COTR and SASE from Compressed Beams

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OUTLINE

Fermilab

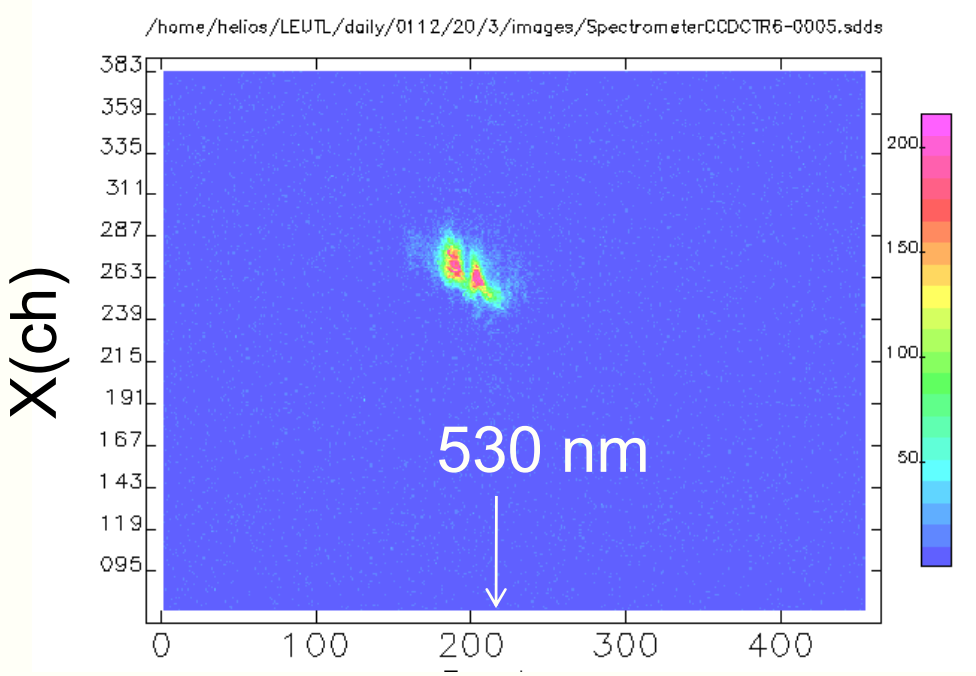
- Introduction
- Experimental background and facility.
- Recent longitudinal space charge (LSC) microbunching instability results via (COTR).
- Comprehensive COTR and SASE data sets from Dec. 20, 2001.
- Summary

Structure in COTR Image Reported in FEL02

- Six years ago we reported a striking localized SASE-induced microbunching as observed via the COTR and in x-λ space of our imaging spectrometer at APS/ANL.
- In FEL02 we postulated there must be a beam structure induced at the chicane that the SASE process preferred.
- At that time there was no theoretical support for longitudinal space charge (LSC) or coherent synchrotron radiation (CSR) induced effects at visible wavelengths.
- We now suggest that those structures were a result of the LSC-CSR microbunching instability that the SASE process preferentially enhanced at 530 nm.

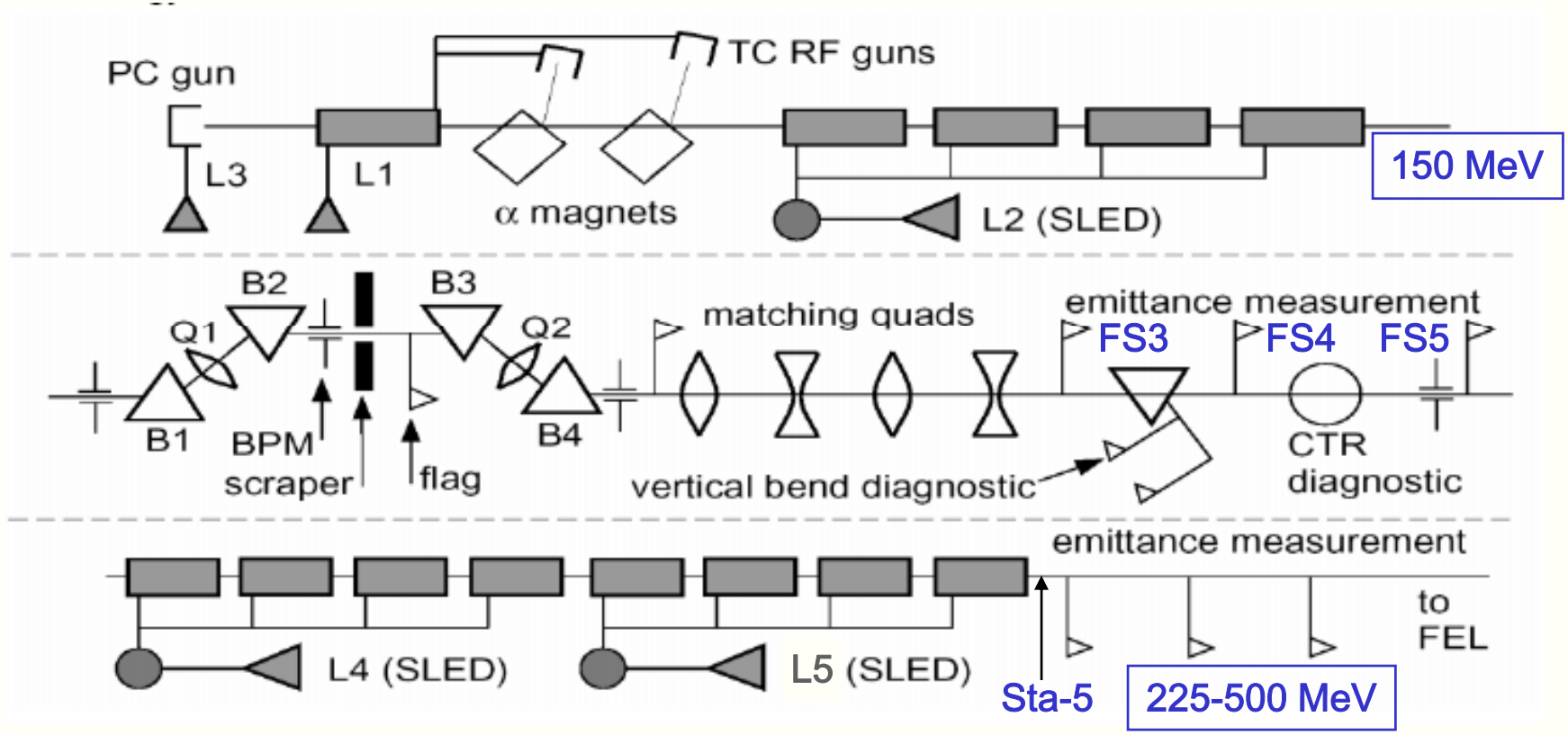
COTR-6 Spectrometer Image From FEL02 Paper

- **The structures are ~250 μm (FWHM), 120 μm apart in x, and 2.9 nm apart in wavelength. Calibration: 0.21 nm/ch.**



