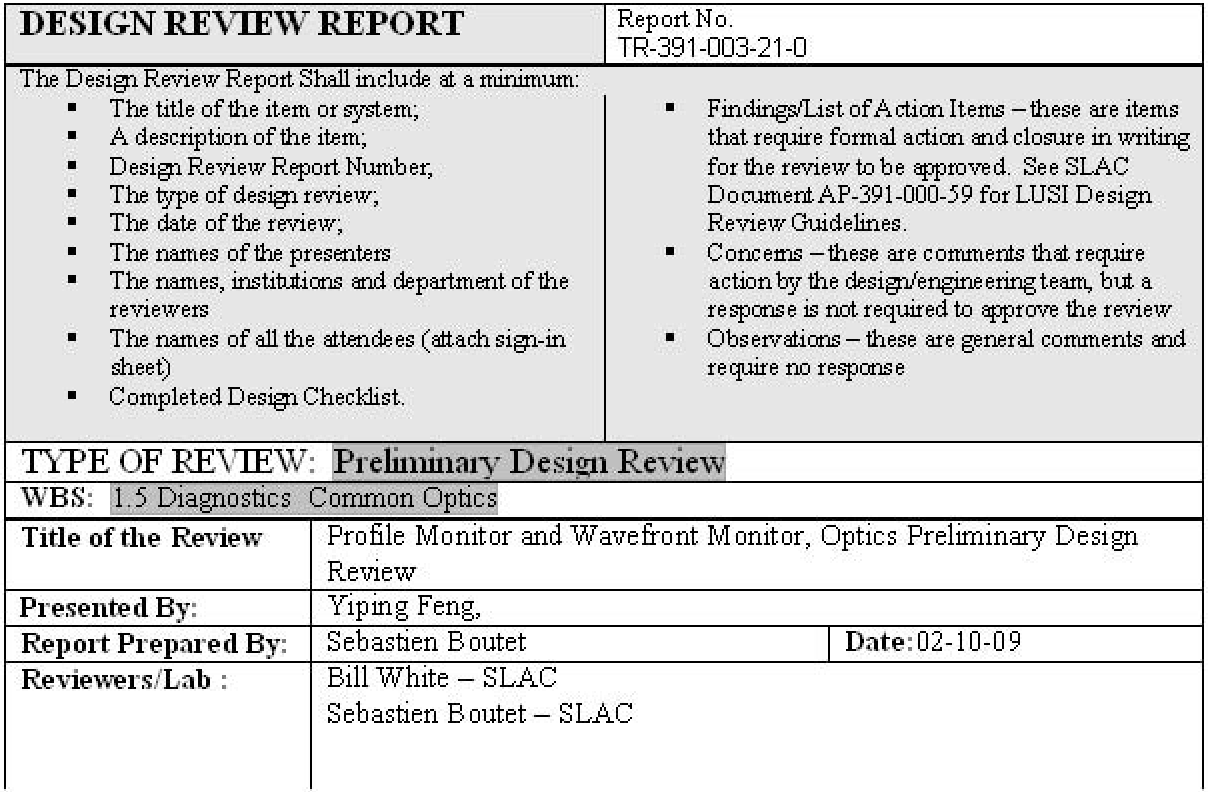

DESIGN REVIEW REPORT

Report No.
TR-391-003-21-0

The Design Review Report Shall include at a minimum:

- The title of the item or system;
- A description of the item;
- Design Review Report Number;
- The type of design review;
- The date of the review;
- The names of the presenters
- The names, institutions and department of the reviewers
- The names of all the attendees (attach sign-in sheet)
- Completed Design Checklist.
- Findings/List of Action Items – these are items that require formal action and closure in writing for the review to be approved. See SLAC Document AP-391-000-59 for LUSI Design Review Guidelines.
- Concerns – these are comments that require action by the design/engineering team, but a response is not required to approve the review
- Observations – these are general comments and require no response

TYPE OF REVIEW: Preliminary Design Review

WBS: 1.5 Diagnostics Common Optics

Title of the Review	Profile Monitor and Wavefront Monitor, Optics Preliminary Design Review	
Presented By:	Yiping Feng,	
Report Prepared By:	Sebastien Boutet	**Date:** 02-10-09
Reviewers/Lab :	Bill White – SLAC Sebastien Boutet – SLAC	

LUSI
Diagnostics and Common Optics

Pop-in Profile/Wavefront Monitors
Optics Review

[sp39100004-1_XRPopInProfMon-PRD]

Yiping Feng – LUSI Instrument Scientist
February 10, 2009

Outline

- Introduction
  - Performance requirements
- Device concept
  - Optical components
    - X-ray scintillator
    - Optical mirror
    - Vacuum window
    - Optical zoom lens
    - Pixelated optical sensor
- Simulations
  - Expected imaging performance
- Surveying
- Size calibration
- Resolution testing

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Introduction

- Performance Requirements
  - Capturing 2D beam profile
  - Operating energy 2-25 keV
  - Variable field of views (FOV) & resolution
    - Large FOV of 25x25 mm^2, 100 μm
    - Small FOV of 2x2 mm^2, 8 μm
  - Capable of high resolution operation
    - Extra-small FOV of 1x1 mm^2 FOV , 4 μm
  - Intensity levels, 256 or 8 bits, w/ goal of 1024 or 10 bits
  - Capable of per-pulse operation
    - Optional for only one per instrument
  - Attenuation acceptable in high fluence
    - Using LCLS designed performance parameters

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Device Concept

- Device concept
  - Technical choices
    - 2D imaging by X-ray direct detection
      - In charge collection mode
        - Can afford high signal-to-noise ratio, but essential to application
      - Quantum efficiency very high
        - > 90% at 8.265 keV
      - Resolution limited to pixel size ~ 100 μm
        - Medium to high resolution capability not possible
      - Dynamic range limited to 10^4 photons/pulse
        - Requiring up to 10^7 in attenuation if 10^{12} γ/pulse in main beam
        - Capable of working w/ spontaneous or monochromatized beam
      - Detector very expensive, cost not viable
      - Detector in-line w/ FEL beam, not compatible w/ instrument's layout except being placed at the end, which is also NOT allowed by radiation physics considerations

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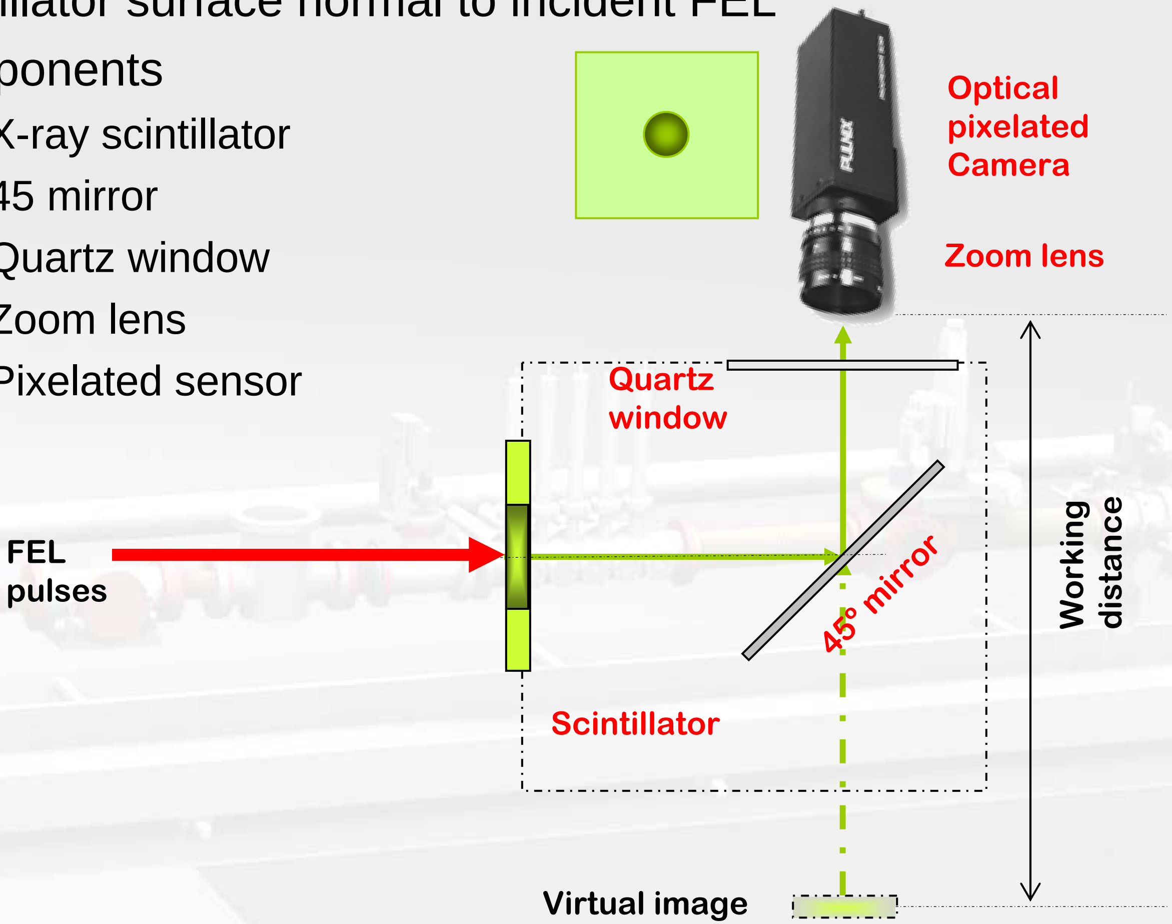
Device Concept

- Technical choices (con’t)
  - Optical imaging by indirect X-ray scintillation
    - Capable of very high spatial resolution
      - 2 μm has been achieved elsewhere
    - Suitable for fully saturated FEL w/ proper attenuation
    - Capable of partial transmission for more elaborate schemes if desired, e.g. AMO implementation
    - Imaging optics not collinear w/ FEL propagation when mirror is used
    - Same concept used
      - By XTOD group for FEE diagnostics – “direct imager”
      - Accelerator group for electron beam diagnostics
    - But inefficient
      - Conversion from X-ray to optical
      - 4π sterradian distribution in optical fluorescence emission
      - Lens system always has limited numerical aperture

Device Concept

- Conceptual geometry
  - Normal incidence
    - Scintillator surface normal to incident FEL
    - Components
      - X-ray scintillator
      - 45 mirror
      - Quartz window
      - Zoom lens
      - Pixelated sensor



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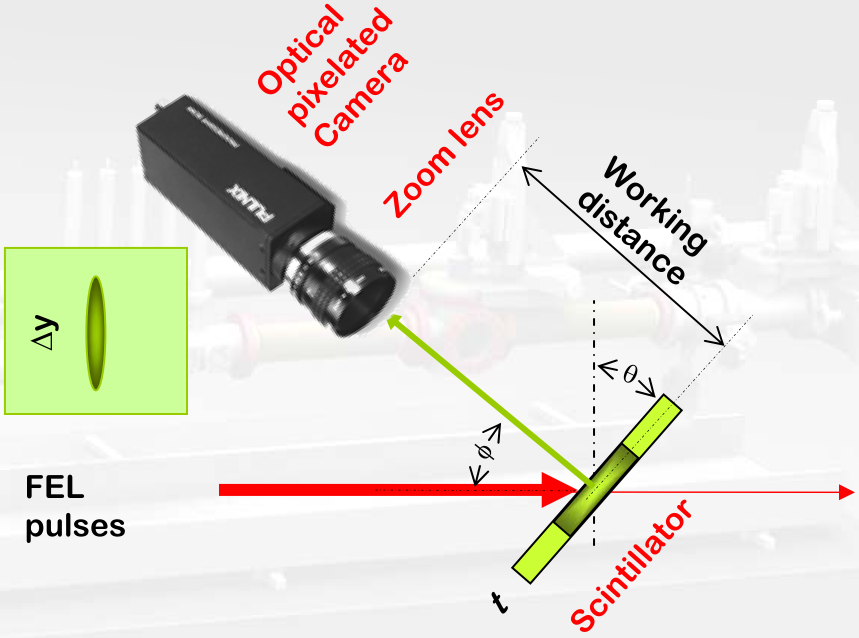
Device Concept

- Conceptual geometry (con’t)
  - Oblique incidence
    - Scintillator surface inclined w/ respect to incident FEL, and axis of optical system normal to scintillator surface
    - Components
      - X-ray scintillator
      - Zoom lens
      - Pixelated sensor
    - Image smearing

