XTOD Diagnostics

Photon Systems Breakout

Lehman Review

July 11, 2007

UCRL-PRES-232792
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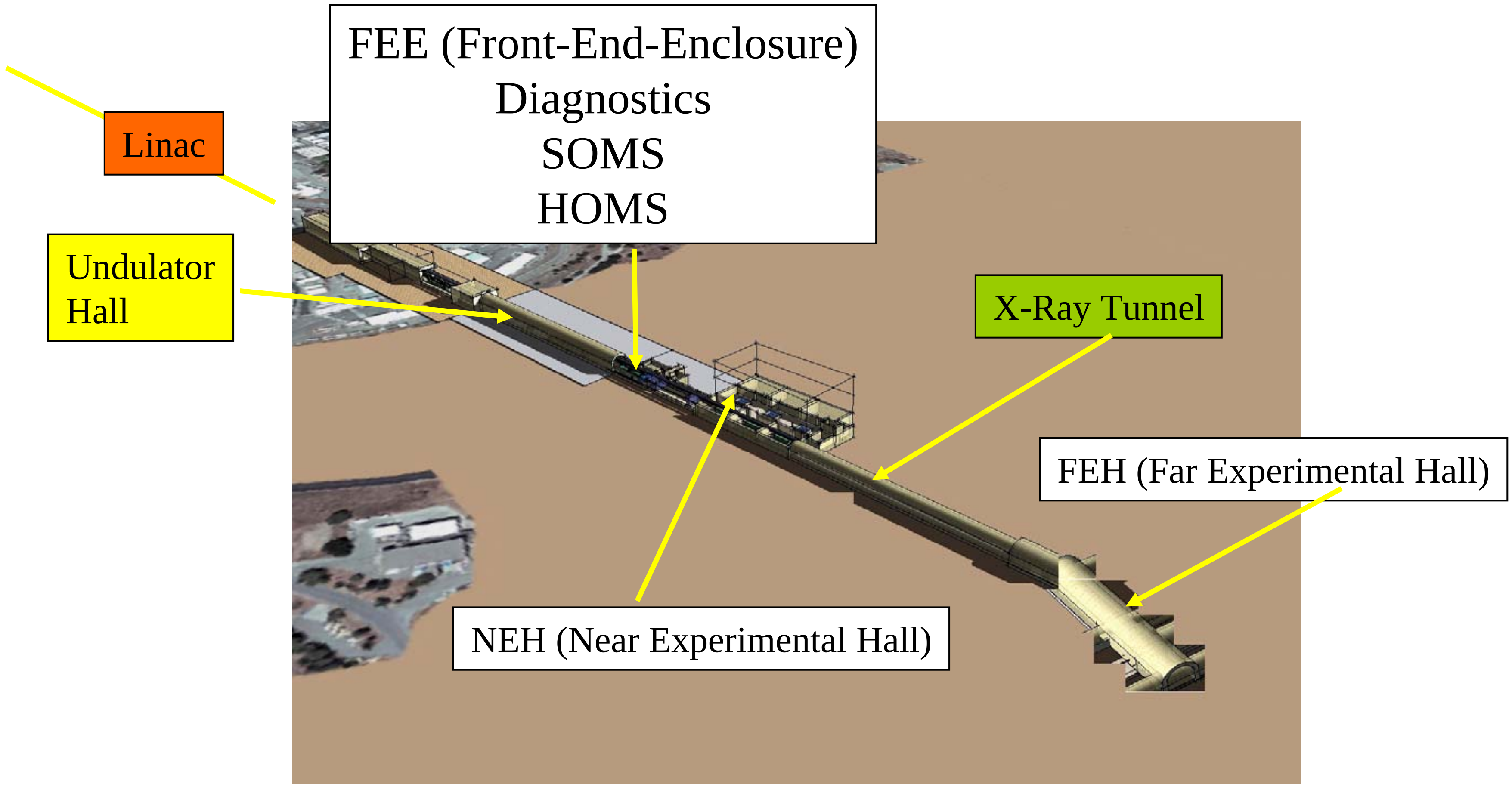
LCLS Layout



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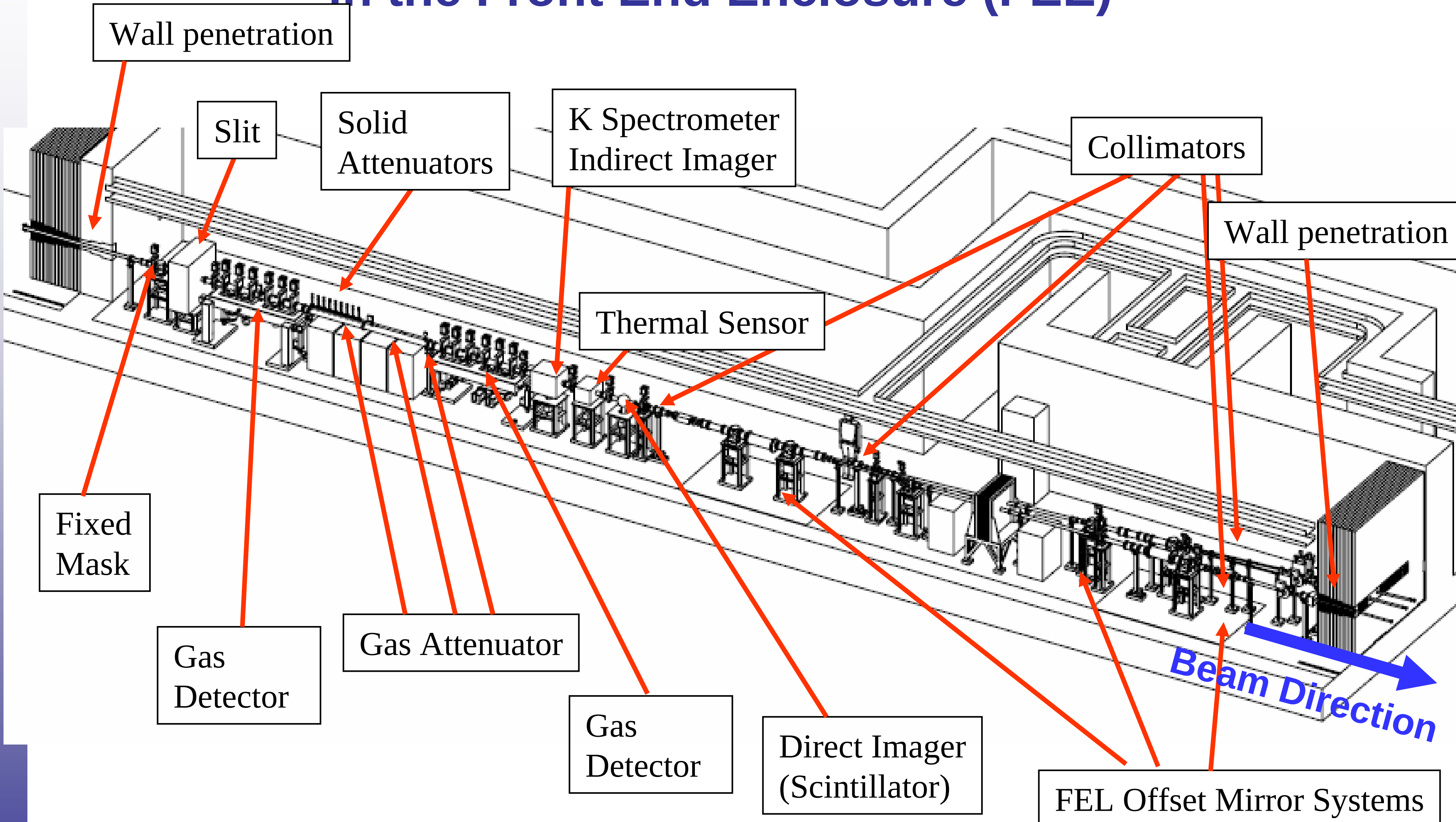
XTOD Commissioning Diagnostics and Offset Mirrors in the Front End Enclosure (FEE)



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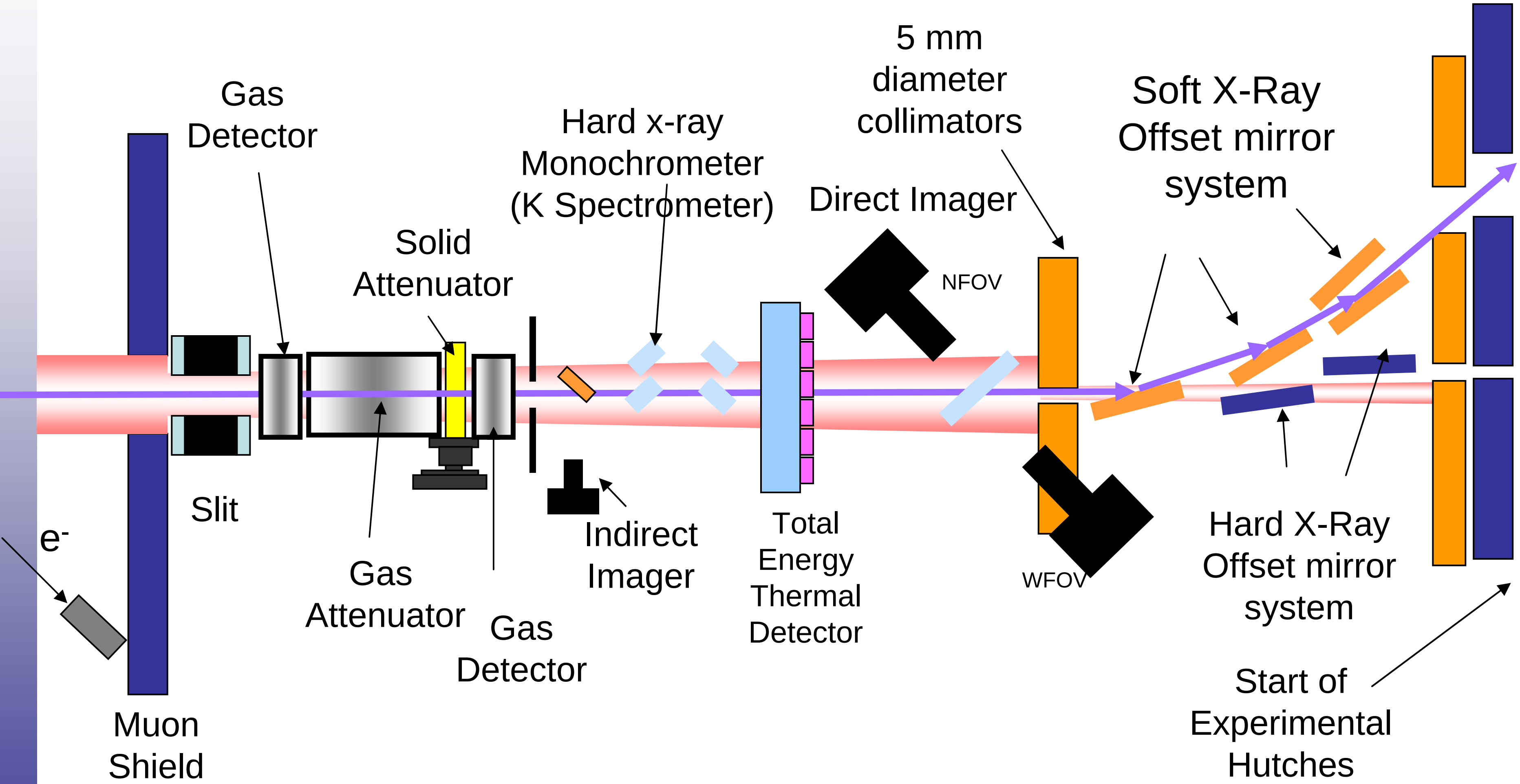
XTOD Optics and Diagnostics in FEE