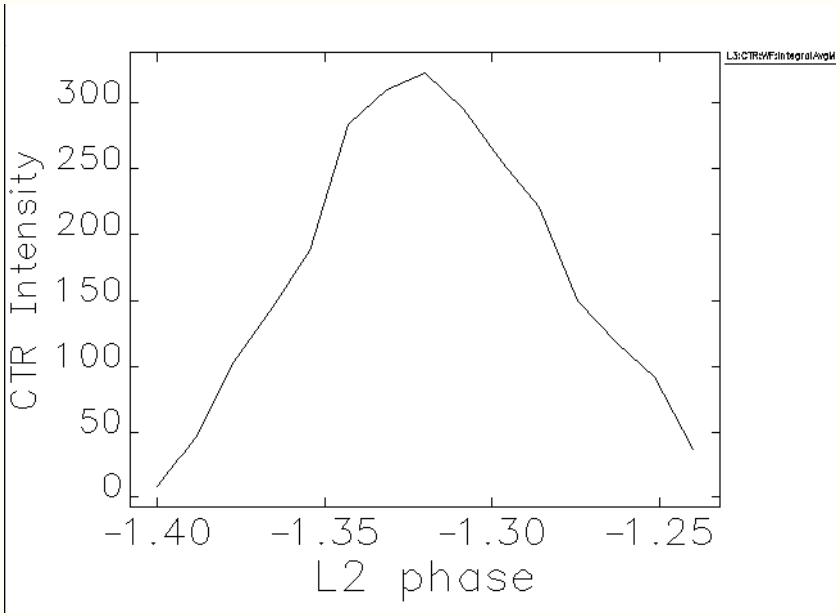
Schematic of the APS Injector Area

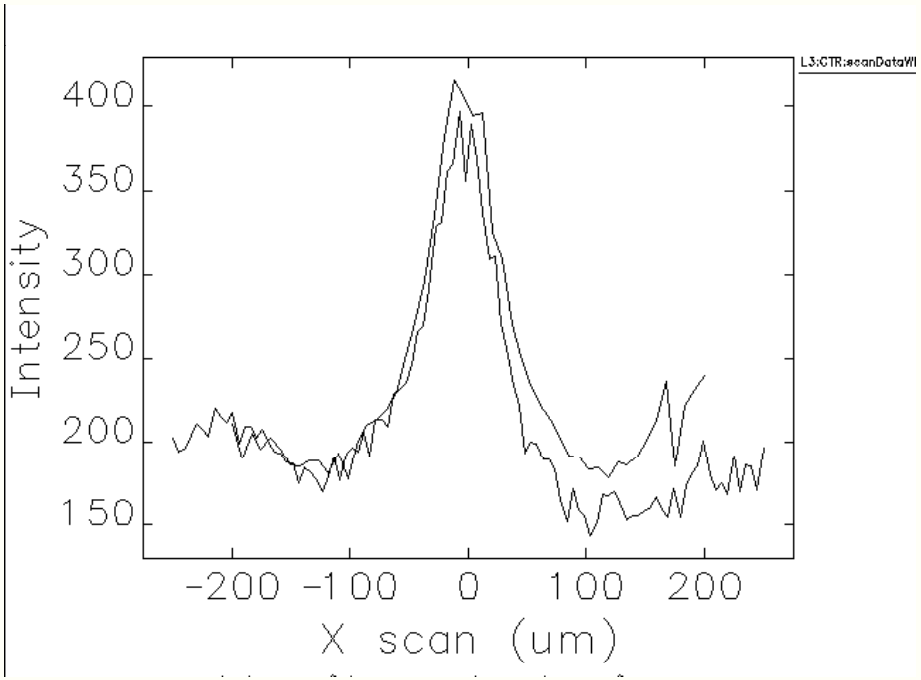
- **Both rf PC gun and rf TC gun beams available for acceleration, compression, and diagnosis.**



FIR CTR Detected with Golay Cell

- **FIR CTR signal varied dramatically by factor of 300 with change in APS L2 accelerating structure phase. Autocorrelation scan's FWHM=65 μm (at right) with round trip of 130 μm implies sub-0.5 ps FWHM e beam.**





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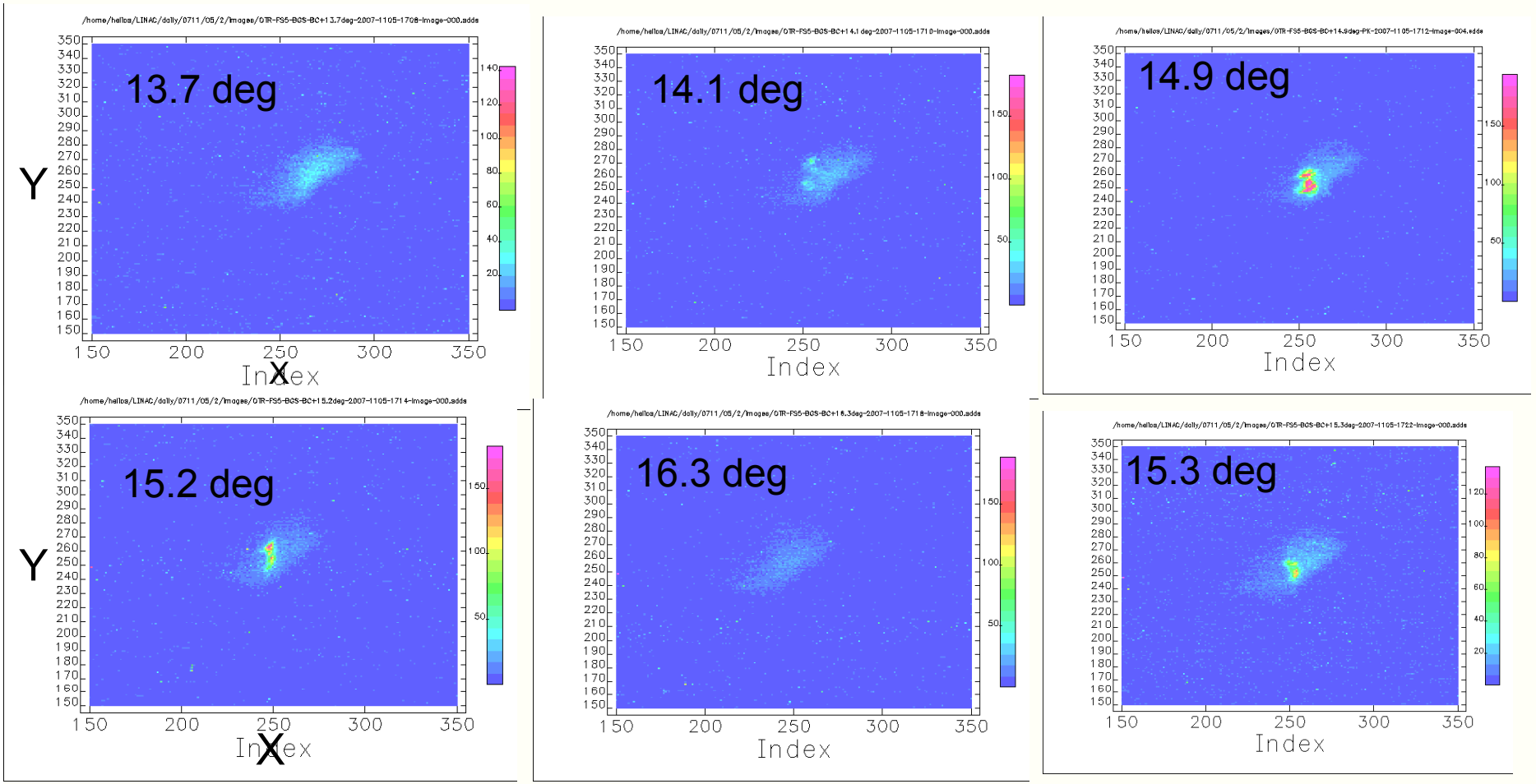
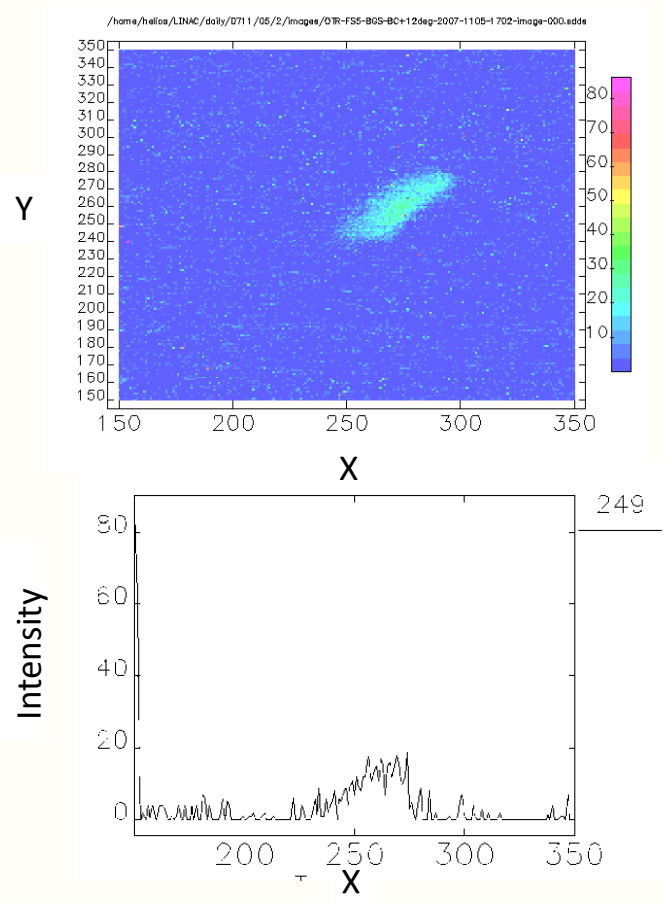
OTR Beam Image Structures Vary with L2 Phase