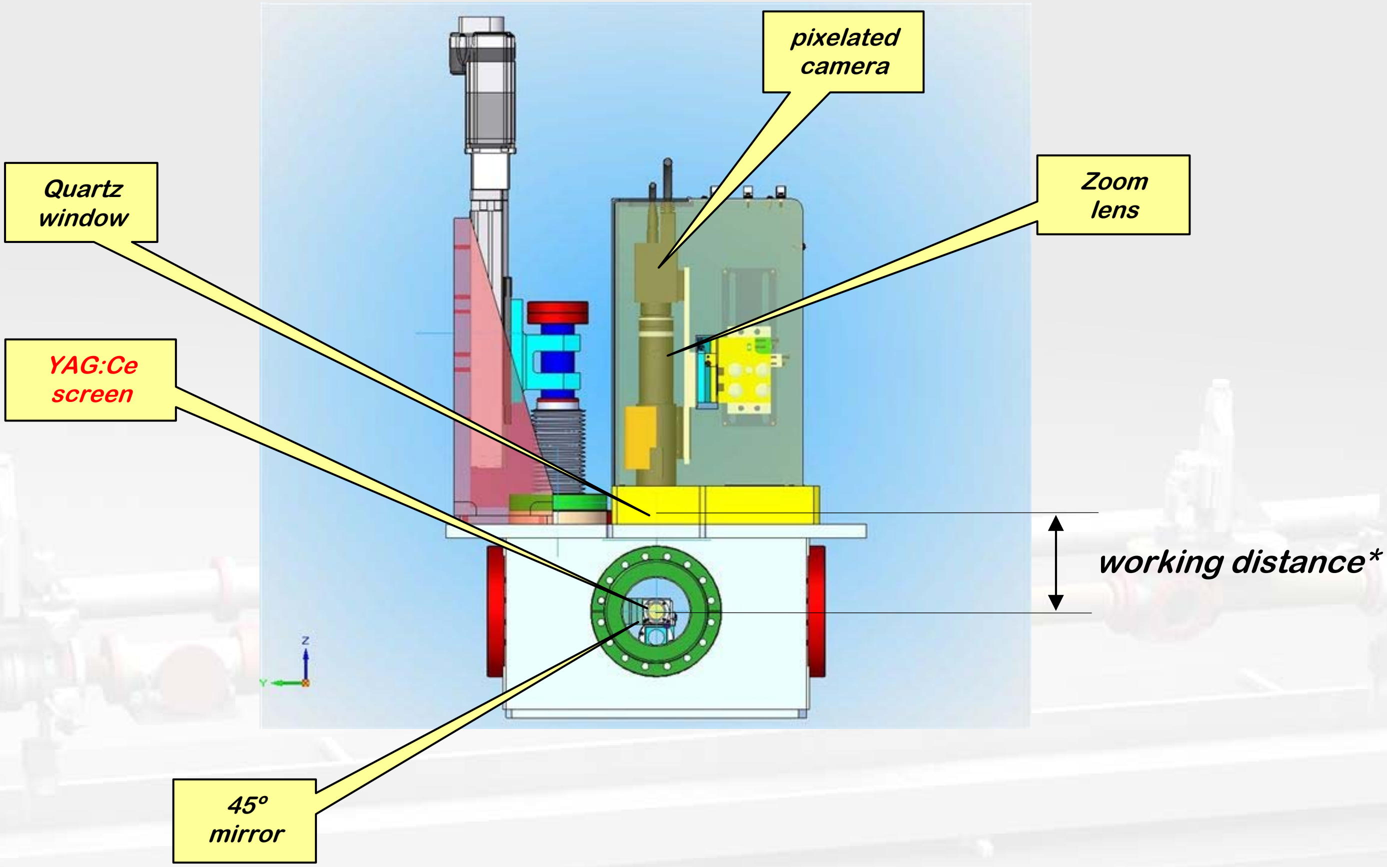
$$\Delta y = t\frac{\sin\phi}{\cos\theta}$$

$$= t \quad if\ \phi = 45^\circ, \theta = 45^\circ$$



Device Concept

- Mechanical model



*Working distance will include distance from YAG screen to 45 mirror

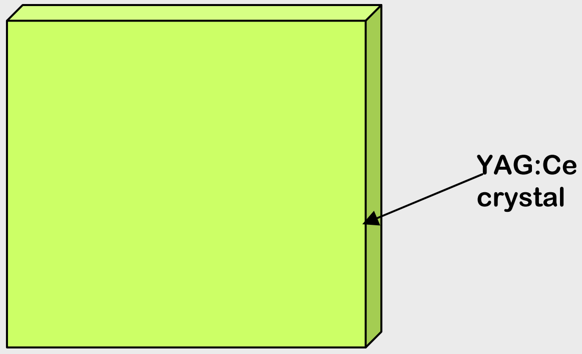
Optical Components

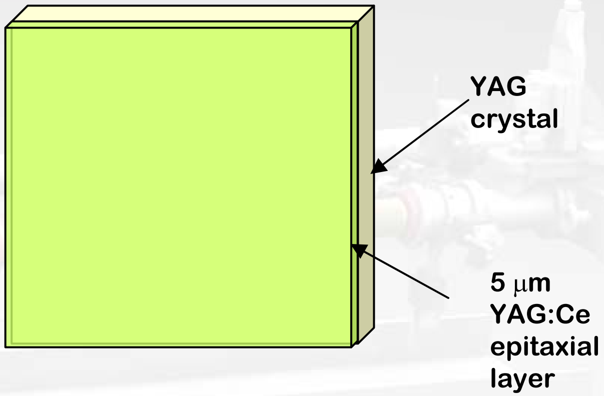
- YAG:Ce scintillation screen
  - characteristics
    - High radiation hardness
      - High melting temperature
      - High thermal conductivity
      - In NEH & FEH, capable of sustain full unfocused X-ray FEL beam at normal incidence w/ moderate attenuation
    - Fast scintillator
    - Good fluorescence yield
      - Peak response (550 nm) matches CCD QE curve
    - High spatial resolution
      - Capable of normal incidence
      - Clear, not diffuse as phosphor
    - Vacuum compatible

YAG:Ce	
Chemical formula	$Y_3Al_5O_{12}$:Ce
Ce doping	0.1 mol%
Melting point	1970 C°
Fluorescence spectral peak	550 nm
Light yield (Ce doping dependent)	80 /10 keV X-ray
Decay constant	70 ns
After glow (at 6 ms)	< 0.005 %
X-ray attenuation length	5 - 35 μm @ 4 - 8.3 keV
Size (diameter/side)	10 - 50 mm
Thickness	50 - 100 μm

YAG:Ce Scintillator

- Size
  - The bigger, the thicker
    - 25x25 mm^2 , 75 μm
    - 12x12mm^2 , 50 μm
- Thickness
  - Affect resolution achievable
    - < Depth of field
    - Requiring telecentric lens if too thick
  - Limited for free standing crystal (>= 50 μm)
  - Thinner sample could be obtained by using epitaxial YAG:Ce on YAG substrate
    - ~ 5 μm epi layer
    - But YAG glows as well affecting resolution





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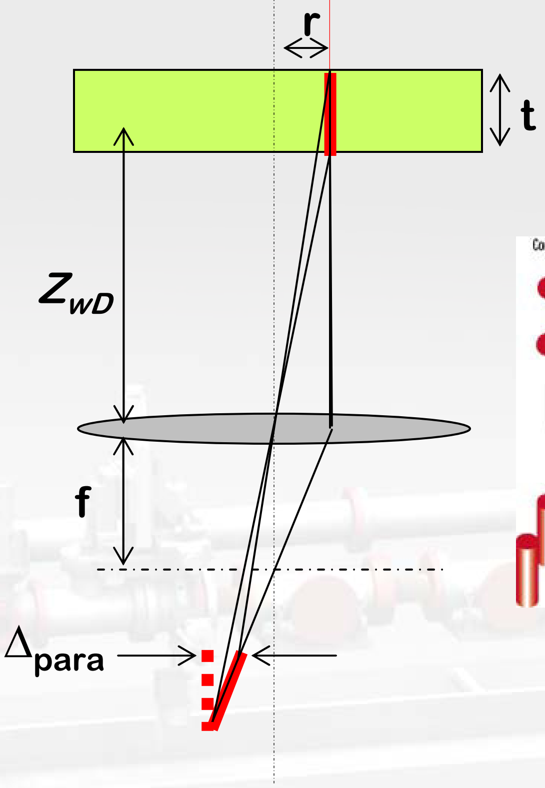
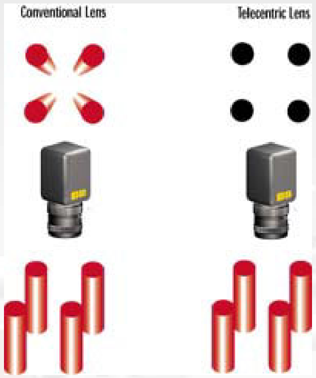
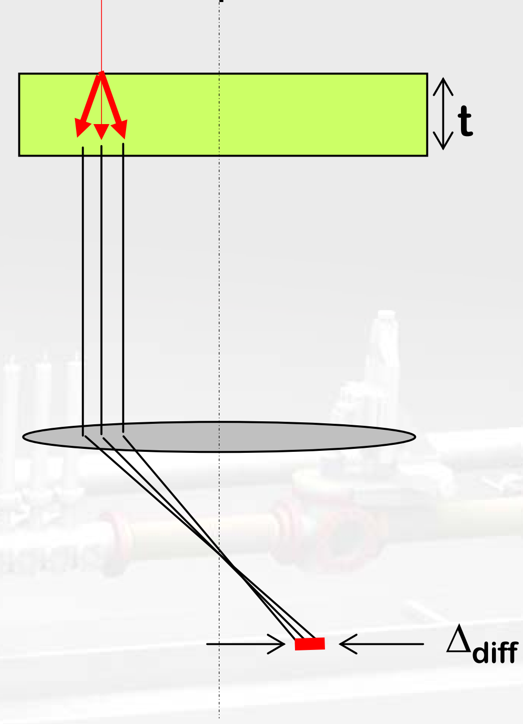
YAG:Ce Scintillator

- Resolution limits
  - Parallaxial distortion
    - Proportional to thickness
  - Diffusive broadening
    - Proportional to thickness







$$\Delta_{para} = -Mtr \big/ \left(Z_{WD} - f \right)$$

$$\Delta_{diff} = \alpha t$$

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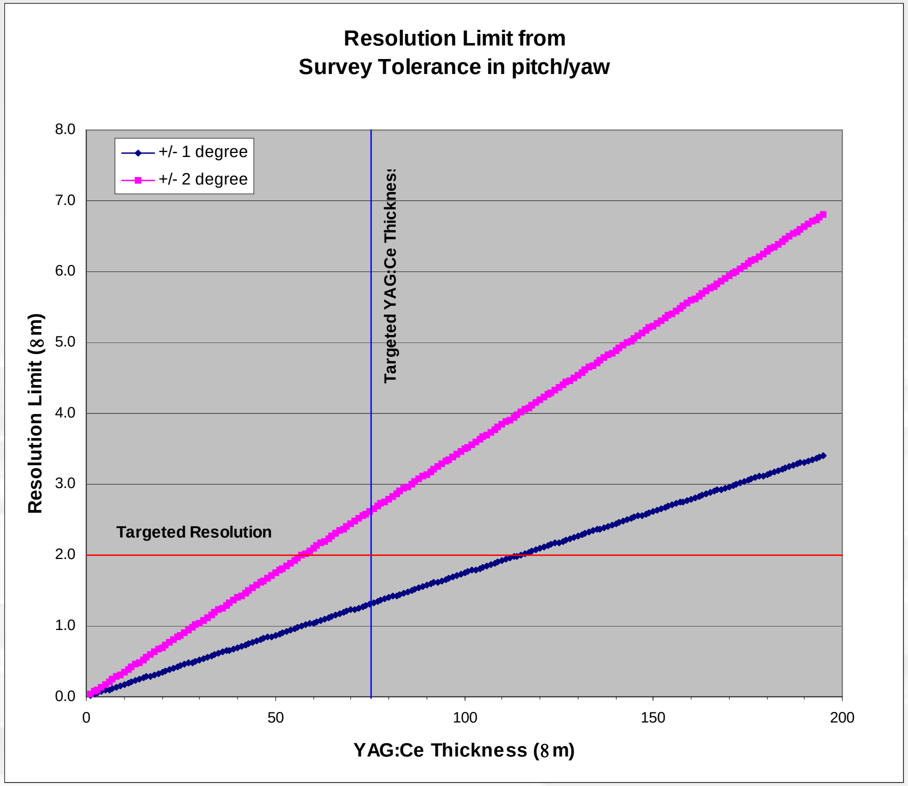
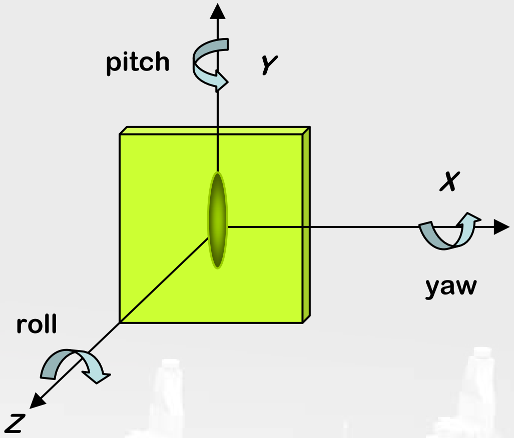
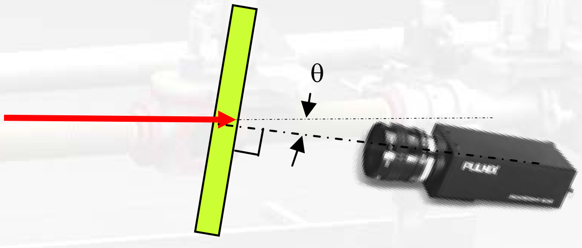
Resolution Limit

from Survey Tolerance w/ Pre-alignment

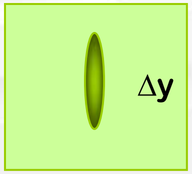
- Alignment tolerance
  - Assuming camera optical axis is perpendicular to scintillator surface via pre-alignment
  - Assembly is then aligned to FEL beam axis





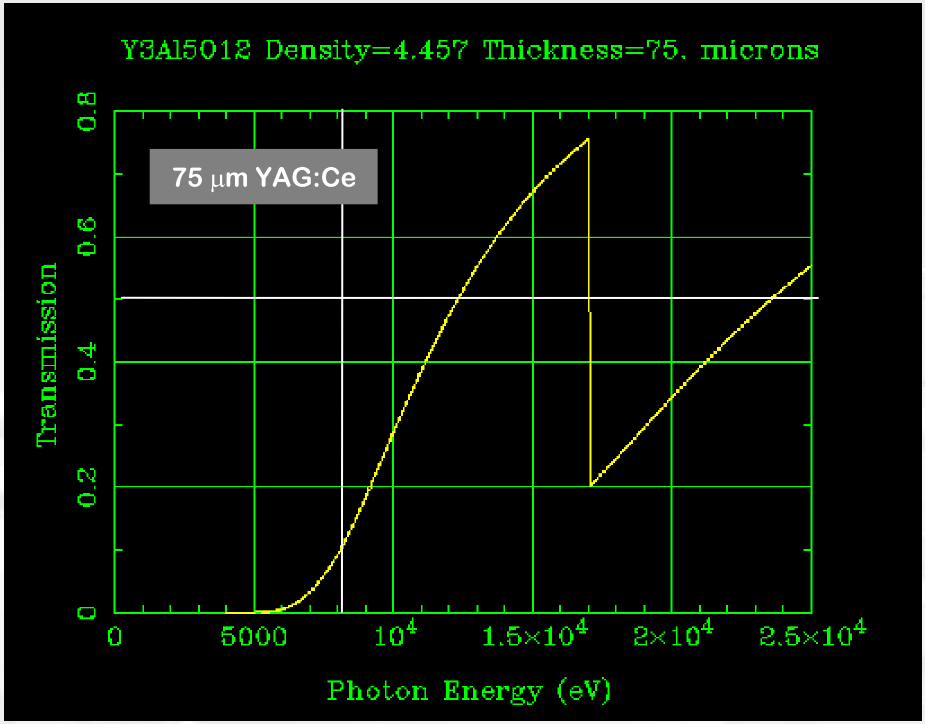


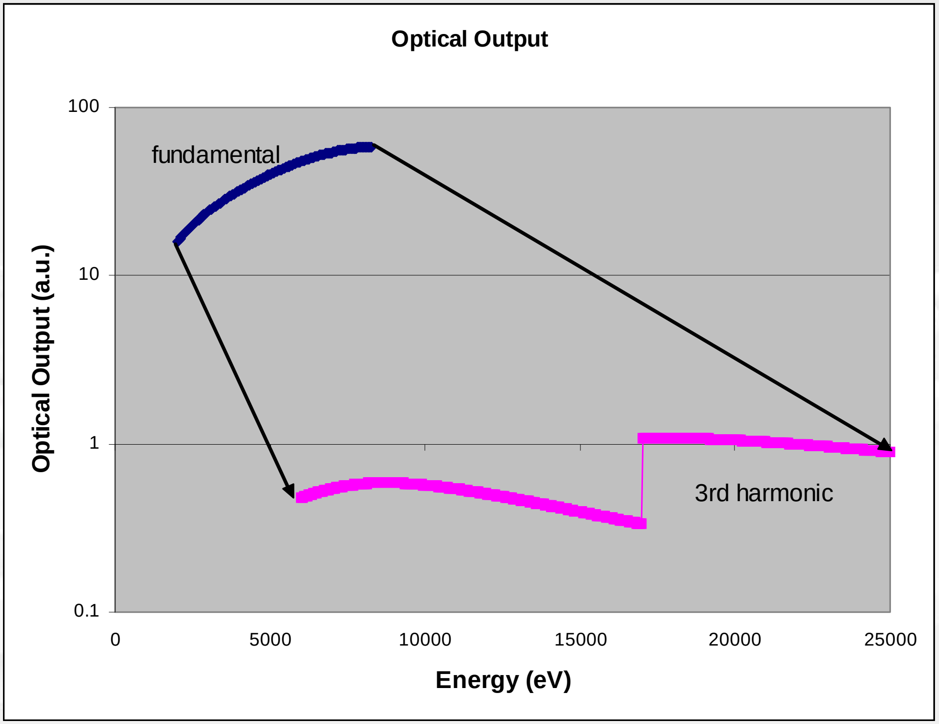
$$\Delta y = t\frac{\sin\theta}{\cos\theta}$$
$$= t\theta \quad if\ \theta\ is\ small$$



