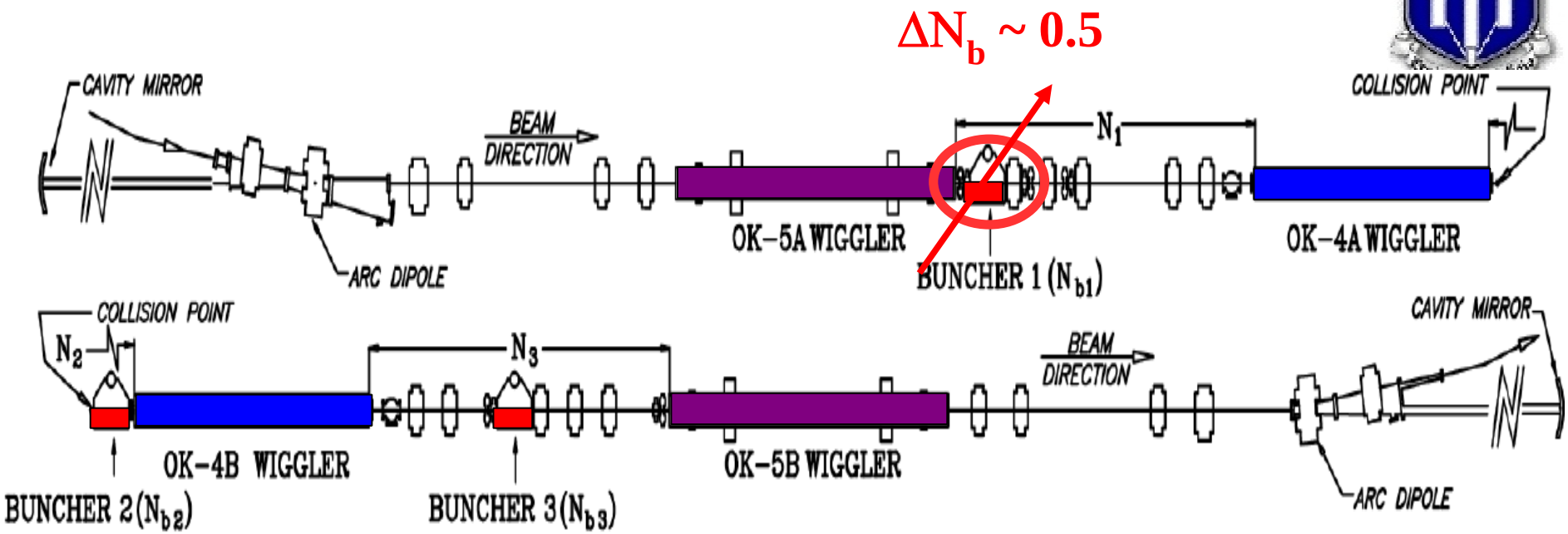
OK-4, OK-5, DOK-1 FEL Gain vs Beam Current