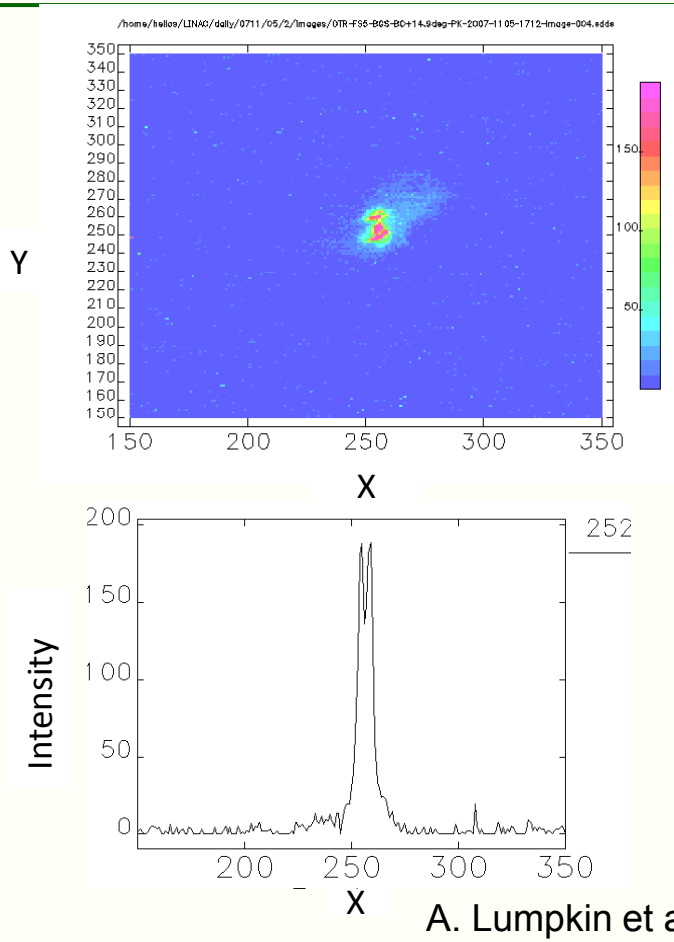
- **Images develop enhanced peaks in x-y space with compression. Footprint is similar (11-05-07 Data).**



Enhanced OTR Images Seen

- **Examples of images and profiles for L2 phase at 12 deg. (L-uncompr.) and L2 phase at 14.9 deg.(R-compr.)**