YAG:Ce Scintillator

- Quantum efficiency
  - 1 - transmission > 20%
  - Optical output weakly energy dependent < a factor 4
    - Lower QE made up by higher photon energy ➔ more optical phonon
    - 1% flux of fundamental for 3rd harmonic





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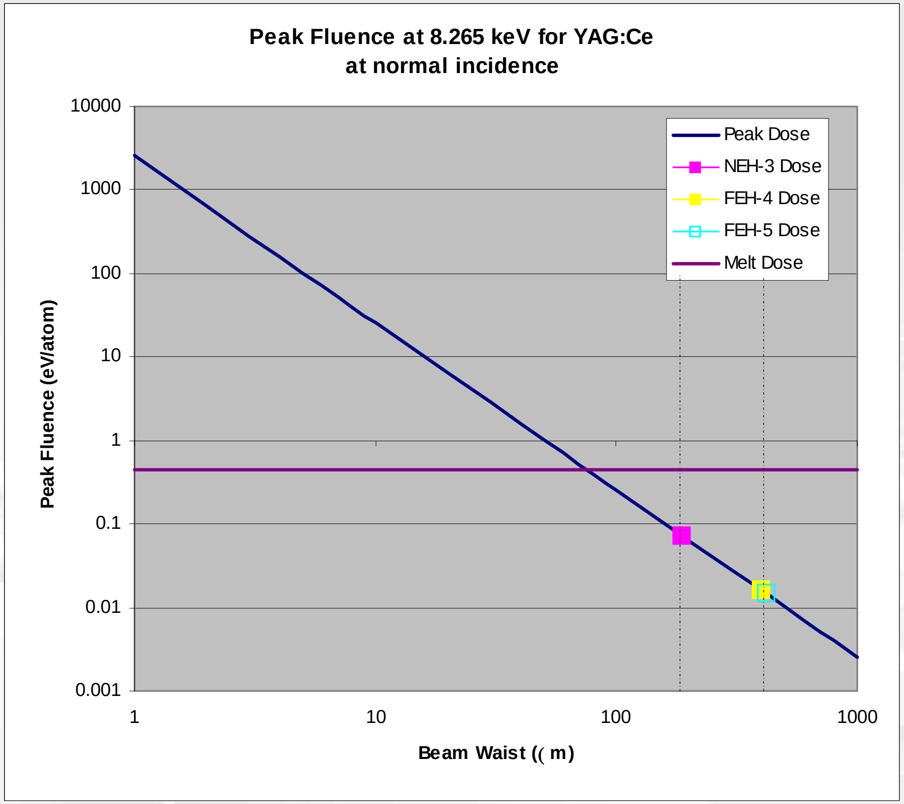
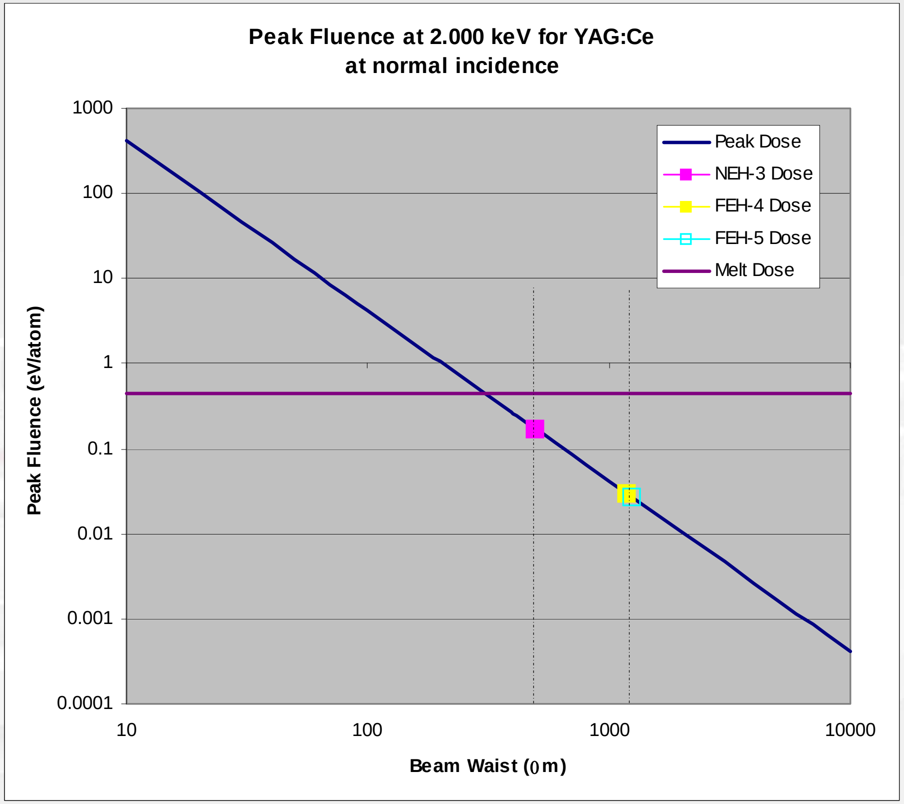
YAG:Ce Scintillator

- Damage consideration
  - Attenuation required at lower energies (< 6 keV) in FEH-3
    - A factor of 10 to 100 will be sufficient





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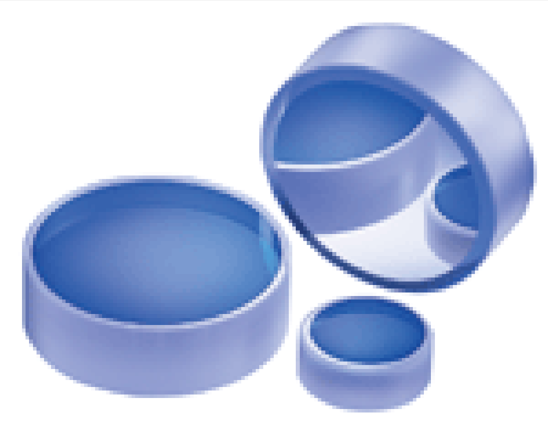
45º Mirror

- Optical Mirror
  - Optical specifications
    - Quality: optical
    - Material: UV grade
    - Transmitted wavefront: $\lambda/4$ @ 632 nm
    - Flatness: $\lambda/4$
    - Scratch-Dig: 20-10
    - Mil-C-675-A adhesion & durability specs
    - Reflectivity: > 95% @ 45º incidence, 475-650 nm
      - Broadband so permitting visual inspection using white light
        - May require metallic coating
        - Or metal mirror
  - Viewing aperture
    - Consistent w/ size of YAG:Ce screen
  - Thickness
    - Not critical



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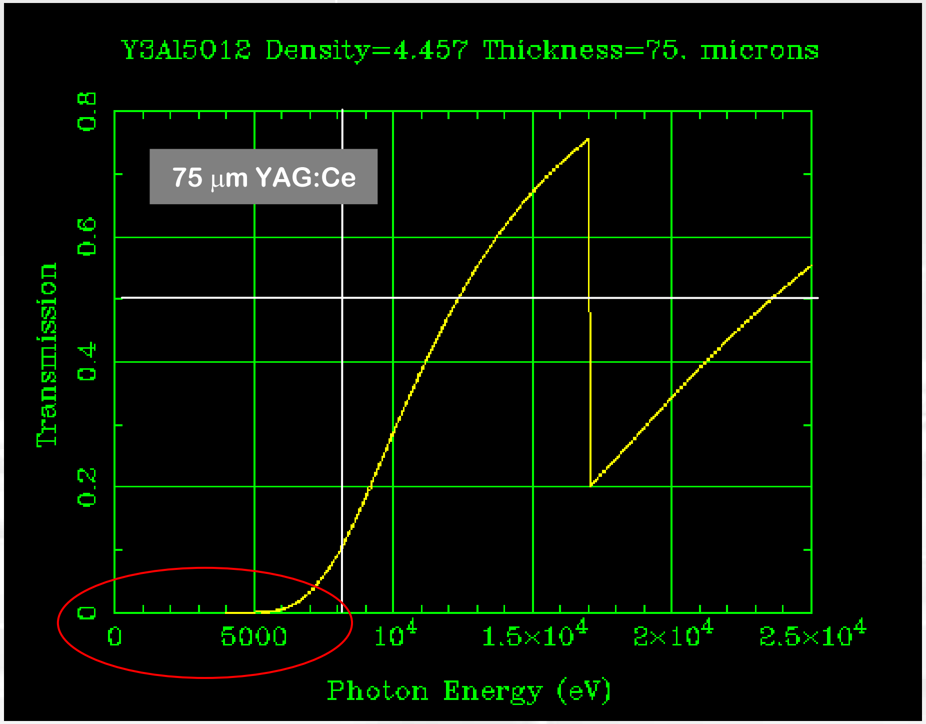
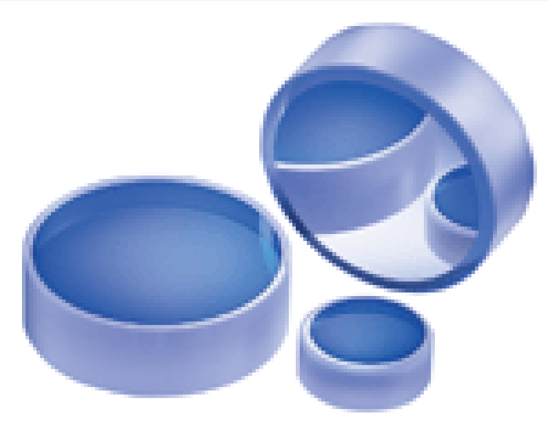
45º Mirror

- Radiation consideration
  - If Al is used, no damage issues
    - Transmission < 0.5% for energy < 6 keV
    - Al is safe in NEH for energy > 6 keV





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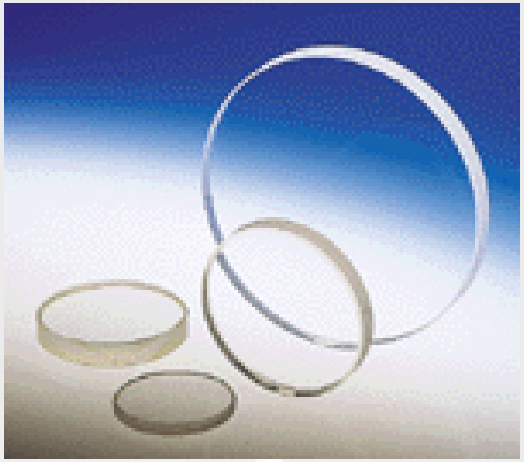
Vacuum Window

- Vacuum Window
  - Optical specifications
    - Material: UV grade
    - Transmitted wavefront: $\lambda/4$ @ 632 nm
    - Flatness: $\lambda/4$
    - Parallelism: 10 arc seconds
    - Scratch-Dig: 20-10
    - Mil-C-675-A adhesion & durability specs
    - AR coating: $R_{ave} < 0.5\%$, 0º incidence, 475-650 nm
  - Viewing aperture
    - Consistent w/ zoom lens
  - Thickness
    - Consistent w/ vacuum requirement and size of the view aperture
  - Radiation consideration
    - Not in direct line-of-sight other than stray radiation



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2D Pixelated Camera

- Fast 2D pixelated camera
  - 1/3 inch optical CCD - Pulnix TM-6740CL (CameraLink)
    - Sensor size - 4.74x3.55 mm^2
    - Optimal response
      - @ 550 nm, QE = 45%
    - 648x484 pixels
    - Progressive scan up to 200 Hz
    - 7.4x7.4 μm^2 square pixels
    - Dynamic range
      - > 10 bit
      - 20 ke$^-$ full well @ 40 MHz
      - 16 e$^-$ noise @ 40 MHz
  - Use Cameralink^{TM} protocol
  - Frame grabber on Linux OS

