Second Harmonic Lasing with Duke OK-4 FEL

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Acknowledgments

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Outline

Can planar wigglers emit second harmonic radiation on-axis?

- 2nd harmonic lasing with Jlab FEL
- Synchrotron radiation power

Second harmonic lasing with Duke OK-4 optical klystron FEL

- Layout of the Duke storage ring and OK-4 FEL
- Second harmonic lasing
- Search for lasing mechanisms

2^{nd} Harmonic Lasing with Jlab FEL

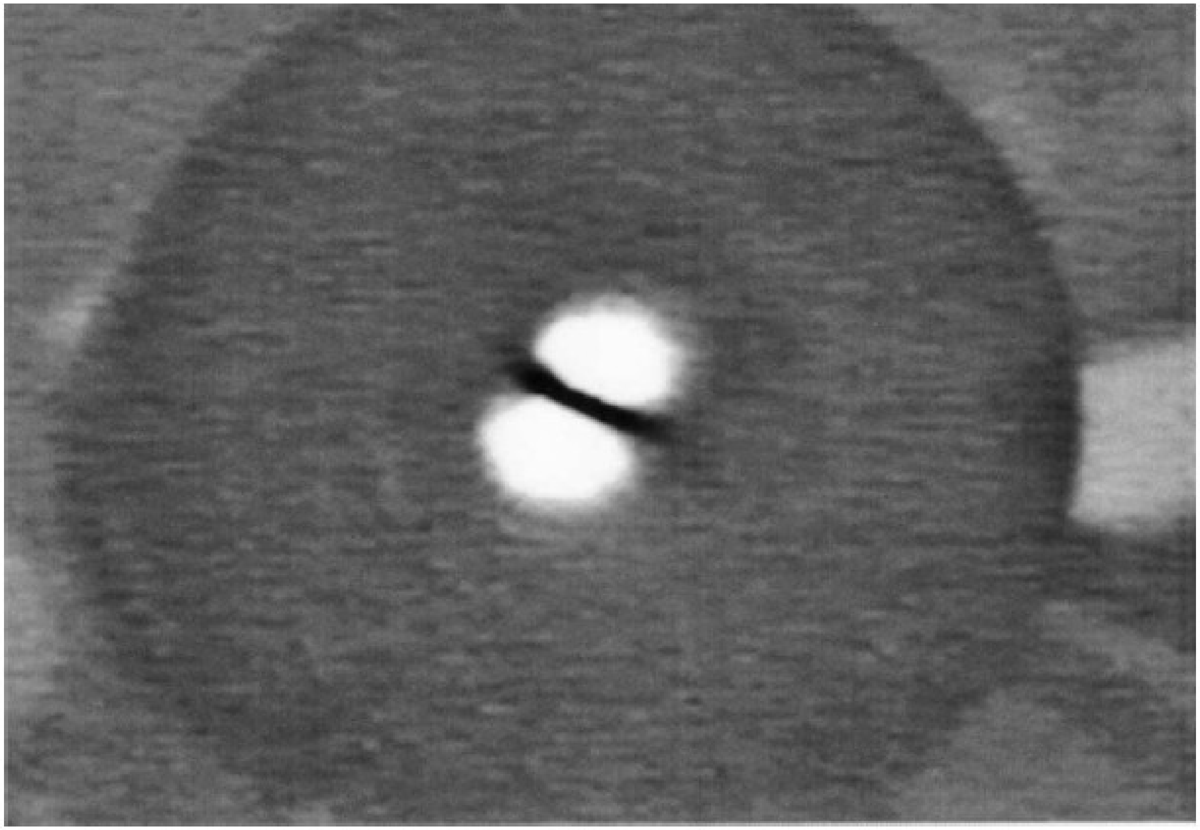


FIG. 4. Infrared impinging on the optical beam dump showing the second harmonic TEM_{01} mode. The image is tilted due to relative misalignments in the system with perhaps additional contributions from coupling due to misalignment in our optical collimator.

G. Neil, *et al*. Second Harmonic FEL Oscillation, PRL, v87, 084801 (2001)

Gain Mechanisms

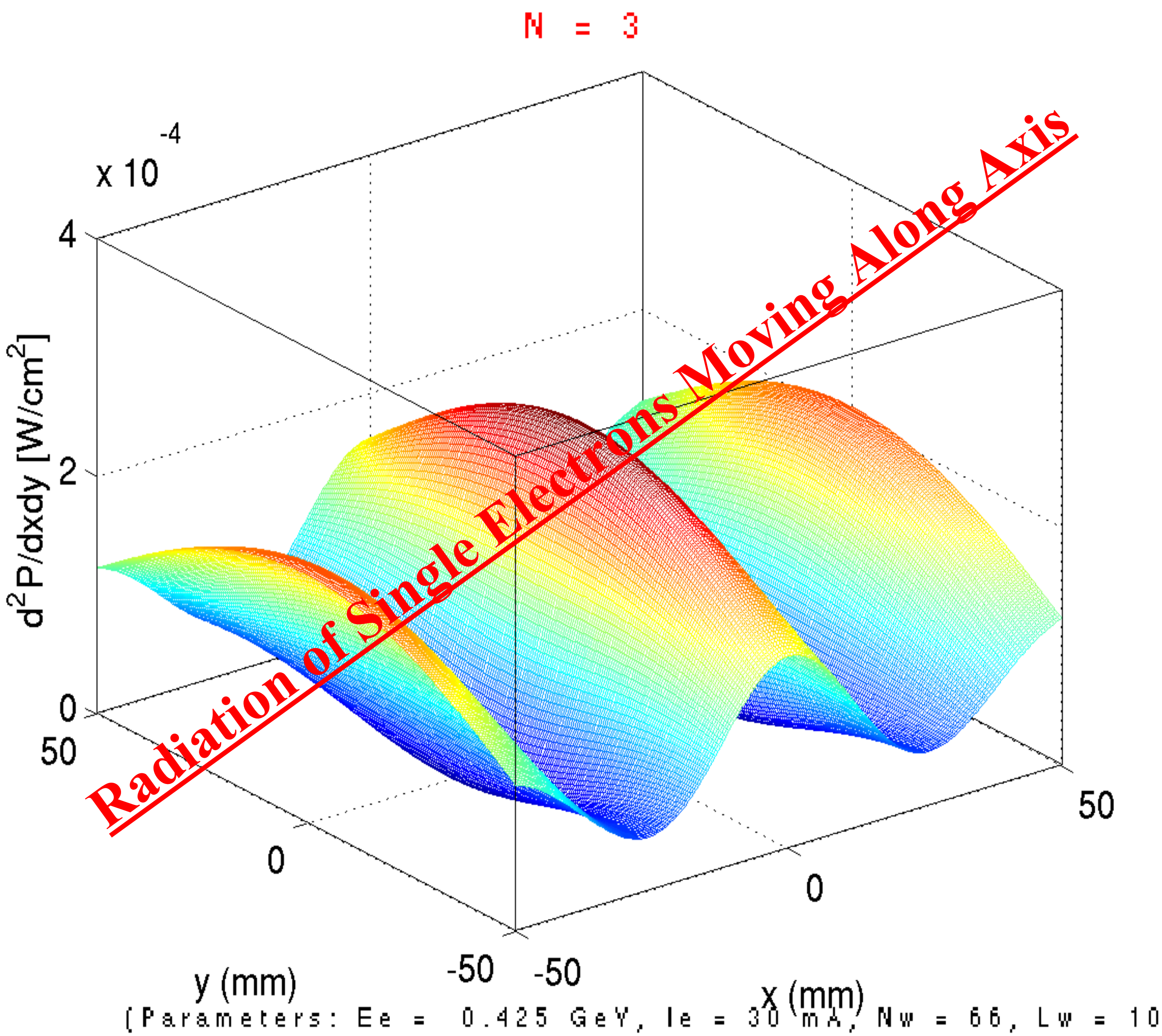
(M. Xie, NIMA, 483, p527 (2002))