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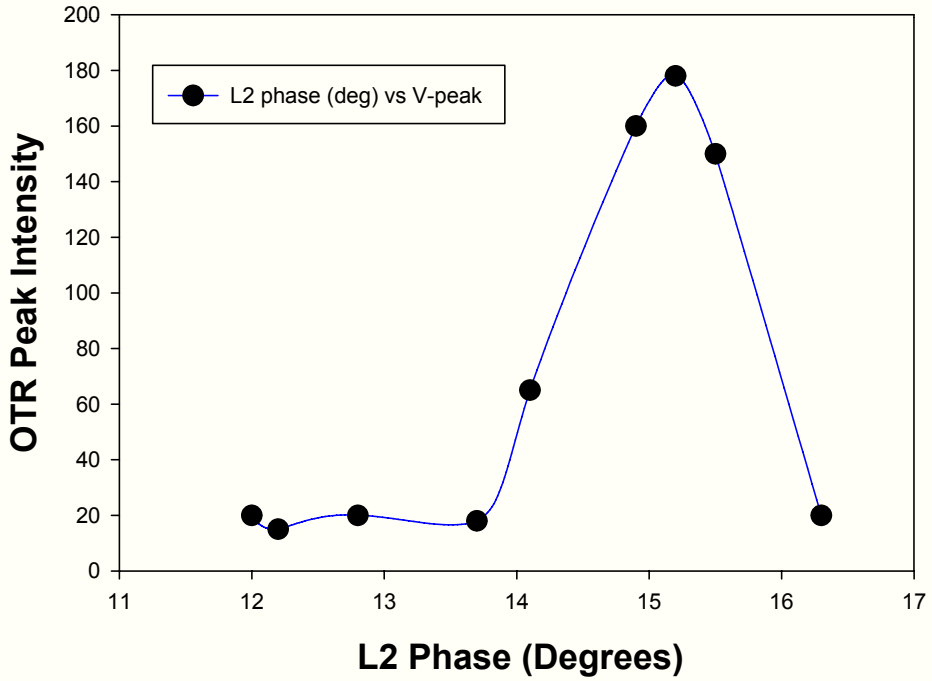
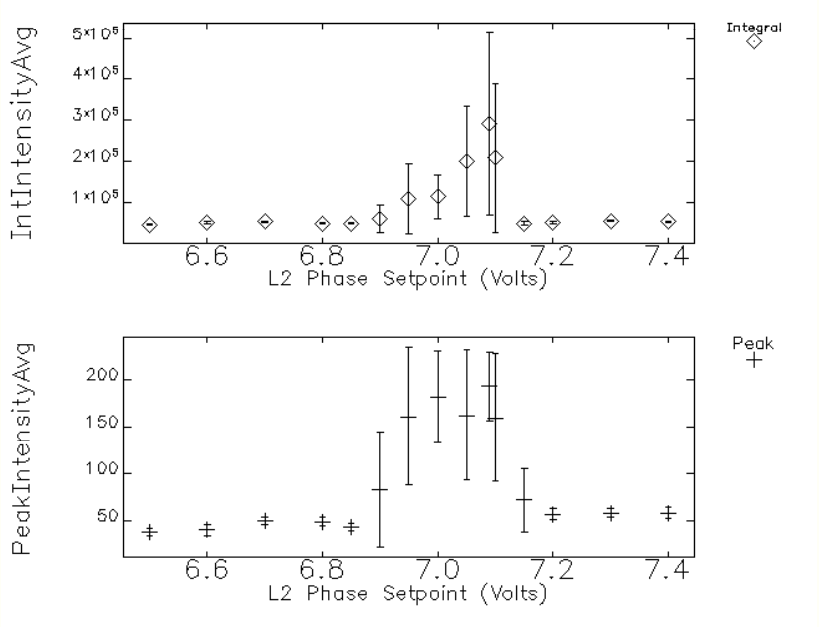
Off-line Analysis on OTR Image Peak Intensity Confirms Phase Effect

- **Localized peak intensity from single-column samples of 150-MeV data.**

Peak intensity and image averages processed for 375-MeV data.





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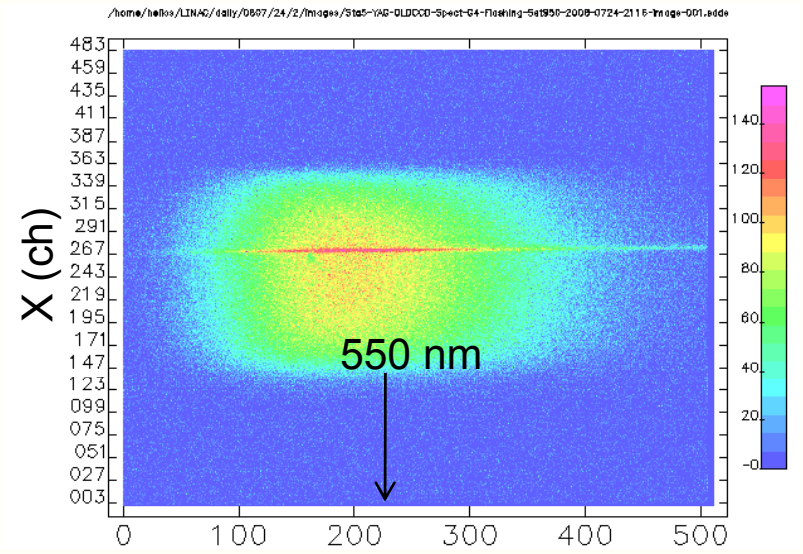
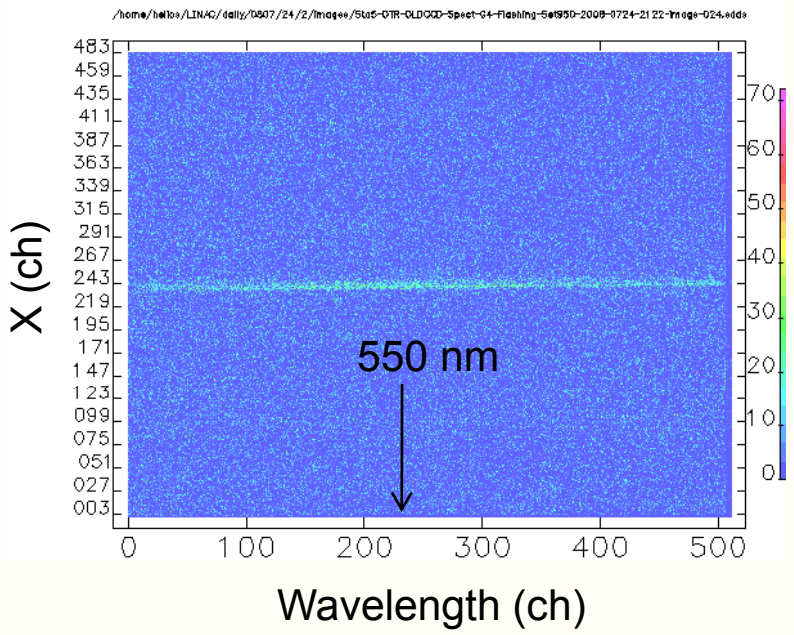
First Imaging Spectrometer COTR Results at Linac (07-24-08)

- **We report our preliminary evidence of broadband COTR emissions with the spectrometer at Sta-5. The image is x-λ space. Wavelength span is ~180 nm with Grating-4.**