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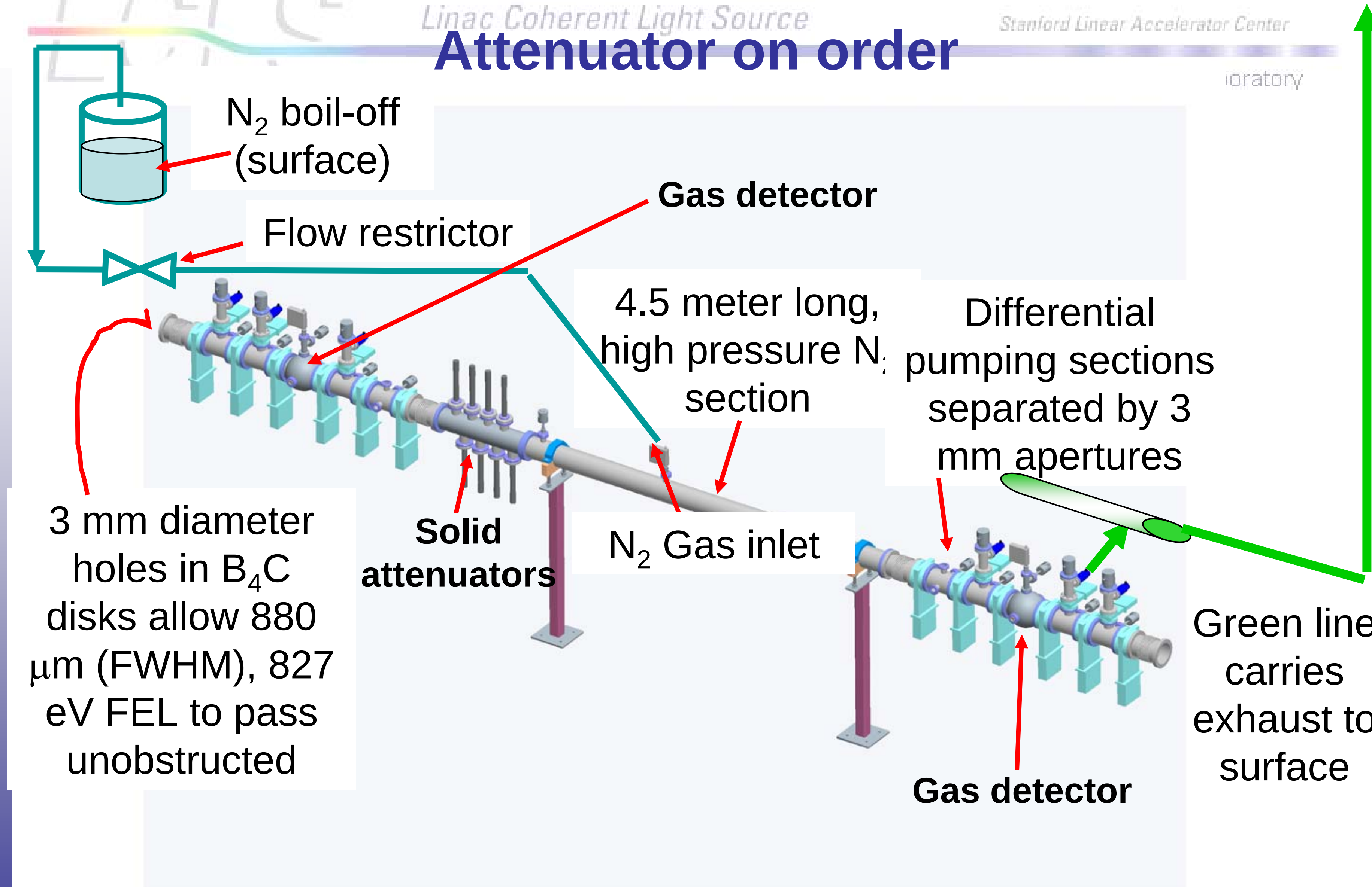
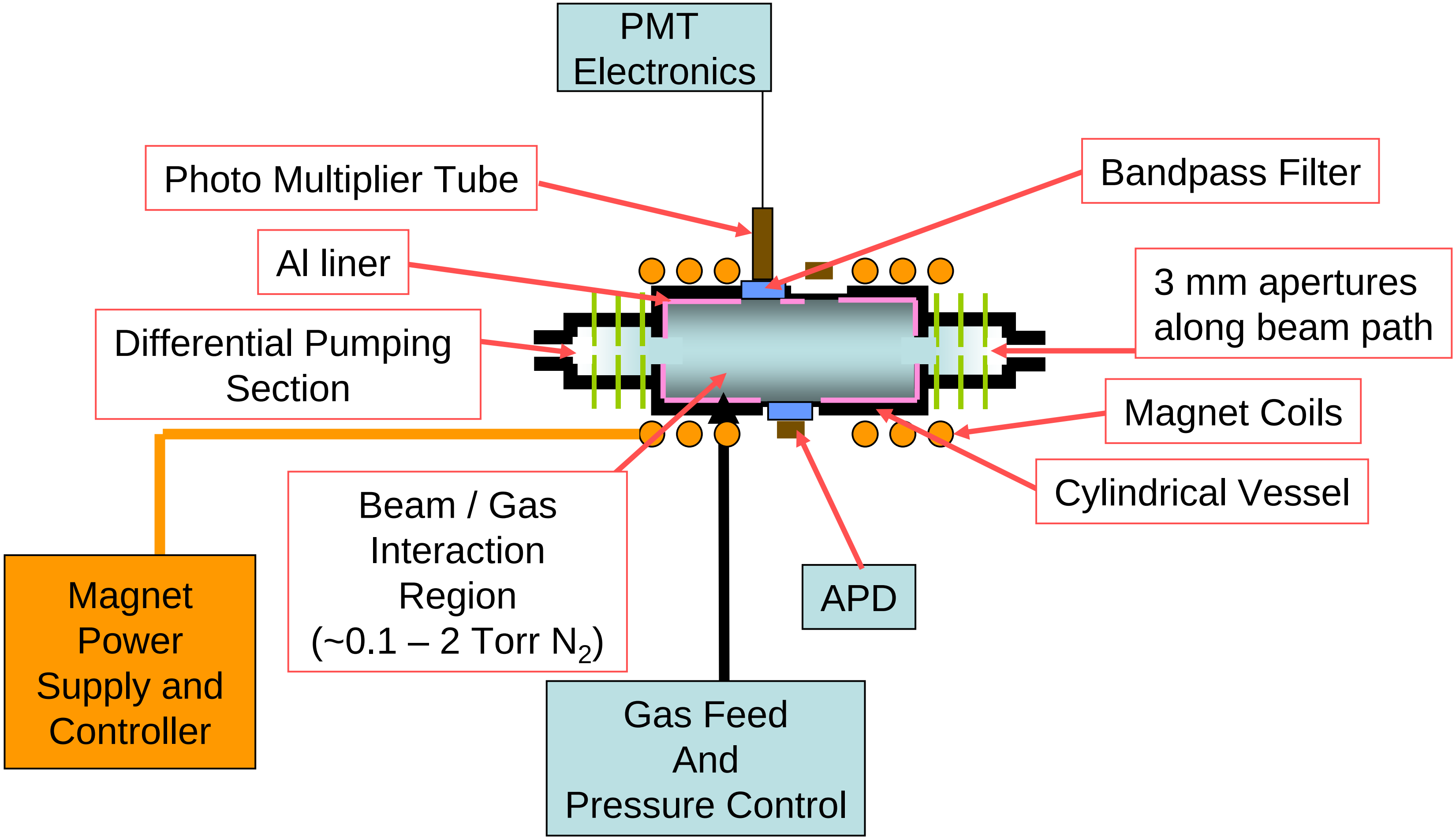
Attenuator on order



Gas detectors share differential pumping with the Gas Attenuator



LCLS X rays cause N_2 molecules to fluoresce in the near UV

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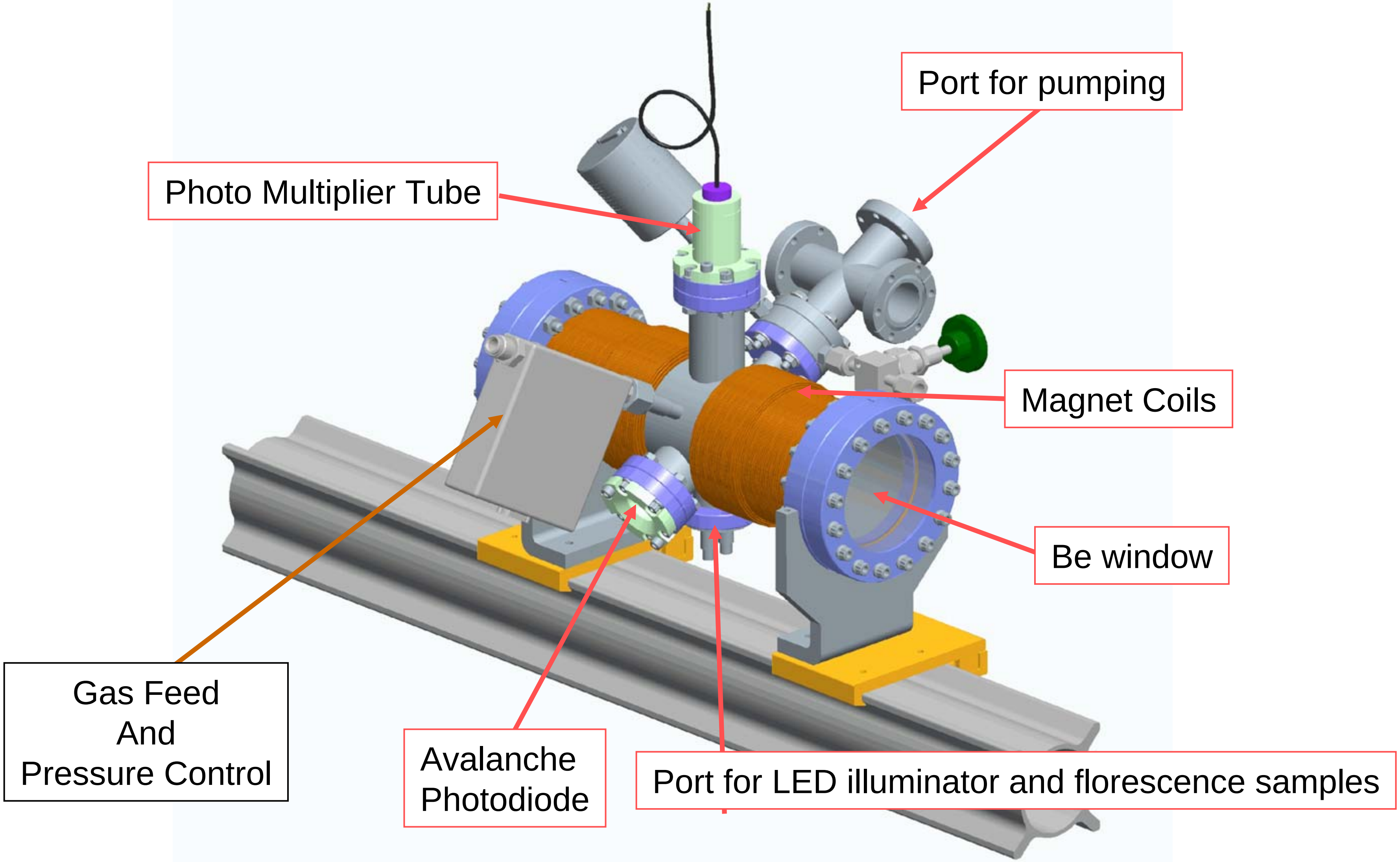
Gas detector SSRL prototype



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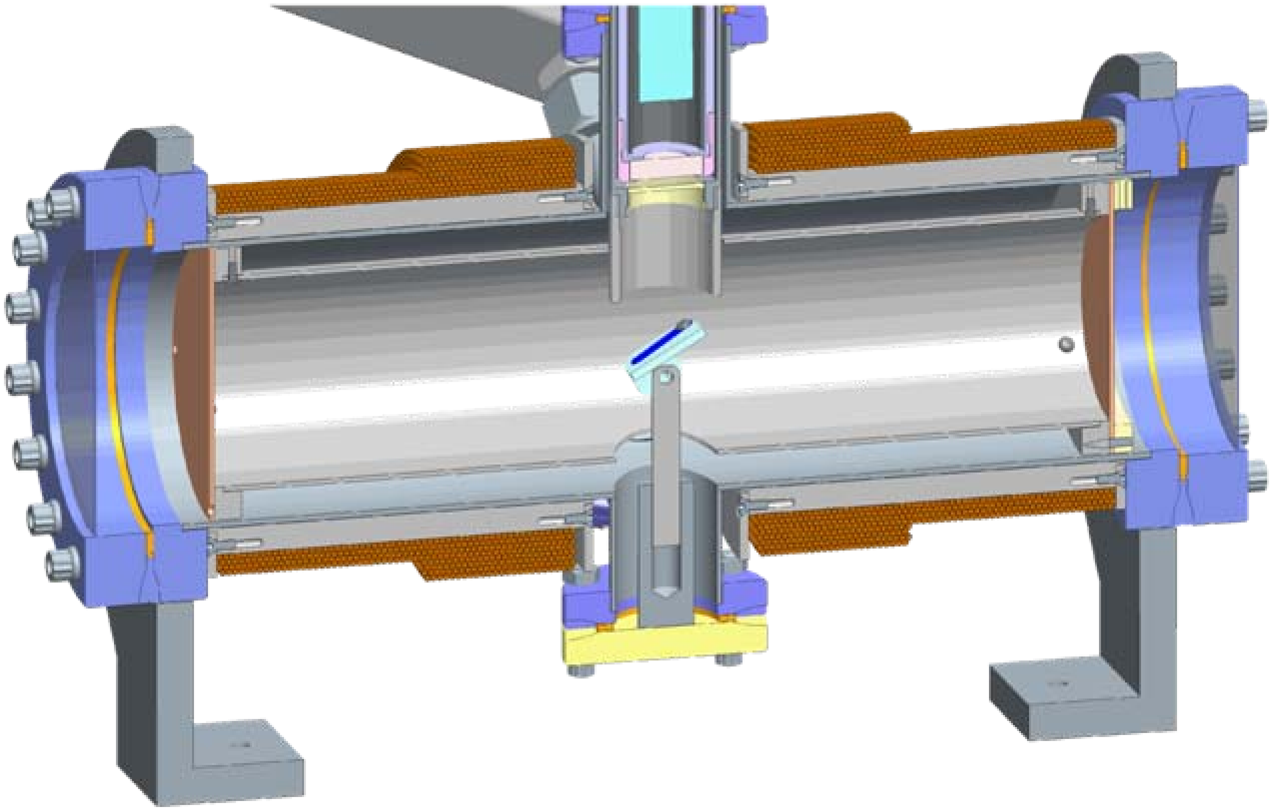
Prototype Gas Detector insert for measuring x ray induced photoemission of candidate wall materials



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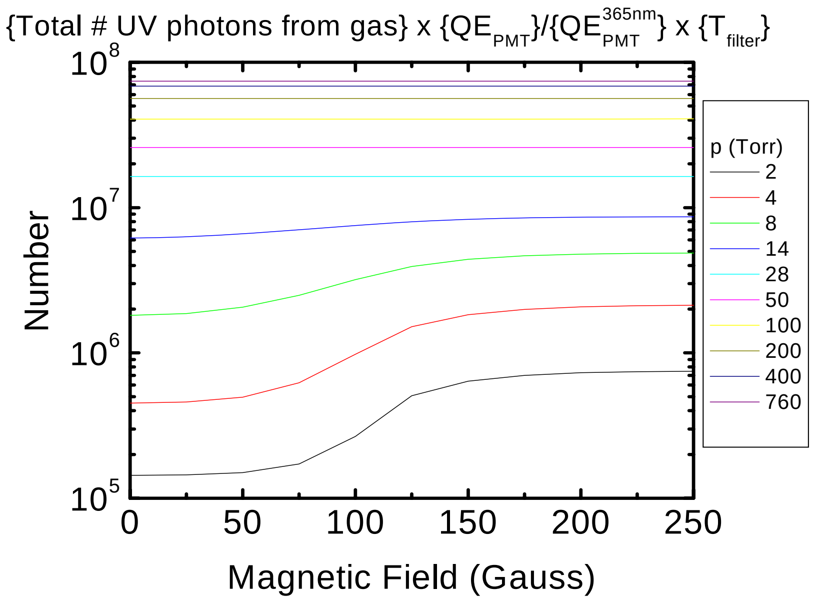
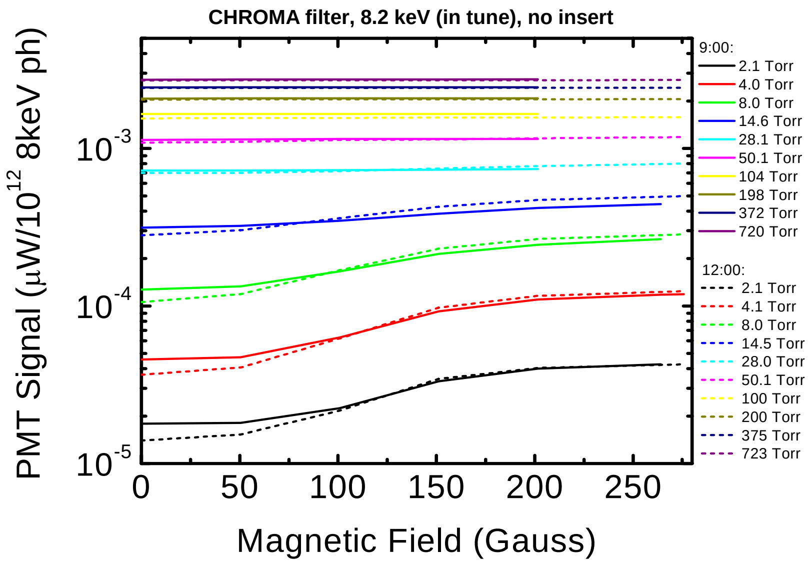
Gas Detector signal vs. magnetic field at various pressures