- **Electron misalignmnet**
- **Field gradient**
- **Longitudinal coupling**

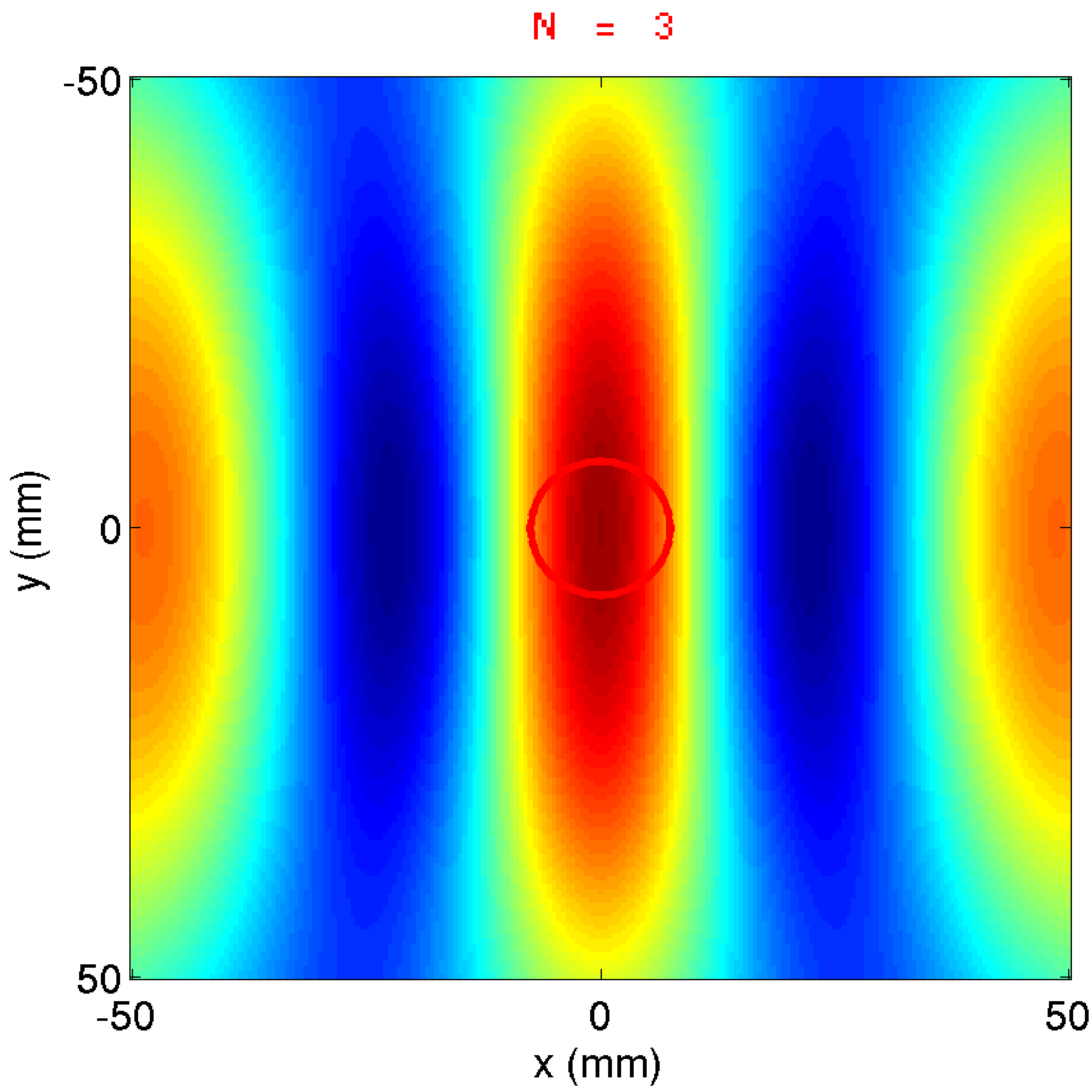
Jlab 2^{nd} Harmonic lasing

- **Antisymmetric resonator mode**
- **Misaligned e-beam orbit w.r.t. optical axis**

Wiggler Spontaneous Radiation into Harmonics



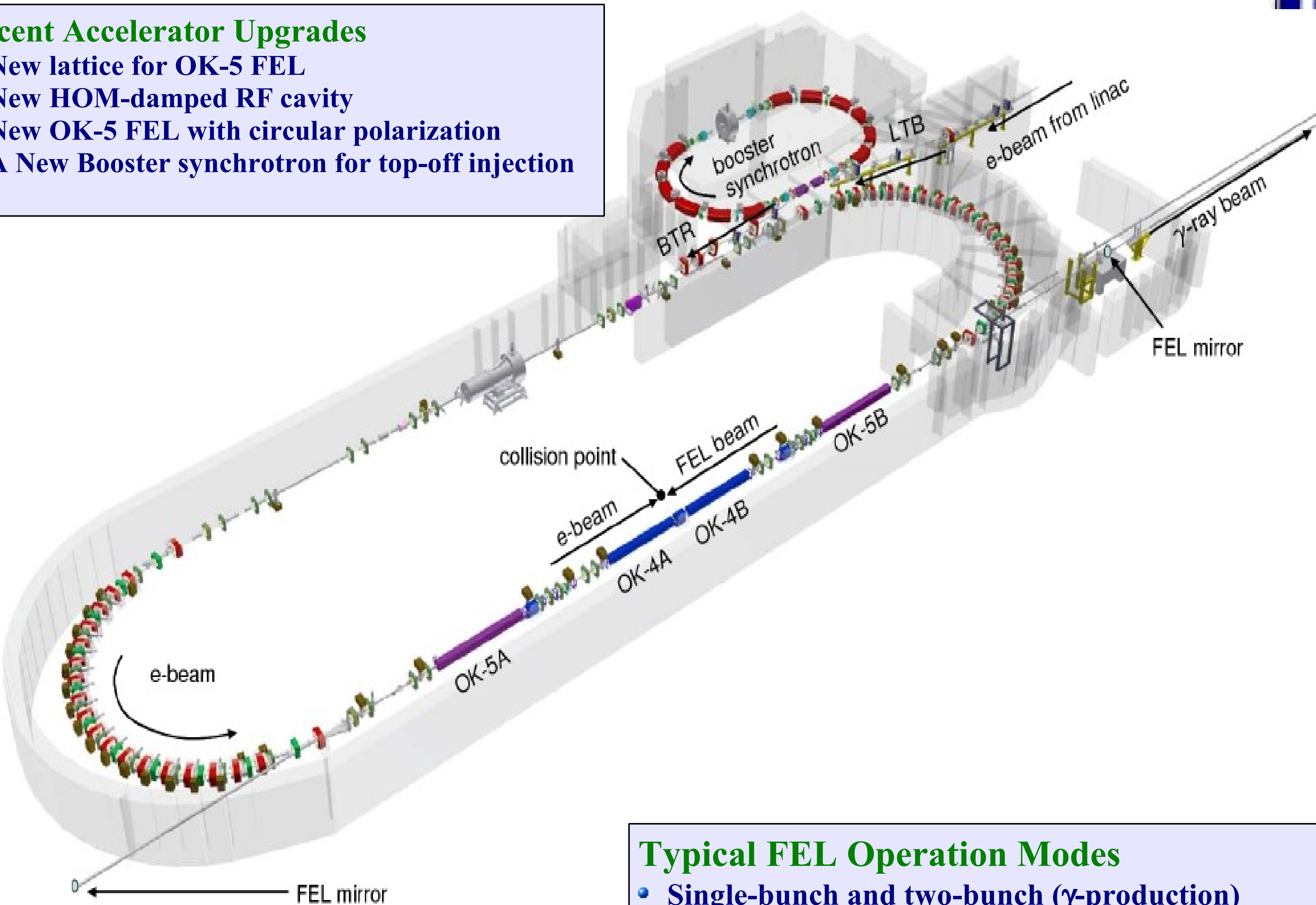
Wiggler Spontaneous Radiation into Harmonics



Layout of the Duke FEL Lab Accelerator Facility

Recent Accelerator Upgrades

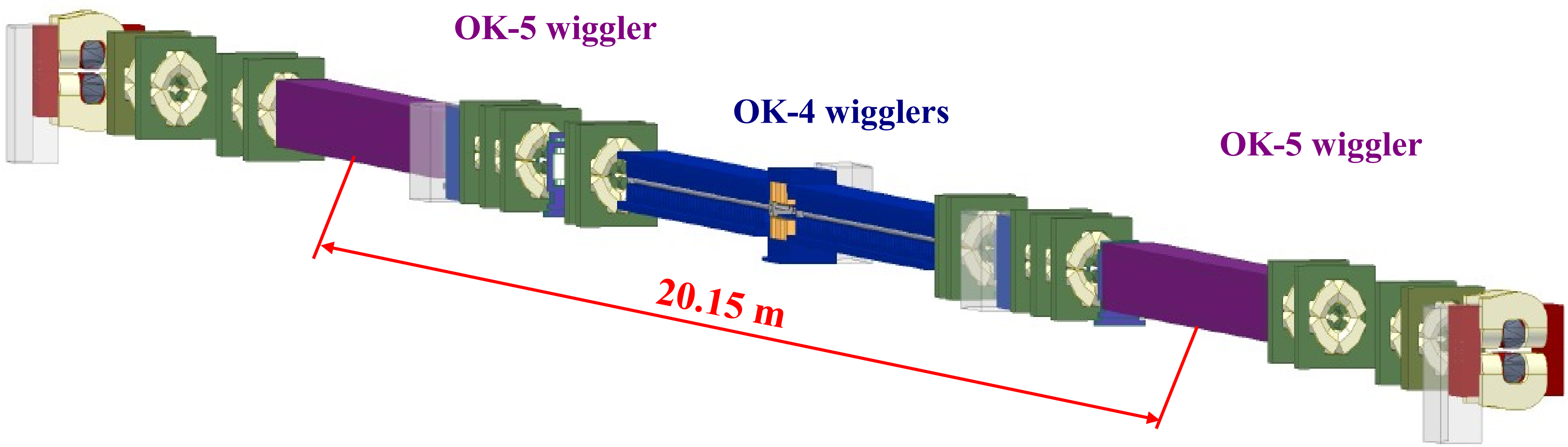
- New lattice for OK-5 FEL
- New HOM-damped RF cavity
- New OK-5 FEL with circular polarization
- A New Booster synchrotron for top-off injection