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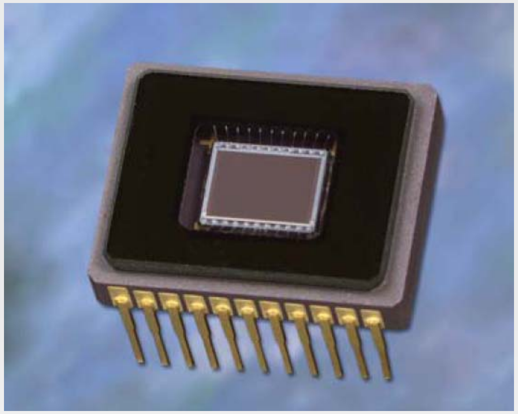
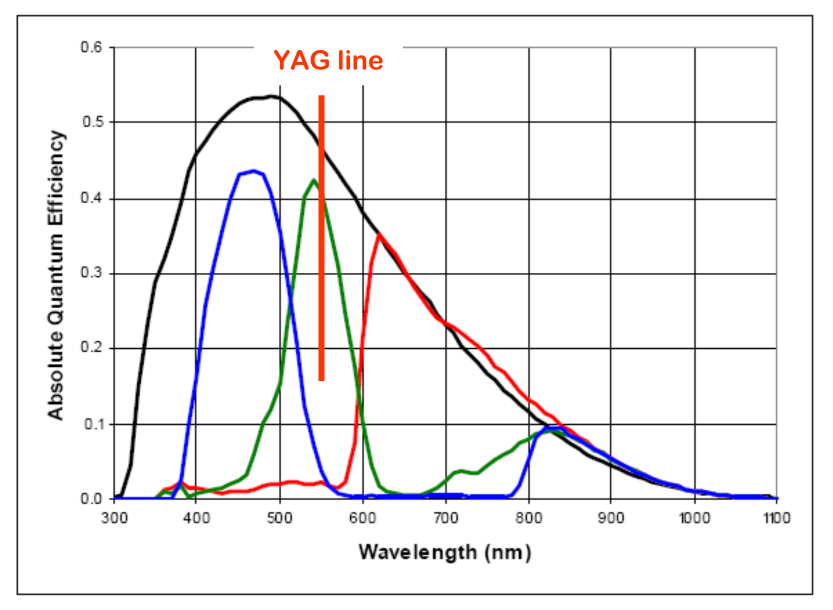
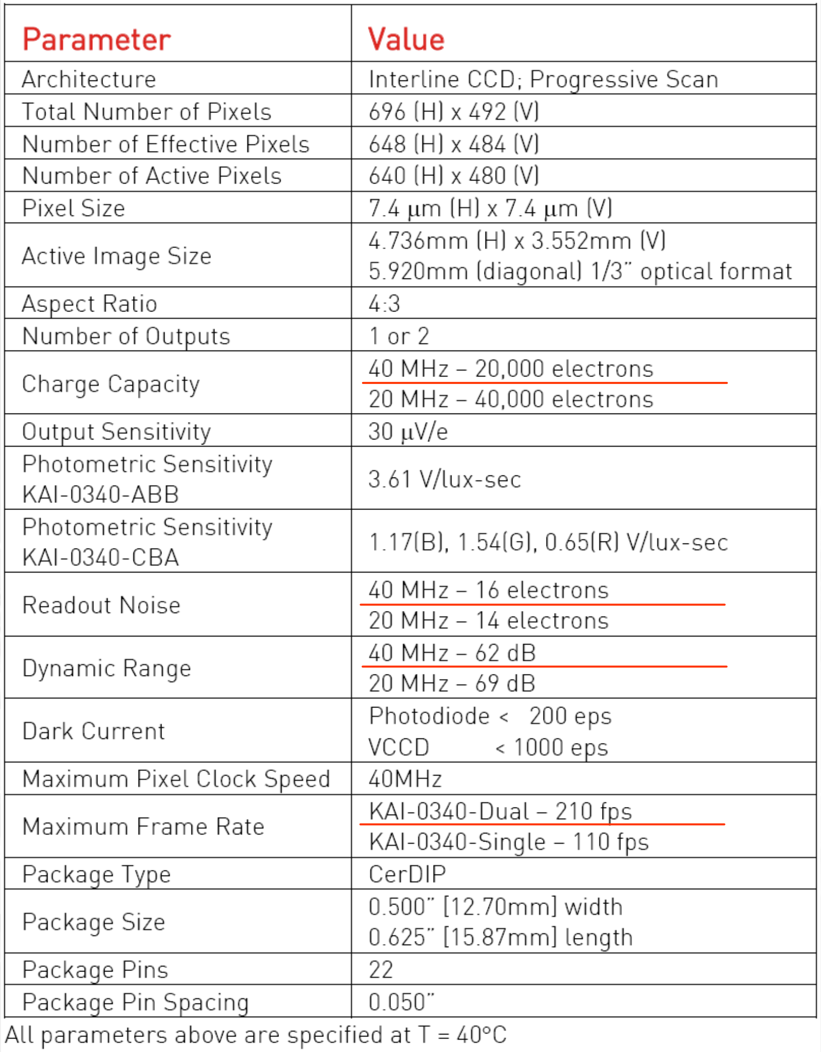
2D Pixelated Camera

- CCD data sheet (Kodak KAI-0340)





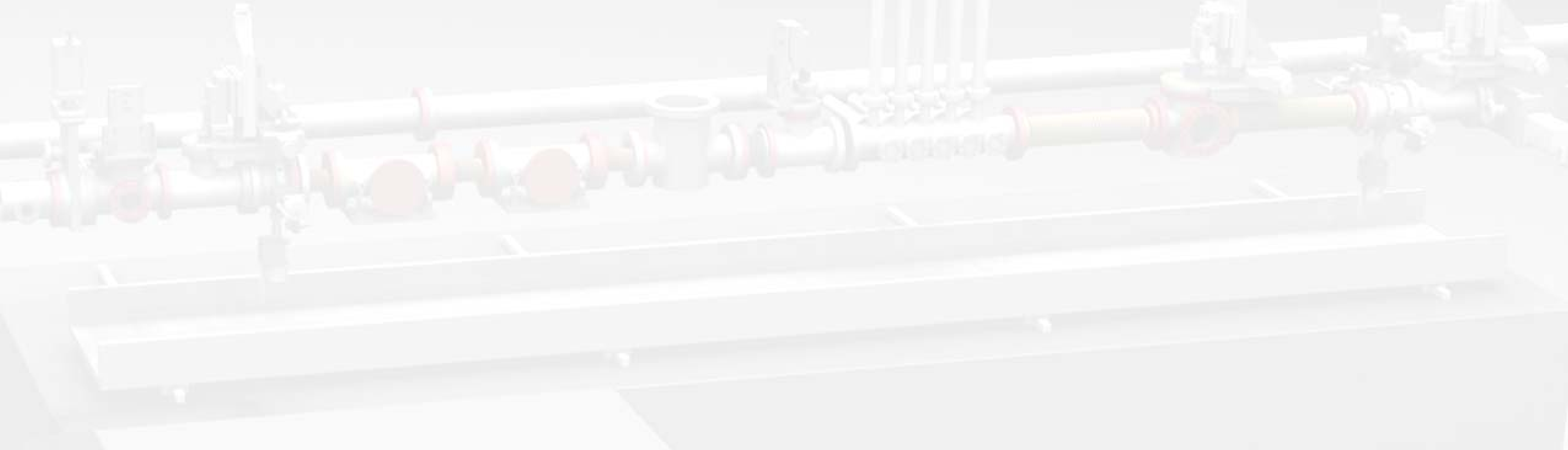


Parameter	Value
Architecture	Interline CCD; Progressive Scan
Total Number of Pixels	696 (H) x 492 (V)
Number of Effective Pixels	648 (H) x 484 (V)
Number of Active Pixels	640 (H) x 480 (V)
Pixel Size	7.4 µm (H) x 7.4 µm (V)
Active Image Size	4.736mm (H) x 3.552mm (V) 5.920mm (diagonal) 1/3" optical format
Aspect Ratio	4:3
Number of Outputs	1 or 2
Charge Capacity	40 MHz – 20,000 electrons 20 MHz – 40,000 electrons
Output Sensitivity	30 µV/e
Photometric Sensitivity KAI-0340-ABB	3.61 V/lux-sec
Photometric Sensitivity KAI-0340-CBA	1.17(B), 1.54(G), 0.65(R) V/lux-sec
Readout Noise	40 MHz – 16 electrons 20 MHz – 14 electrons
Dynamic Range	40 MHz – 62 dB 20 MHz – 69 dB
Dark Current	Photodiode < 200 eps VCCD < 1000 eps
Maximum Pixel Clock Speed	40MHz
Maximum Frame Rate	KAI-0340-Dual – 210 fps KAI-0340-Single – 110 fps
Package Type	CerDIP
Package Size	0.500" [12.70mm] width 0.625" [15.87mm] length
Package Pins	22
Package Pin Spacing	0.050"

All parameters above are specified at T = 40°C

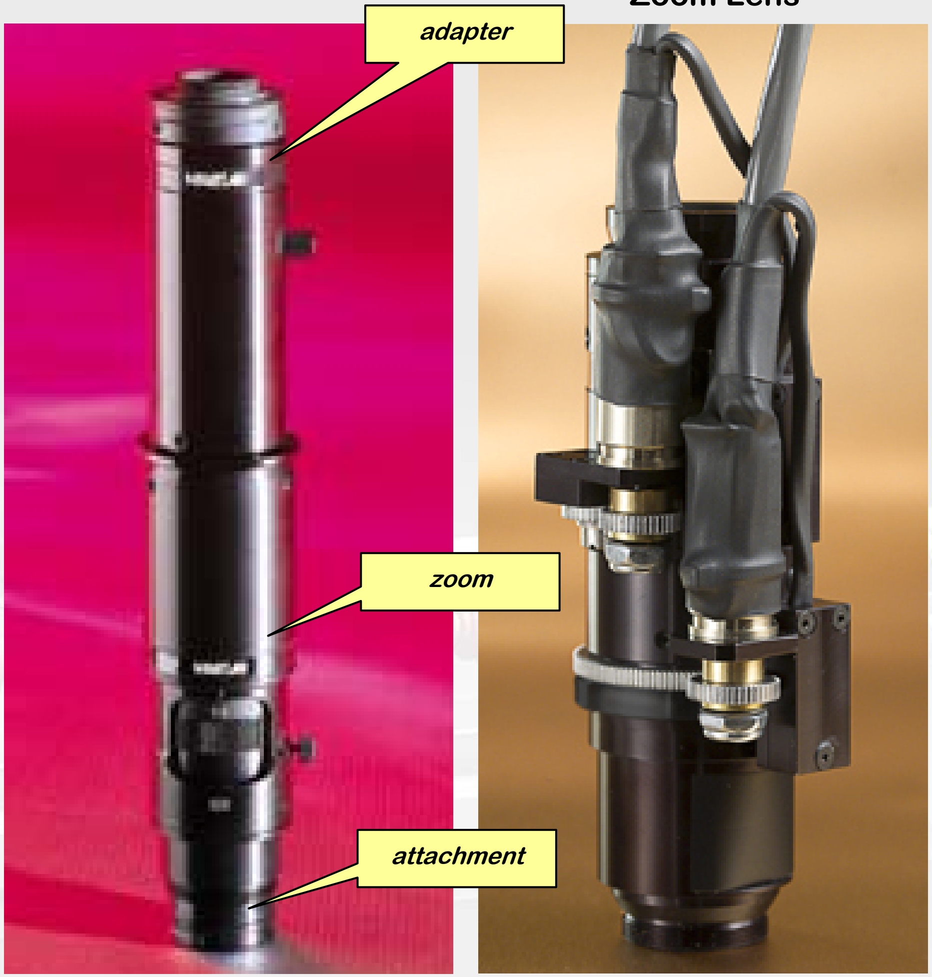
2D Pixelated Camera

- Frame rate
  - @ 30 Hz for all cameras except one per instrument @ 120 Hz
  - With CameraLink^{TM} protocol, 120 Hz frame rate could be readily achieved w/ ¼ Mpixel cameras, thus not driving the design other than a cost increase < $500
  - In almost all case, the resolution of the current system will be lens-limited
    - Working distance is limiting the available NA
    - More pixels would <u>not</u> improve resolution for high magnification settings



Zoom Lens

- Zoom lens (Navitar)
  - Modular/flexible design
    - Attachment+zoom+adapter
  - Large range of FOV ~ 12x
    - Maintaining focus while zooming
  - Good working distance
    - 165, 108, 86 mm
    - Trade-off btw FOV and resolution
  - Sufficient depth of field
    - ~ Min. 200, 89, 50 μm
  - Sufficient NA
    - Max. NA ~ 0.05, 0.075, 0.1
  - Readily Motorizable
    - Focus or zoom or focus&zoom



Zoom Lens

Motorized Zoom Lens

Zoom Lens

- Zoom selection

FOV = D/Sys. Mag.
D_{camera} = 3.6 mm
1/3 Mpixel CCD 7.4 μm

Optical resolution

Matching pixel size $= \Delta_{optical} \frac{Sys.Mag}{2}$

12X Zoom Combinations	W.D.	System Mag.		N.A. -obj-		Feature Size micron		Pixel Size microns		Depth of Field	
Lens Attach. + Prime Lens + Adapter		Low Mag.	High Mag.	Low Mag.	High Mag.	Low Mag.	High Mag.	Low Mag.	High Mag.	Low Mag.	High Mag.
0.5x + 12X Zoom + 0.5x	165	0.14	1.75	0.009	0.051	18.52	6.60	2.59	5.82	6.17	0.19
0.5x + 12X Zoom + 0.67x	165	0.19	2.35	0.009	0.051	18.52		3.60	7.68	6.17	0.19
0.5x + 12X Zoom + 1.0x	165	0.29	3.50	0.009	0.051	18.52		5.38	11.45	6.17	0.19
0.5x + 12X Zoom + 1.33x	165	0.39	4.66	0.009	0.051	18.52		7.22	15.51	6.17	0.19
0.5x + 12X Zoom + 2.0x	165	0.58	7.00	0.009	0.051	18.52		10.74	22.89	6.17	0.19
0.5x + 12X Zoom + 3.5x	165	1.02	12.30	0.009	0.051	18.52		18.89	40.95	6.17	0.19
0.75x + 12X Zoom + 0.5x	108	0.22	2.62	0.014	0.076	11.90	4.39	2.61	5.81	2.55	0.09
0.75x + 12X Zoom + 0.67x	108	0.29	3.52	0.014	0.076	11.90		3.45	7.73	2.55	0.09
0.75x + 12X Zoom + 1.0x	108	0.44	5.25	0.014	0.076	11.90		5.24	11.52	2.55	0.09
0.75x + 12X Zoom + 1.33x	108	0.58	6.98	0.014	0.076	11.90		6.90	15.49	2.55	0.09
0.75x + 12X Zoom + 2.0x	108	0.87	10.50	0.014	0.076	11.90		10.35	23.05	2.55	0.09
0.75x + 12X Zoom + 3.5x	108	1.53	18.40	0.014	0.076	11.90		18.20	40.84	2.55	0.09
None + 12X Zoom + 0.5x	86	0.29	3.49	0.019	0.101	9.26	3.30	2.68	5.82	1.39	0.05
None + 12X Zoom + 0.67x	86	0.39	4.69	0.019	0.101	9.26		3.42	7.74	1.39	0.05
None + 12X Zoom + 1.0x	86	0.58	7.00	0.019	0.101	9.26		5.09	11.55	1.39	0.05
None + 12X Zoom + 1.33x	86	0.77	9.31	0.019	0.101	9.26		7.13	15.54	1.39	0.05
None + 12X Zoom + 2.0x	86	1.16	14.00	0.019	0.101	9.26		10.17	23.10	1.39	0.05
None + 12X Zoom + 3.5x	86	2.03	24.50	0.019	0.101	9.26		18.79	40.91	1.39	0.05