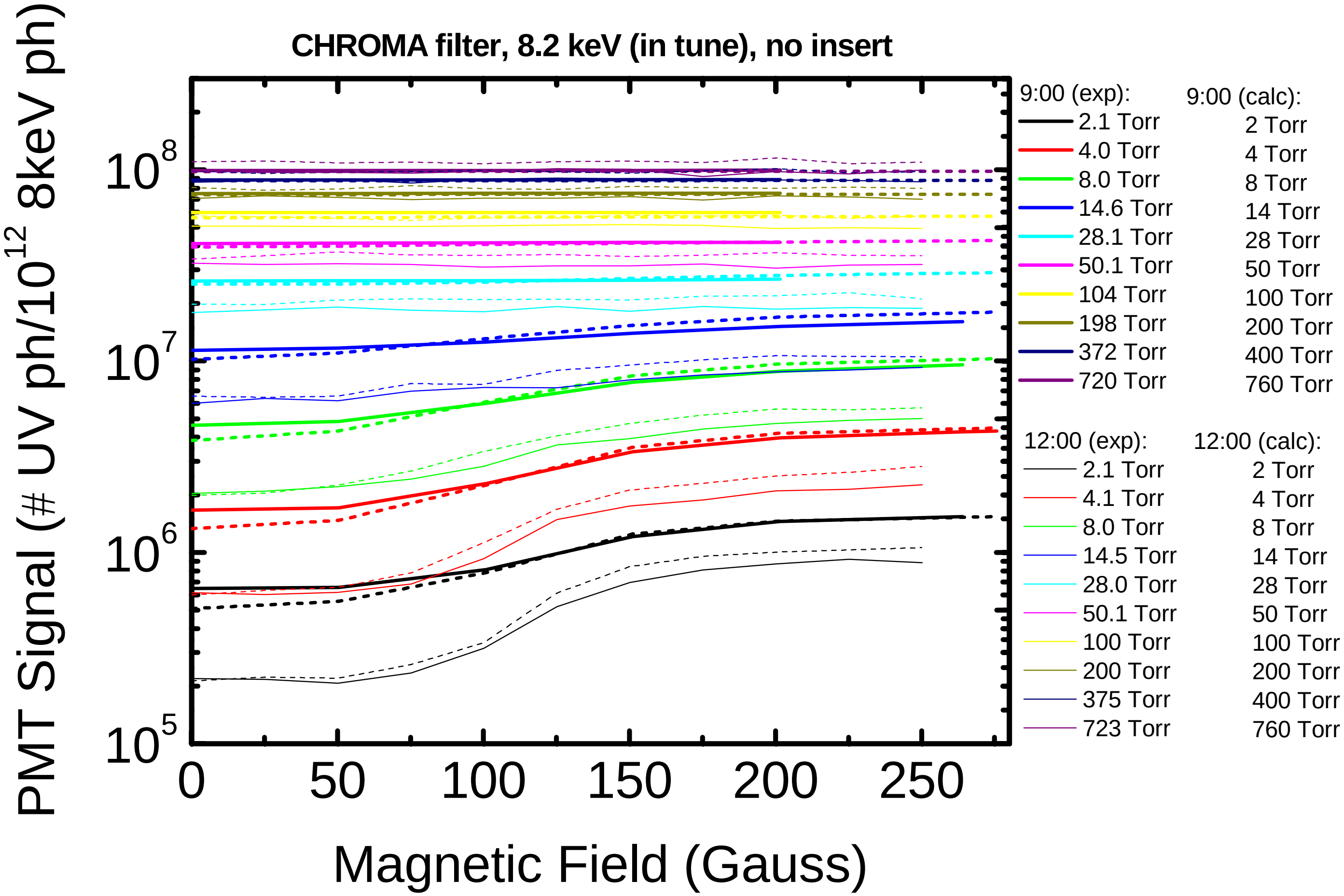
Simulated



Measured

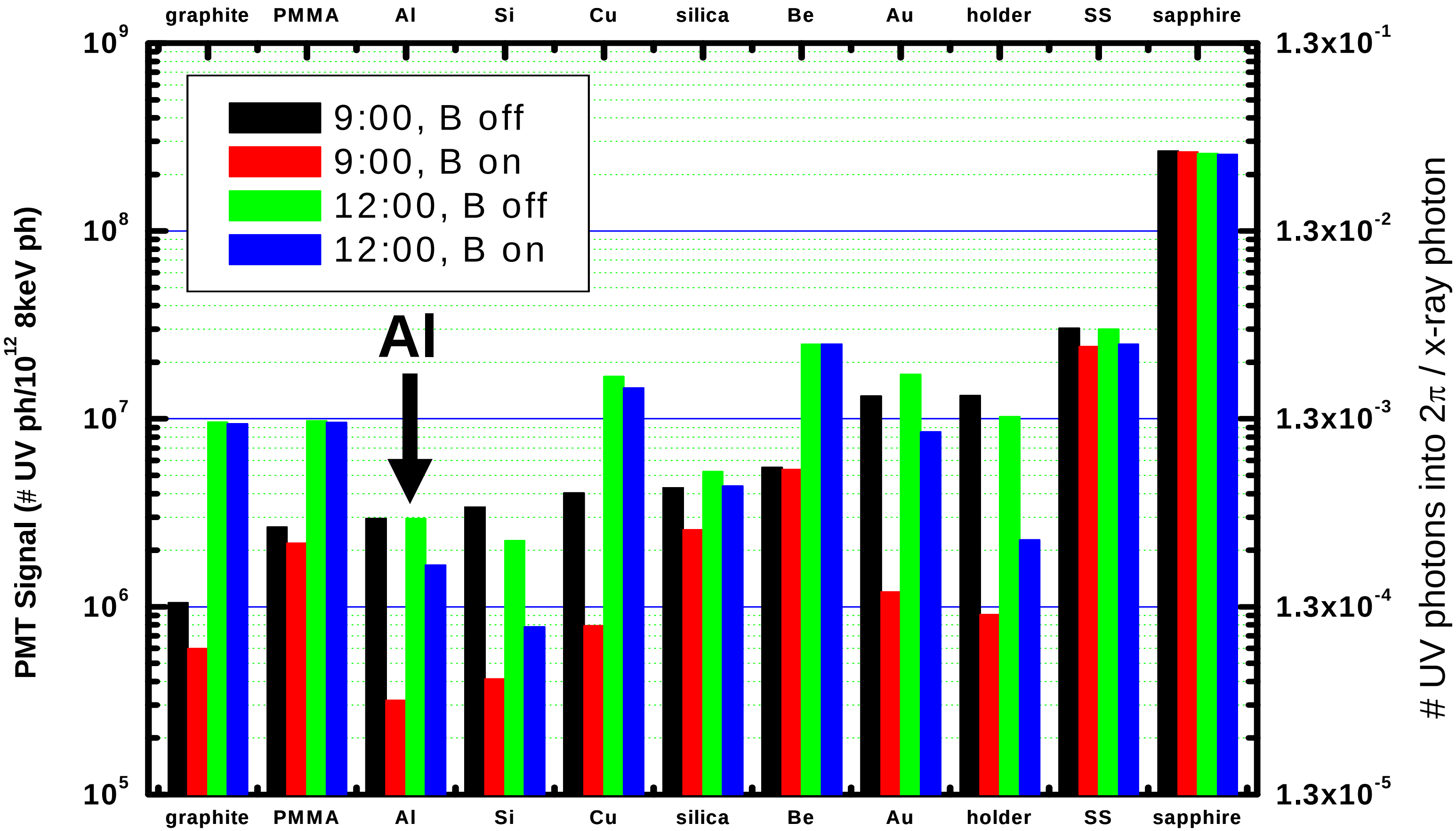


Results of SSRL Gas Experiments: Comparison Model and Experiments (2X correction of calculated signal)



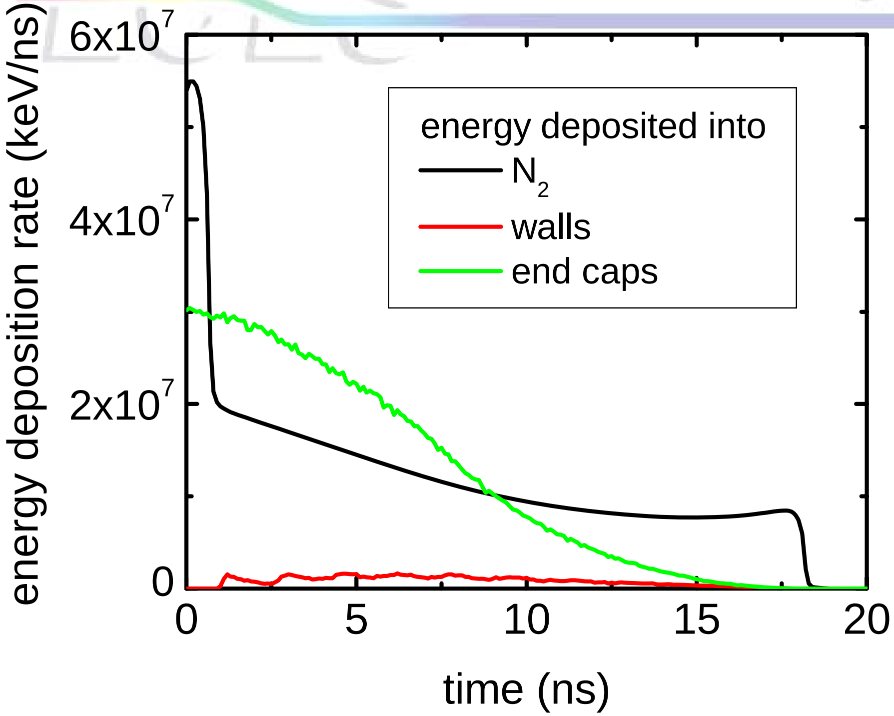
We suspect that discrepancy at lower pressures is due to photo electrons (and secondaries?) hitting the chamber ends

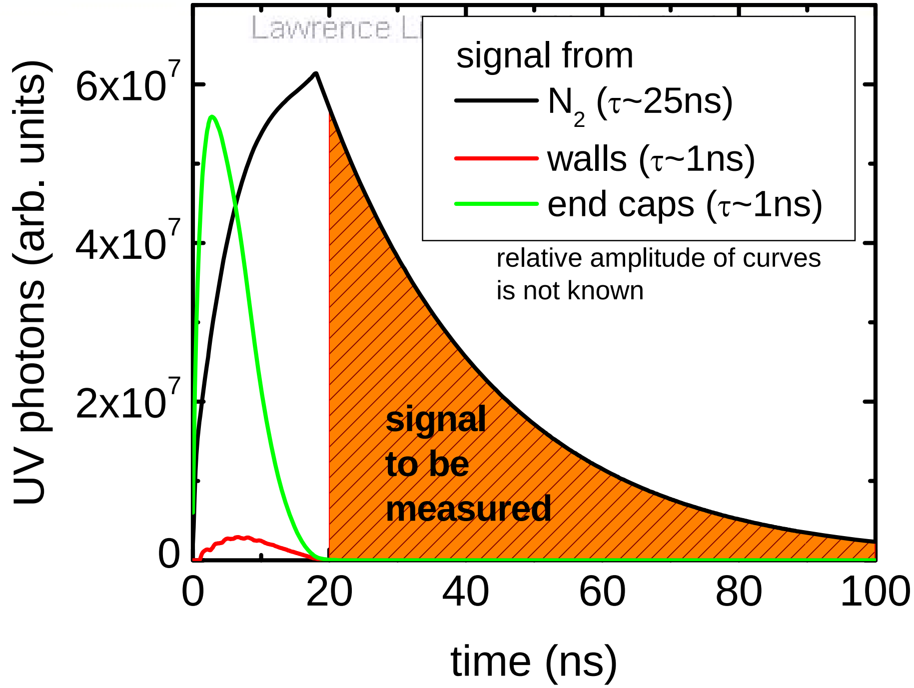
Measured luminescence of solids at 8 keV



UV signal closely represented by 9:00, B on (red): **Al is the best**

Time dependence of gas detector signal from the 8keV fundamental





	UV signal within
X rays scattered into walls	~ 1 ns
X rays scattered into detector window	?
Photoelectrons hitting walls	0 – 18 ns
Photoelectrons hitting end caps	0 – 15 ns
Secondaries hitting walls and end caps	0 – 200 ns (?)
Energy of photoelectrons deposited into N_2	0 – 45 ns

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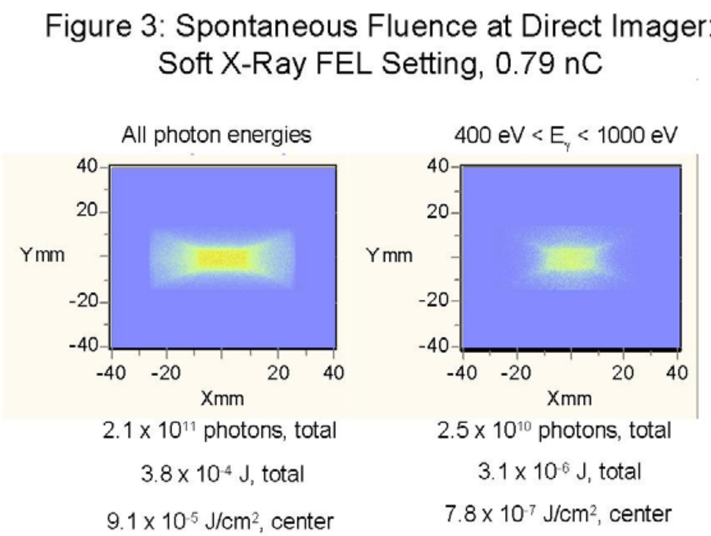
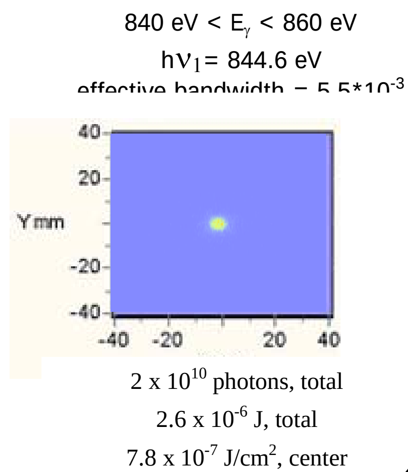
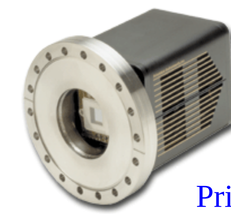
Indirect imager finds spontaneous core

Raw soft spontaneous

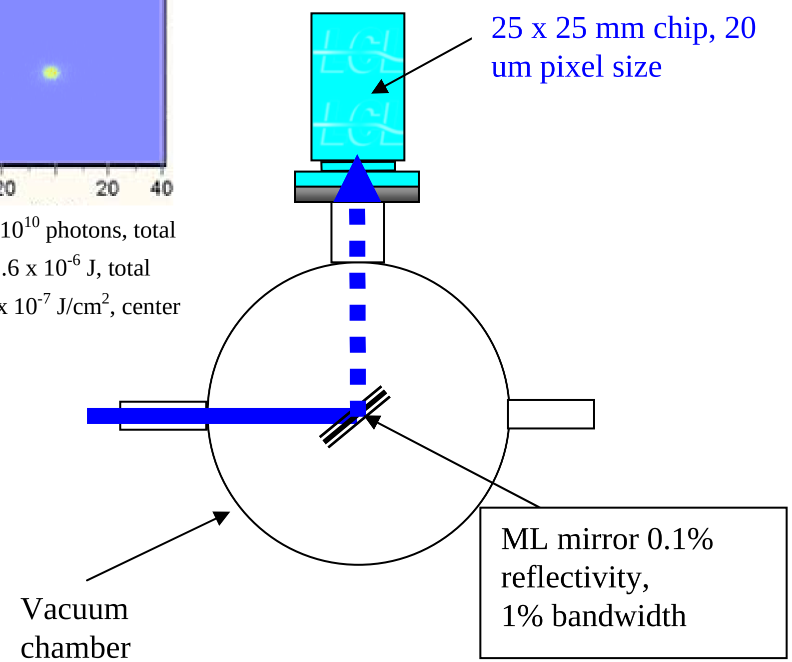


After reflection





Princeton Instruments back illuminated CCD camera
25 x 25 mm chip, 20 um pixel size