Typical FEL Operation Modes

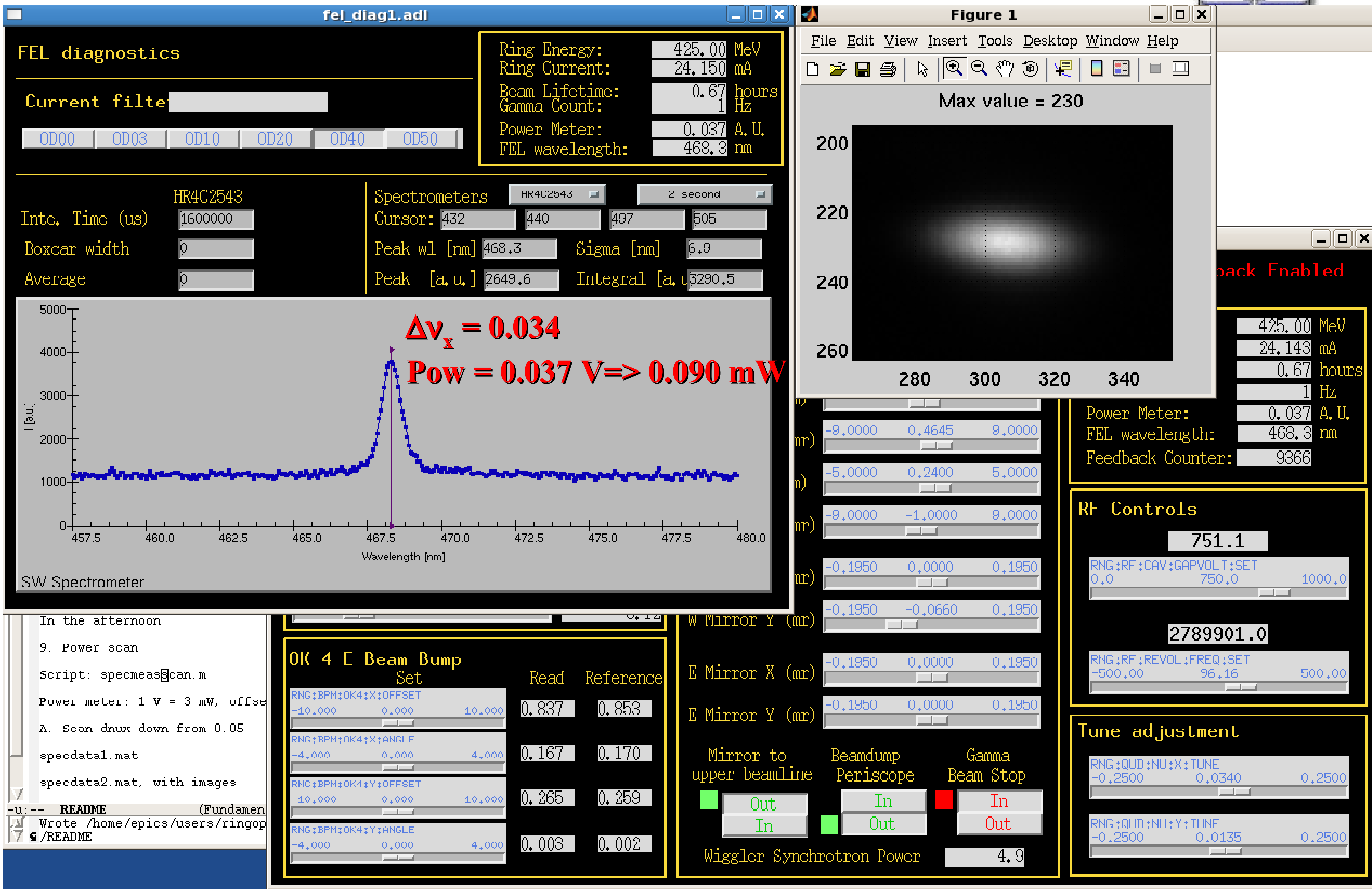
- Single-bunch and two-bunch (γ-production)
- High single-bunch current operation (up to 95 mA)

Layout of Duke FELs



Tune knobs: $d\nu_x$, $d\nu_y$

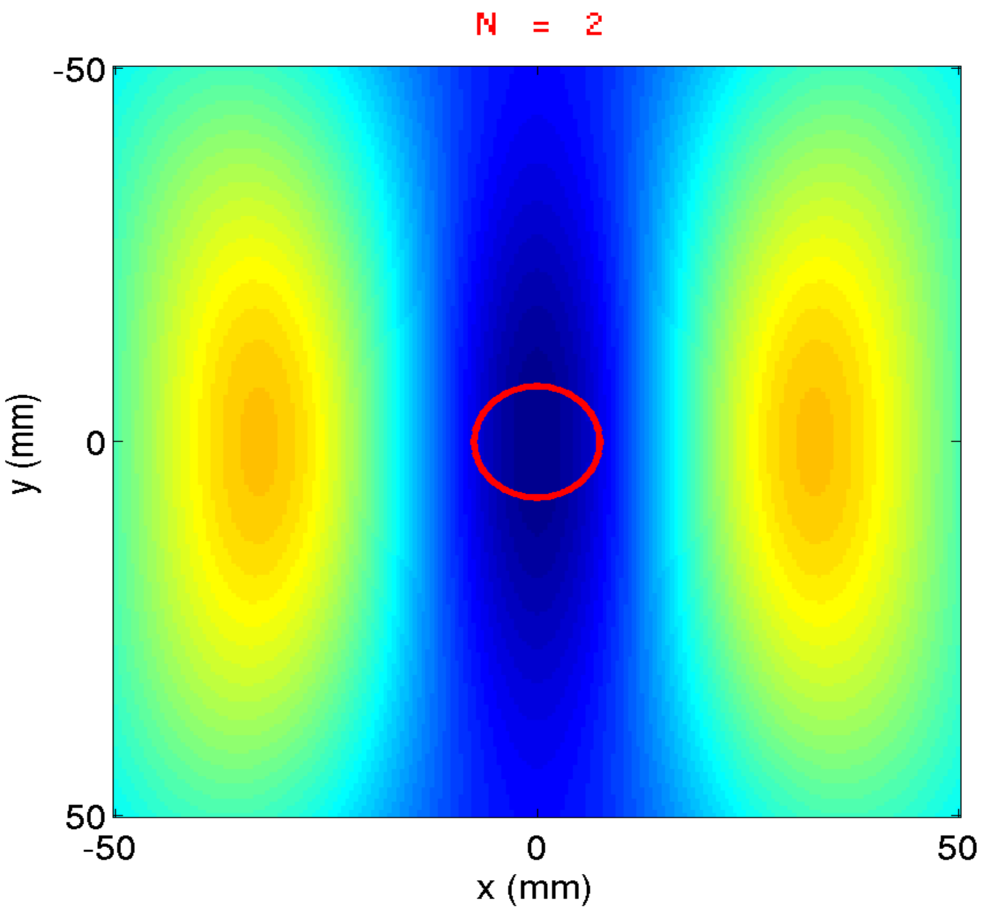
2nd Harmonic Lasing



2^{nd} Harmonic Lasing with Planar OK-4 Optical Klystron

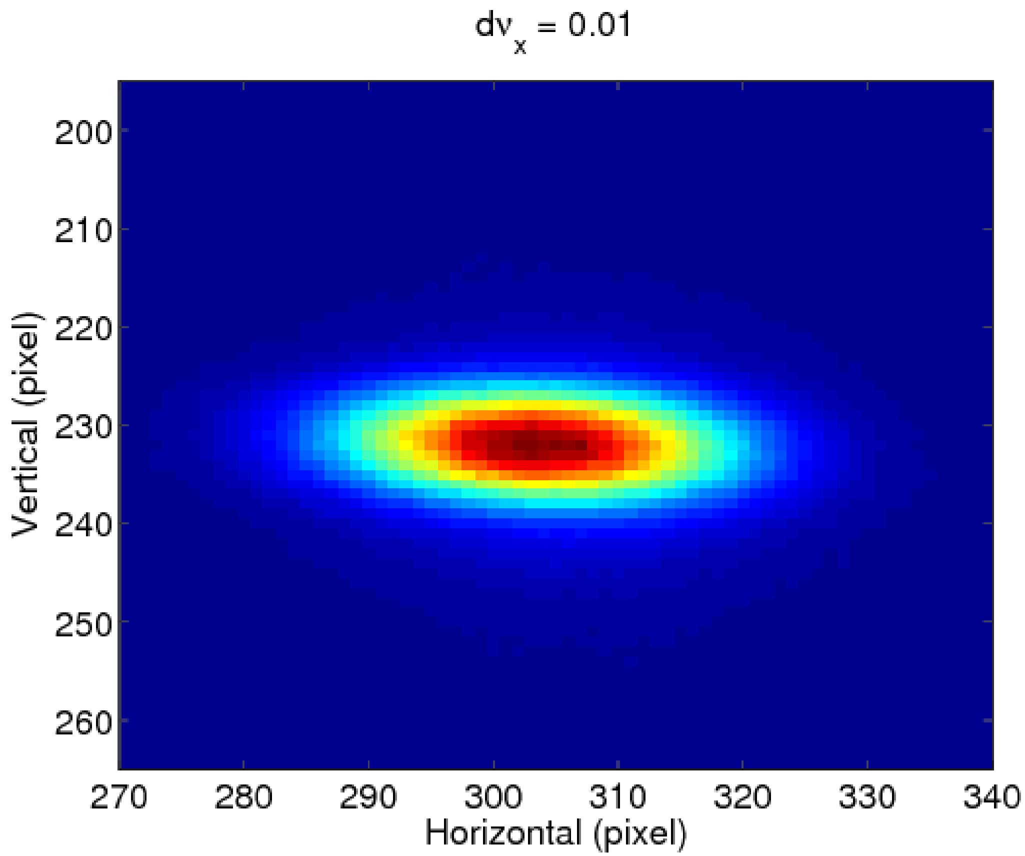
OK-4 Optical Klystron:

- Two planar wigglers sandwiching a buncher
- E-beam: 425 MeV
- Fundamental: ~934 nm
- High finesse optical cavity: with high reflectivity mirrors in 465 – 472 nm
- Resonator length: 53.73 m

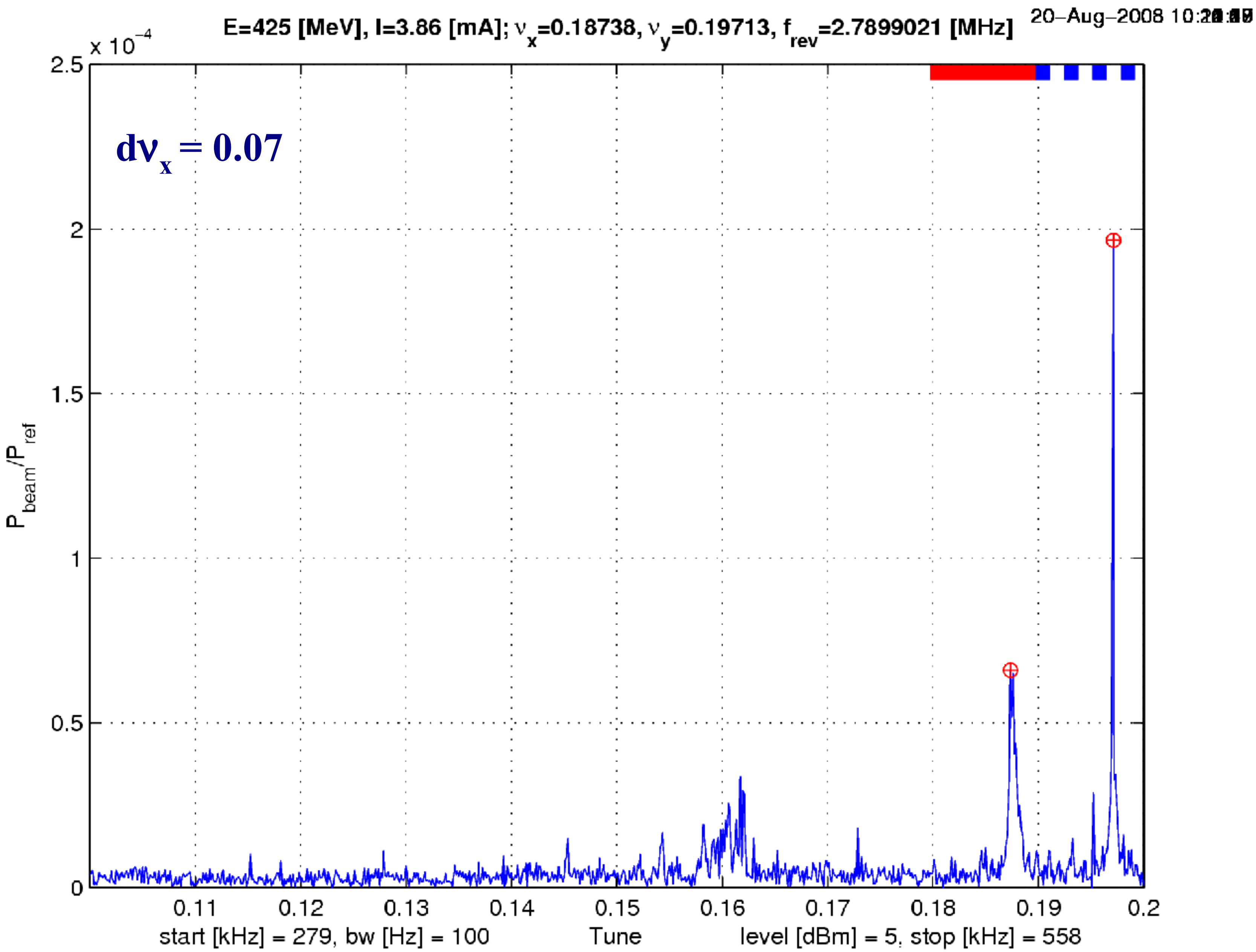


2nd Harmonic Lasing with Planar OK-4 Optical Klystron

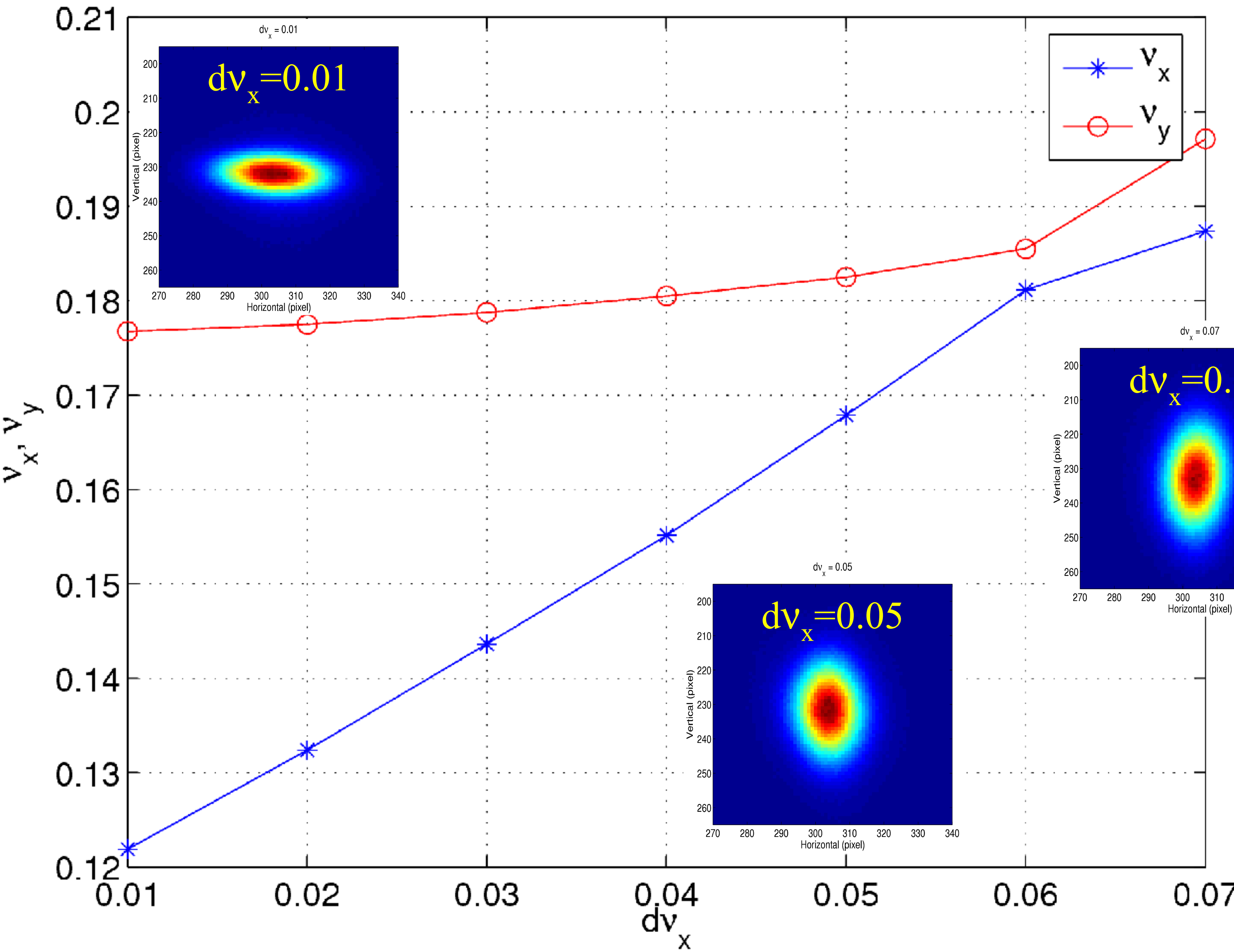
E-Beam Images While Tuning Toward Coupling Resonance



