The Compact Light Source

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Outline

- Introduction to the Compact Light Source
- A look at the hardware
- Recent results of the CLS
- Conclusion

History

- **The Compact Light Source is spin off from research aimed at producing high-quality electron beams for High Energy Physics.**
  - "Laser-Electron Storage Ring," Z. Huang and R. D. Ruth (SLAC), Phys. Rev. Lett., 80:976-979, 1998.
- **Lyncean Technologies, Inc.**
  - 5 ½ year-old corporation formed to develop the Compact Light source.
  - Founders: R. Ruth, Jeff Rifkin and Rod Loewen
  - Compact Light Source prototype funding:
    - Fast-Track SBIR, Protein Structure Initiative I, National Institute of General Medical Sciences, NIH

The Compact Light Source (CLS)

- **What is it?**
  - **The Compact Light Source is a table top synchrotron light source with a laser undulator that can service up to three x-ray beam lines.**

- **How is this possible?**

Reducing the Scale to Laboratory Size

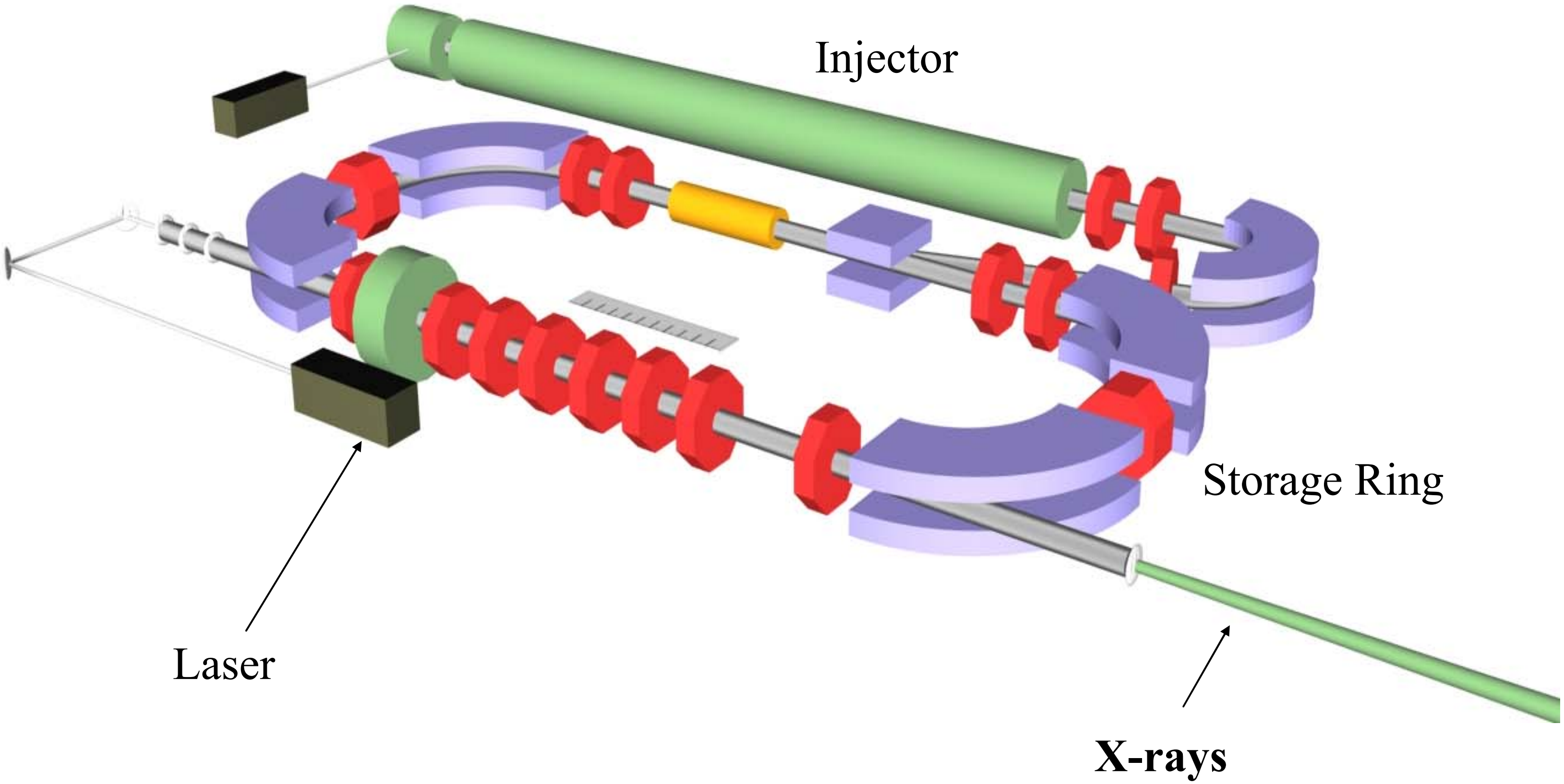
- **What is the Basic Idea?**
  - Large Synchrotron Light Sources
    - Electron storage ring (high energy, large)
    - Undulator magnet technology
  - Compact Light Source
    - Electron storage ring (low energy, small)
    - Laser technology
  - 5 GeV => 25 MeV (factor of 200)
  - Laser undulator - period = ½ μm:
    - 20,000 periods, 10 T field
  - X-rays: λ_x = 1Å, tunable from 7 to 35 keV, later up to 70+ keV

What is a “Laser Undulator”?

- **Laser beam collides with a bunch of electrons**
  - Acts just like a long undulator
  - Causes the beam to wiggle at one half the laser wavelength.
- **This effect is just Compton scattering (inverse Compton).**
- **Compton scattering = undulator radiation**
  - With an optical wavelength undulator.
- **But there is a technical difference, with a laser undulator**
  - Must bring the light pulse back each time the electron bunch passes.

A Conceptual Picture of the CLS

(The 30 cm ruler in the middle is shown for scale.)



CLS animation

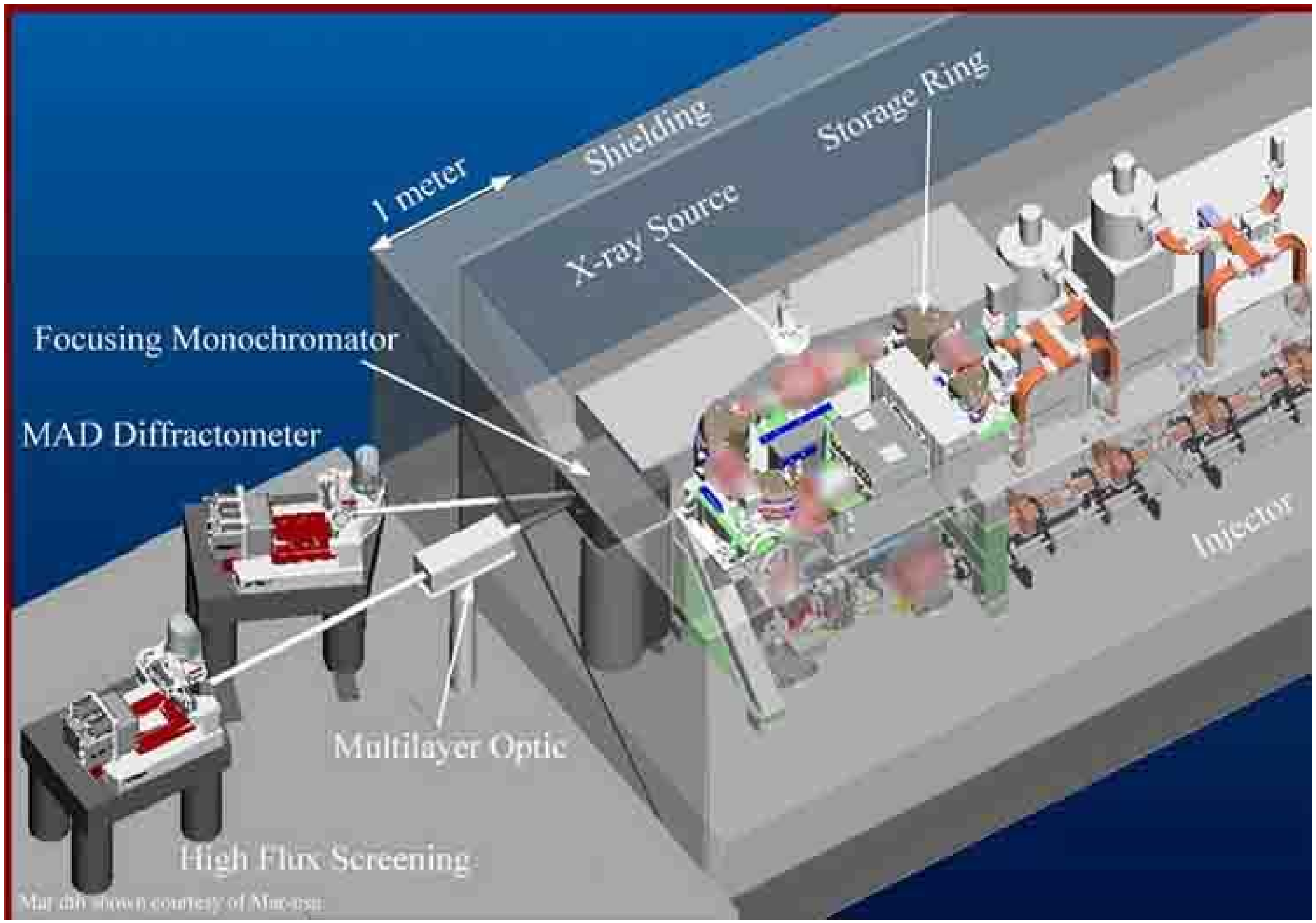
Intensity and Brightness

- **The target intensity delivered from the CLS for nominal operation**
  - 10^{10}/sec in $2x10^{-4}$ band width.
  - 10^{12}/sec in 2% band width
  - Approximately proportional to the bandwidth.
- **These values are for nominal operation, ultimate performance will be substantially more.**
- **Source size can be 30 μm rms.**
- **Few mrad divergence, variable.**