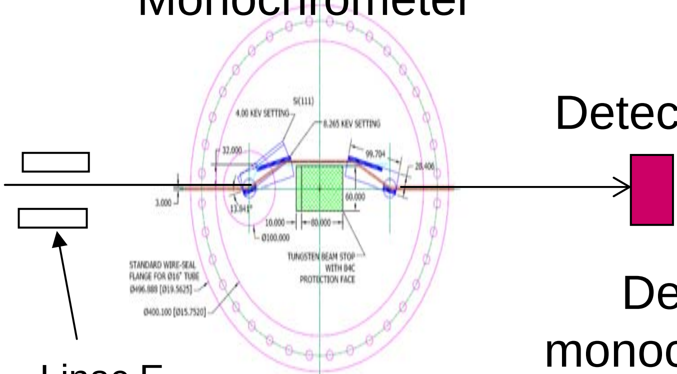


Status Indirect Imager:
PRD in progress

Channel-cut Si Monochrometer will be used to measure relative K of two undulator segments

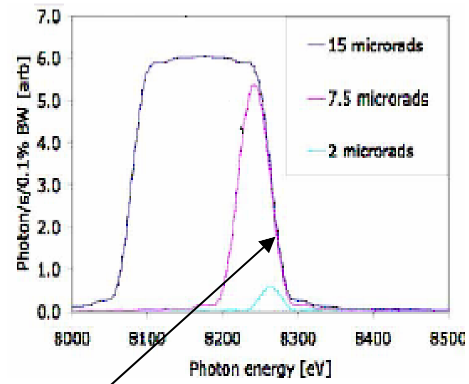
Monochrometer

Detector



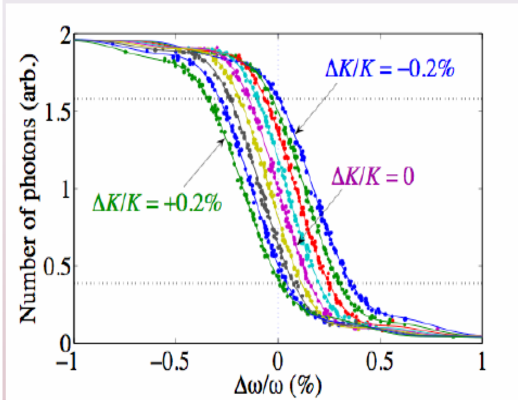
Linac E variation and measurement

Detector monochrometer measures intensity at a single point



Two undulator spontaneous spectrum. Falloff of high energy tail is independent of aperture

Use linac E variation and measurement to obtain other points along curve



Two undulator spontaneous high energy falloff has highest slope when $\Delta K/K=0$.

Status K Spectrometer:
PRD in progress

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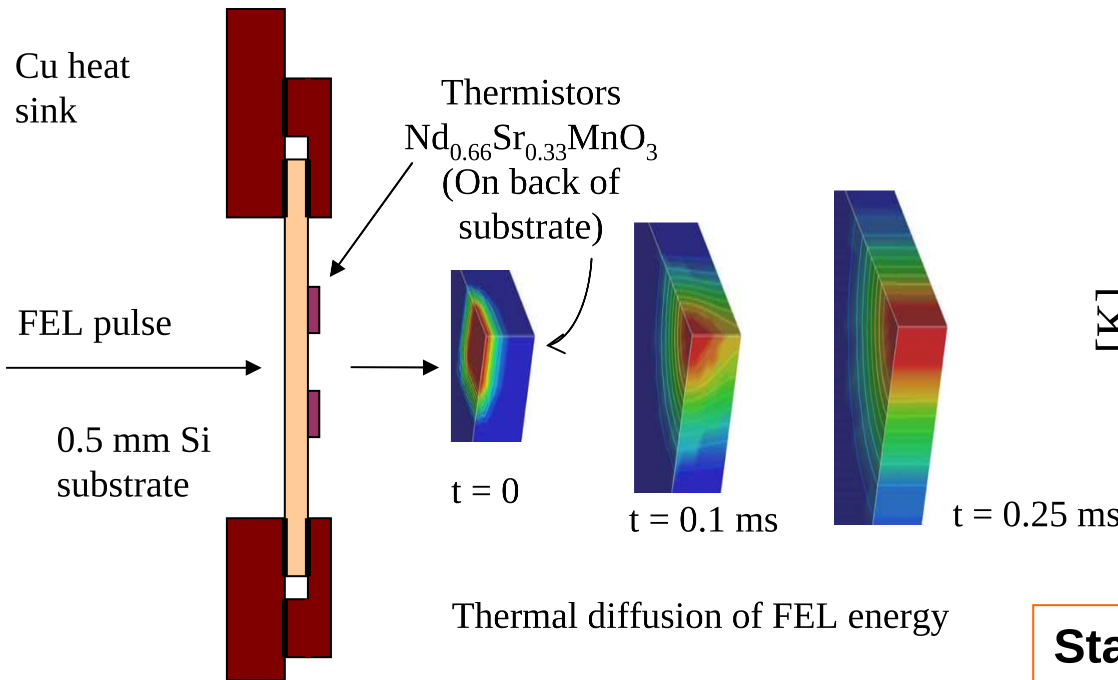
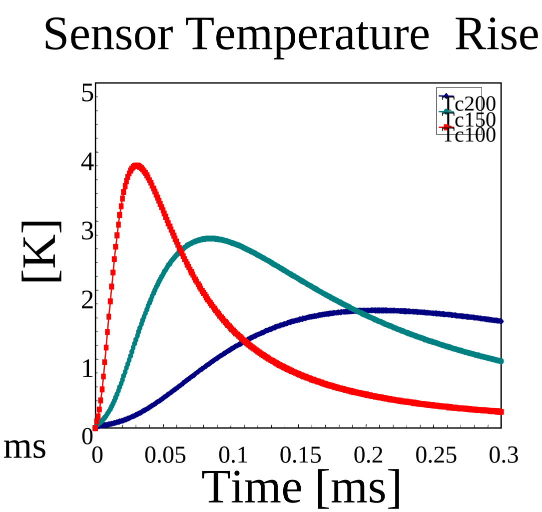
Total Energy (Thermal) Sensor provides calibrated measurement of FEL pulse energy

Measures FEL energy deposition through temperature rise



Thermal diffusion of FEL energy



Status Thermal Sensor:
PRD done
SCR done
PDR done
Prototype done
FDR in progress

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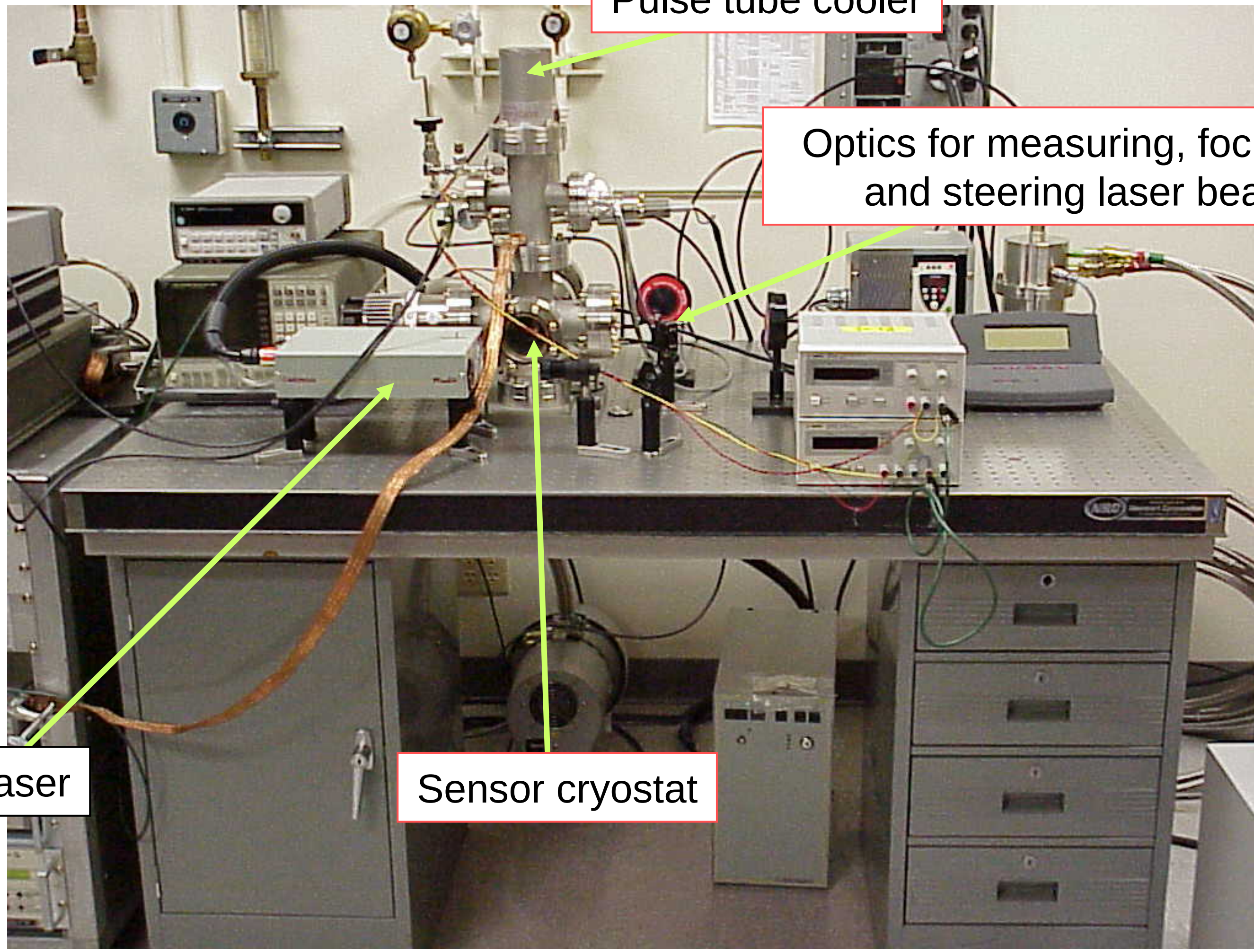
Thermal sensor prototype



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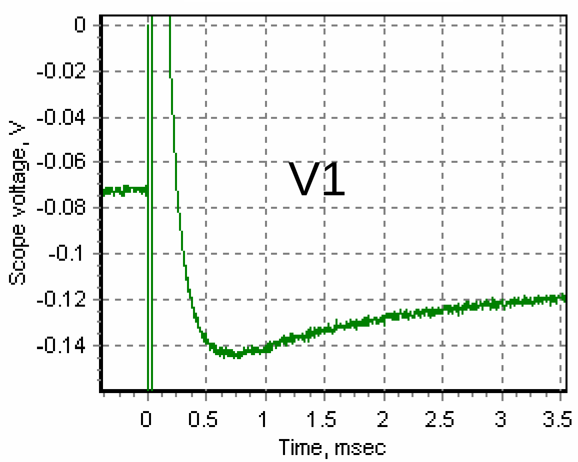
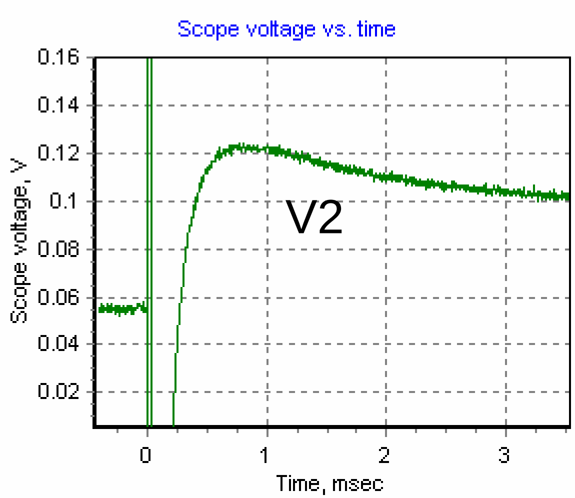
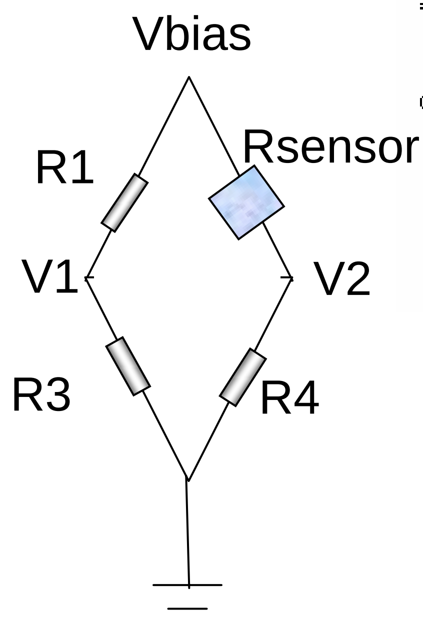
Thermal sensor signal at 1mJ