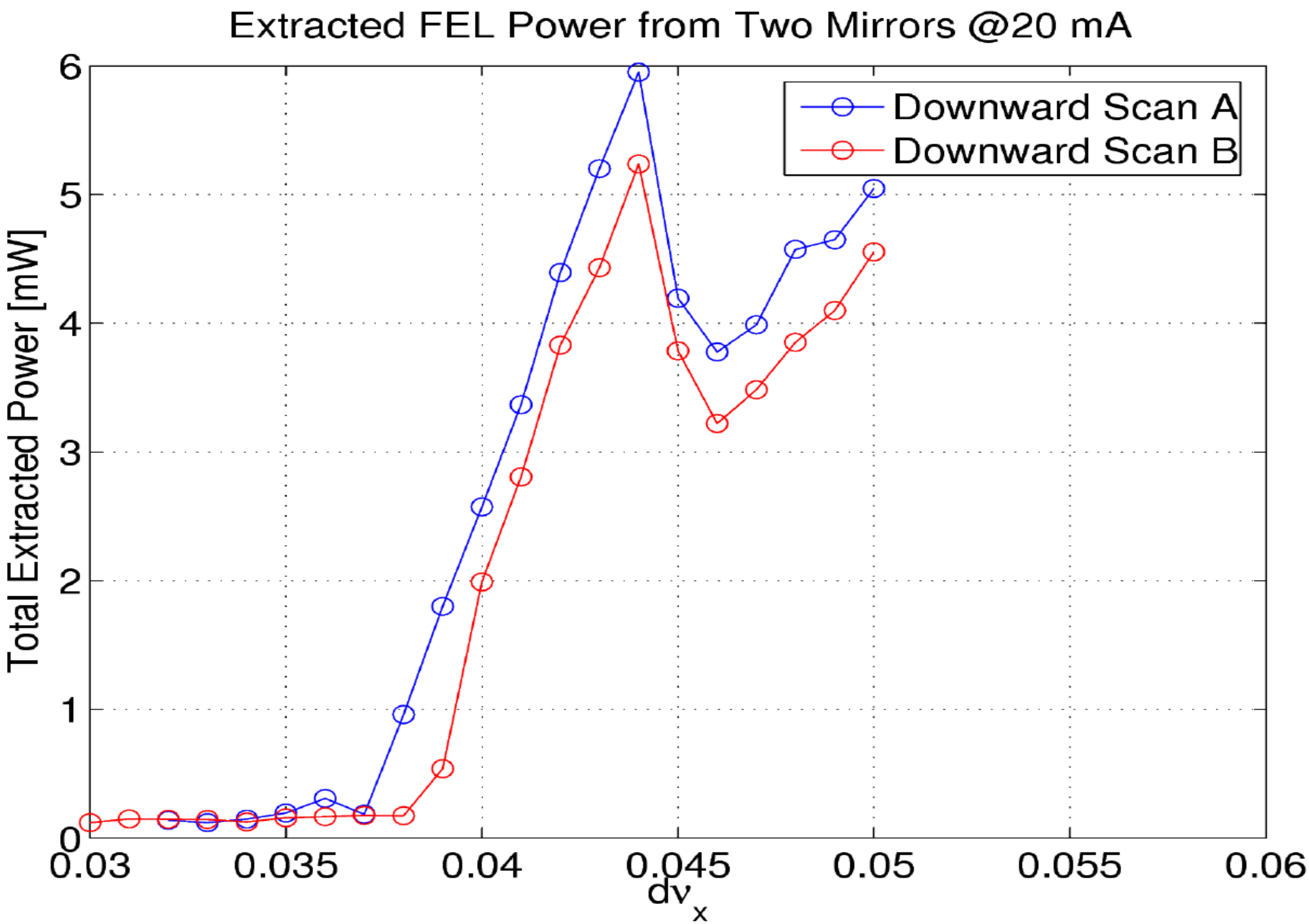
Betatron Tunes



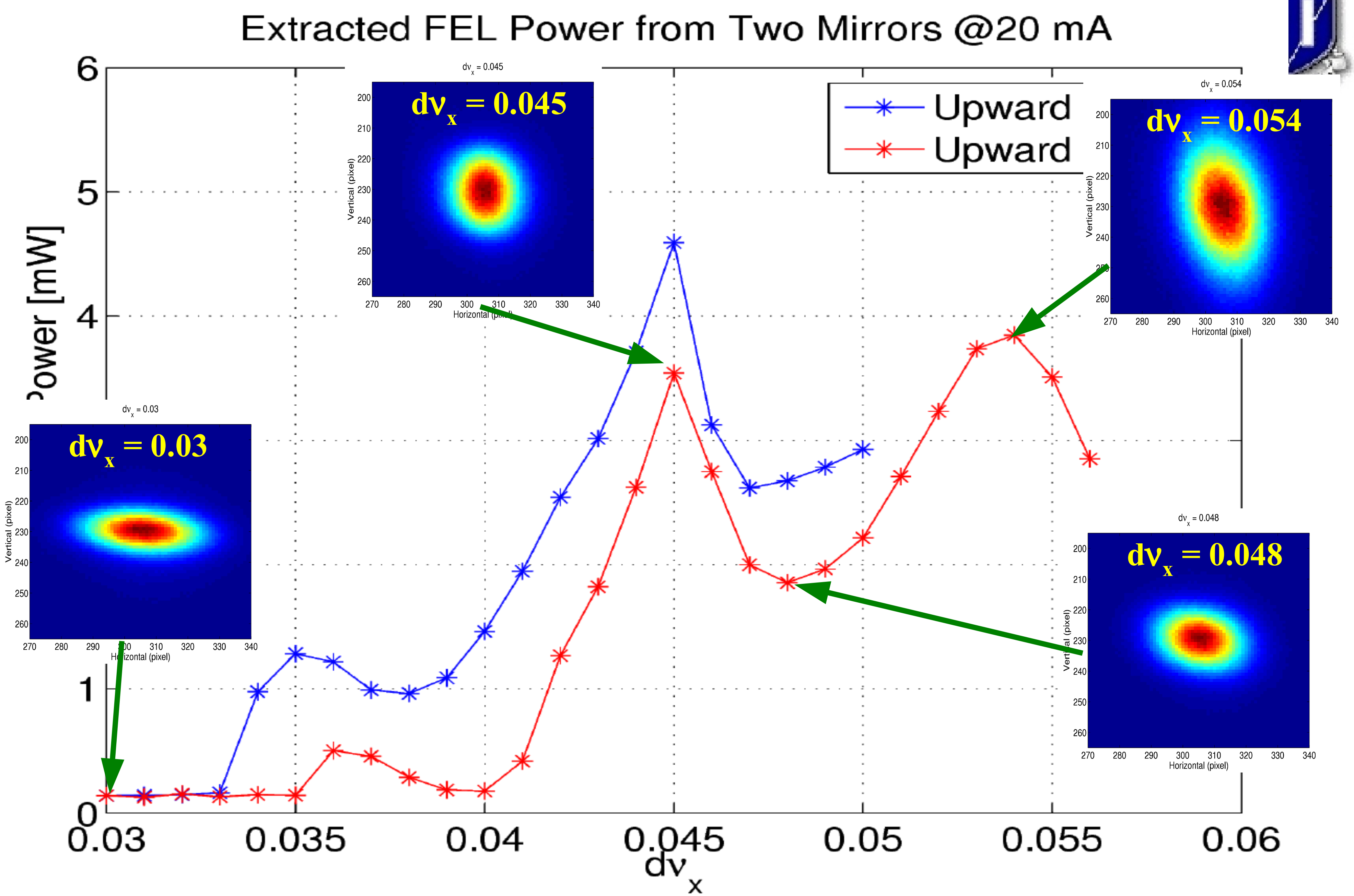
Tuning Over Coupling Resonance



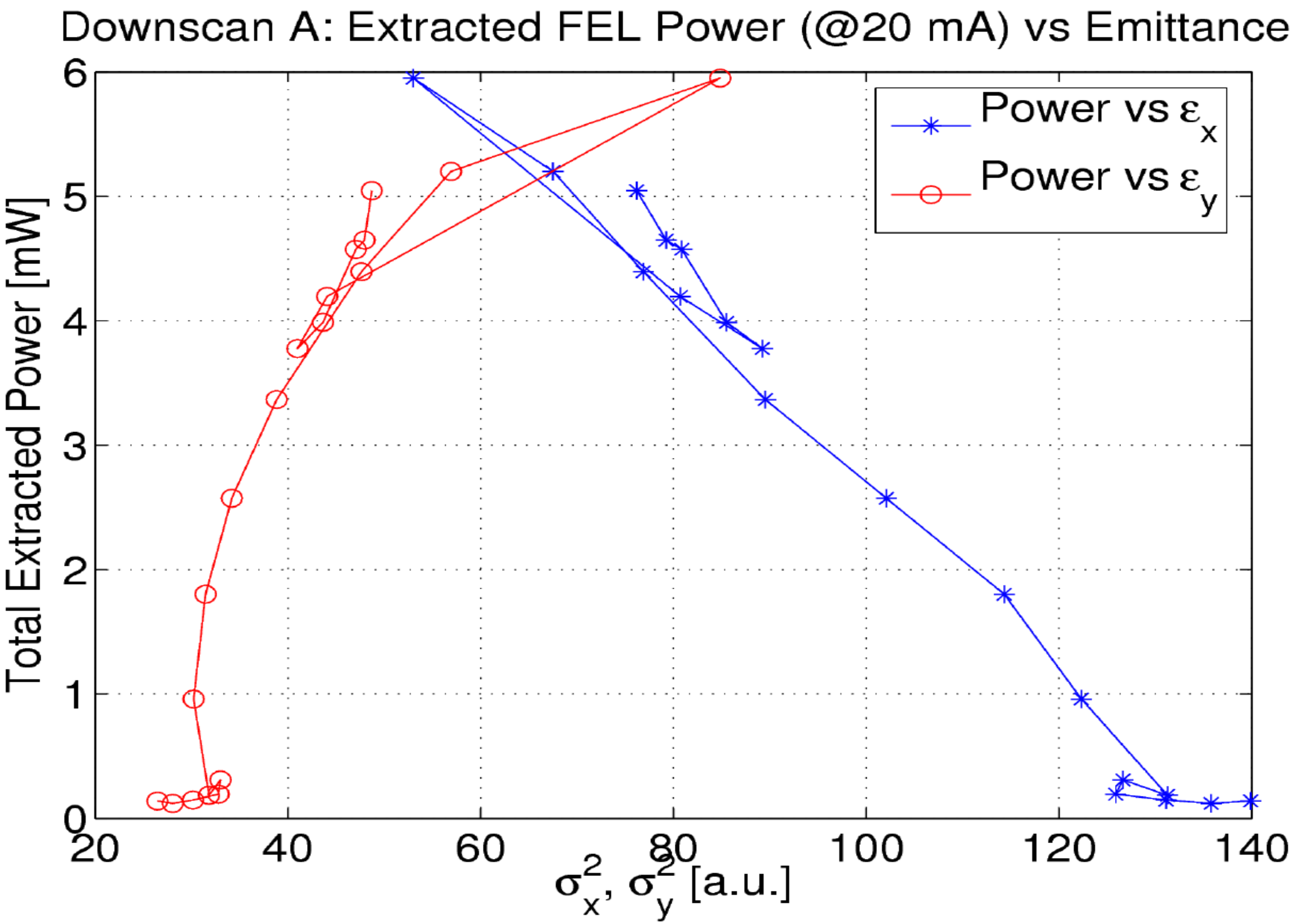