Config.- A
(WFOV)
25 mm

Config.- B
(NFOV)
12 mm

Optional
Config.- C
(MACRO)
6.2 mm

2x of listed values
based on Rayleigh Criteria

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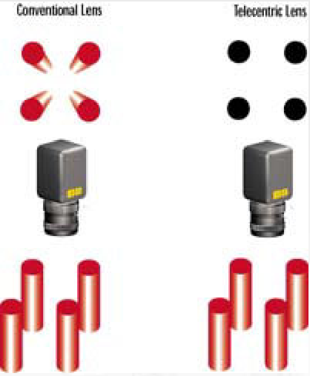
Zoom Lens



- Working distance (W.D.) & Depth of field
  - Resolution generally would increase when going to smaller focal length (thus shorter working distance) for a given optics diameter
    - It is thus desirable to use a lens system that has shorter W.D. if the requirements for the field of view (FOV) could be met.
    - In addition, light collection efficiency is higher at short W.D.
  - However, there are other resolution effects that must be considered, such as the parallaxial distortion.
    - When the object is extended in the direction of the optical axis, parallaxial effects can smear the resolution by appearing in the image space being tilted away from the axis.
    - Only telecentric lens system could correct for this kind of distortion
      - But, telecentric lens is expensive
      - Light collection efficiency lower
    - Or thinner YAG:Ce screen
  - Depth of field
    - DOF generally decreases with W.D.
    - At 86 mm or shorter, the DOF would be smaller than the thickness (75 μm) of the YAG:Ce screen

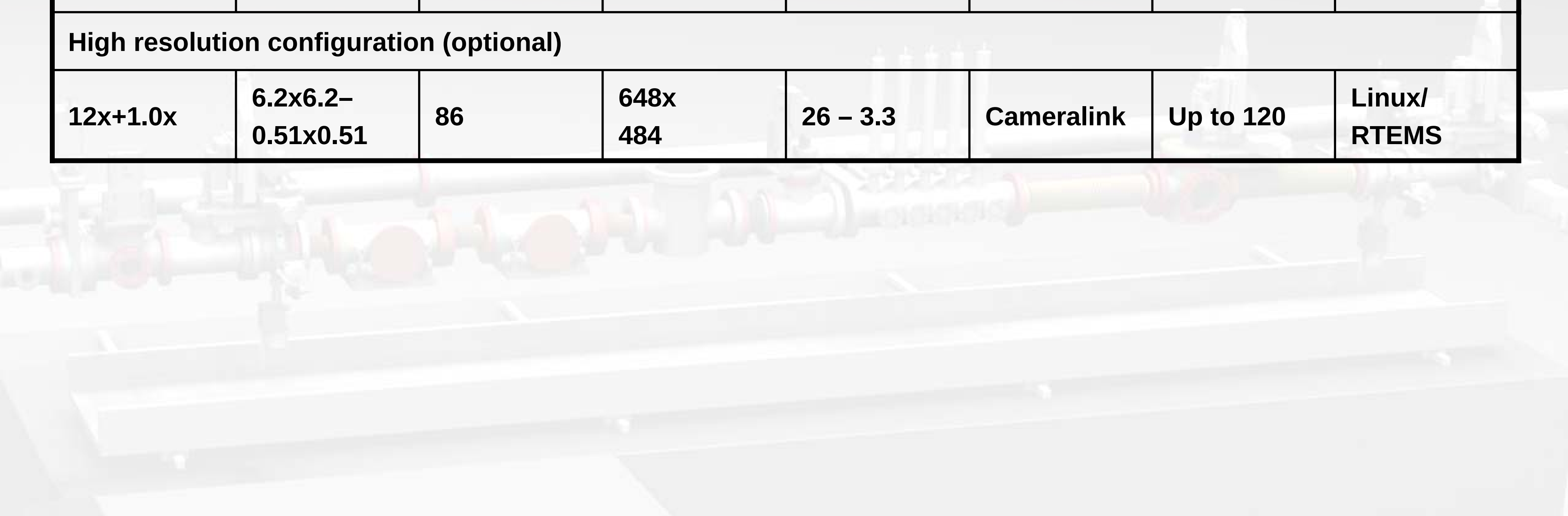
Zoom Lens

- Working distance & Depth of field (con't)
  - W.D. of 165 & 108 mm was a good comprise
    - Resolution limited to 6.6 μm & 4.4 μm
    - Parallaxial distortion limited to < 3 μm
    - Light collection seems adequate
    - Good depth of field @ 200 & 89 μm, making focusing requirement somewhat relaxed
  - Shorter W.D. would be required if higher resolution (< 3 μm) is required, or light collection is an issue with 165 & 108 mm system
    - Change W.D. to 86 mm
    - Would work w/ 50 μm YAG:Ce to reduce parallaxial distortion
- Focus test
  - DOF > 89 μm, > YAG:Ce thickness of 75 μm
    - Thus focusing requirement could be easily met
  - See surveying and calibration
    - Use scratches on YAG:Ce screen
    - Or use test patterns

Zoom Lens/Camera Configuration

- Configurations

Config. (att.+zoom+ adapter)	Zoom lens FOV (mm^2)	Working Distance (mm)	# of pixels	Expected resolution (μm)	Digital output	Frame rate	Frame grabber OS
0.5x+12x+ 0.5x	25.7x25.7 – 2.06x2.06	165	648x 484	106 – 8.5	Cameralink	Up to 120	Linux/ RTEMS
0.75x+12x+ 0.67x	12.4x12.4 – 1.03x1.03	108	648x 484	51 – 4.4	Cameralink	Up to 120	Linux/ RTEMS
High resolution configuration (optional)							
12x+1.0x	6.2x6.2– 0.51x0.51	86	648x 484	26 – 3.3	Cameralink	Up to 120	Linux/ RTEMS



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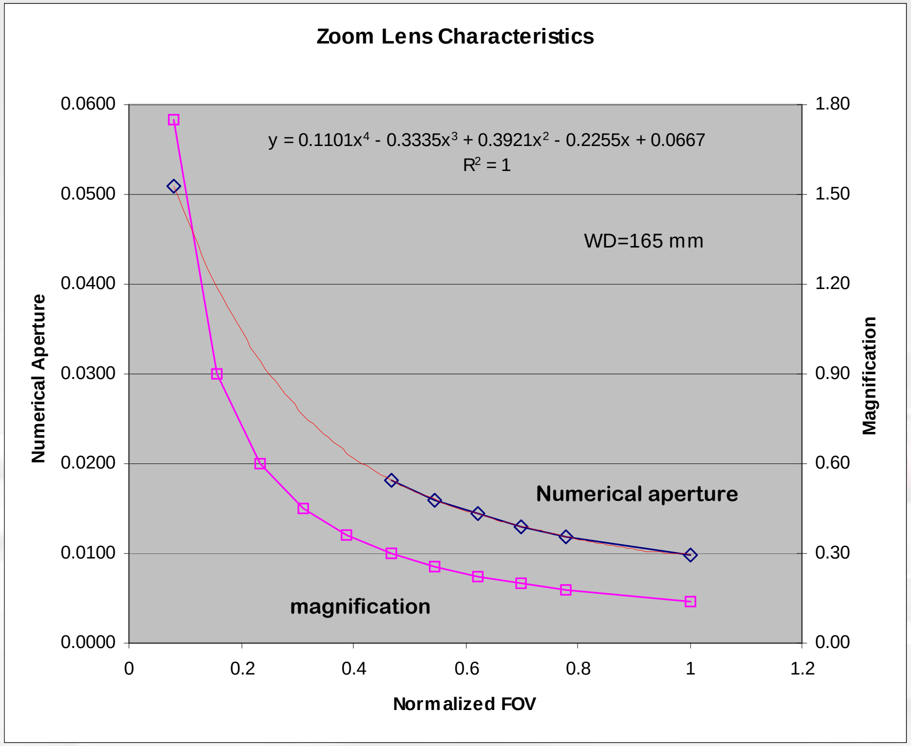
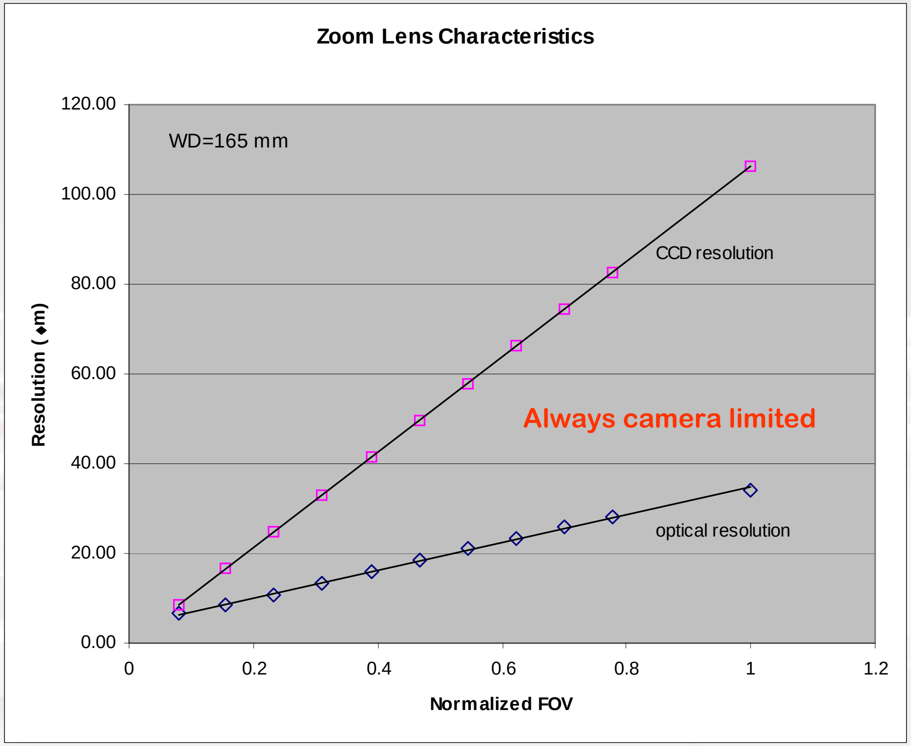
Lens Characteristics

- Lens/camera config. A
  - CCD chip 3.6 mm in height
  - FOV 25.71 mm (3.6 mm/Magnification)





LUSI LCLS Ultrafast Science Instruments

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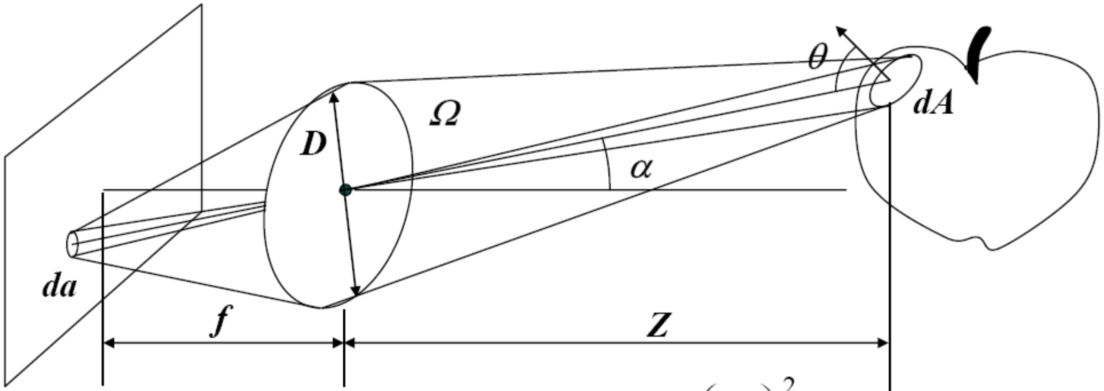
DCO

Signal Calculations

- Image Brightness

Pixel Brightness and Scene Brightness



$$\frac{da\cos\alpha}{(f/\cos\alpha)^2} = \frac{dA\cos\theta}{(Z/\cos\alpha)^2} \Longrightarrow \frac{dA}{da} = \frac{\cos\alpha}{\cos\theta}\left(\frac{Z}{f}\right)^2$$

$$dP = L\,dA\,\Omega\cos\theta \Longrightarrow dP = L\,dA\,\frac{\pi}{4}\left(\frac{D}{Z}\right)^2\cos^3\alpha\cos\theta$$

$$E = \frac{dP}{da} = L\frac{dA}{da}\frac{\pi}{4}\left(\frac{D}{Z}\right)^2\cos^3\alpha\,\cos\theta \Longrightarrow \boxed{E = \frac{\pi}{4}\left(\frac{D}{f}\right)^2\cos^4\alpha\ L}$$

Radiance

Irradiance

Signal Calculations

- Factors Considered
  - Radiance
    - FEL energy and flux
    - YAG photoelectric effect %
    - YAG Fluorescence yield and distribution
      - Assuming uniform over 4π
  - Irradiance
    - Numerical aperture
    - YAG refractive index
  - Losses
    - Quartz window transmission
    - CCD surface reflection
  - CCD quantum efficiency

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Simulations

- Expected performance

Beam size in vertical (FWHM/ waist in μm)	Field of View (mmxmm)/ [Resolution (μm)]	Image size on ½ CCD sensor (# of pixels)	# of e^- per pixel @ 1.5×10^{12} photons @ 8 keV & 75 μm YAG	Attenuation needed to match full well (20k e^-)	Notes
221/188	24x24 [99]	4x4	1.08×10^{7}	542	Reduces damages
	2x2 [8.3]	46x46	1.91×10^{6}	96	Reduces damages
489/416	24x24 [99]	8x8	2.22×10^{6}	111	Reduces damages
	2x2 [8.3]	101x101	3.92×10^{5}	20	FEL only
221/188 (high resolution configuration)	4.7x4.7 [19]	19x19	2.66×10^{6}	133	Reduces damages
	0.8x0.8 [3.3]	114x114	8.23×10^{5}	41	FEL only