Energy Range and Tunability

- **The flux of the CLS is ~ independent of x-ray energy.**
  - At the higher energies, it increases with $E^{1/2}$
- **The central value of the x-ray energy is set by the energy of the stored electron beam, which can be adjusted quickly.**
- **The natural x-ray energy spread ~ 2 percent FWHM.**
- **Max energy is 16 keV for crystallography model.**
- **The CLS is capable of and designed for up to 35 keV.**
- **70+ keV is possible with an upgrade.**

The Compact Light Source with End Stations



A Look at the CLS Hardware

- The CLS design is based on decades of experience building electron beam storage rings.
- It's engineered to be an affordable, reliable, user-friendly product.
- The CLS prototype is a production prototype.
- In the following slide show we show some of the hardware.
- CLS Hardware

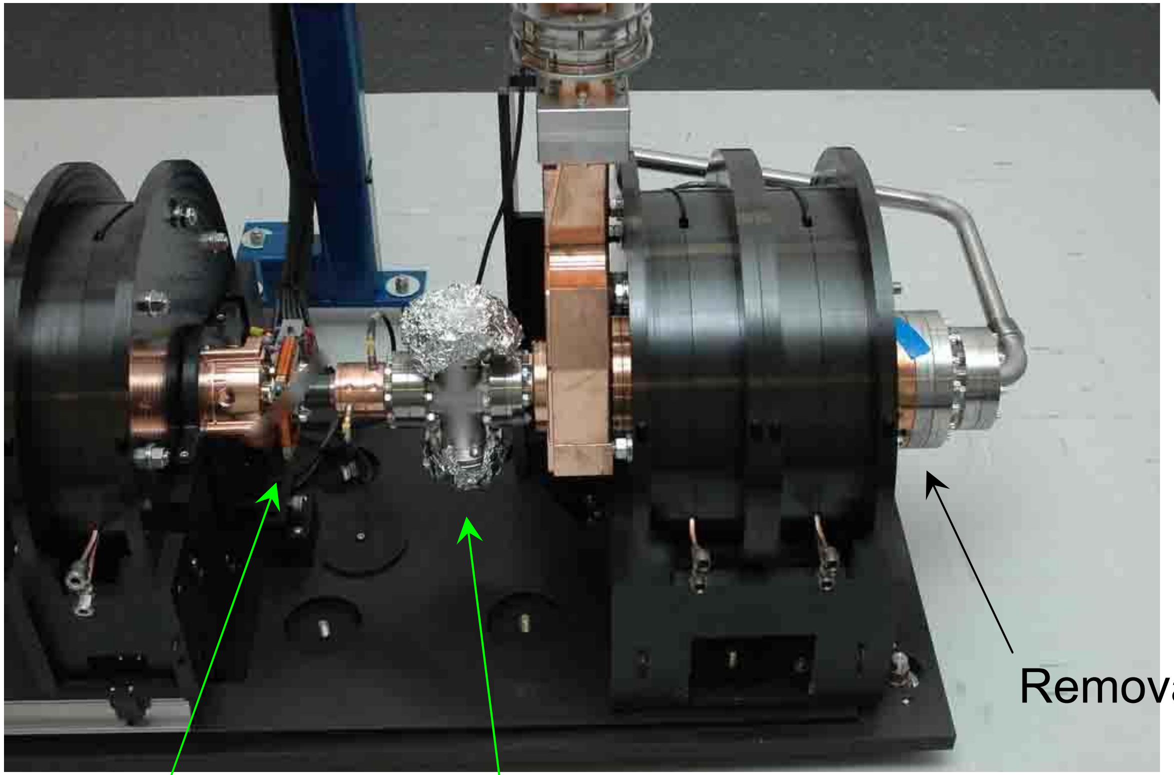
Initial Tests of the CLS Prototype

- We have completed initial commissioning the electron beam systems.
- We have completed initial commissioning of the Optical Cavity.
- Optical Cavity was installed in late January 2006.
- Combined systems tested for 1 month.
- First X-rays February 23, 2006.
- Optical cavity optimization, spring 2006.
- Focused x-ray spot, June 4, 2006.
- Electron beam development—Fall 2006.
- X-ray spectrum and flux studies—Winter 2006-2007.
- Present activities—Increasing x-ray flux.
- Next—diffraction and data set collection.
- Overview of CLS/CXS Prototype testing.

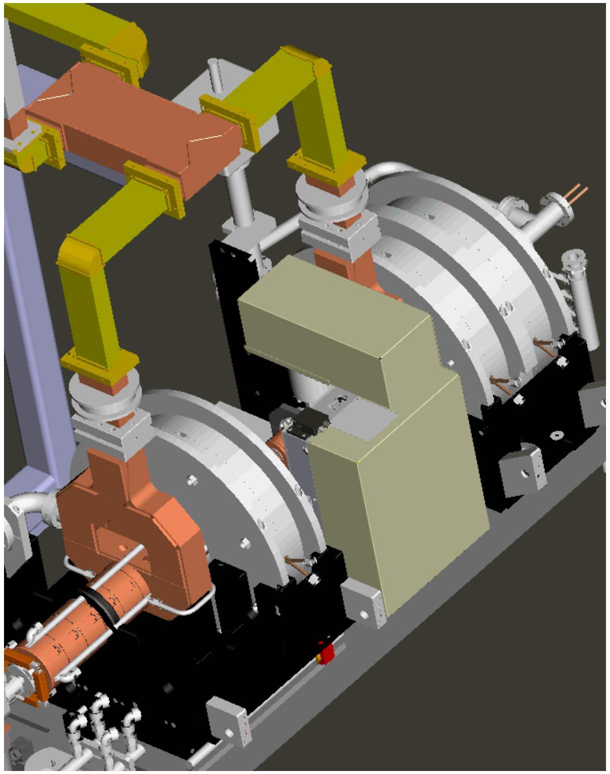
Upcoming Plans

- **We are tuning up both the laser and electron beam using the x-ray output.**
- **Using Mar 165 CCD detector as well as an Amptek for spectrum analysis.**
- **Continue tuning with focused and unfocused x-ray beams.**
- **First data sets are planned very soon with ATCG3D**
  - Thanks to Mar USA for the loan of a Mar 165 CCD and a Mar desk top beamline for initial testing.
  - Thanks to Oxford Cryosystems for the loan of a Cryostream.
- **Increase flux over the next several months.**