Scanning 2nd Harmonic Lasing Power



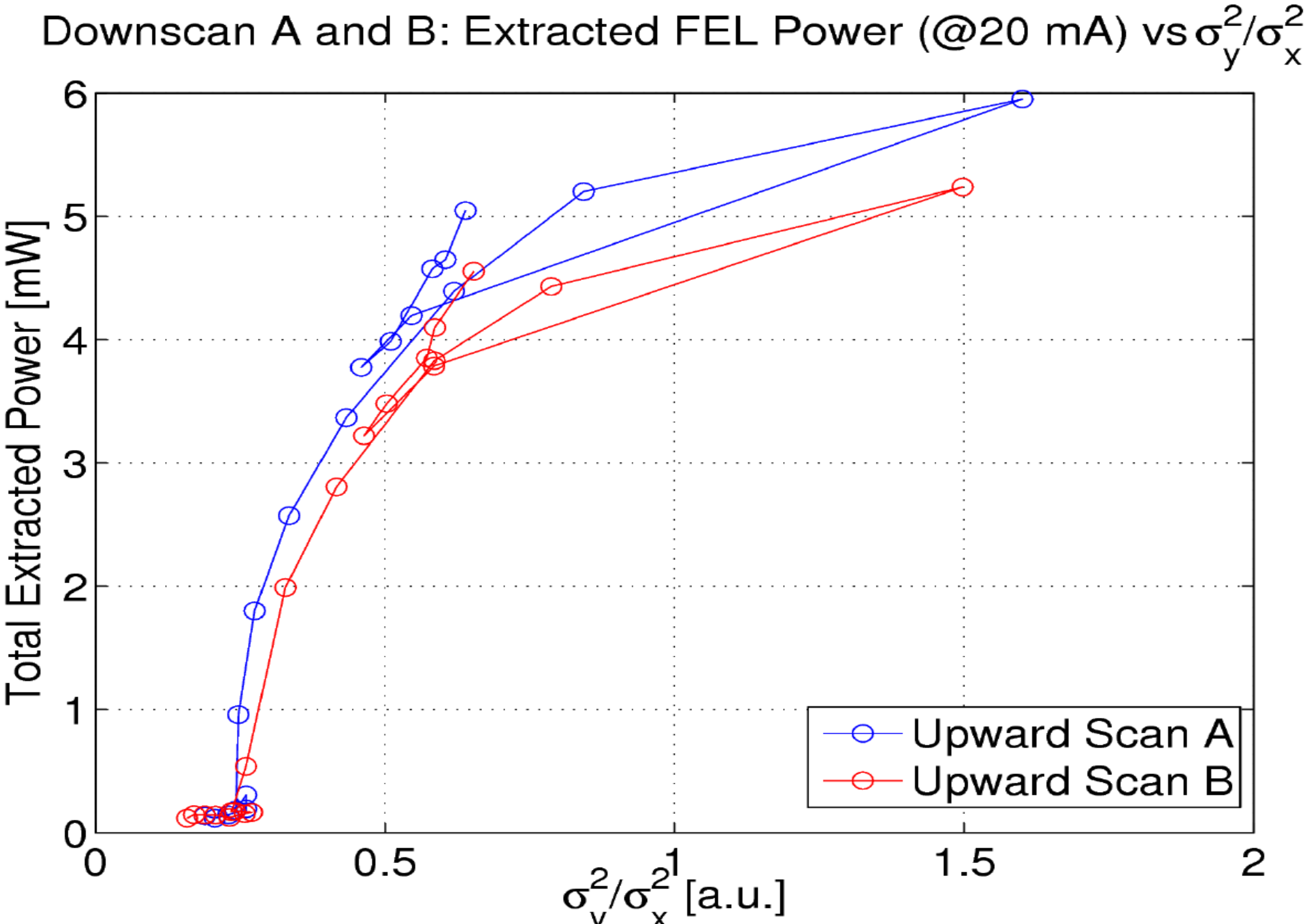
Scanning 2nd Harmonic Lasing Power



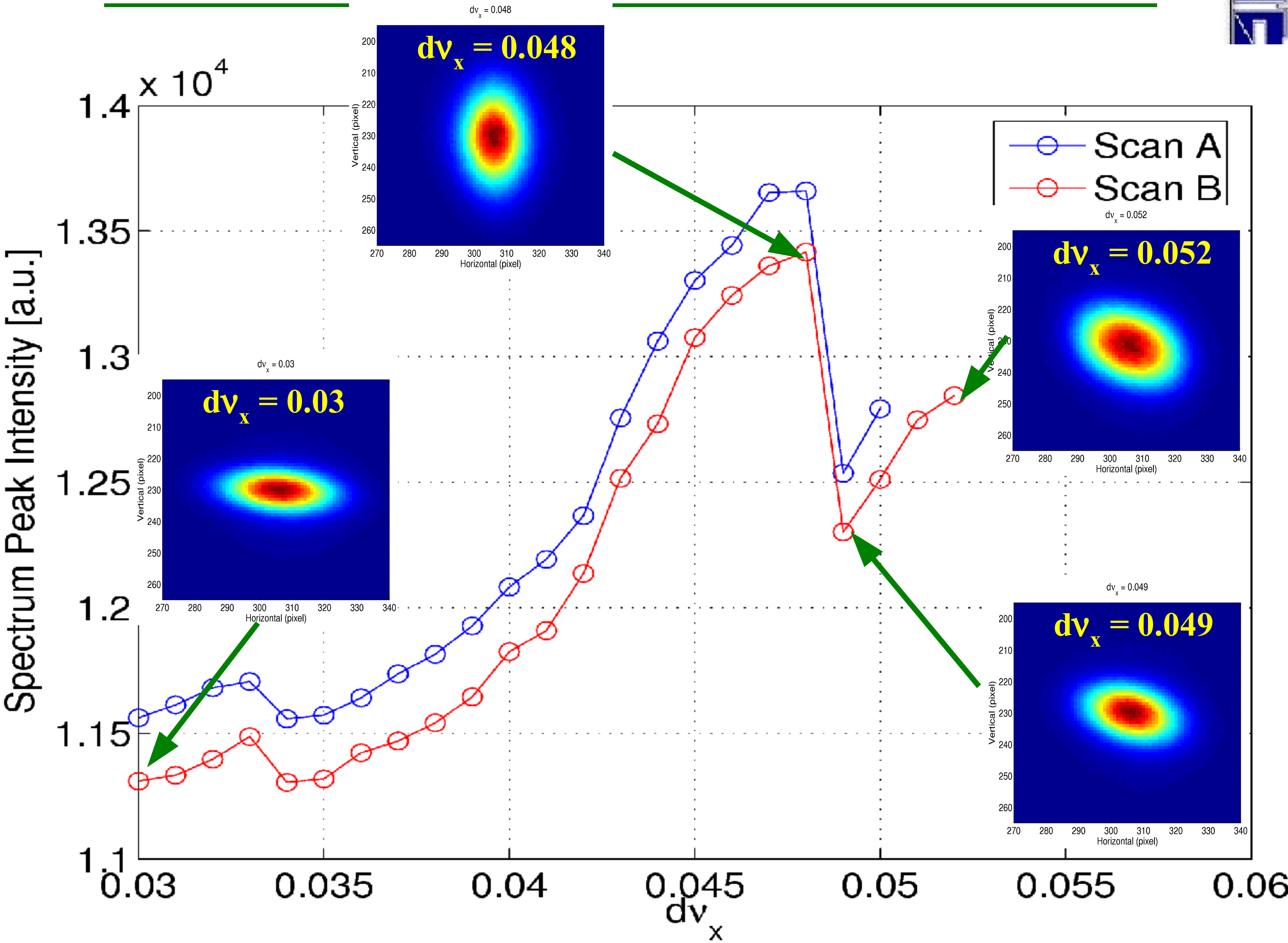
Harmonic Lasing Power vs Emittance