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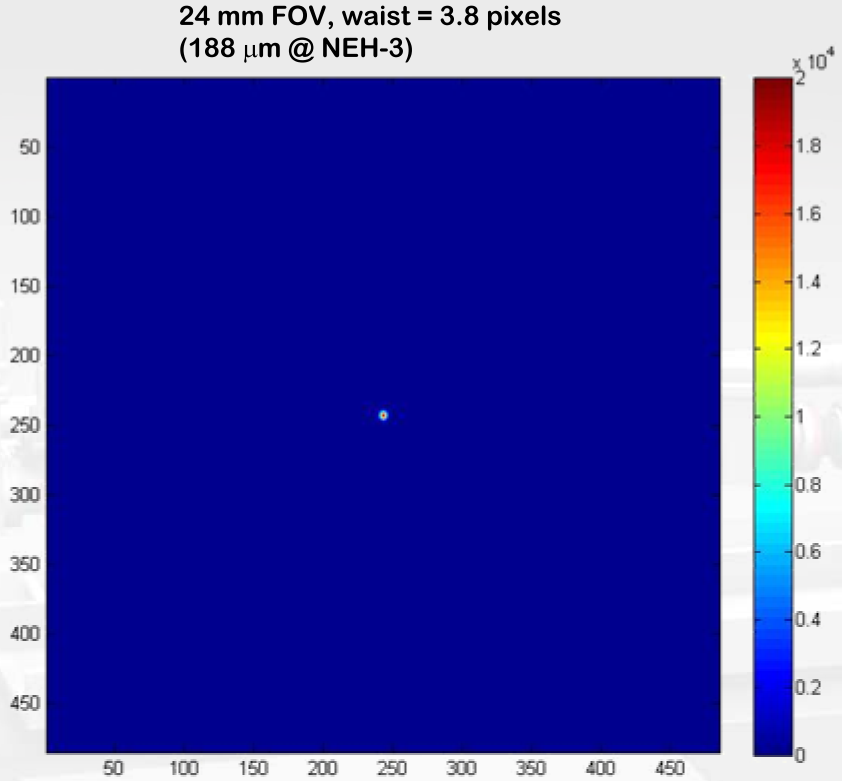
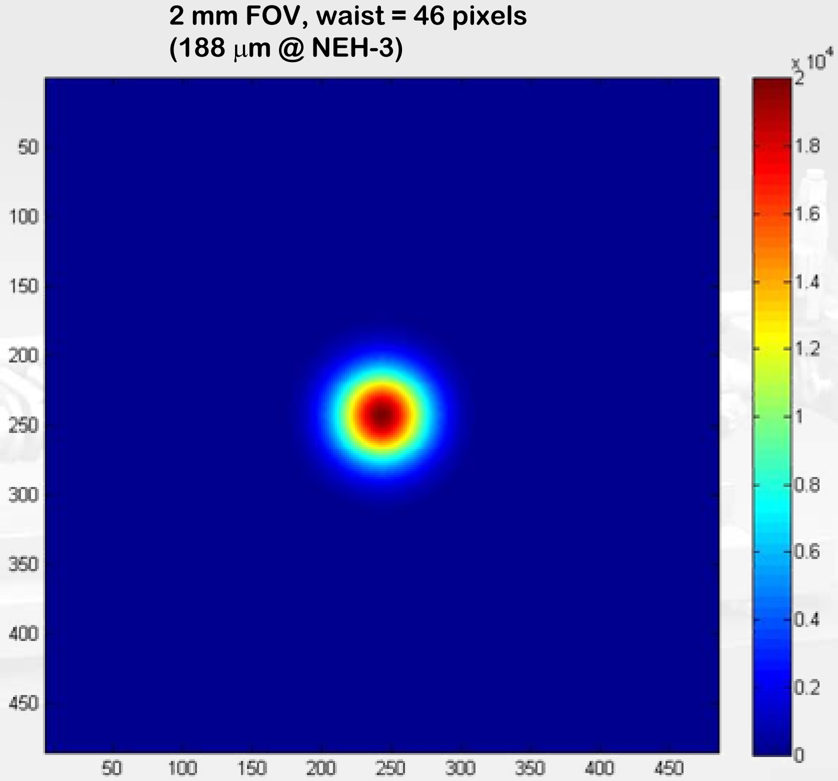
Alignment Operation

- Operation for XPP in NEH-3
  - Aligning optical components
    - Beam-finding in large FOV
    - Fine-tuning in small FOV



24 mm FOV, waist = 3.8 pixels (188 μm @ NEH-3)



2 mm FOV, waist = 46 pixels (188 μm @ NEH-3)

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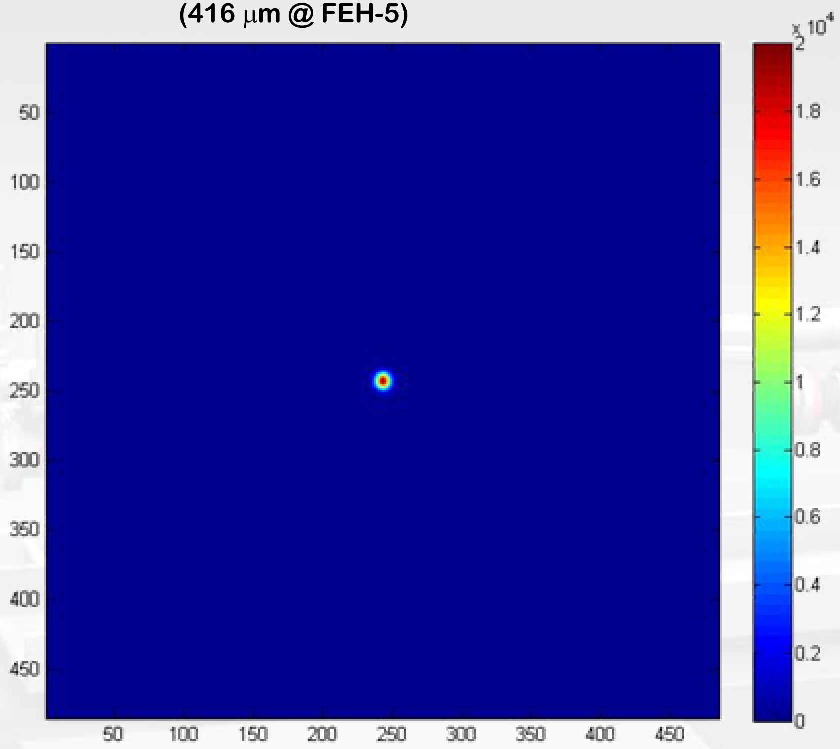
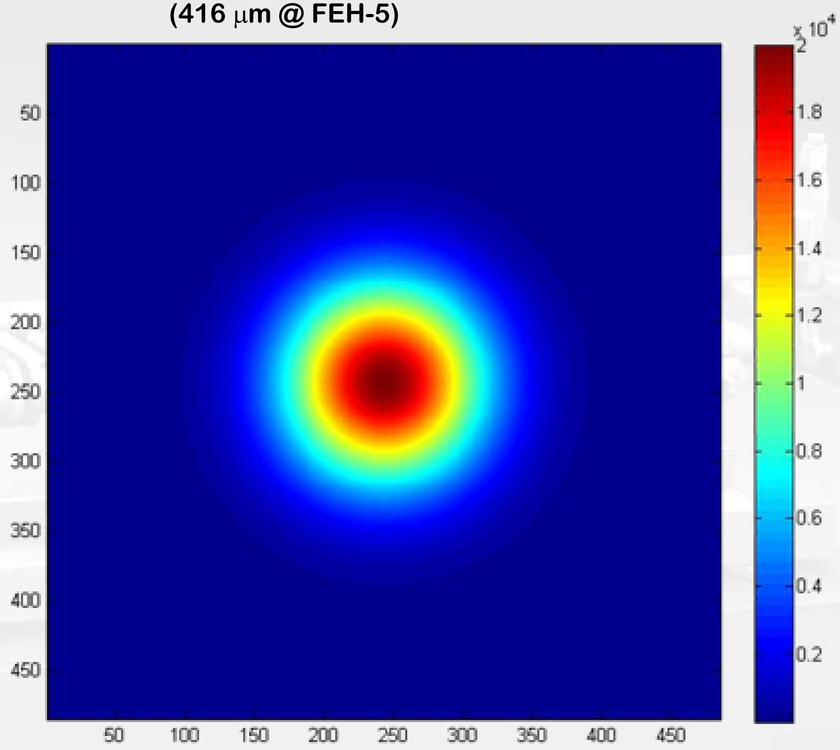
Alignment Operation

- Operation for XCS/CXI in FEH-4/5
  - Aligning optical components
    - 2x bigger beam size

24 mm FOV, waist = 8.4 pixels
(416 μm @ FEH-5)



2 mm FOV, waist = 101 pixels
(416 μm @ FEH-5)



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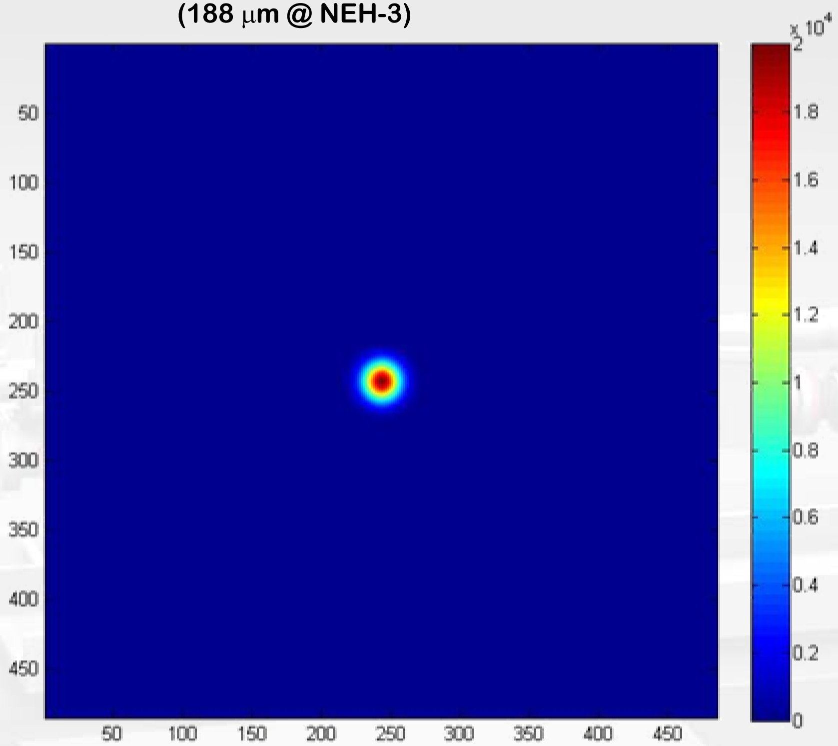
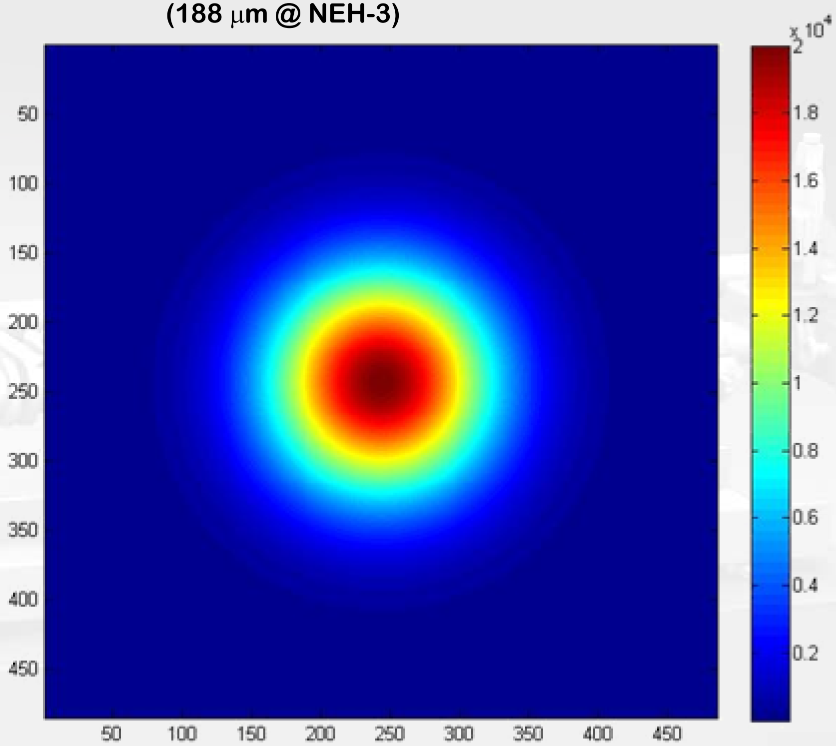
FEL 2D Imaging

- Imaging for XPP in NEH-3
  - Use optional config.
  - Higher resolution (~3.3 μm)
- FEH operation very similar

4.7 mm FOV, waist = 19.4 pixels
(188 μm @ NEH-3)