RF Gun



RF Gun Laser System



Cathode Cleaning for High Quantum Efficiency

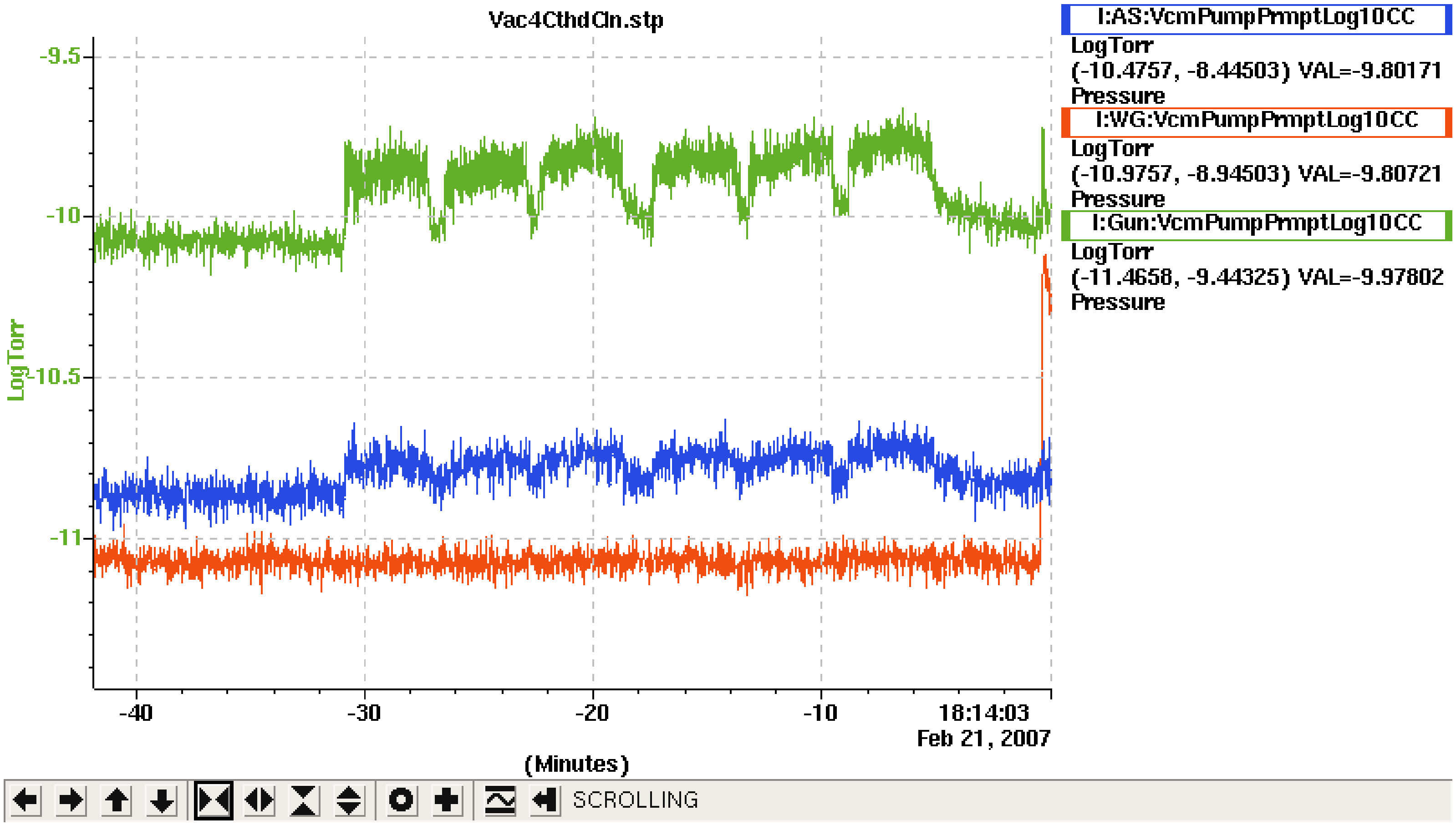
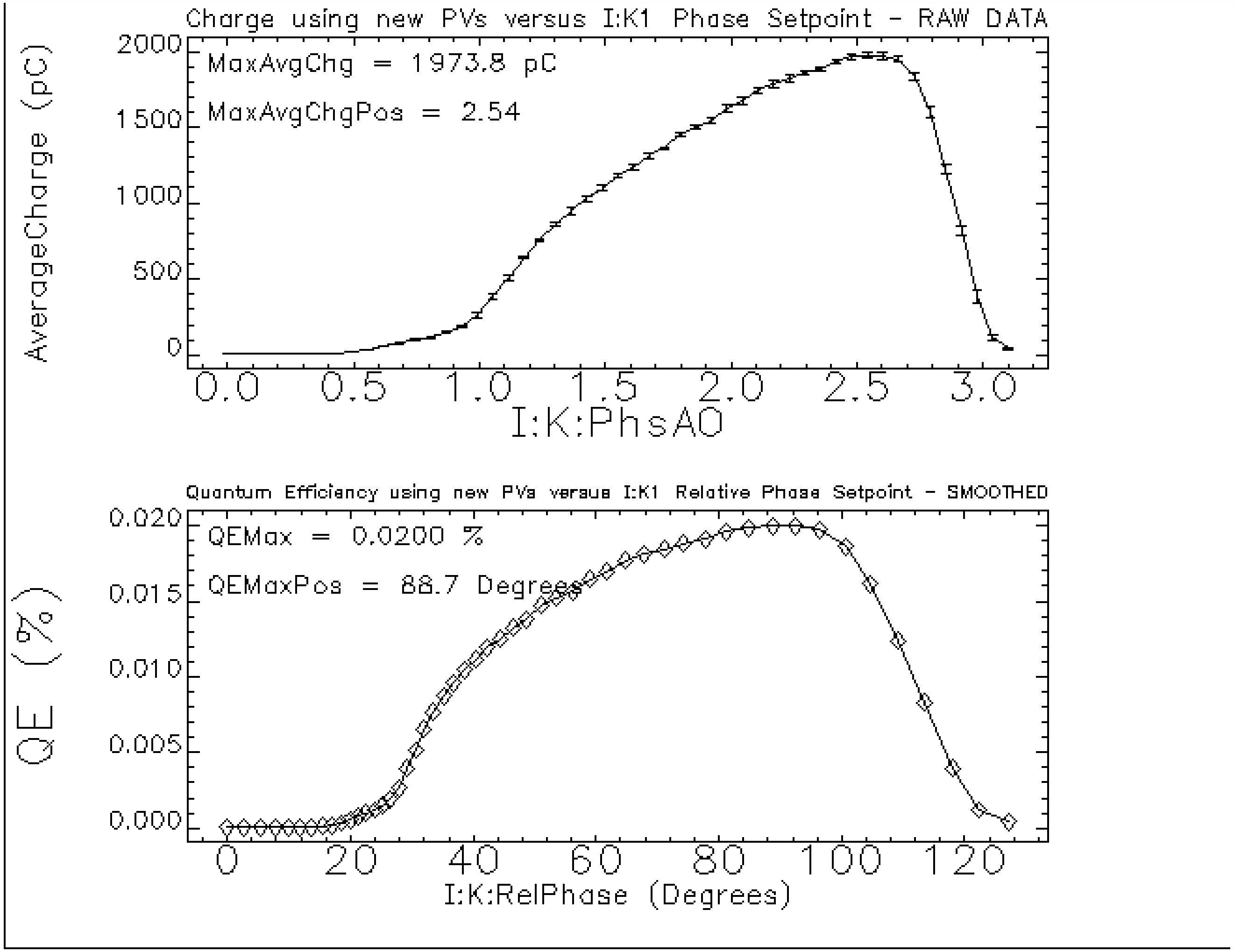
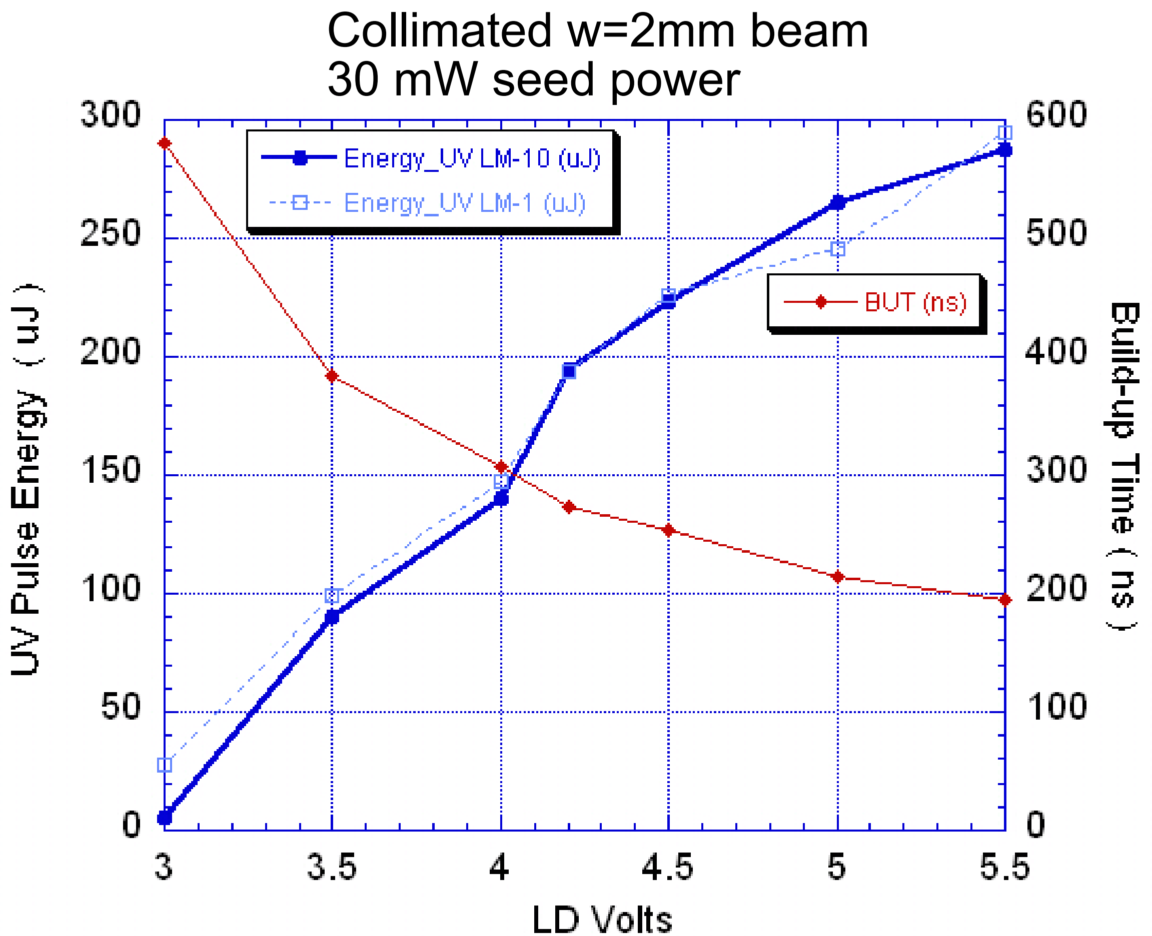