YAG:Ce plus Mirror



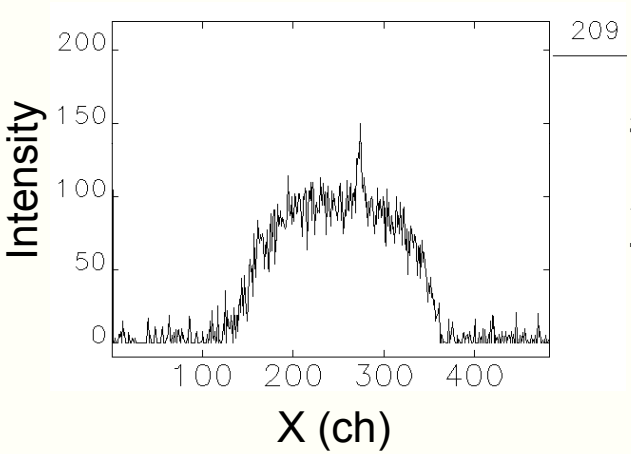
OTR mirror only

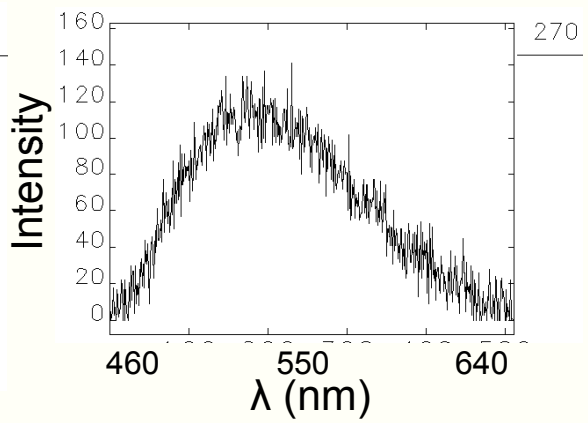


First Imaging Spectrometer Results

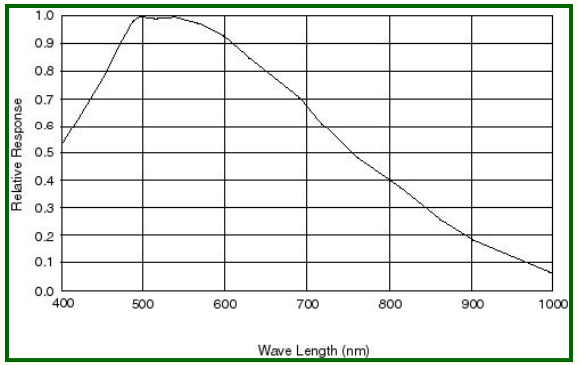
- **Preliminary processing of YAG:Ce and COTR images.**
- **Sub-0.4 micron longitudinal spikes implied?**

YAG Profiles

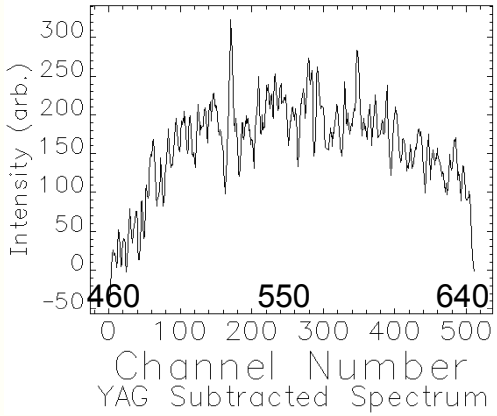


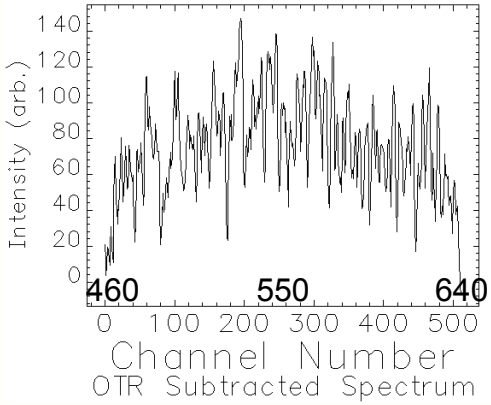


CCD Camera Response



COTR spectra with BG subtraction and 3-ch smoothing.



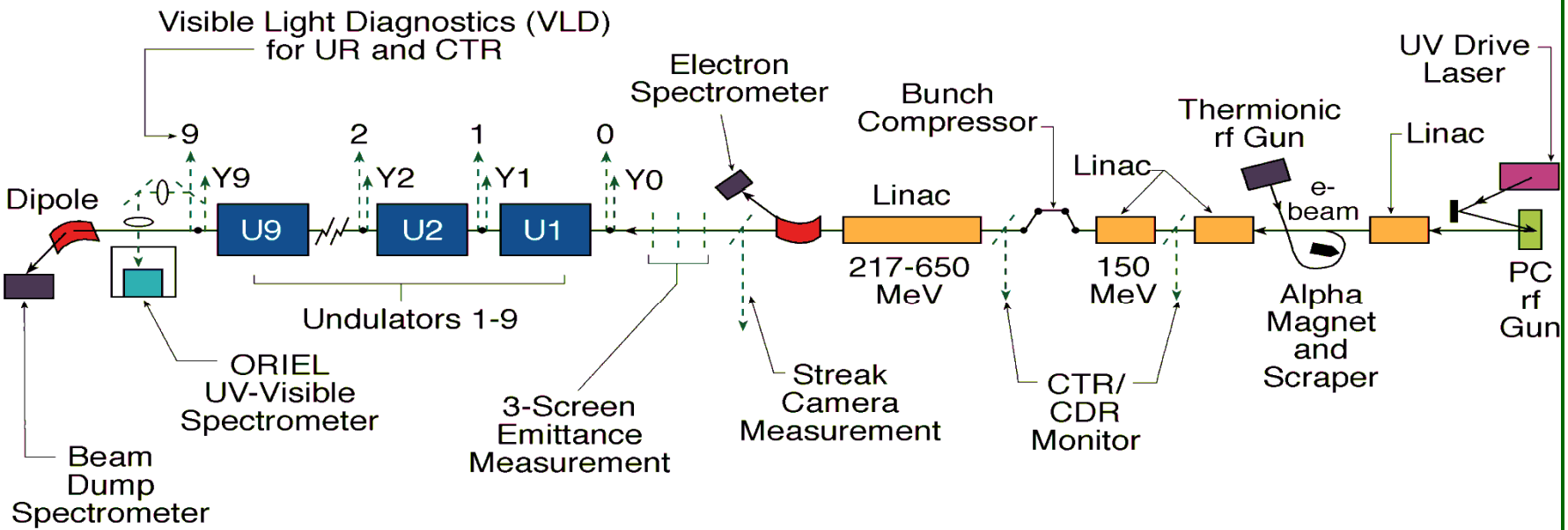


COTR and SASE Tests (12-20-01)