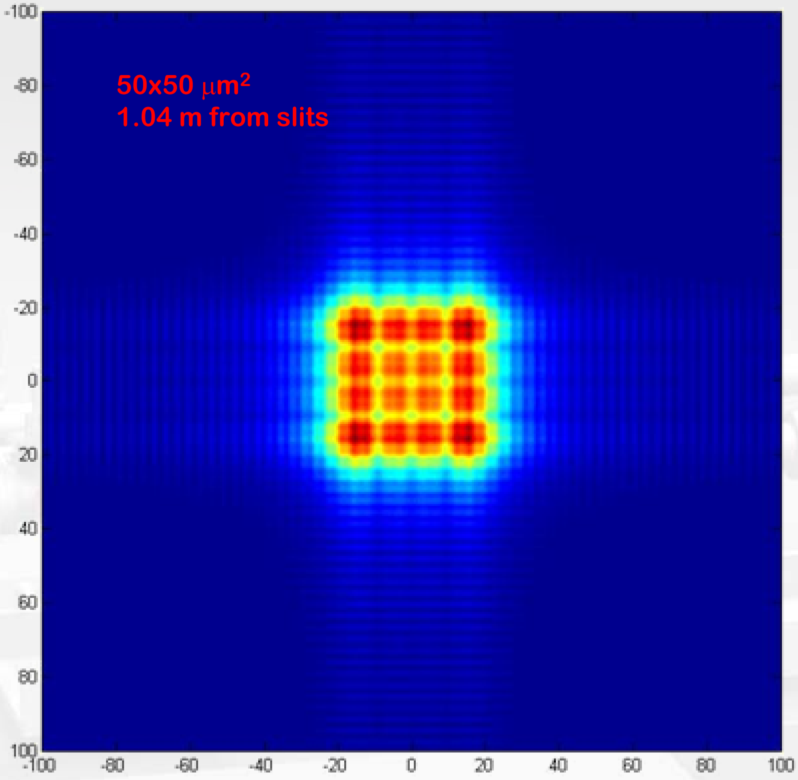


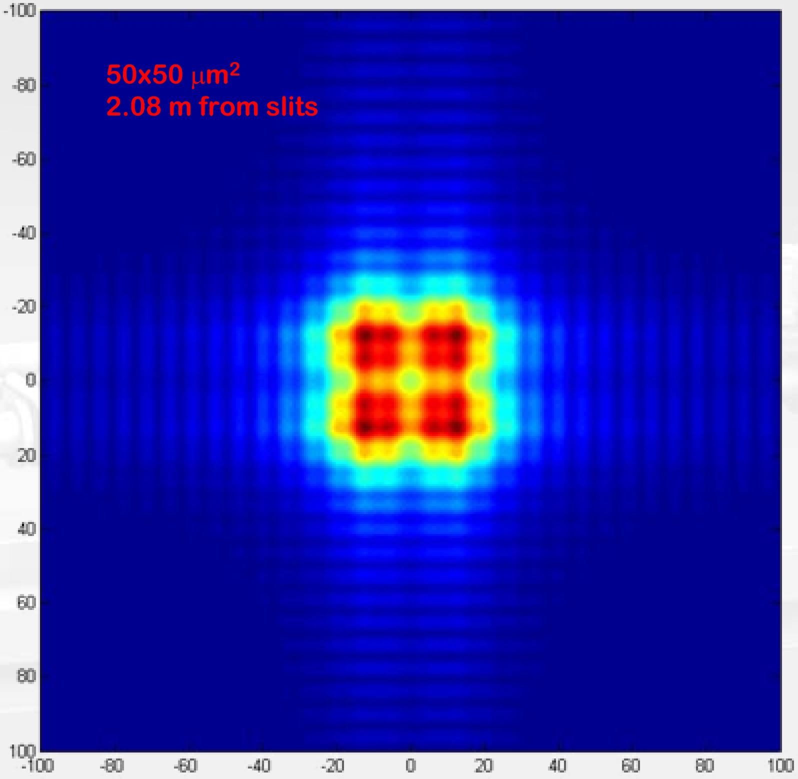
800 μm FOV, waist = 114 pixels
(188 μm @ NEH-3)



Diffraction Effects

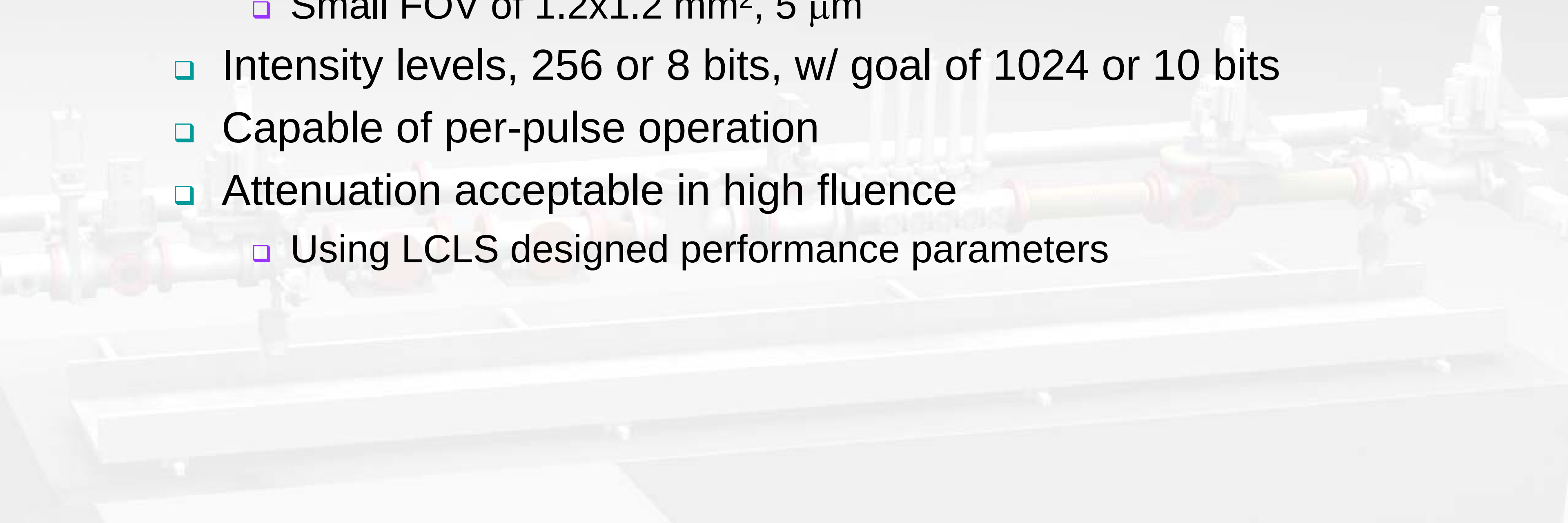
- Imaging for XPP in NEH-3
  - Coherence leads to diffraction effects
    - Slits
    - Surface roughness





Wavefront Monitor

- Performance Requirements
  - Capturing 2D beam profile
  - Operating energy 2-25 keV
  - Variable field of views (FOV) & resolution
    - Large FOV of 24x24 mm^2, 100 μm
    - Medium FOV of 12x12 mm^2, 50 μm
    - Small FOV of 1.2x1.2 mm^2, 5 μm
  - Intensity levels, 256 or 8 bits, w/ goal of 1024 or 10 bits
  - Capable of per-pulse operation
  - Attenuation acceptable in high fluence
    - Using LCLS designed performance parameters



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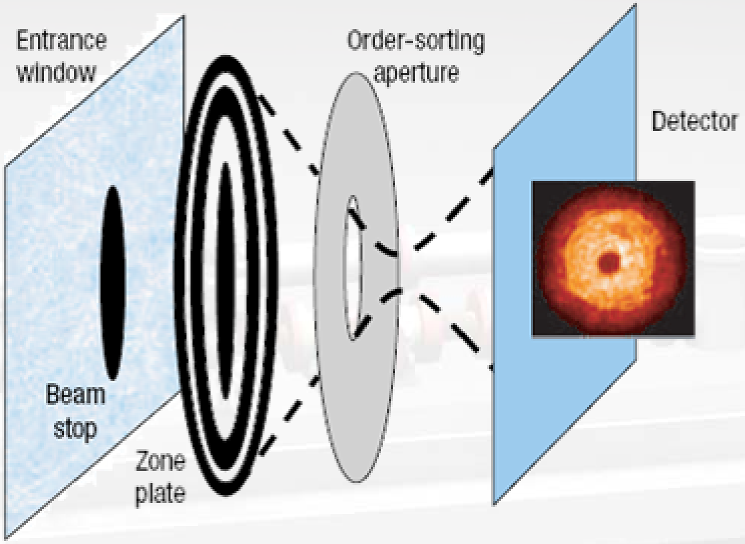
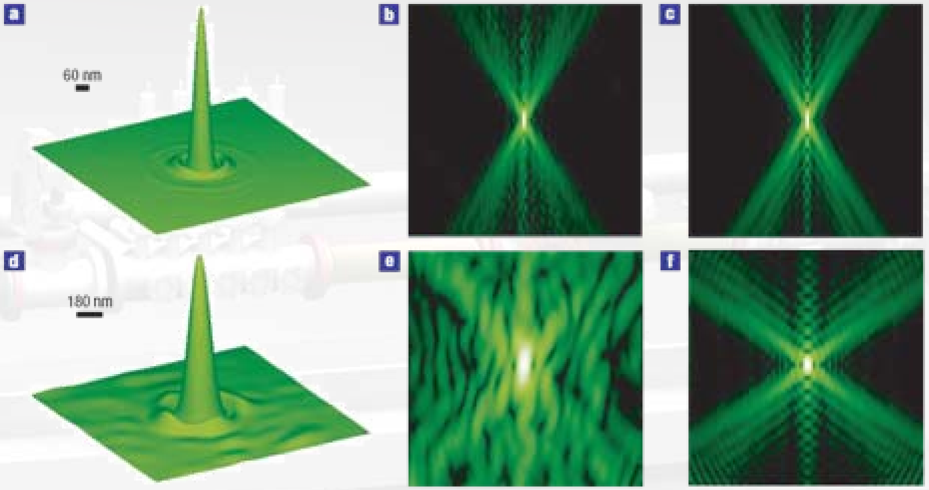
Diffractive Wavefront Reconstruction

- The oversampled diffraction pattern of focus (sample) is measured.
- The focal spot is iteratively reconstructed using standard phase retrieval methods
  - propagating wave from optic to focus and then to detector plane.
  - The constraints are applied at optic and detector planes.

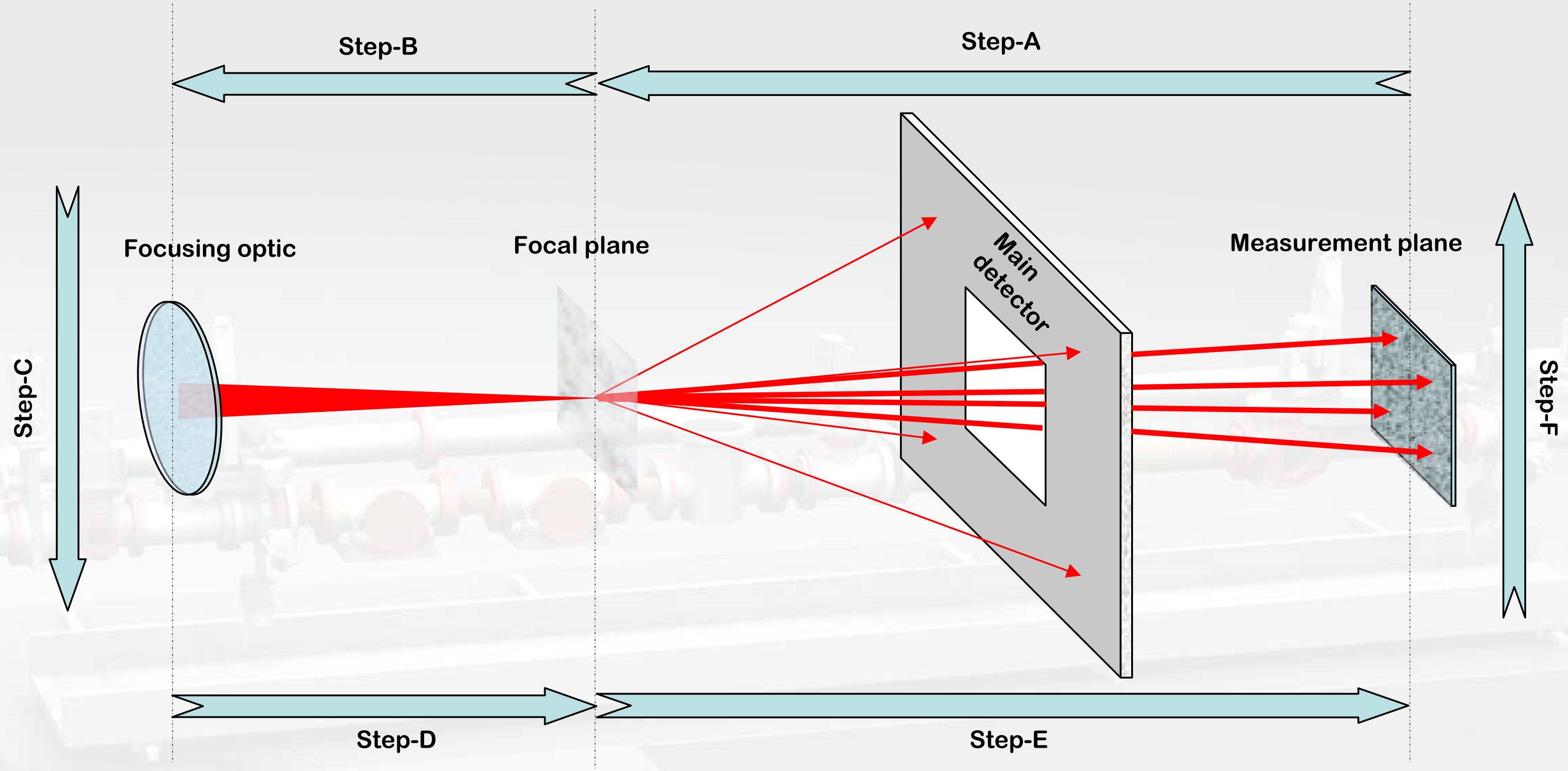




H. M. Quiney et al. ***Nature Physics*** **2**, 101 - 104 (2006)

Diffractive Wavefront Reconstruction

- Wavefront monitor
  - Iterative phase retrieval



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Simulations

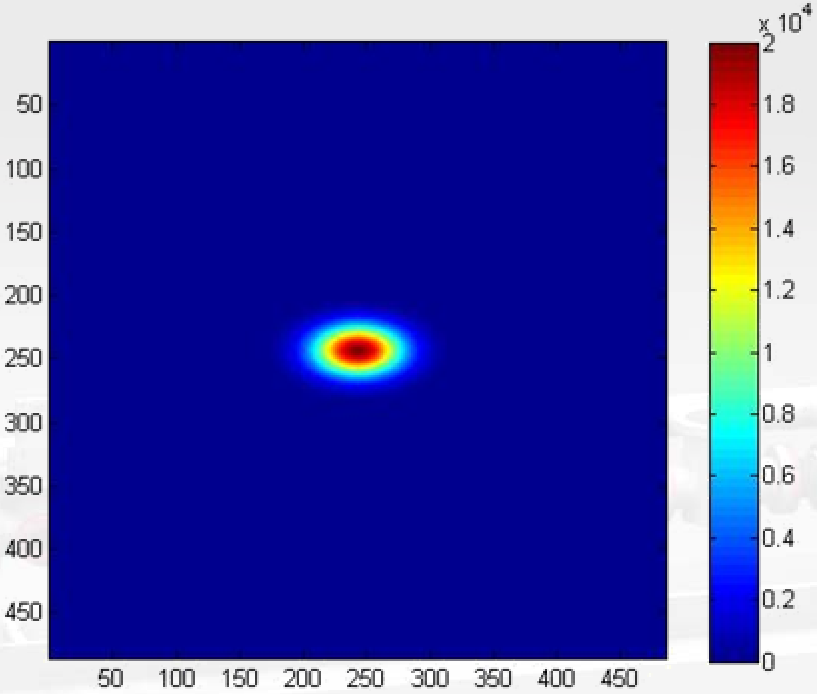
- Expected performance

Beam size in vertical (FWHM/ waist in µm)	Field of View (mmxmm)/ [Resolution (µm)]	Image size on ½ CCD sensor (# of pixels)	# of e^- per pixel @ 1.5×10^{12} photons @ 8.3 keV & 75 µm YAG	Attenuation needed to match full well (20k e^-)	Notes
1567/1331 (0.1 µm focus)	24x24 [99]	27x48	2.17×10^5	11	FEL only
	8x8 [33]	81x143	1.50×10^5	8	FEL only
714/606 (1.0 µm focus)	12x12 [50]	24x26	8.30×10^5	42	Reduces damages
	2x2 [8.3]	147x156	1.84×10^5	9	FEL only
75/63 (10 µm focus & high resolution configuration)	1.2x1.2 [5]	26x26	1.08×10^7	538	Reduces damages
	0.80x0.80 [3.3]	38x38	7.26×10^6	363	Reduces damages