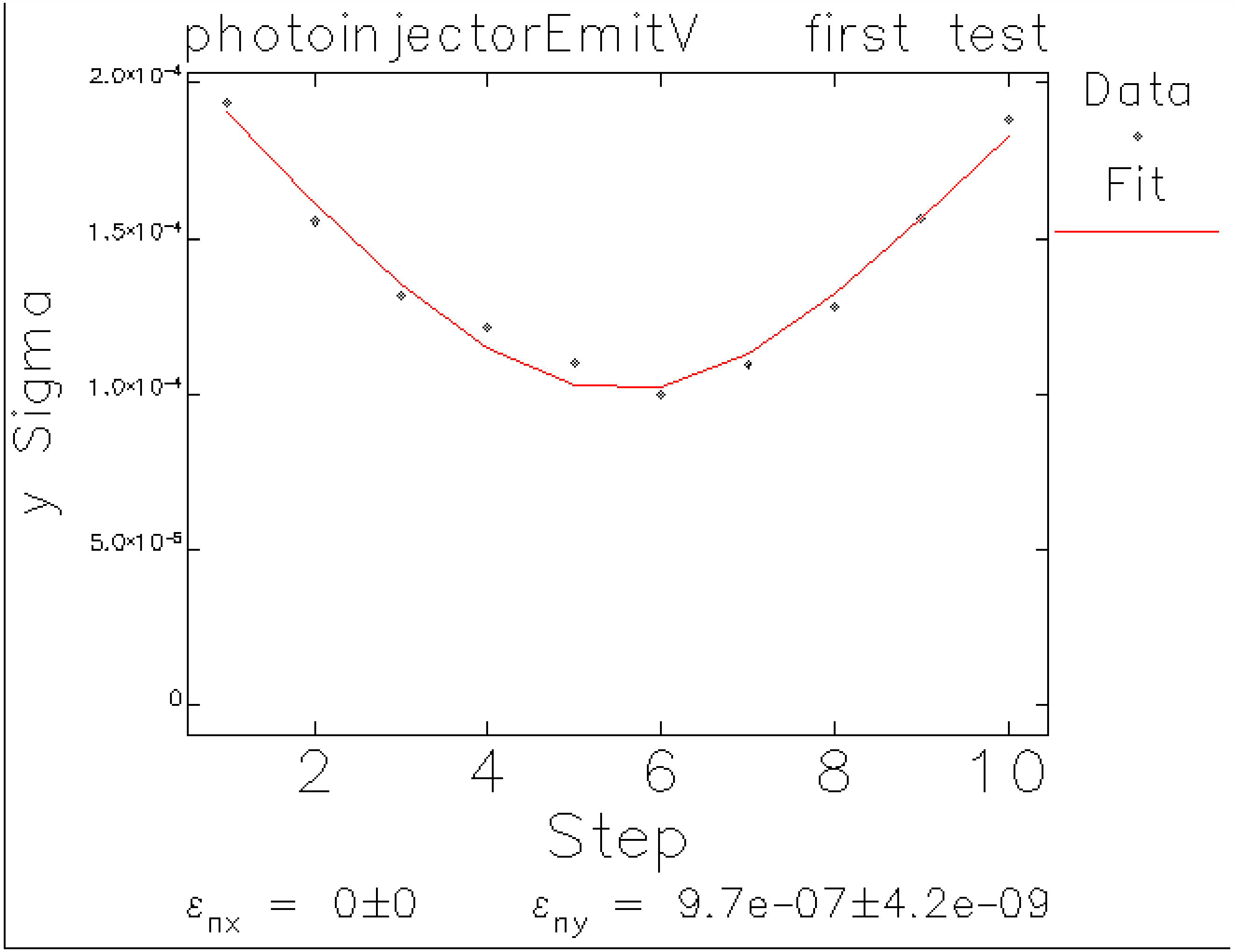
Photo Injector: Electron Beam Intensity

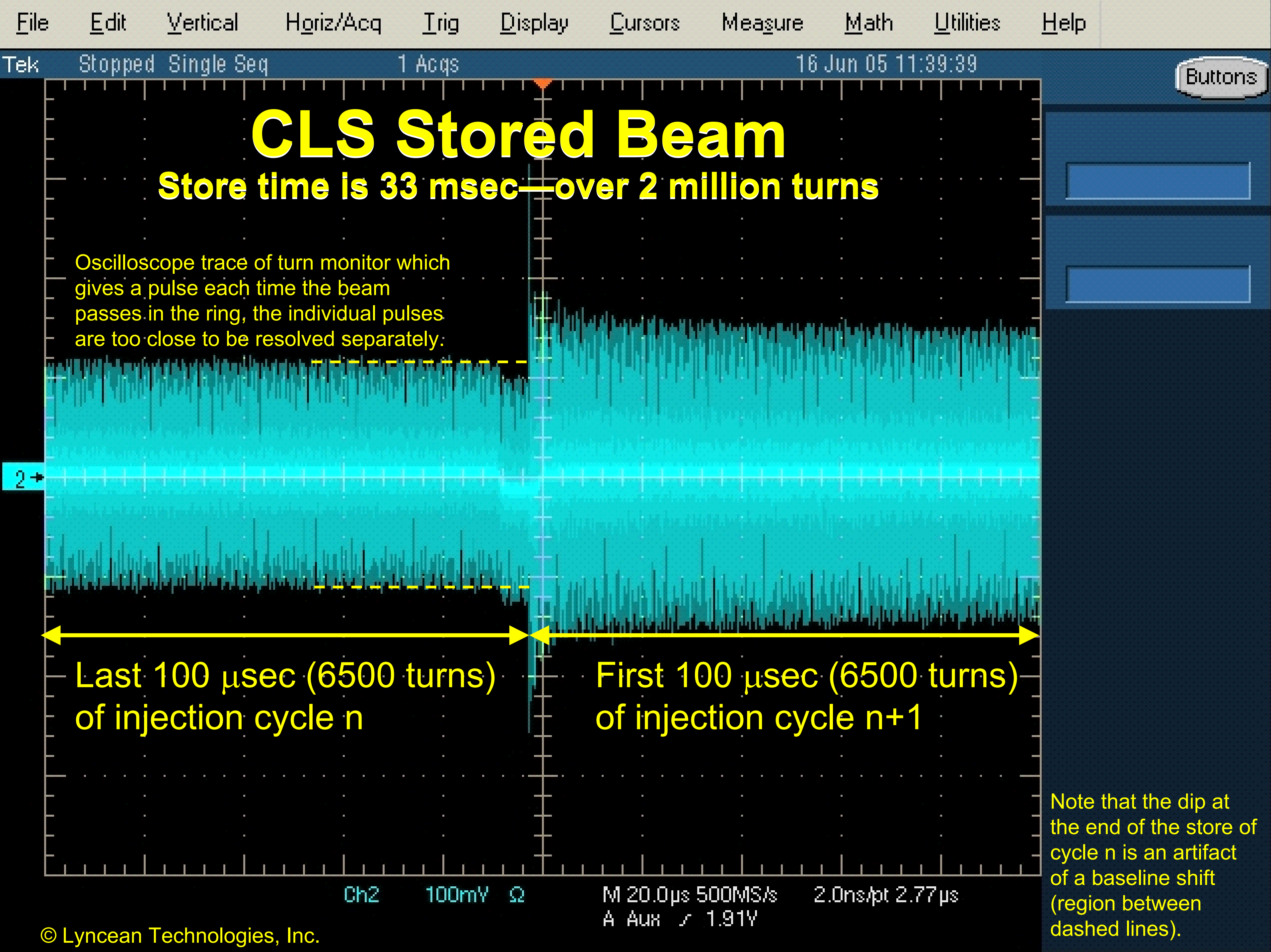


Performance of Production Regen

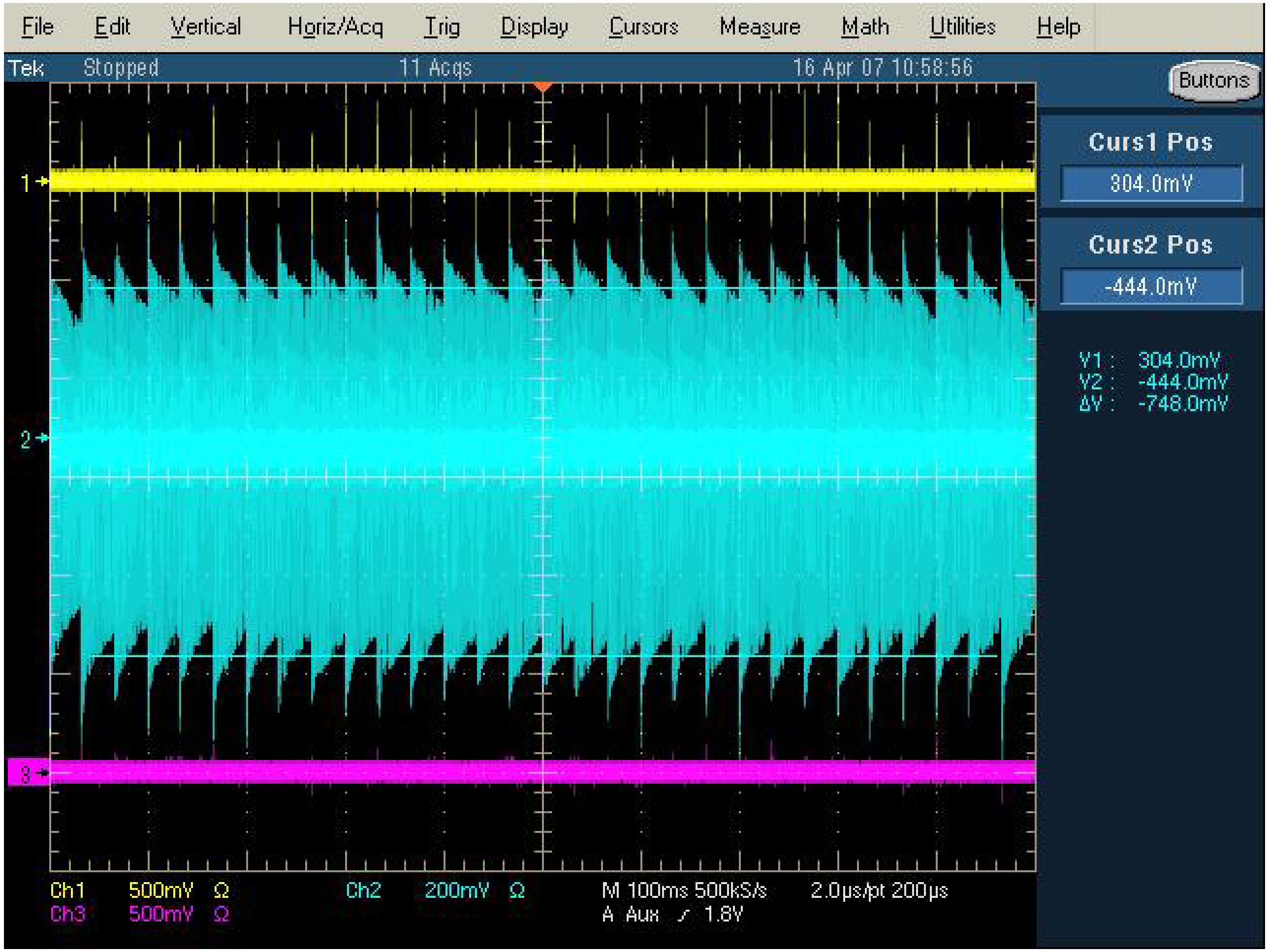


Measured Electron Beam Emittance
recent measurement



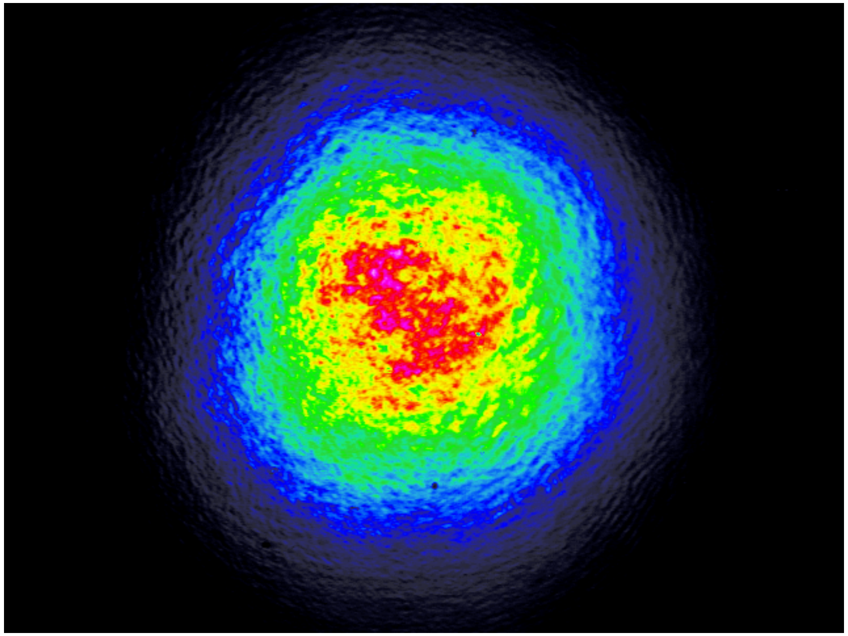

File Edit Vertical Horiz/Acq Trig Display Cursors Measure Math Utilities Help
Tek Stopped Single Seq 1 Acqs 16 Jun 05 11:39:39
Buttons
CLS Stored Beam
Store time is 33 msec—over 2 million turns