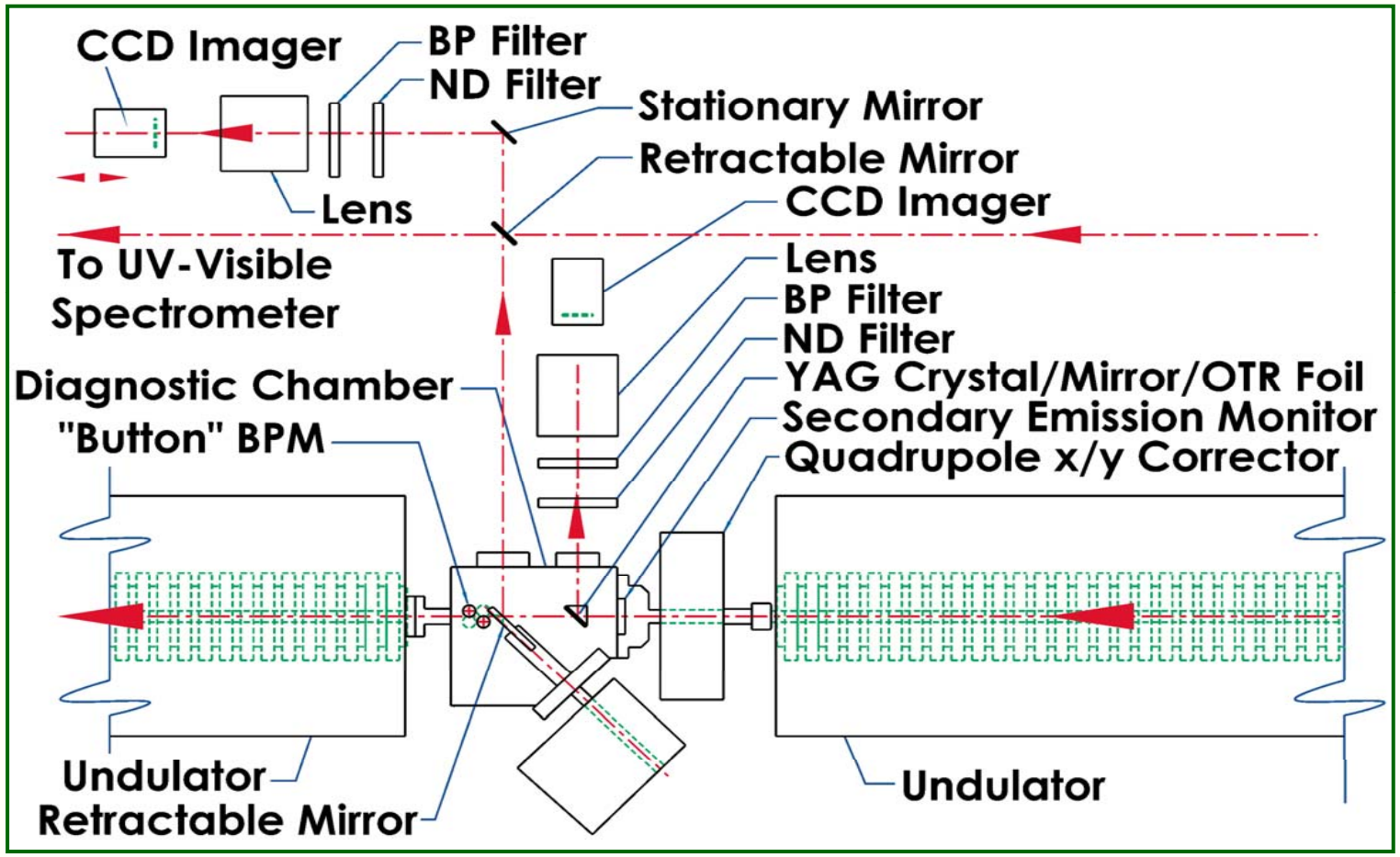
- Comprehensive z-dependent data sets taken on late shift on 12-20-01. SASE fundamental at 530 nm.
- Sets taken for both 120 and 300 A peak current.
  - Both OTR and SASE data taken at each undulator station.
  - Near–field taken for OTR/COTR; Near-field taken for SASE.
    - VLD0 is *before* first undulator; VLDN is the station after undulator N.
    - Both 500-nm short pass and ND filter data taken for OTR.
    - Single SP filter attenuates SASE-induced microbunching at 530 nm by 100.
    - 100 images taken for each configuration at each VLD.
- LSC-related microbunching instabilities are now recognized as being detectable via visible light COTR.
- Revisit the data to look for new aspect.

Schematic of APS Linac

- **Flexible system with three guns and one bunch compressor.**



Intraundulator Diagnostics Stations Used to Track Evolution of Microbunching and SASE.

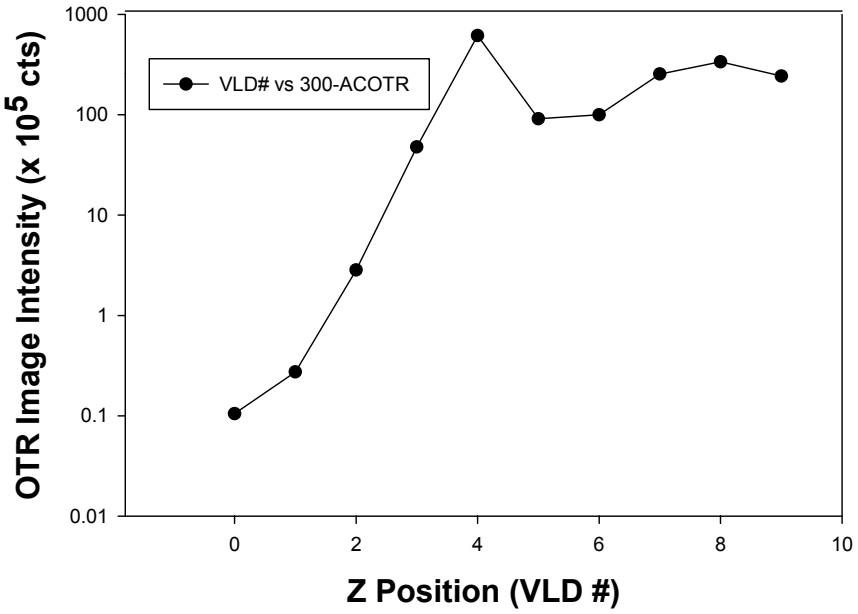


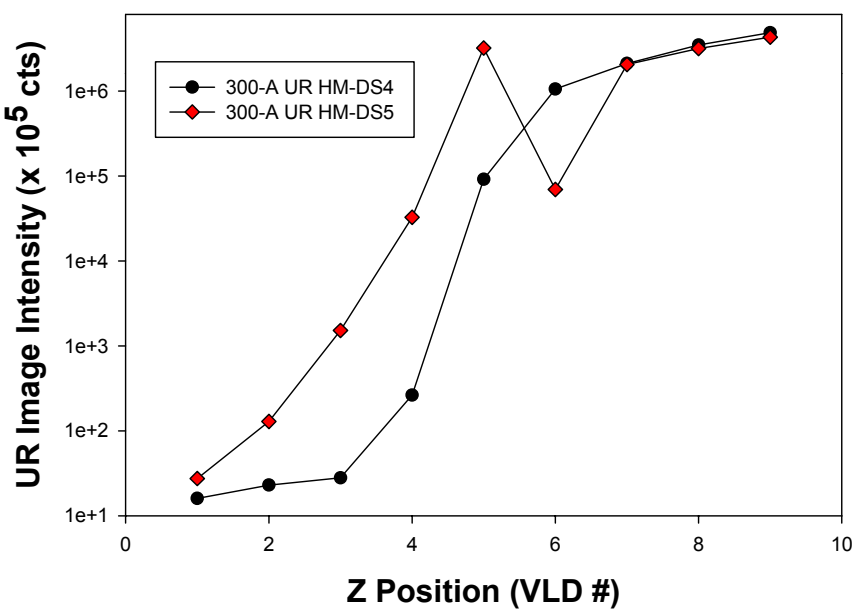
PC rf Gun Beam Setup (12-20-01)

Parameter	Uncompressed	Compressed
Beam Energy (MeV)	217 MeV	217
Emittance x (mm mrad)	4.6 after chicane	4.1 after chicane
Emittance y (mm mrad)	4.3 after chicane	4.2 after chicane
Peak Current (A)	120	300
Bunch Length (ps rms)	1.6	0.65
Charge (pC)	450	450
Energy Spread (%)	0.1-0.2	< 0.1

COTR/SASE Gain Curves at 300 A with LSC (12-20-01 data)

- **Gain saturates by the end of undulator 5 on average with 300 A beam and the LSC microbunching inducements.**