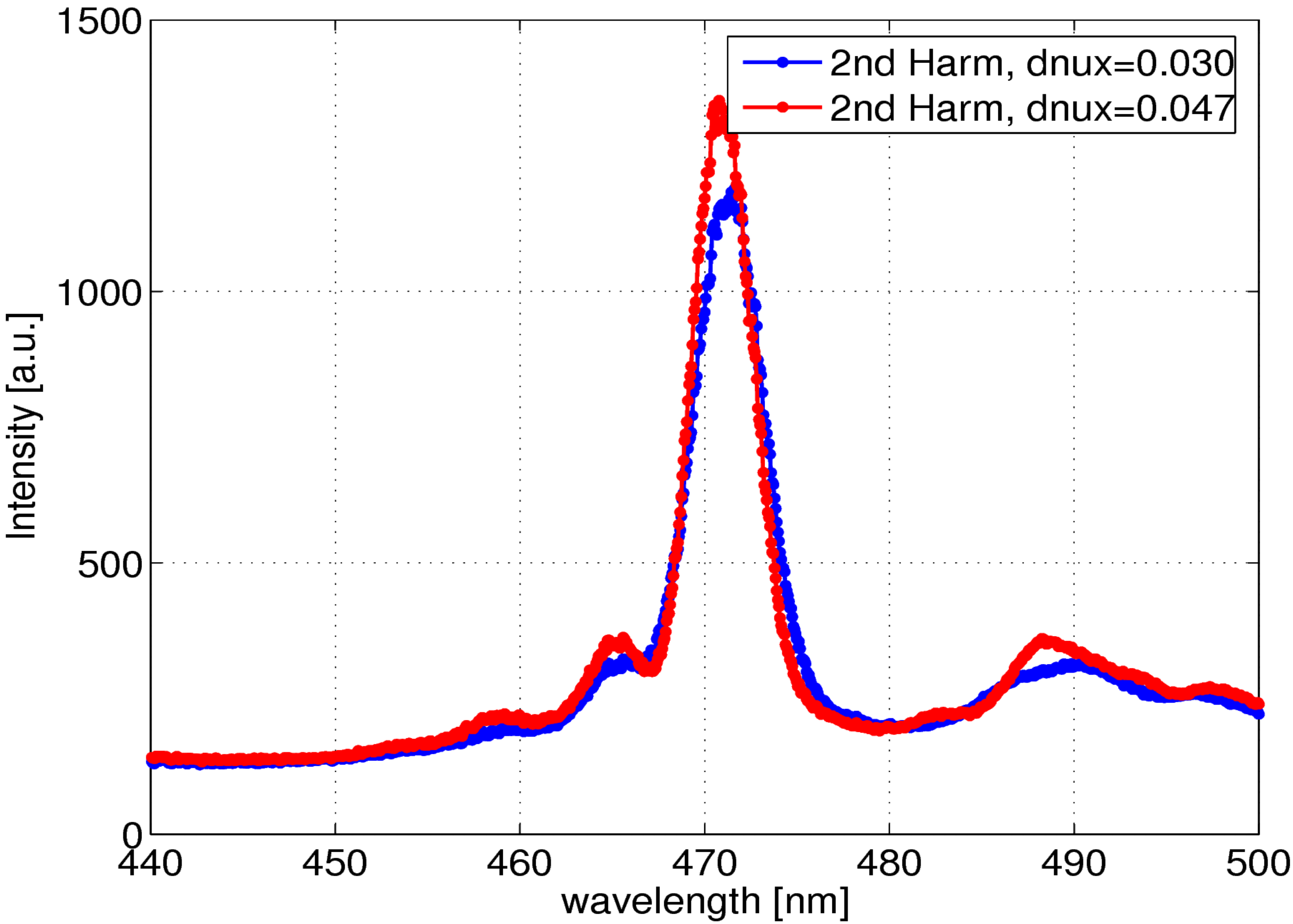
Harmonic Lasing Power vs Emittance



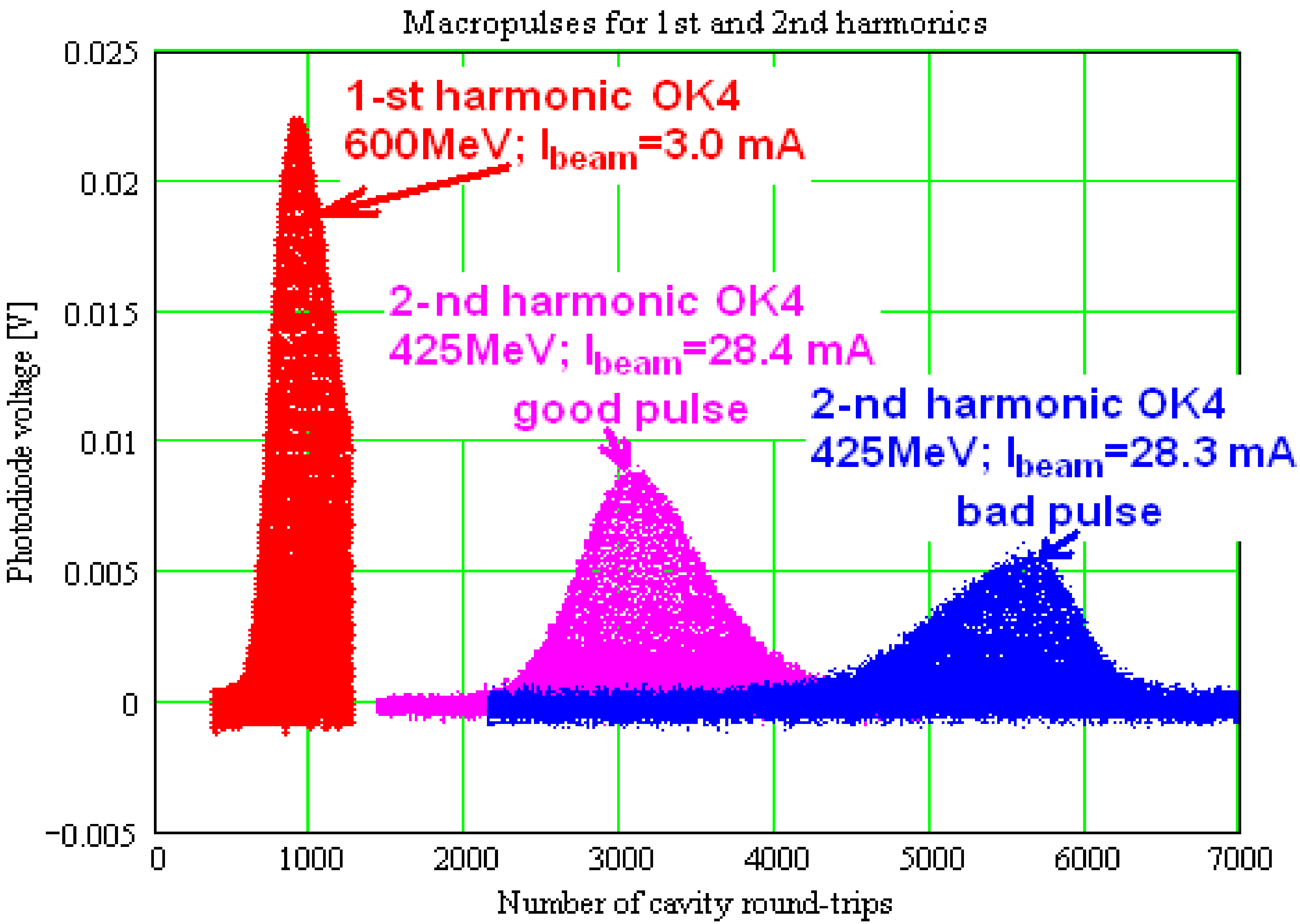
Scanning 2nd Harmonic Spontaneous Radiation Power