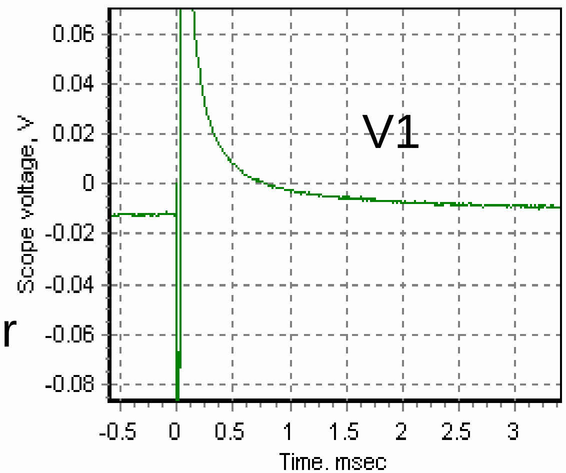
2 volt bias

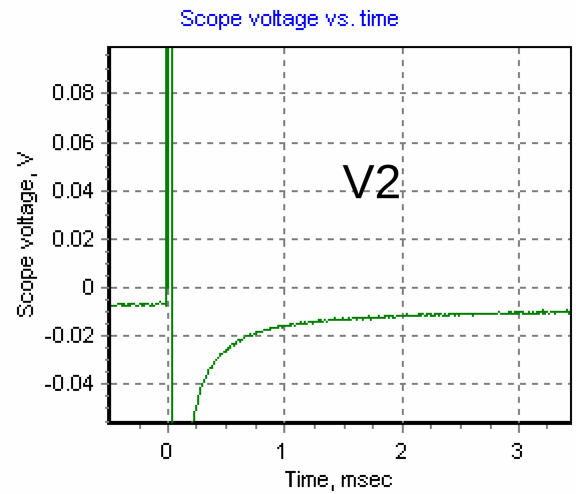




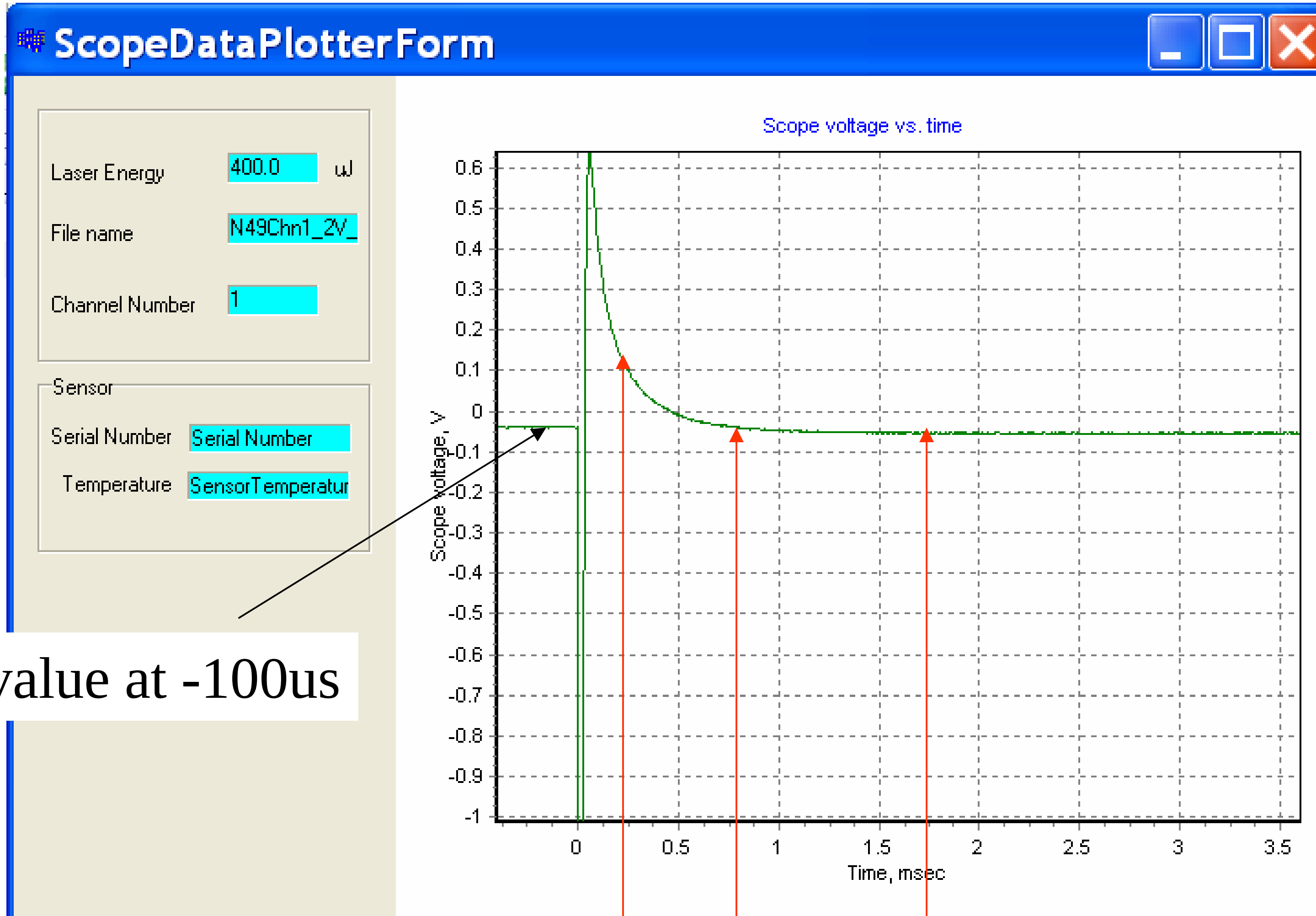


0 volt bias





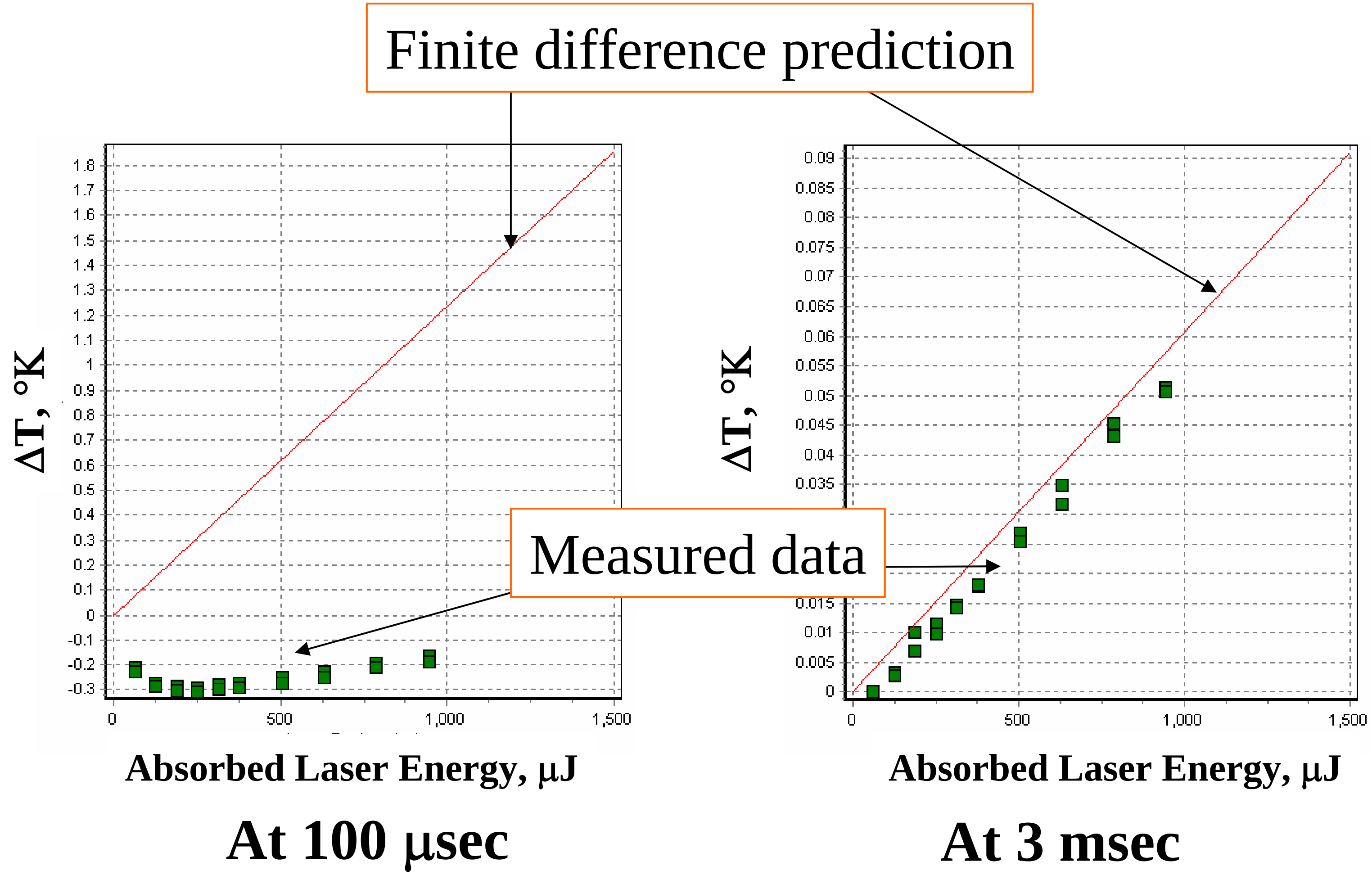
Channel 1 pulse at 400 uJ with 2V bias



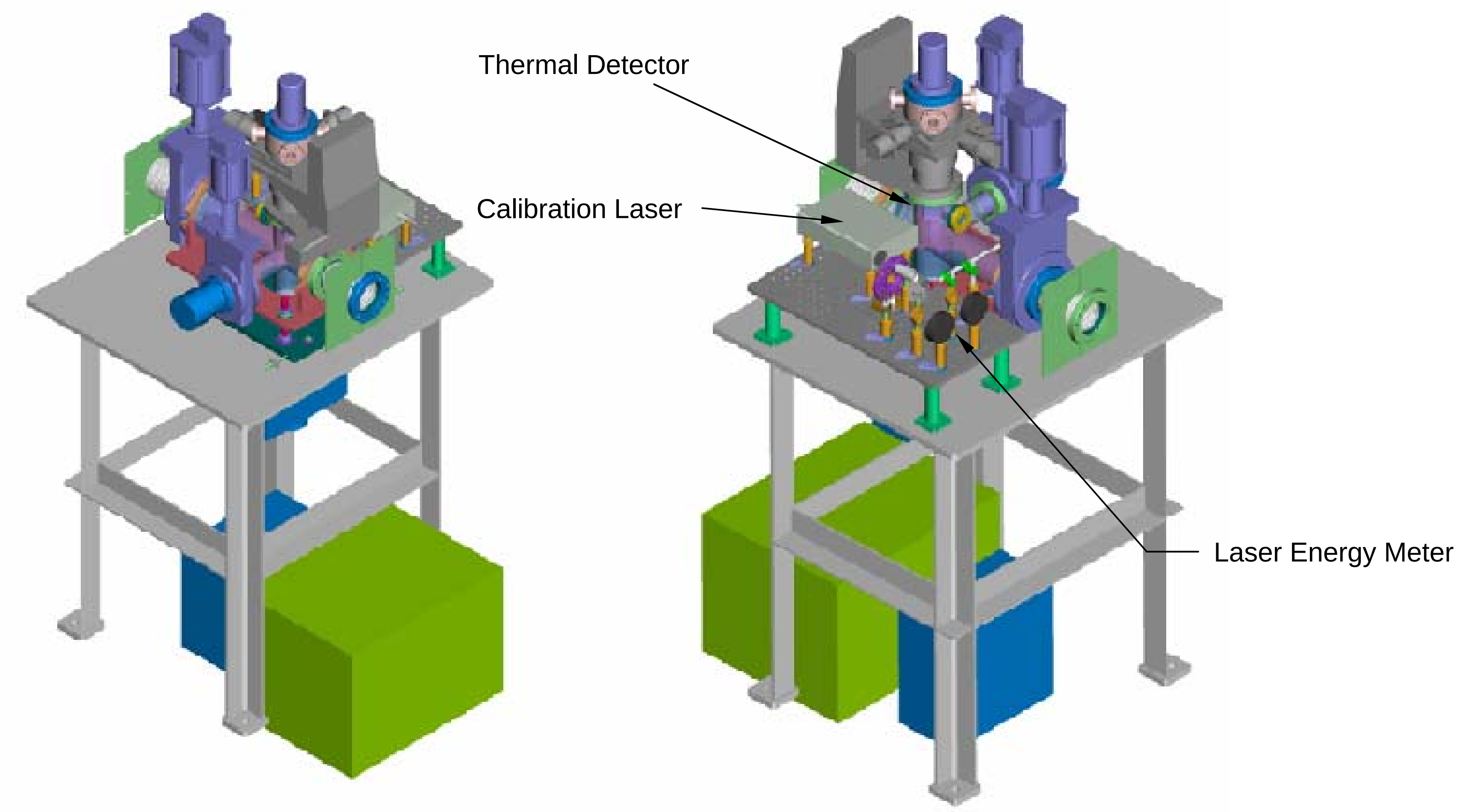
Subtract value at -100us

Sample voltages at particular times, convert to ΔRcmr then to ΔT

Total energy prototype measured and predicted signal



Thermal sensor, preliminary design



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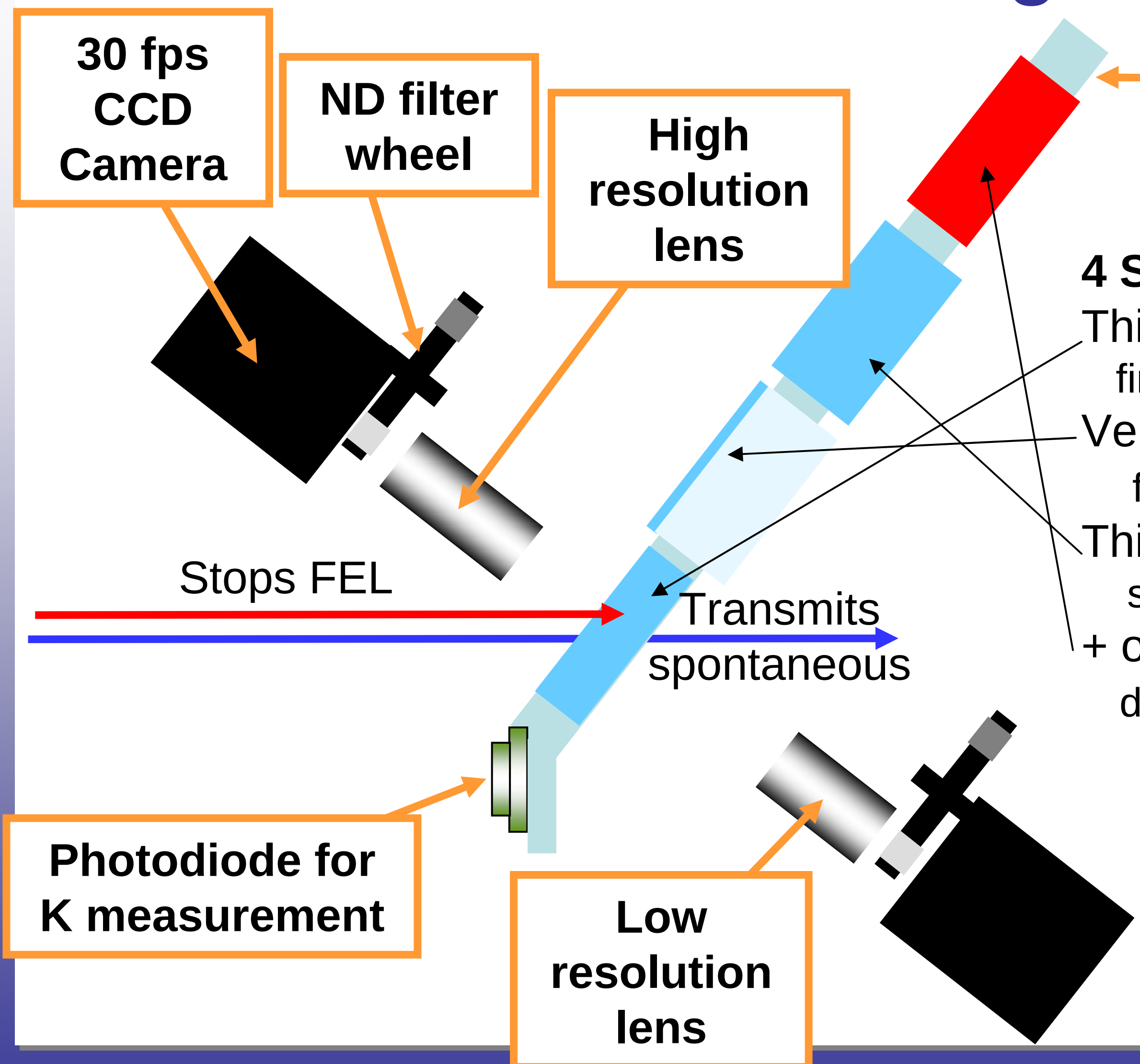
Direct Imager