Oscilloscope trace of turn monitor which gives a pulse each time the beam passes in the ring, the individual pulses are too close to be resolved separately.
2
Last 100 μsec (6500 turns) of injection cycle n
First 100 μsec (6500 turns) of injection cycle n+1
Note that the dip at the end of the store of cycle n is an artifact of a baseline shift (region between dashed lines).
Ch2 100mV Ω
M 20.0μs 500MS/s 2.0ns/pt 2.77μs
A Aux ⌿ 1.91V
© Lyncean Technologies, Inc.

Recent Running

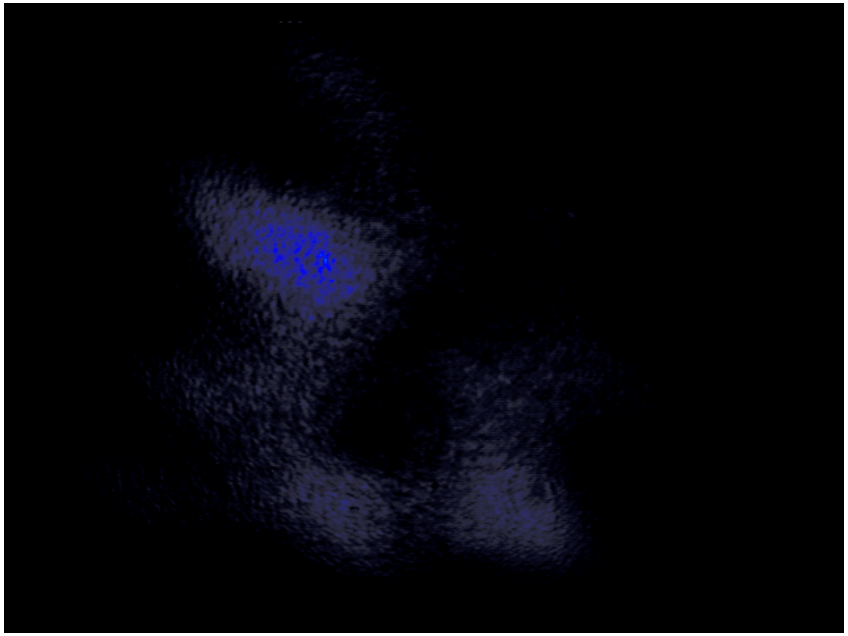


Optical Cavity

Unlocked Cavity (total reflection)