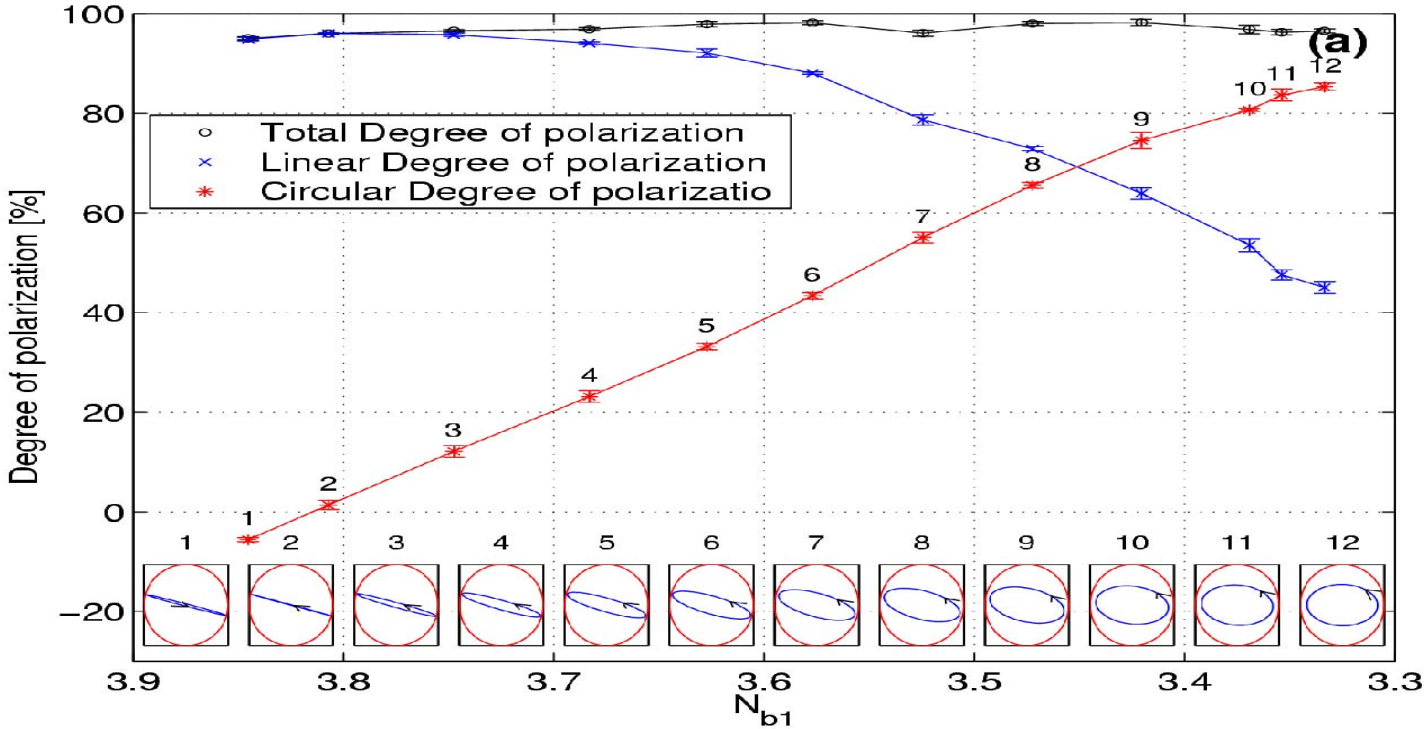
- **Microwave instability region: Gain ~ $I_b^{2/3}$**

- **DOK-1 gain ~2.2-2.3 times OK-4 gain + OK-5 gain**

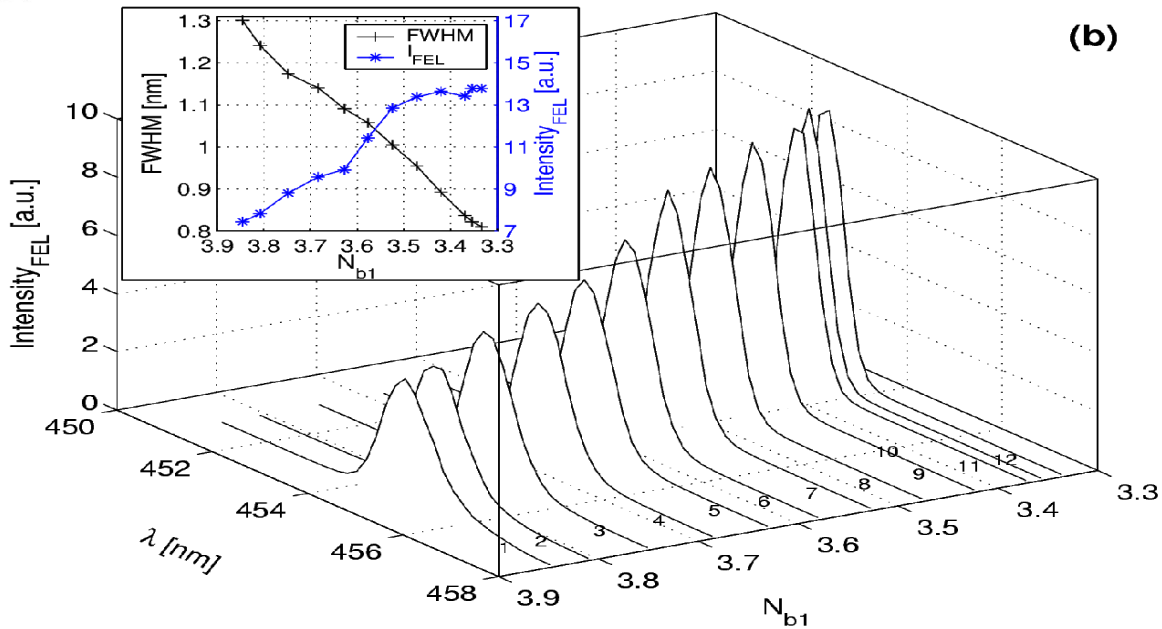
Switching FEL Polarization (One-Buncher Knob)