4 Scintillators:

Thin, stops 8 keV FEL
find soft x-ray FEL

Very thin, stops 826 eV FEL
find soft x-ray FEL

Thick, stops spontaneous
spontaneous studies

+ one other for tests
diamond

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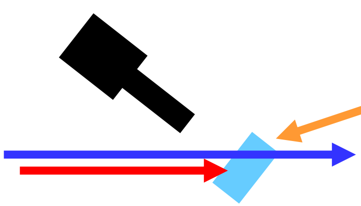
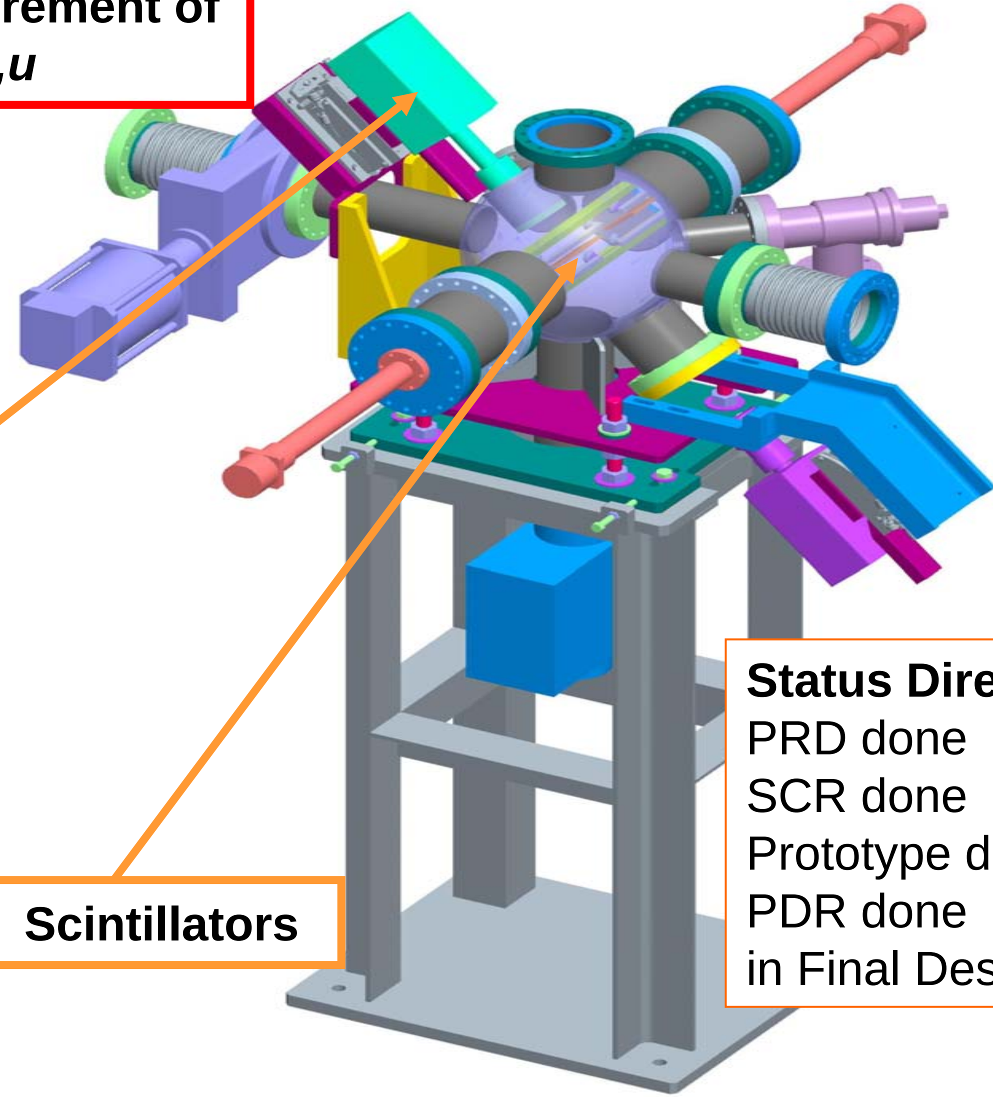
Direct Imager, preliminary design

Single shot measurement of *f(x,y), x, y ,u*

Camera



Scintillators



Status Direct Imager:
PRD done
SCR done
Prototype done
PDR done
in Final Design

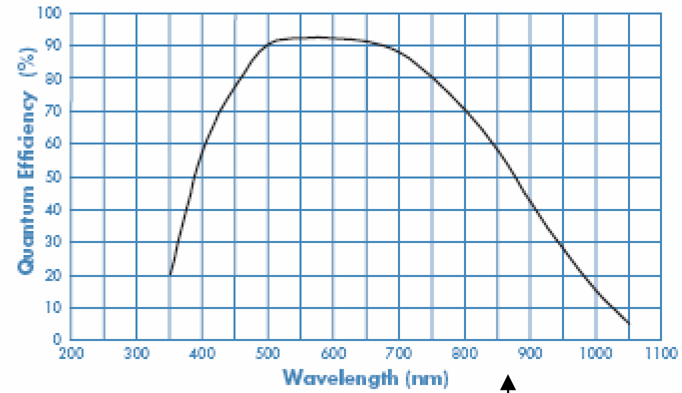
PHOTOMETRICS®
a division of Roper Scientific, Inc.

Cascade:512B

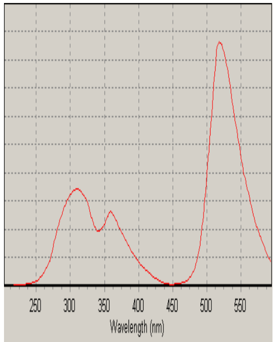
512 x 512 imaging array | 16 x 16-μm pixels

The Cascade:512B digital imaging system from Photometrics® offers very high sensitivity through the use of *on-chip multiplication gain.* A back-illuminated 512 x 512-pixel array (16 x 16-μm pixels) enhances this sensitivity, while providing outstanding quantum efficiency and good field of view. The 16-bit, thermoelectrically cooled system can be operated at 10 MHz for high-speed image visualization or more slowly for high-precision photometry. Supravideo frame rates are achievable via subregion readout or binning. The camera can be configured with dual amplifiers to ensure optimal performance not only for applications that demand the highest available sensitivity (e.g., GFP-based single-molecule fluorescence) but also for those requiring a combination of high quantum efficiency and wide dynamic range (e.g., Ca^{++} ratio imaging).

CCD image sensor	e2v CCD97; back-illuminated, frame-transfer CCD with on-chip multiplication gain	
CCD format	512 x 512 imaging pixels; 16 x 16-μm pixels; 8.2 x 8.2-mm imaging area (optically centered)	
Linear full well single pixel output node	200 ke- 800 ke- ("on-chip multiplication gain" amplifier)	
Digitizer type	16 bits @ 10 MHz, 5 MHz, and 1 MHz	
	"On-chip multiplication gain" amplifier (port #1)	"Traditional" amplifier (port #2)
Read noise	~45 e- rms @ 5 MHz ~60 e- rms @ 10 MHz *Read noise effectively reduced to <1 e- rms with on-chip multiplication gain enabled*	~10 e- rms @ 1 MHz ~15 e- rms @ 5 MHz
On-chip multiplication gain	1 to 500x (guaranteed) 1 to 1,000x (typical) Software controlled in 4,096 steps	Not applicable
Parallel (vertical) shift rate	2.0 μsec/row	
CCD temperature	-30˚C (regulated)	
Dark current	1.0 e-/p/s @ -30˚C (0.5 e-/p/s @ -30˚C typical)	
Binning	Flexible binning capabilities in parallel direction; 1 through 6 binning in serial direction	
Operating environment	0 to 30˚C ambient, 0 to 80% relative humidity noncondensing	



Camera QE



Scintillator emission spectrum

Region

Binning	512 x 512	256 x 256	128 x 128	64 x 64
1 x 1	29	54	95	155
2 x 2	56	95	155	227
4 x 4	98	155	227	295
6 x 6	130	195	262	329

(Frames per second)

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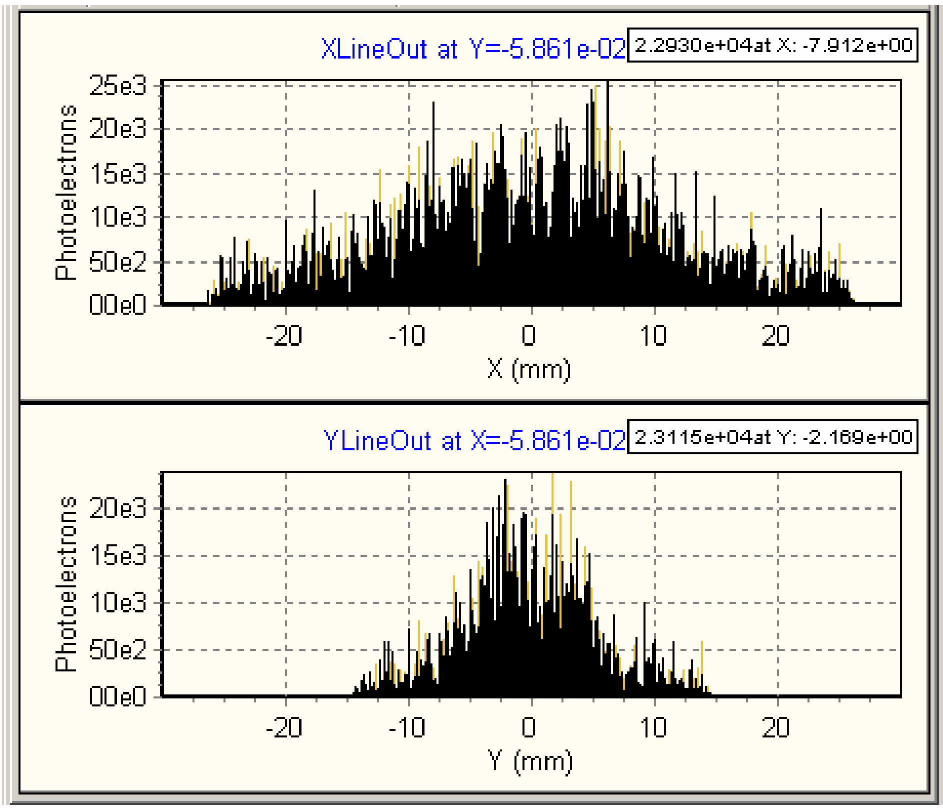
Soft X-Ray Spontaneous signal in WFOV Direct Imager