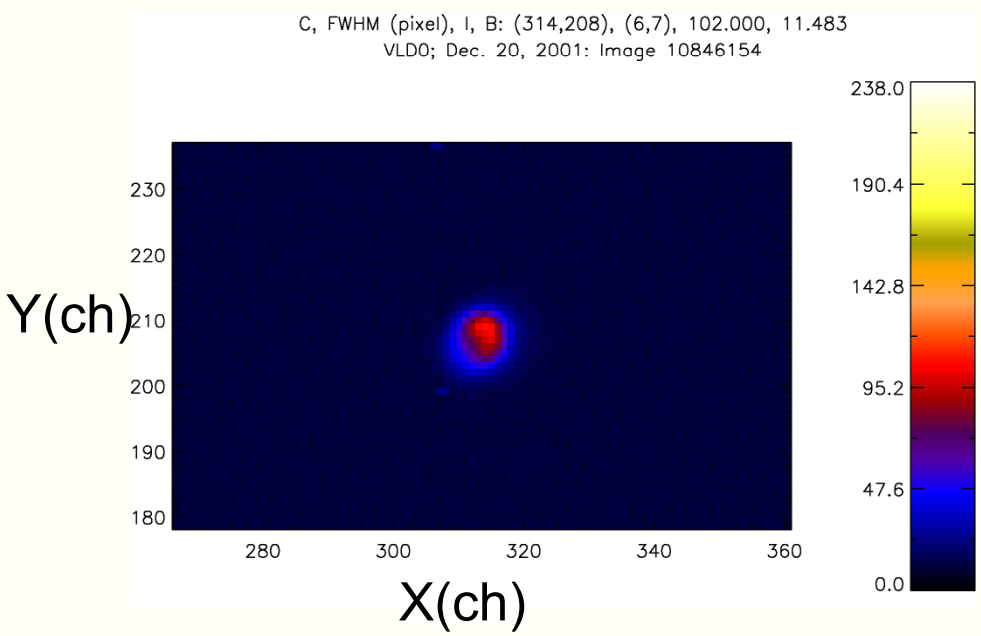




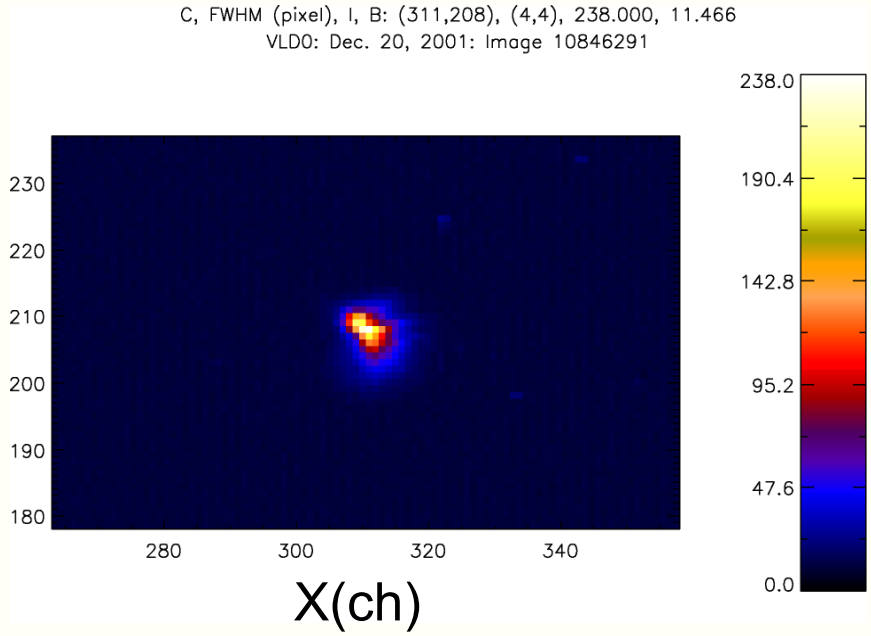
VLD0: OTR Before Undulator 1

- **For similar charge, OTR Images at 120 A (L) and 300 A (R) have quite different intensities with structures seen in the latter.**

120 A: ND 0.0



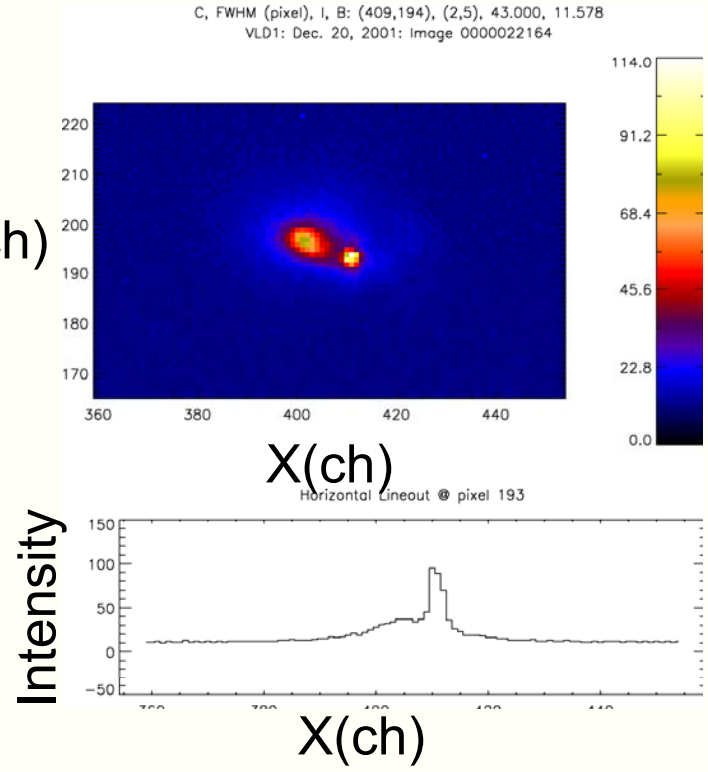
300 A: ND 0.5



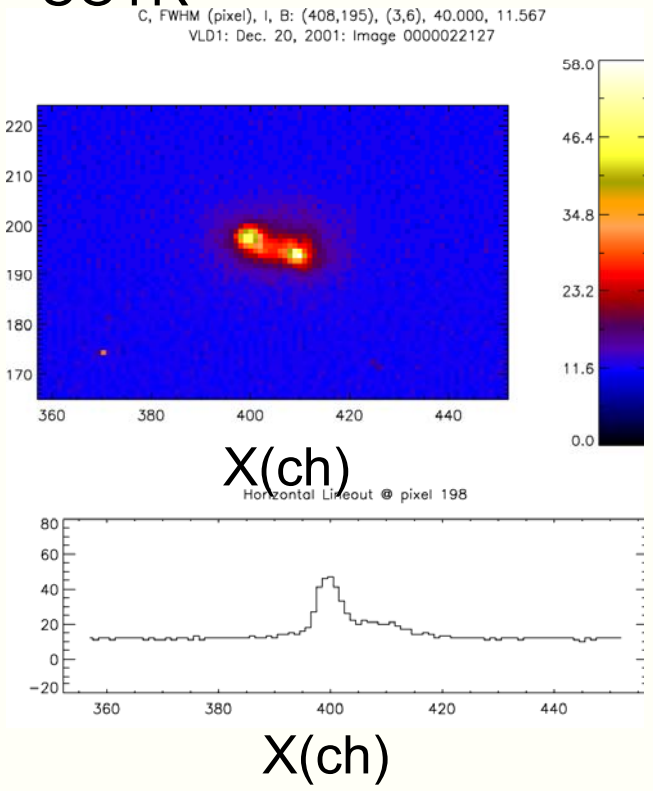
VLD1: OTR/COTR after Undulator 1 at 300 A Peak Current