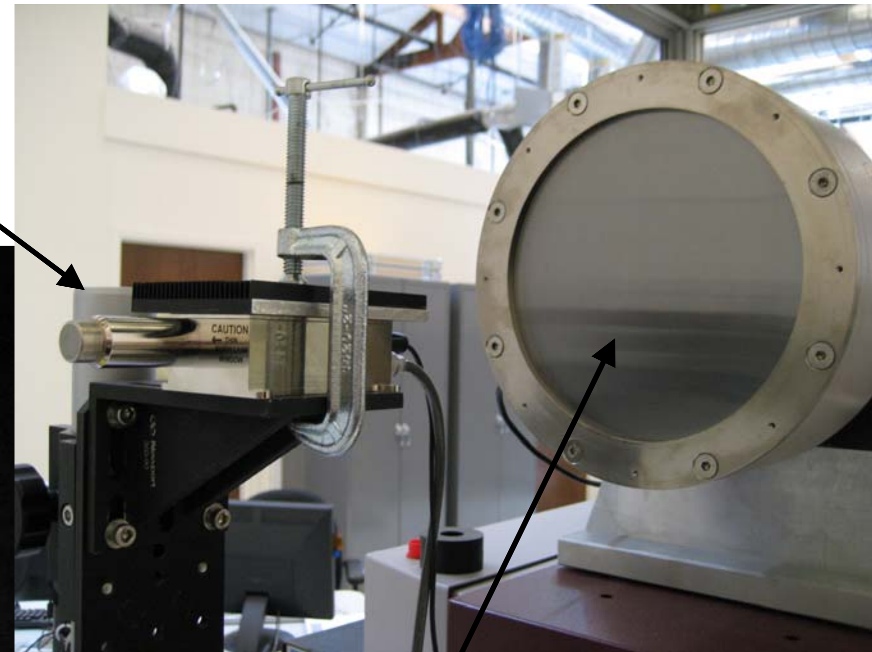


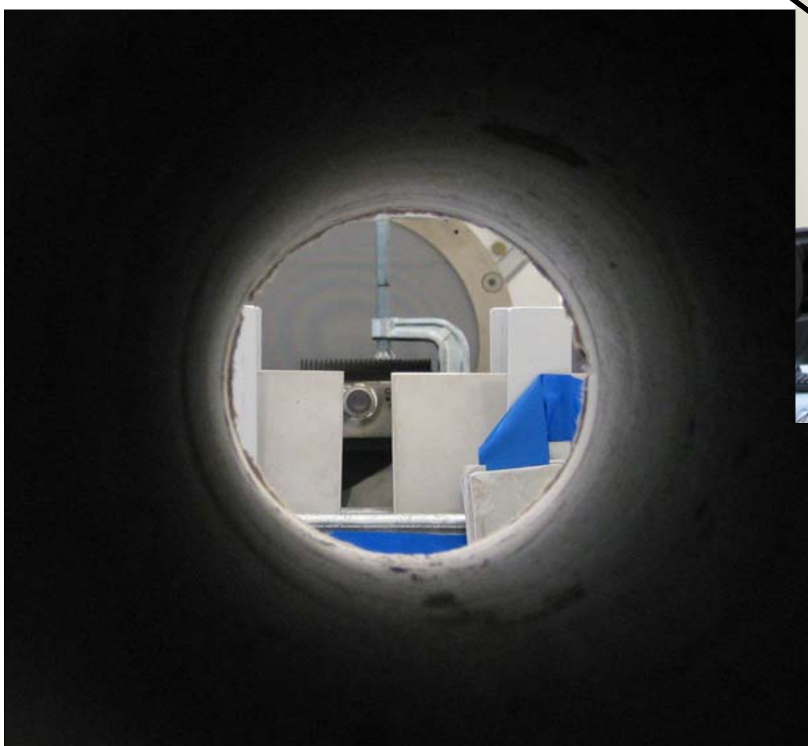
Locked Cavity (<20% reflection)



X-ray Detectors

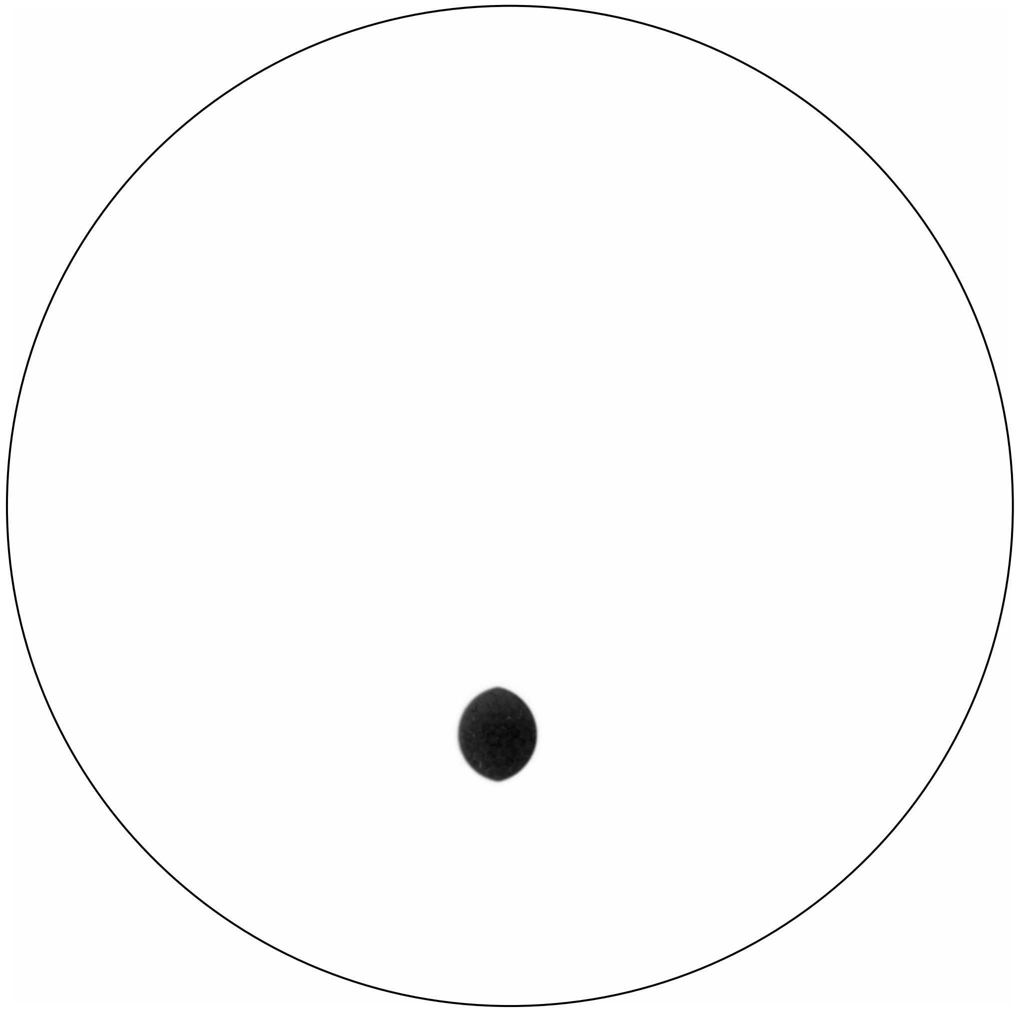
- **Amptek Si dispersive detector**
  - Energy spectra
  - Not for intensity