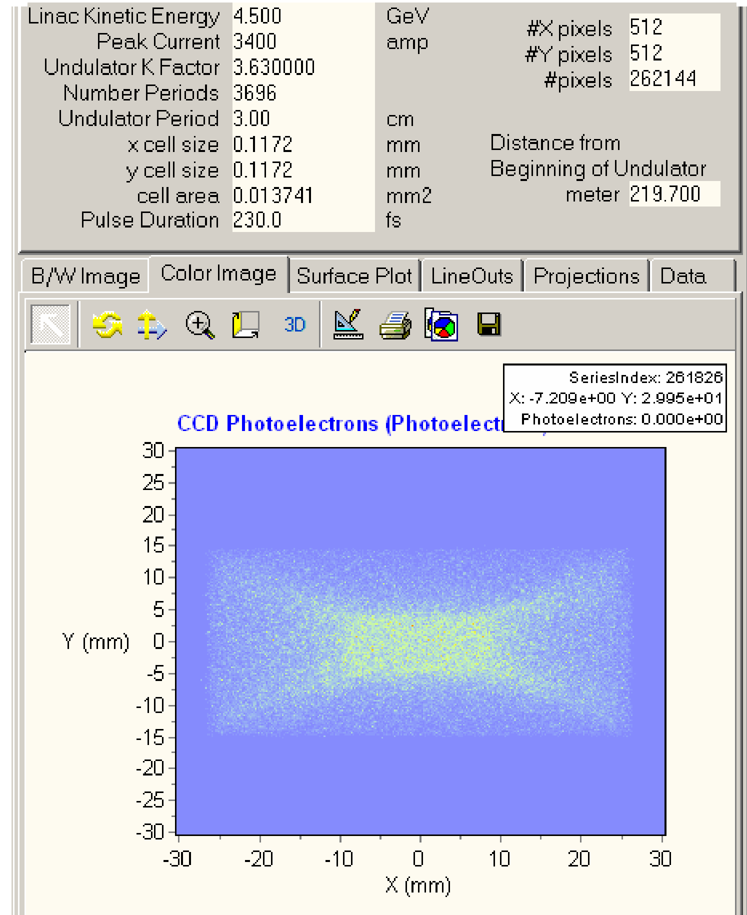
Lawrence Livermore National Laboratory

Absorbed in 5 um YAG,
Maximum ~ 20,000 photoelectrons/pixel

Camera: Photometrics 512B

Objective: Navitar Platinum 50
Power: 0.1365
NA: 0.060





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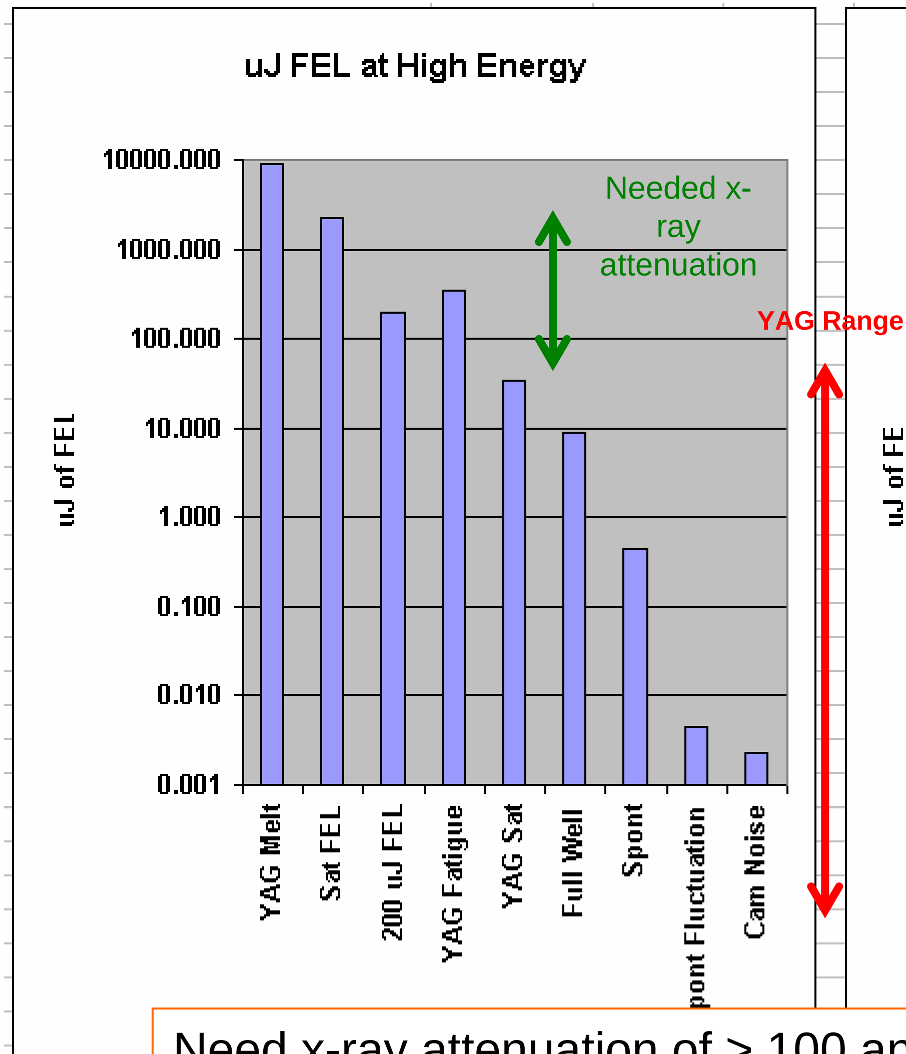
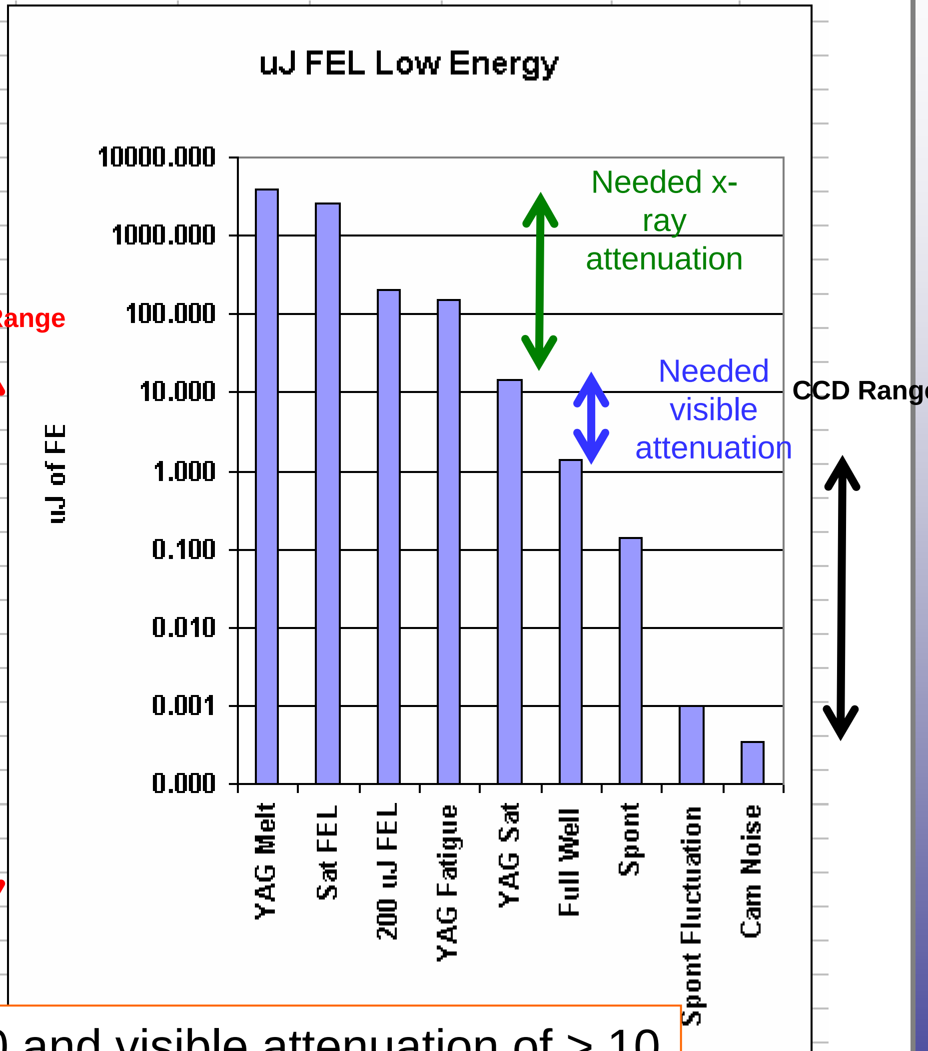
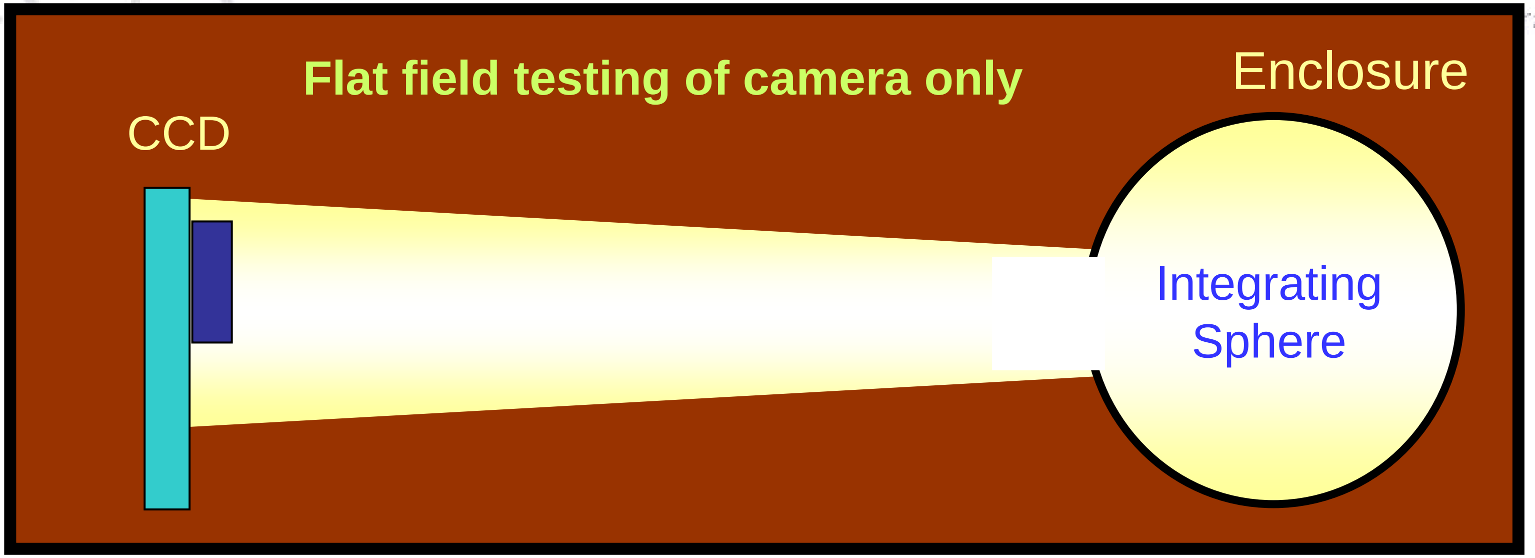
Scintillator signals in FEL equivalents

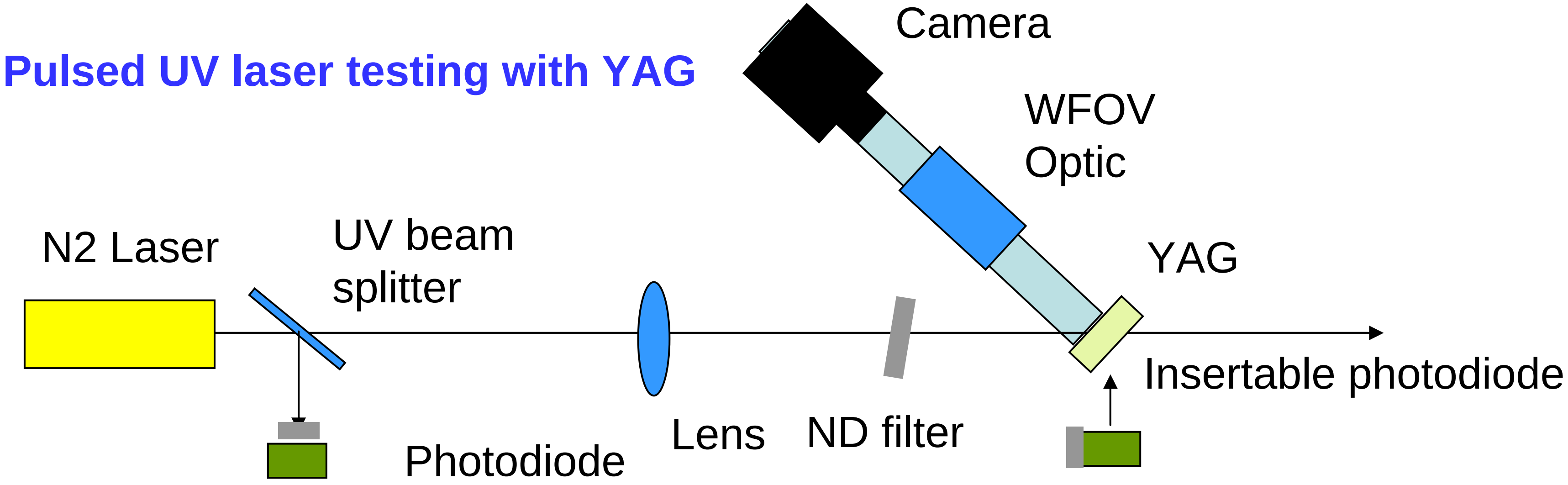




Need x-ray attenuation of > 100 and visible attenuation of > 10

Prototype Direct Imager testing





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Photon Transfer Curve

$$\sigma^2 = G \cdot \bar{d} + \sigma^2_{\text{Readout}}$$

Our fit:

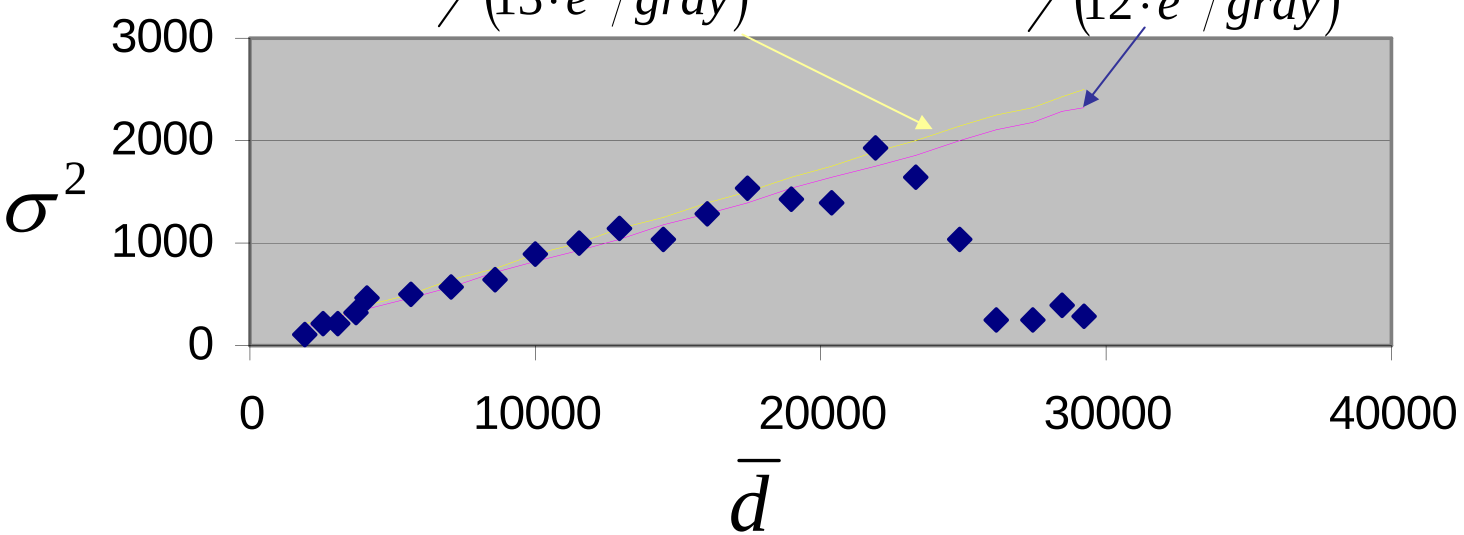
$$\sigma_{\text{Readout}} = (5 \pm 50) \cdot e^-$$

$$G = 1 / (13 \cdot e^- / gray)$$

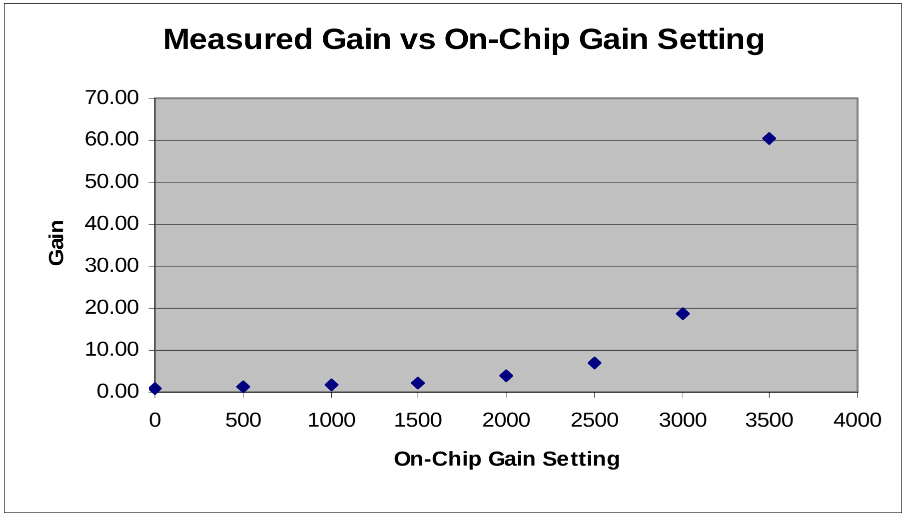
Manufacturer:

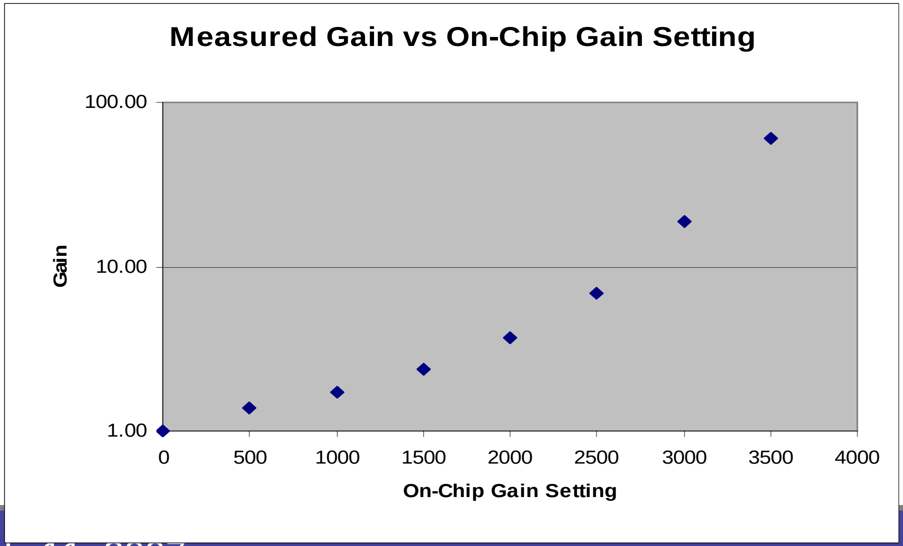
$$\sigma_{\text{Readout}} = 75 \cdot e^-$$

$$G = 1 / (12 \cdot e^- / gray)$$



Cascade 512B on-chip gain measurements





Gain: 1
On-Chip: 0 to 4000,
Exposure Time: 5 to 190
Lamps: 1, 2

Measured Gain = Slope g(j)/Slope g(0)

On-Chip Gain	Slope	Measured Gain
0	45.09	1.00
500	62.44	1.38
1000	77.59	1.72
1500	106.06	2.35
2000	168.20	3.73
2500	307.83	6.83
3000	848.24	18.81
3500	2723.20	60.39