DOK-1 FEL Polarization Switch

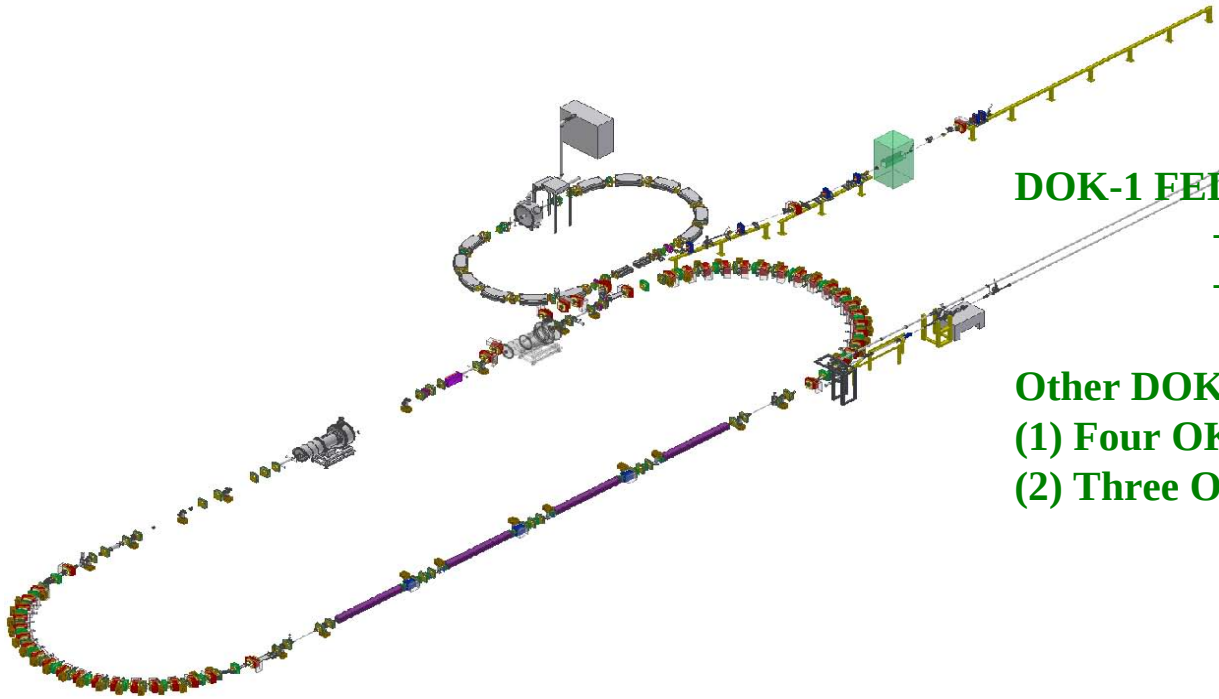


- N_{b1} changes by 0.52 (from 3.85 to 3.33)
- Linear Pol: 95% to 45%
- Circular Pol: -6% to 85%
- Wavelength, λ, 455 to 453 nm
- Δλ, 1.30 nm to 0.81 nm
- Power increased by a factor of two