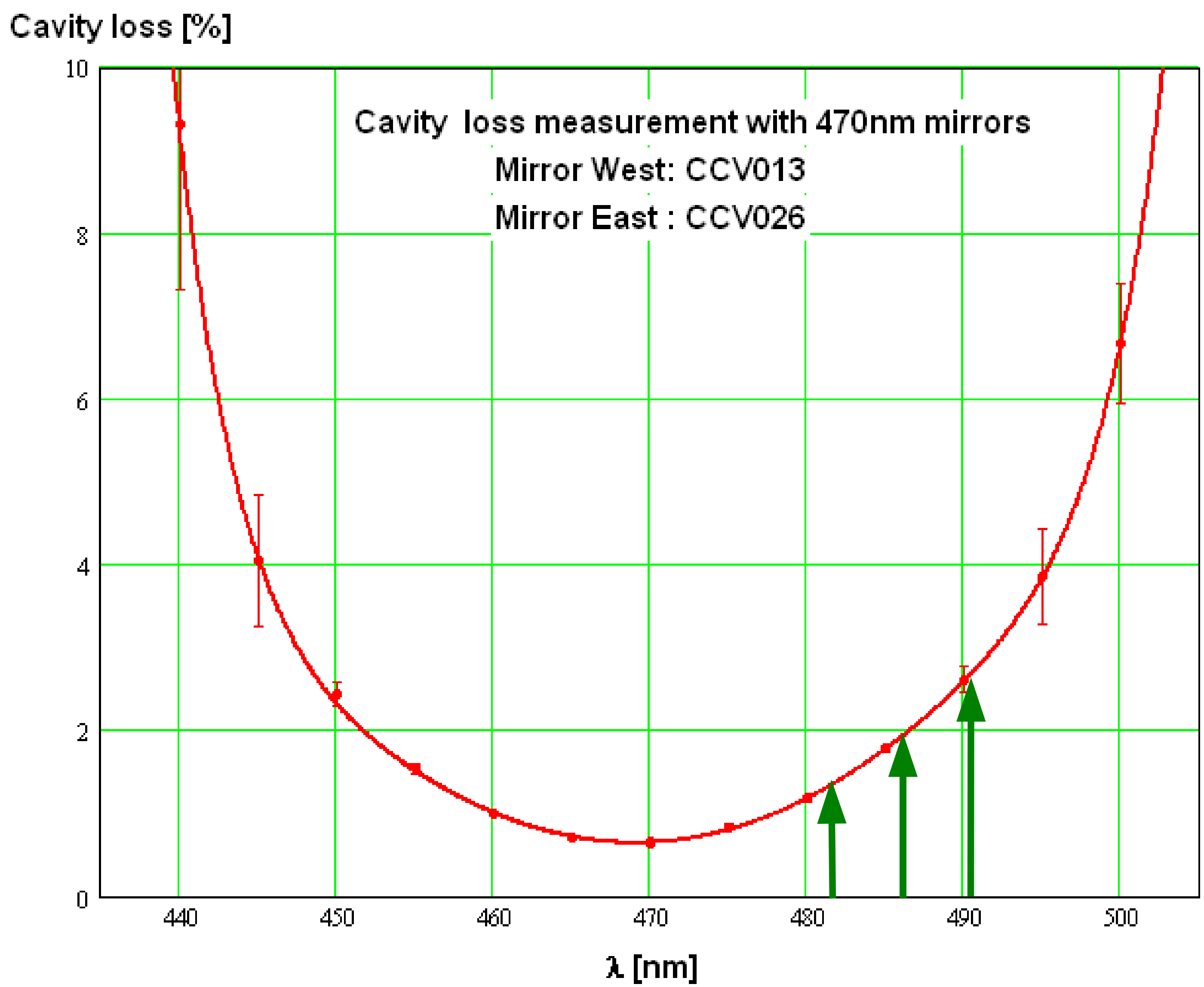
Spontaneous Spectra: 2nd Harmonic



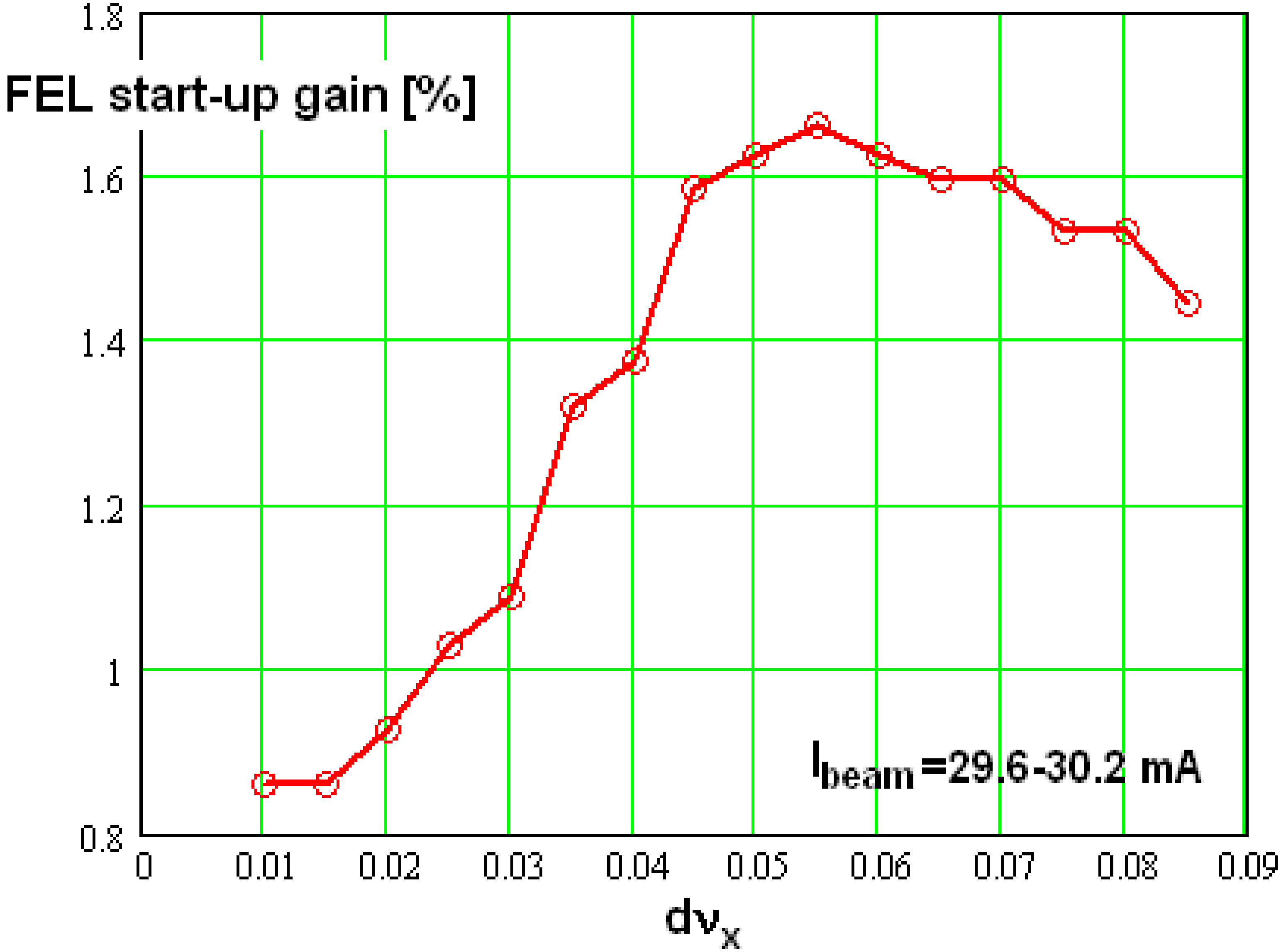
Giant-Pulse Using Gain-Modulation



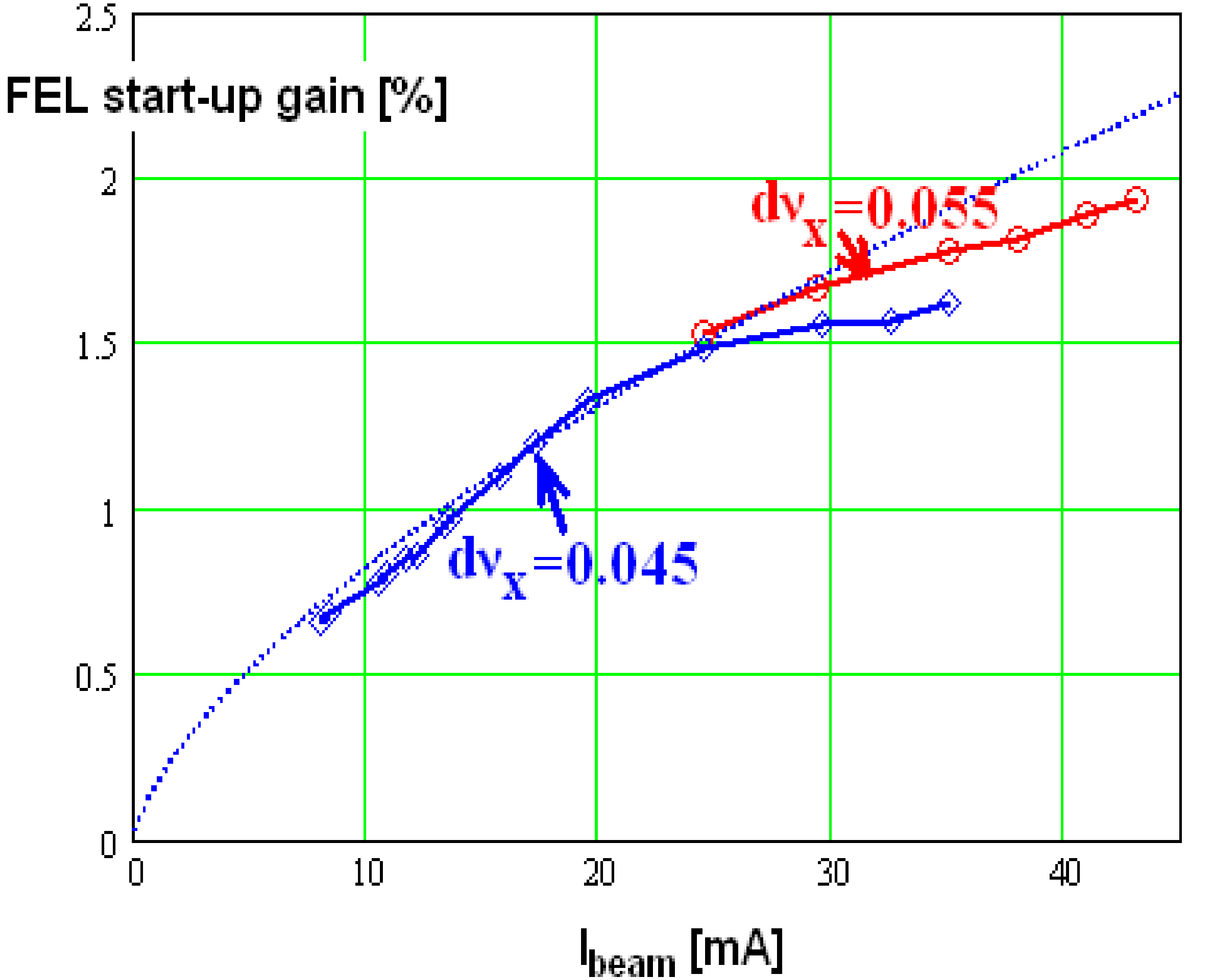
Gain Estimate: Cavity Loss



Gain vs Lattice Tuning



Gain vs Bunch Current



Summary on Lasing of 2nd Harmonic Oscillator

2nd Harmonic Lasing Demonstrated with OK-4 Optical Klystron

- Gain: up to 2.5% per pass
- Tot Extracted Power: ~ 15 mW @ 30 mA; ~ 10 to 15% of fundamental lasing
- Laser Spatial Mode: TEM_{00}
- Narrower detuning

2nd Harmonic Lasing with Lattice Tuning

- FEL gain/power increases as vertical emittance increases
- TEM10 mode is not observed

New Findings

- Substantial on-axis 2nd harmonic spontaneous radiation power inside the fundamental Gaussian mode area
- Stable on-axis TEM00 mode FEL operation with significant output power