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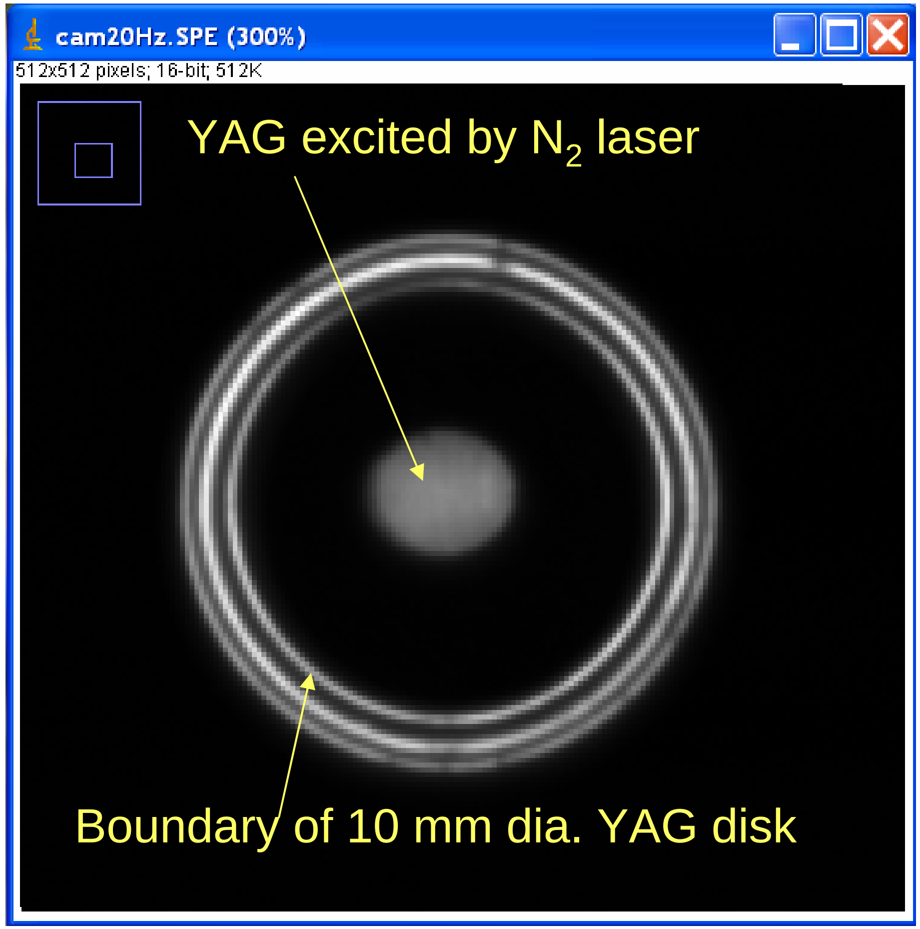
Direct Imager image of N_2 laser excited YAG scintillator at 20 Hz



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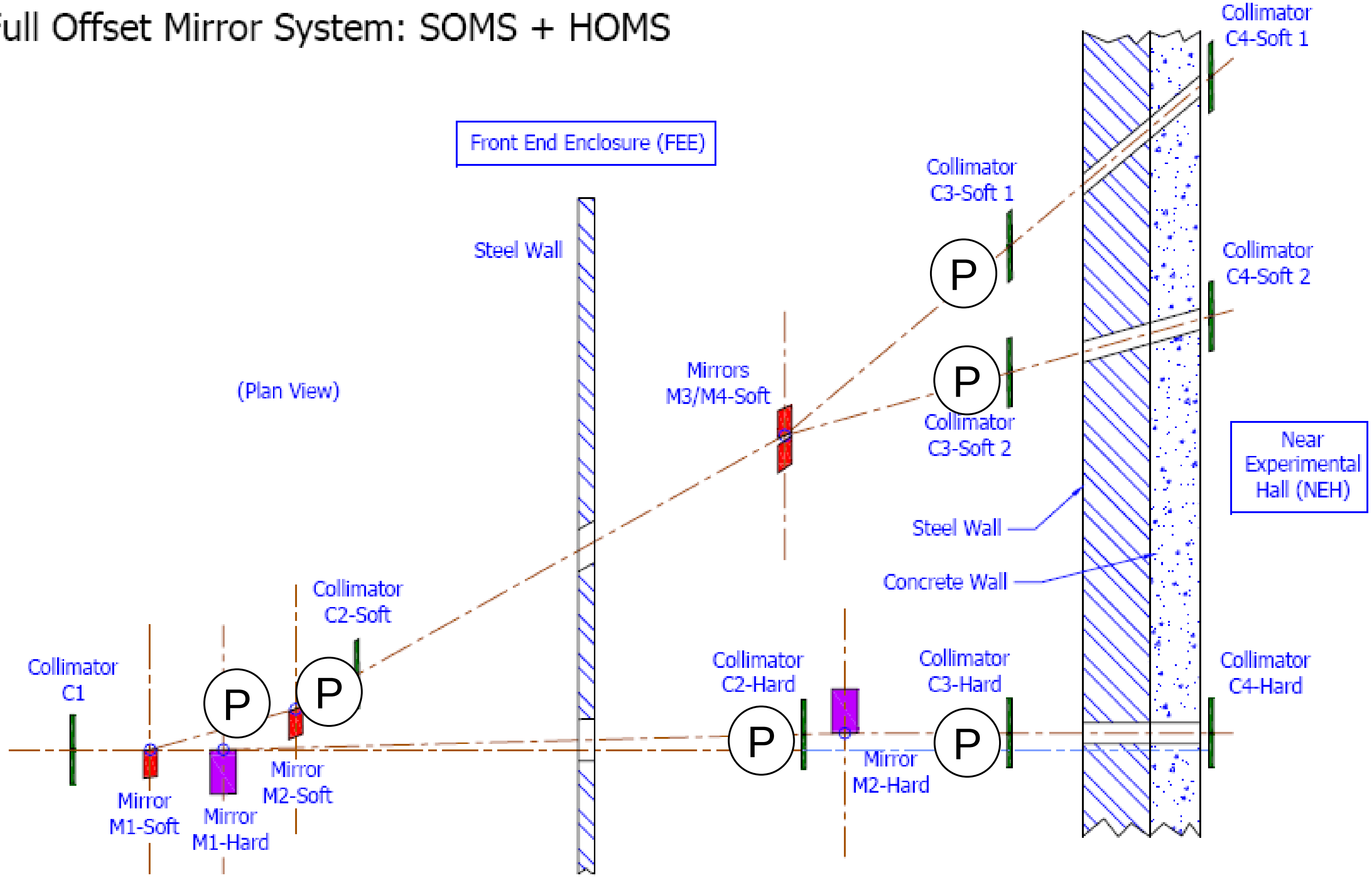
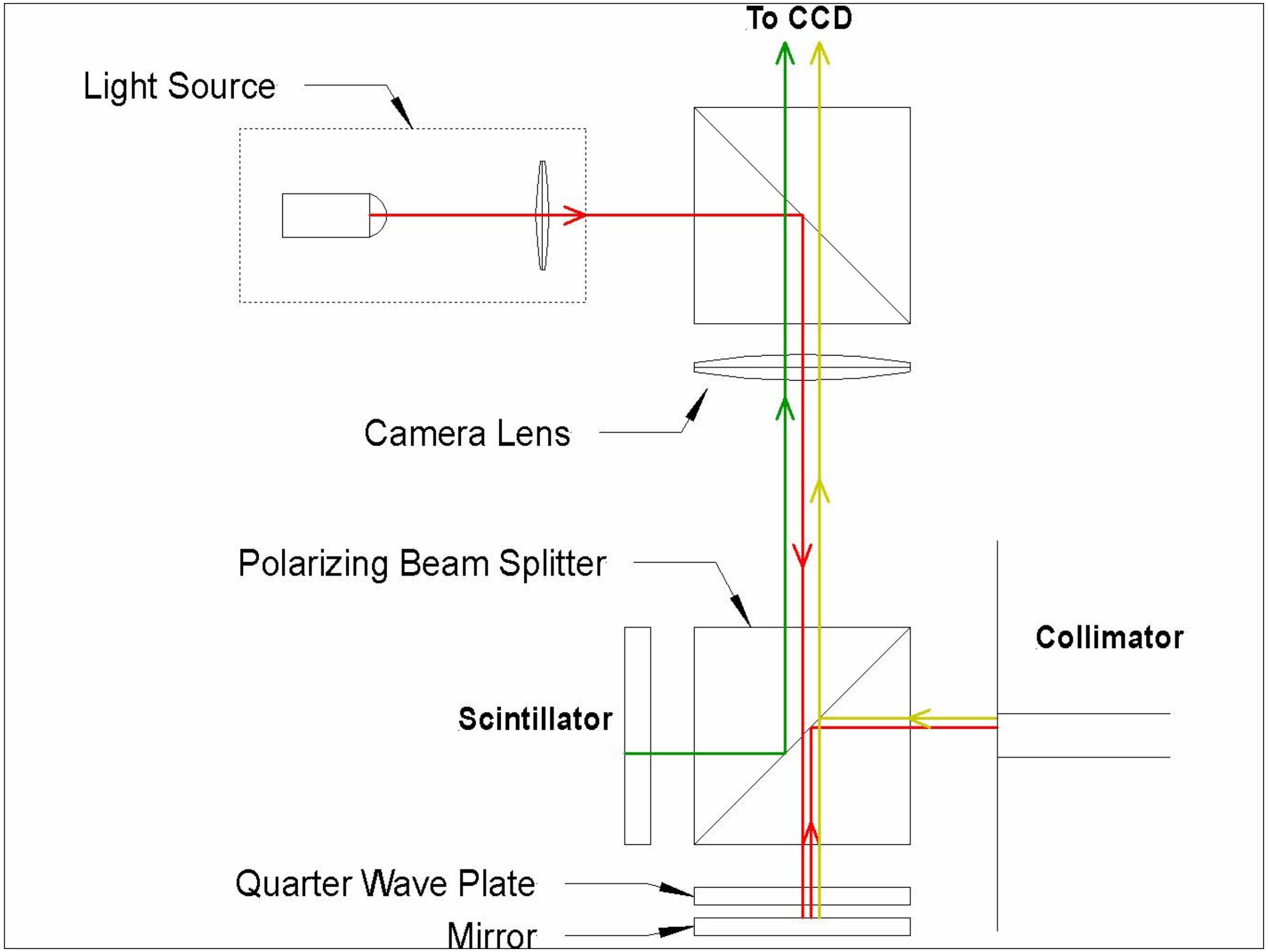
FEL Offset Mirror Systems have "Pop-in" imagers for alignment

Full Offset Mirror System: SOMS + HOMS



Bidirectional Popup Viewer allows viewing of the x-ray beam and the collimator



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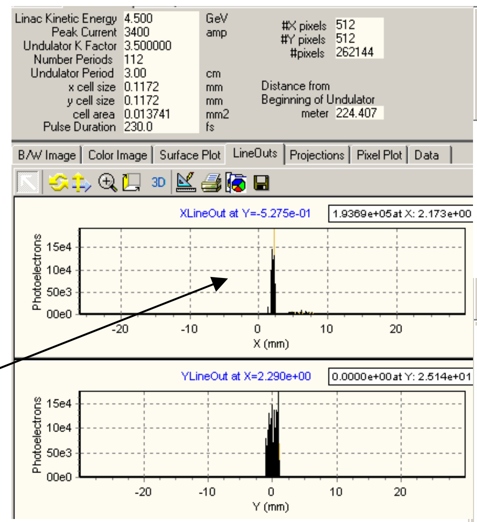
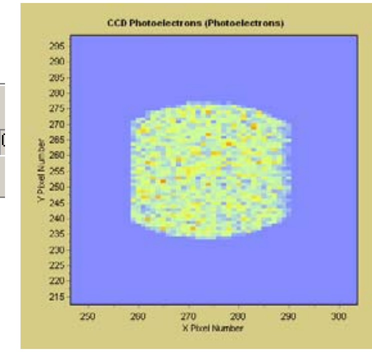
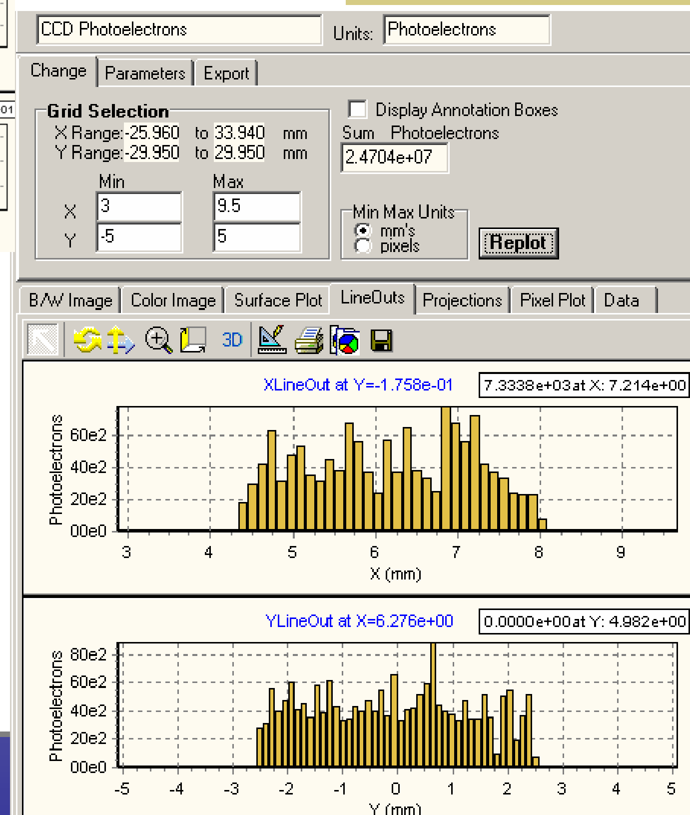
We are studying expected signal levels in the Pop-in cameras

Low Energy, All undulator modules
100% Spontaneous
Propagated through fixed mask, pipes
12 Boron Carbide windows are open
Slit is open
No attenuation, no gas detector
Photons absorbed in 1 mm YAG,
Full Well: 200,000

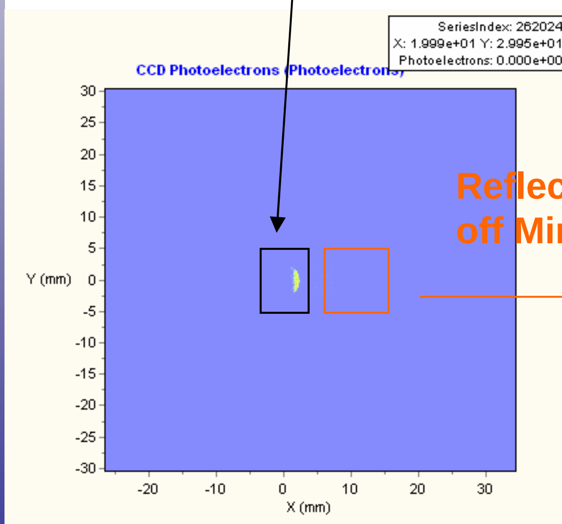
photoelectrons ~ 5660 per pixel



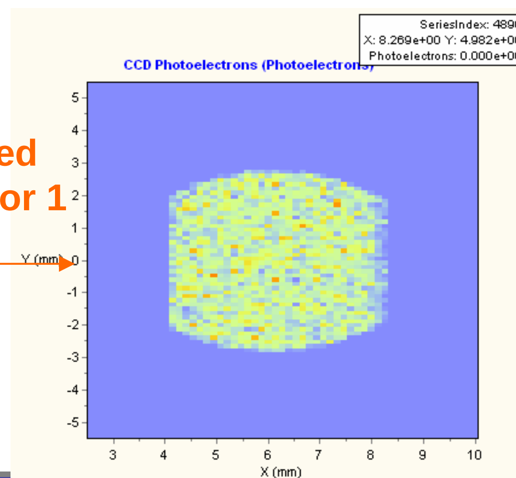




Misses Mirror 1



Reflected off Mirror 1



Summary

- Progress continues on XTOD diagnostics:
  - Procurement - Slit, Fixed Mask, Attenuator
  - PDR – Direct Imager, SOMS, Thermal Detector
  - SCR – K-Spectrometer
  - PRD – HOMS, Indirect Imager

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