Kwang-Je Kim, *Circular polarization with crossed-planar undulators in high-gain FELs*, NIMA 445, 2000

Versatility of DOK FELs



DOK-1 FEL = Two OK-5 wigglers
+ Two OK-4 wigglers
+ Three bunchers

Other DOK FEL configurations:
(1) Four OK-5 wigglers + Three bunchers
(2) Three OK-5 wigglers + Two bunchers

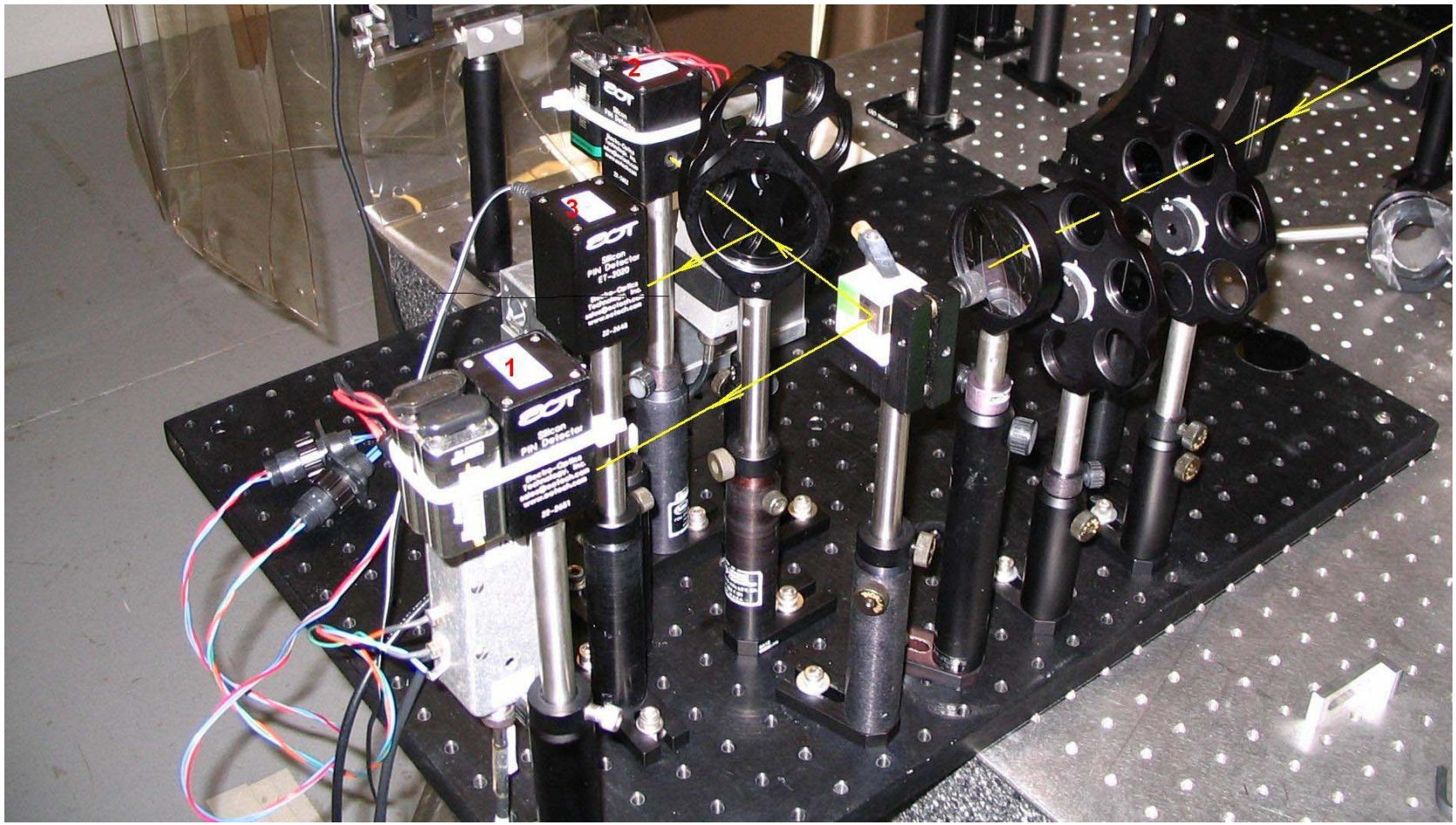
- **Versatility of DOK FELs on Duke Storage Ring**
  - **High power VUV operation below 190 nm**
  - **VUV coherent harmonic generation: 3-wiggler DOK-FEL + harmonic wiggler**
  - **UV-VUV FEL with fast switchable left/right circular polarizations**
  - **Driver for the High-Intensity-Gamma-ray Source (HIGS)**
  - **Exciting facility for FEL research**