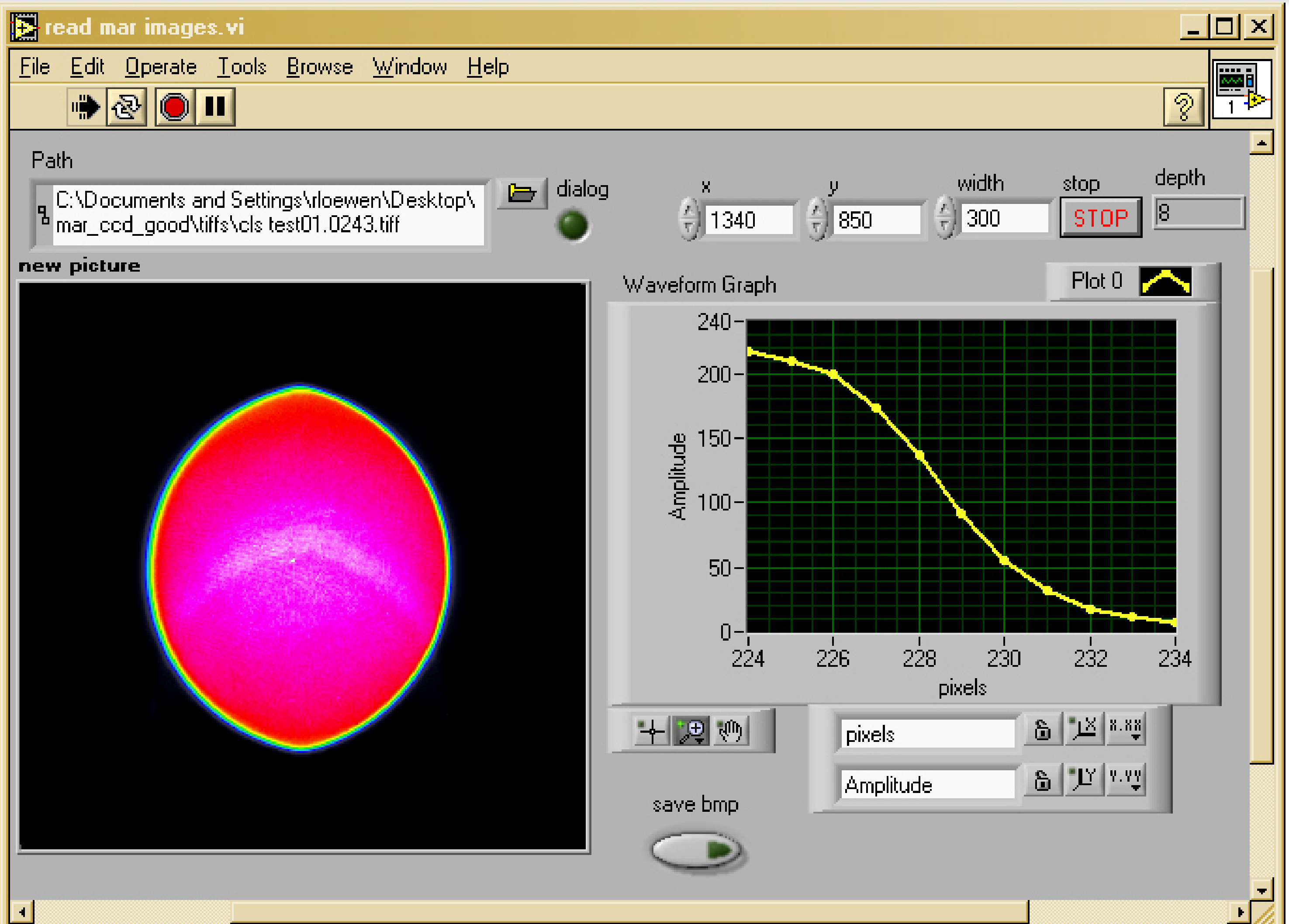


Mar CCD Area Detector
- Total flux
- 79 μm/pixel
- 16 bit depth

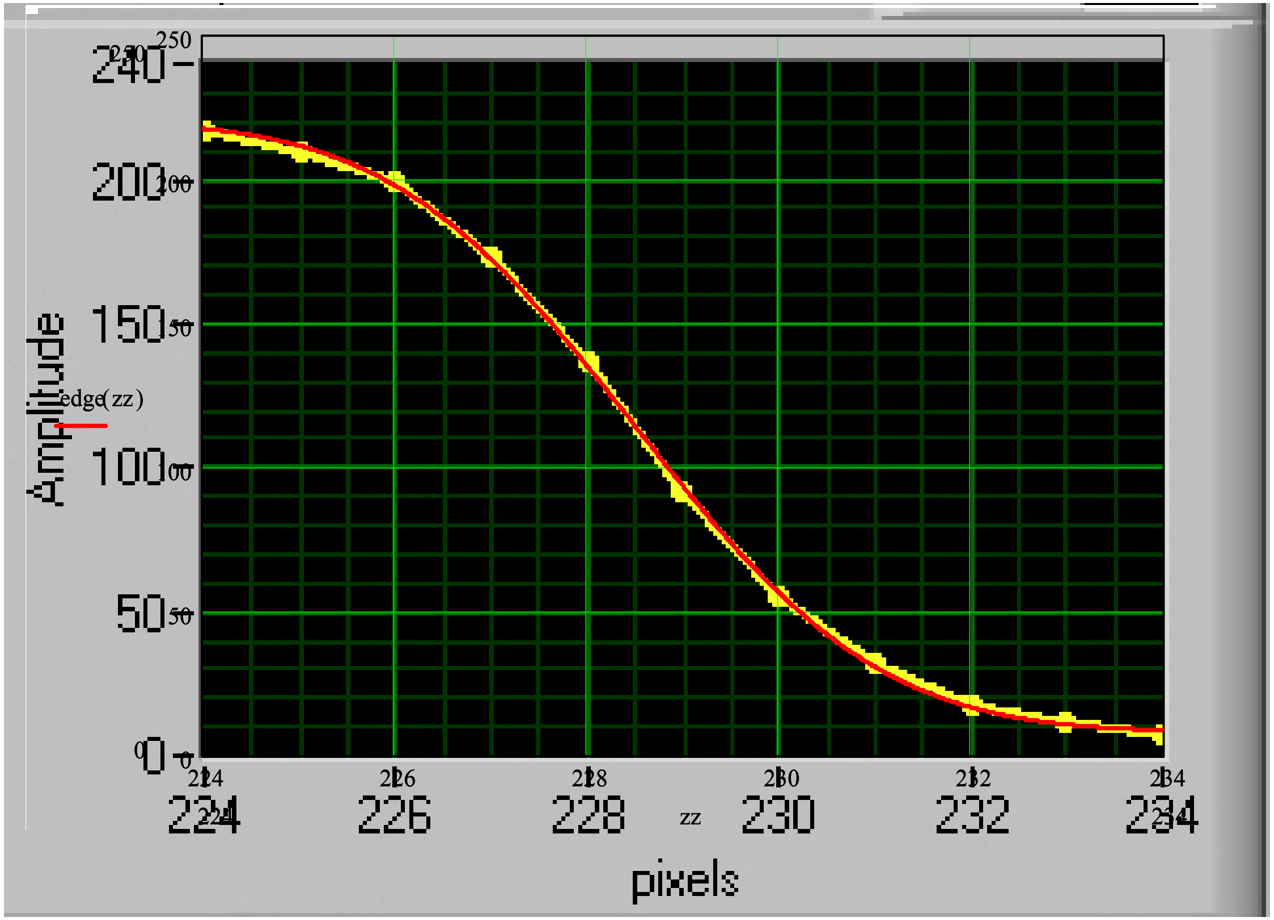
Full MarCCD Image



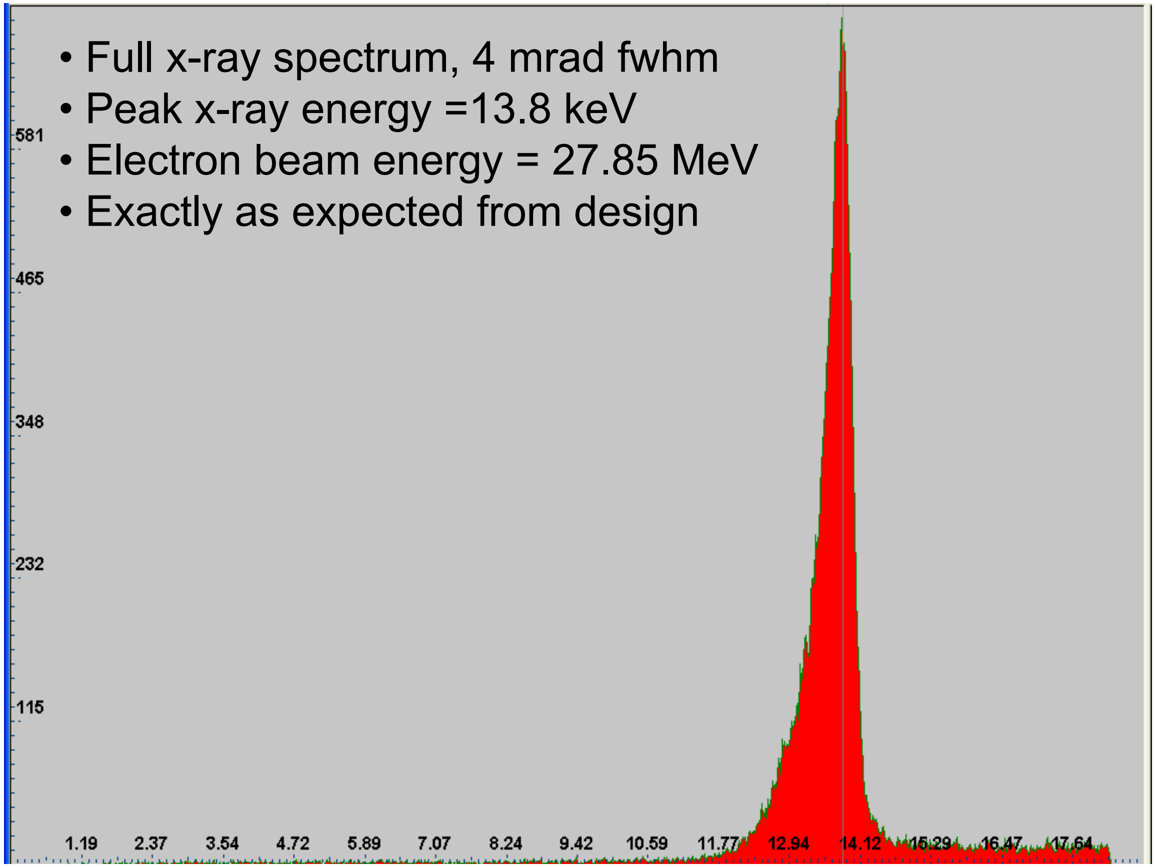
Mar Image of Interaction Point



Fit of edge to extract IP spot size



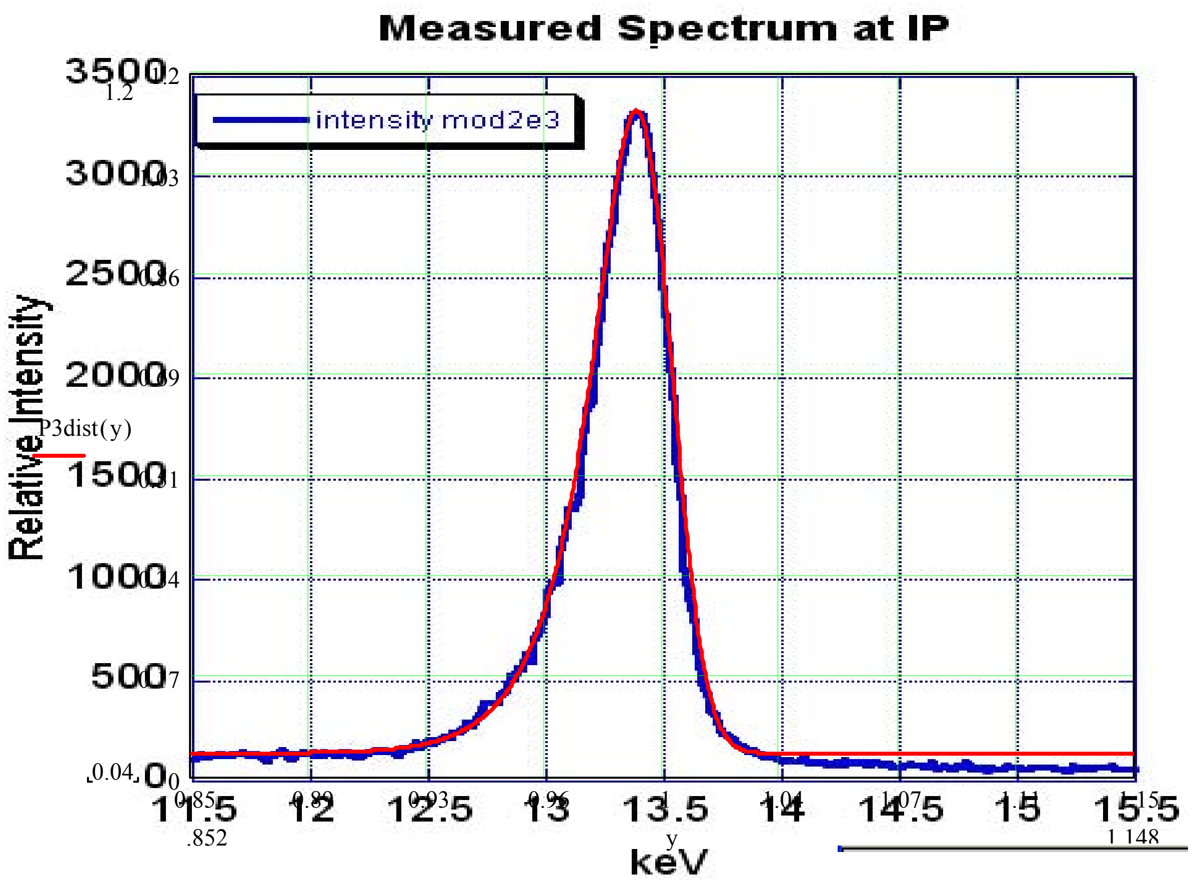
Straight Ahead X-ray Spectrum



X-ray Energy in KeV

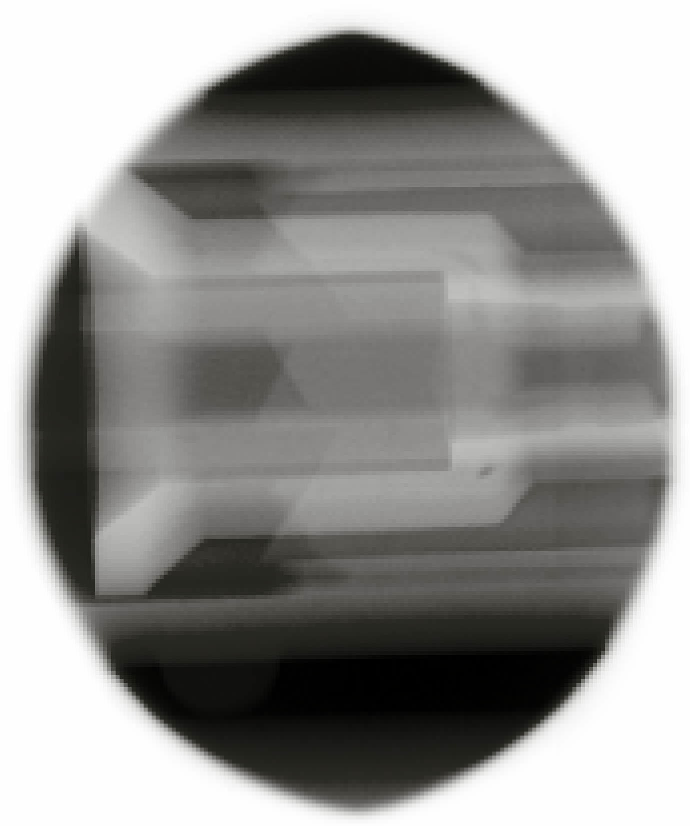
Measured and Calculated Spectrum

σ_θ = 1.75 mrad, σ_δ = .004

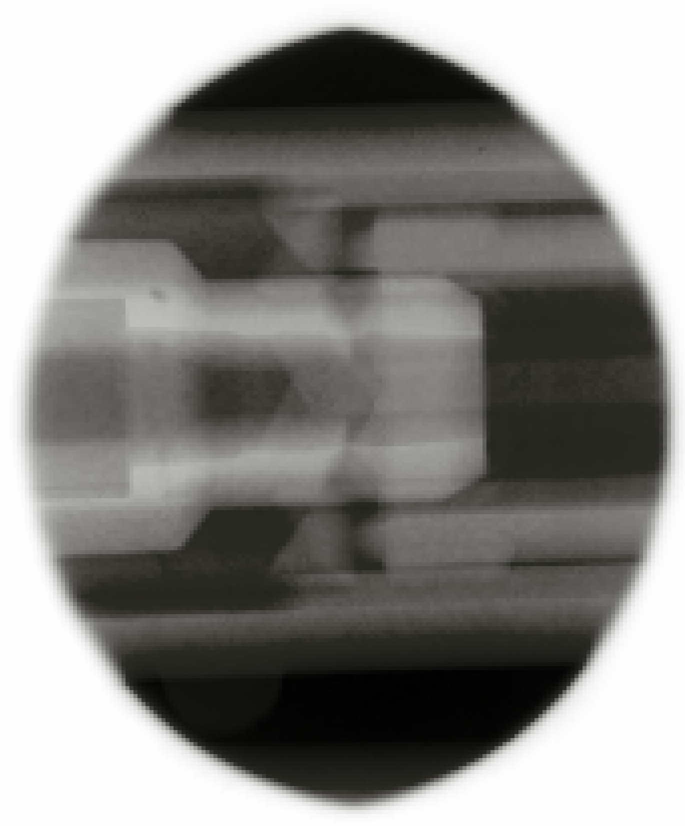


Quick x-ray of Ron's pen

- **Unclicked**



- **Clicked**



Utilizing the X-ray Beam

- **The optics required for the CLS beam are relatively straightforward and inexpensive.**
  - No cooling required.
- **A one to one image of the x-rays emerging from the interaction point yields a 30 μm rms spot.**
- **Up to three beamlines are possible.**
  - One straight ahead (for high flux screening)
  - One on each side (for MAD/SAD data collection)
- **Narrow band optics (focusing monochromator) have already been tested (Jens Als-Nielson collaboration, benders developed by JJ x-ray.)**
- **Multilayer Optics prototype on loan from Copenhagen University has been successfully tested (developed by J A-N and Annette Jensen, NBI in collaboration with the Danish Space Research Institute, benders also by JJ x-ray.)**

Summary of X-ray Experiments

- **We measure intensities and spot sizes and get consistency with measurements of x-ray flux.**
- **We have used the x-ray beam to determine the luminous spot.**
- **We can use the spectrum to determine the electron beam emittance (using beta function measured with optics).**
- **X-ray flux is rising exponentially as we squeeze the spot and increase intensity.**
- **Diffraction and data sets are imminent**

Acknowledgements

- **For advice, encouragement and collaboration**
  - Sebastian Doniach, Stanford
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  - Lance Stewart, deCODE
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PSI

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ATCG3D
Accelerated Technologies Center for Gene to 3D Structure