- **Shortpass filter blocks the 530-nm fundamental microbunching signal (L). (12-20-01 Data)**

500 nm SP:LSC COTR



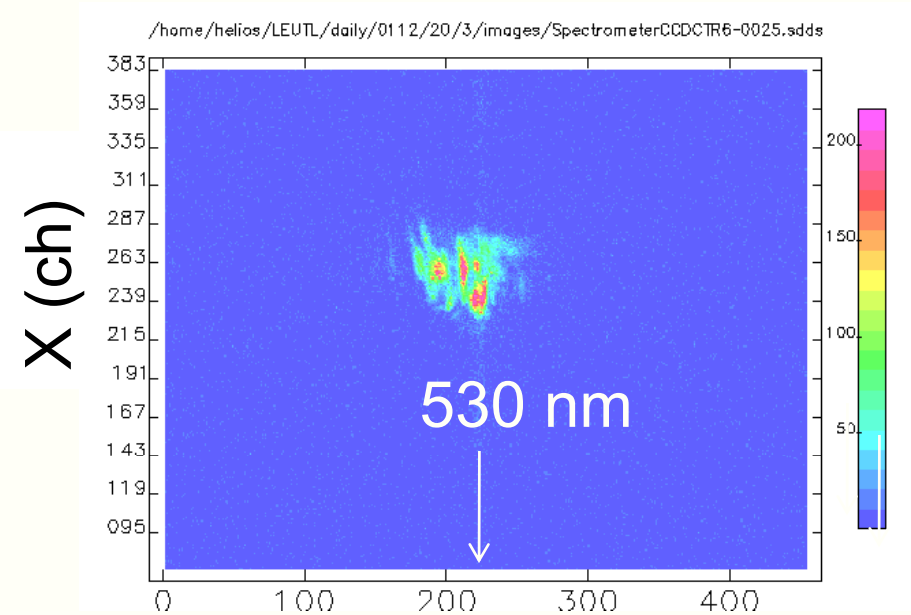
ND1.0: LSC- + SASE-Induced COTR



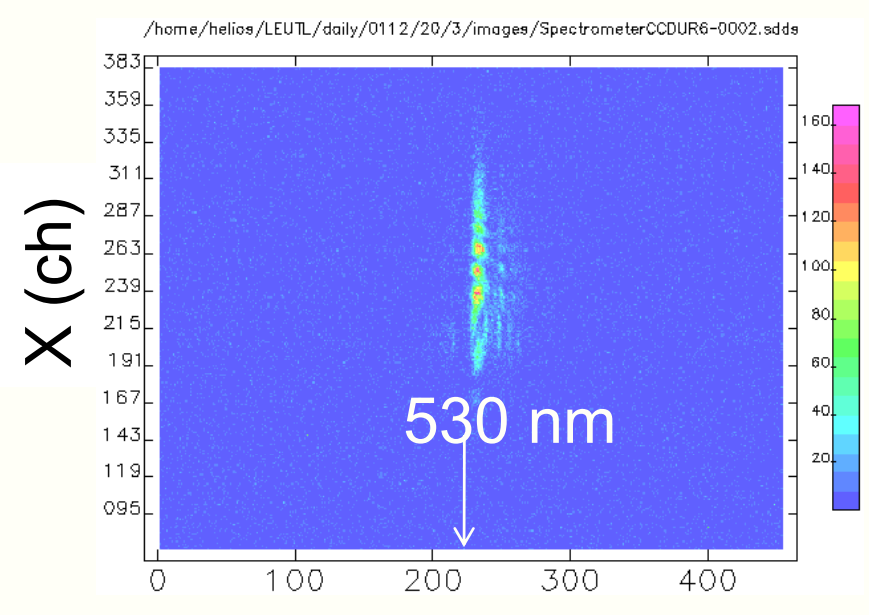
VLD6: COTR and SASE Images

- **Imaging spectrometer shows structures in x-λ space near 530 nm fundamental. (12-20-01 data)**

COTR



SASE



SUMMARY

- LSC-CSR related microbunching instabilities are now recognized as being detectable via visible light COTR.
  - Identified now in 2001 APS OTR experimental data.
- We report strong evidence for the effects on a past visible light SASE FEL experiment at APS by the spatially localized LSC-CSR-induced microbunching beam structures that evidently encourage startup.
- Need start-to-end simulations with Genesis or Ginger runs to improve understanding.
- Explore other data in visible, UV, and VUV at APS.
  - Will structures seen in vis-UV be enhanced in VUV also?
- How many other FEL experiments showed LSC-related effects?

ACKNOWLEDGEMENTS

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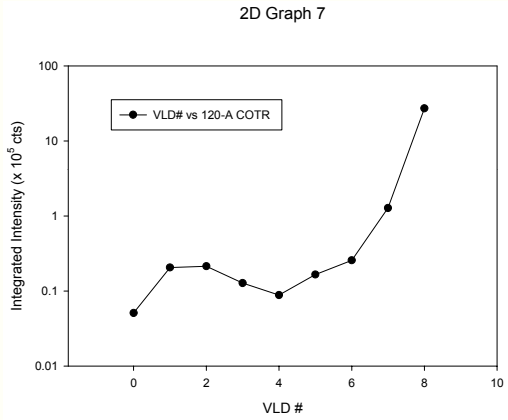
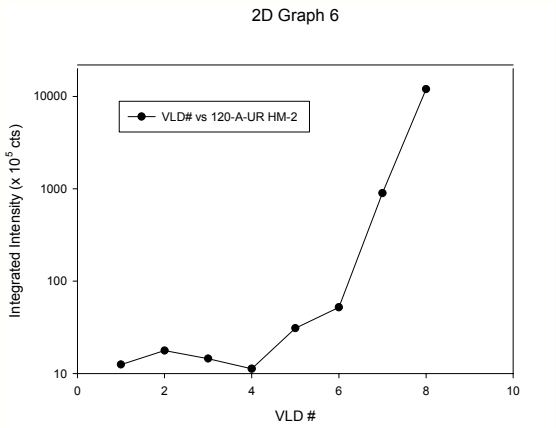
- They acknowledge W. Berg and S. Shoaf of Argonne for relocating the optical spectrometer with controls to the linac optics lab.

COTR and SASE Gain Curves

- **Gain saturates by the end of undulator 4 on average with 300-A beam and the LSC microbunching inducements.**

120 A Gain





300 A Gain