Summary

- Demonstrated New Capabilities of DOK-1 FEL
  - Highest FEL gain among storage ring based FELs
- Key thrusts for Duke FEL research in the near future
  - VUV FEL operation below 190 nm for user programs
  - Coherent VUV harmonics generation driven by DOK-FEL
  - Wide – range wavelength tuneability with broadband mirrors
  - FEL mirror research:
    - ❖High extracted power operation: > 1W in UV (single bunch)
    - ❖Improving lifetime of UV/VUV mirrors

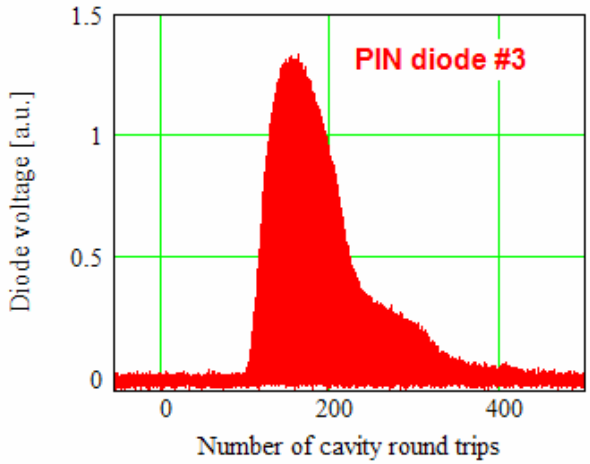
New Three Stage set-up for the Loss/Gain Measurement

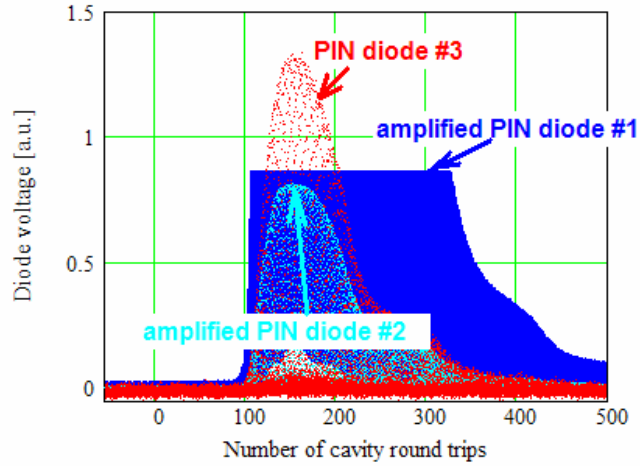
- Three (or more if needed) fast PIN diodes (τ_{pulse}~3 nS)
- Two (or more if needed) splitters and filter wheels
- Two (or more if needed) broad band (>20 MHz) low noise amplifiers

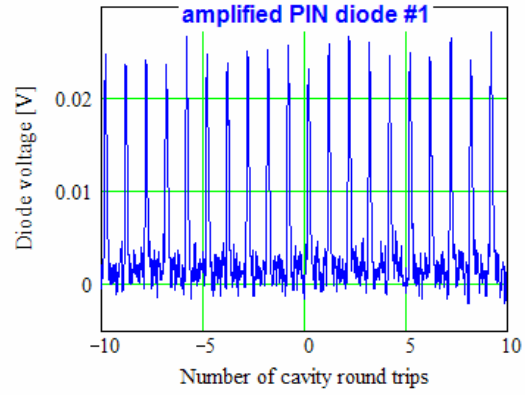


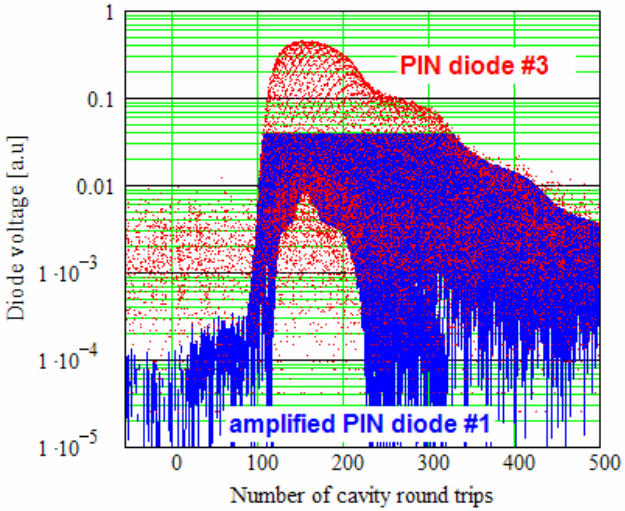
DOK-1 Gain Measurement, Aug.2007

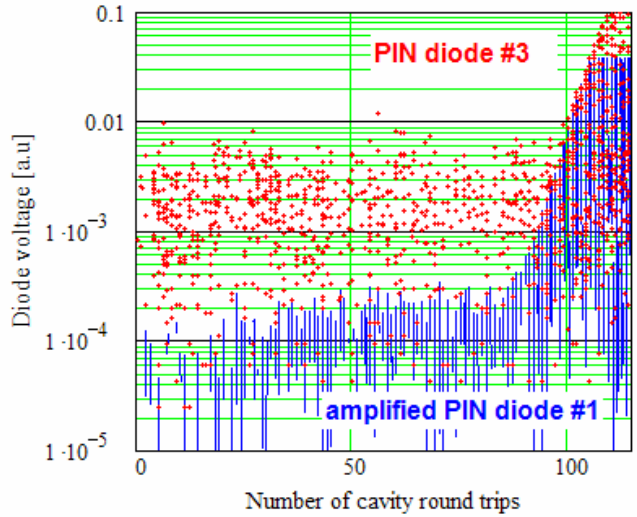
E_{beam}=600MeV; I_{bunch}=15.7mA; λ=383nm; Gain=33±5%

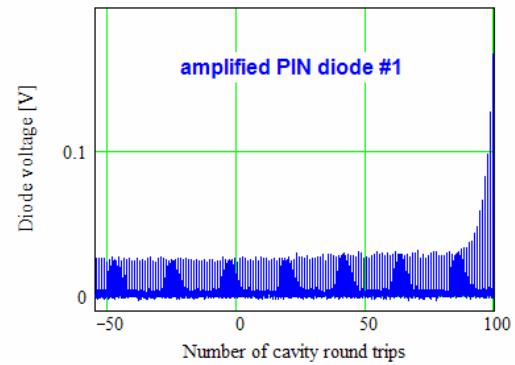












Note: zero-th round-trip time coincides with start-up of the gain modulator pulse

DOK-1 FEL Lasing