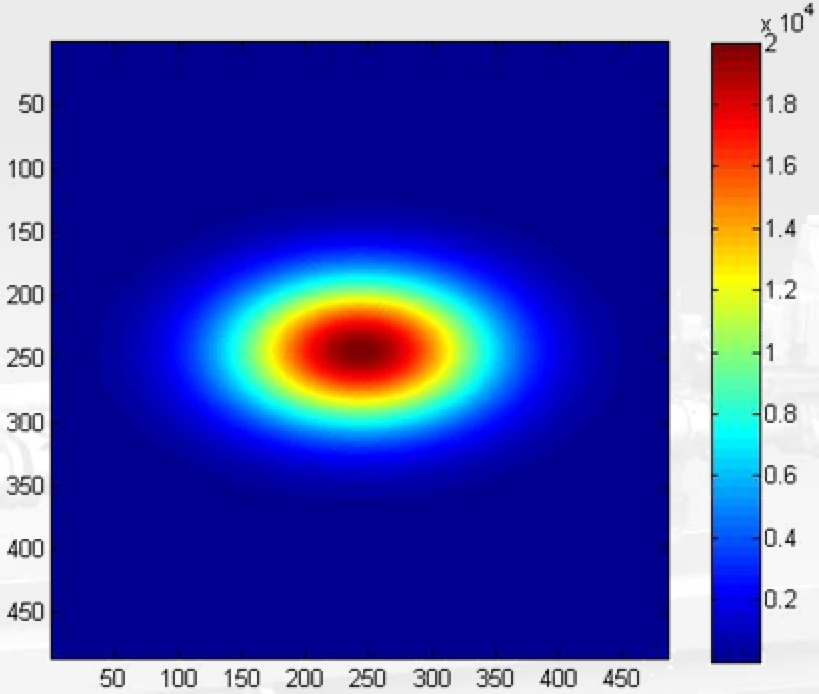
Wavefront Characterization

- Wavefront measurement in FEH-5
  - 0.1 μm KB (***in Q space***)

24 mm FOV, waist = 27x48 pixels
(0.1 μm focusing @ FEH-5 @ 3 m from focus)



8 mm FOV, waist = 81x143 pixels
(0.1 μm focusing @ FEH-5 @ 3 m from focus)

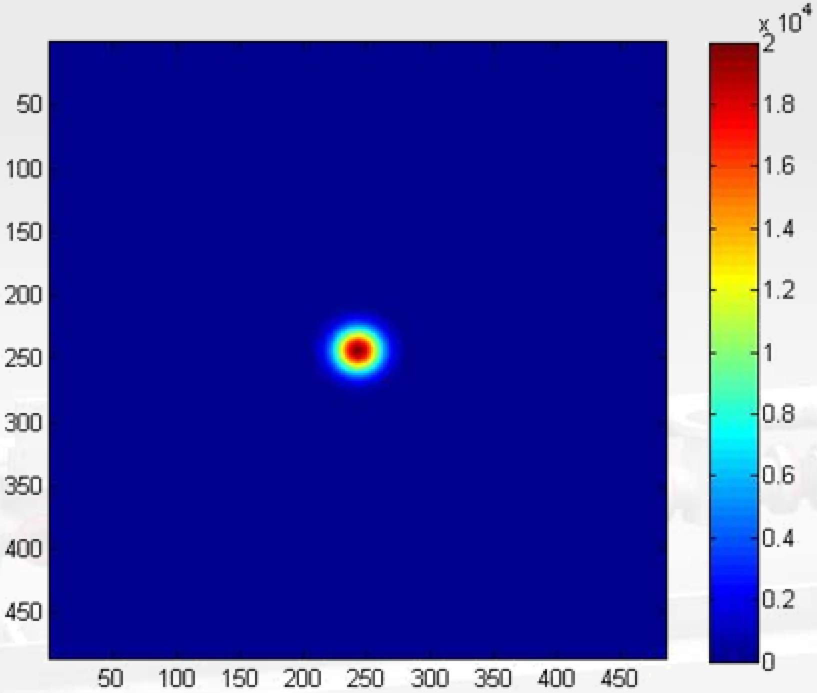


- 60 Å resolution, 1.44 μm FOV, 242 resolving power
- Revealing features outside of focal region

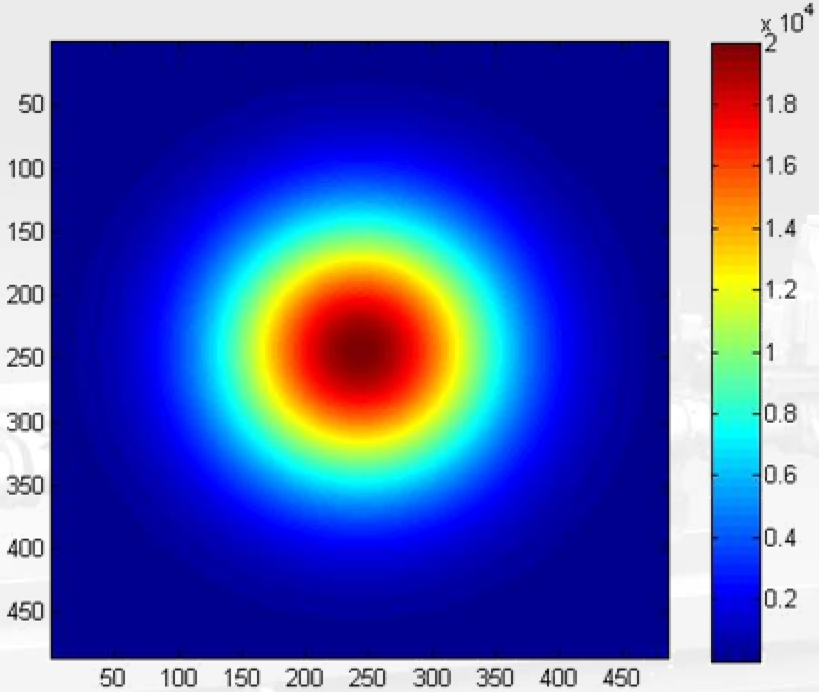
Wavefront Characterization

- Wavefront measurement in FEH-5
  - 1.0 μm KB (***in Q space***)

12 mm FOV, waist = 24x26 pixels
(1.0 μm focusing @ FEH-5 @ 11 m from focus)



2 mm FOV, waist = 147x156 pixels
(1.0 μm focusing @ FEH-5 @ 11 m from focus)

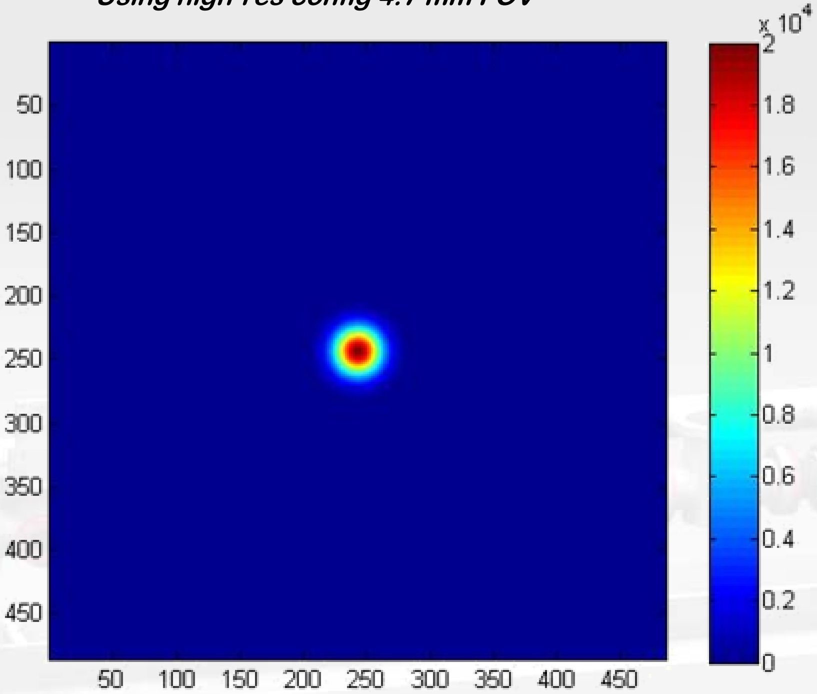


- 438 Å resolution, 10.6 μm FOV, 242 resolving power
- Revealing features outside of focal region

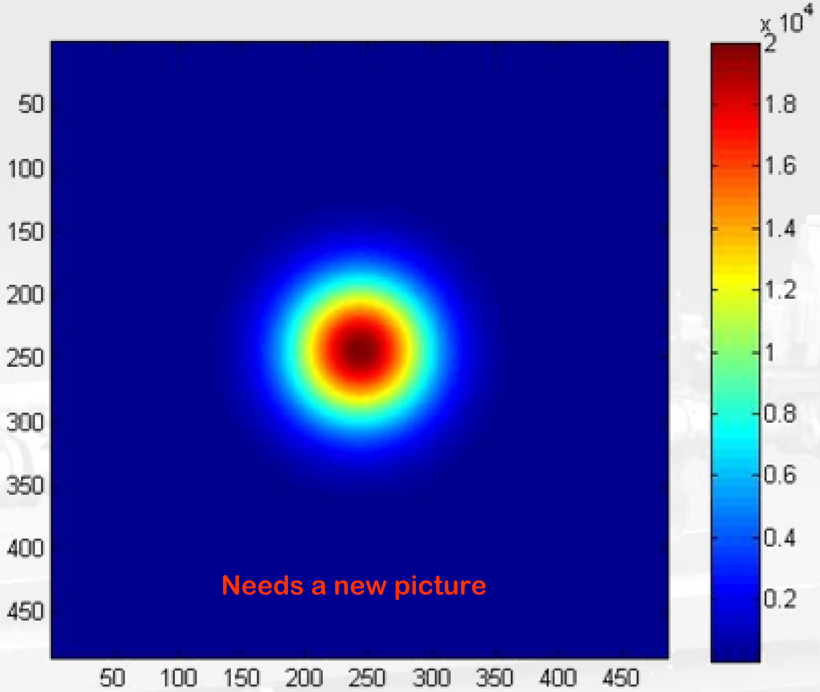
Wavefront Characterization

- Wavefront measurement in FEH-5
  - 10 μm Be Lens (***in Q space***)

1.2 mm FOV, waist = 26x26 pixels
(10 μm focusing @ FEH-5 @ 11 m from focus)
Using high-res config 4.7 mm FOV



800 μm FOV, waist = 38x38 pixels
(10 μm focusing @ FEH-5 @ 11 m from focus)



Needs a new picture

- 0.44 μm resolution, 106 μm FOV, 242 resolving power
- Revealing features outside of focal region

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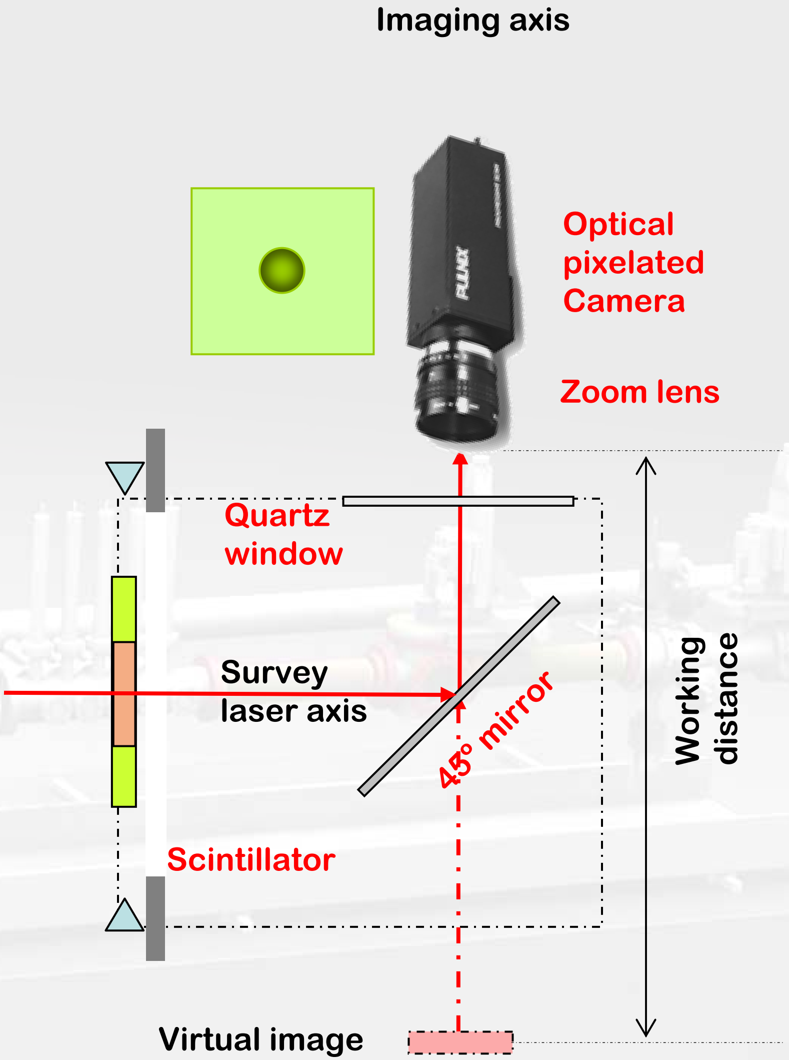
Surveying & Calibration

- Surveying
  - Bench top alignment
    - Use survey laser to establish alignment of laser to fiducials on vacuum housing
      - To ±1°
    - Establish the imaging axis relative to fiducials on the vacuum housing
      - To ±1°
    - Set YAG:Ce screen surface to be perpendicular to laser
      - To ±1°
      - Reflection due to high index
        - $n_{YAG} = 1.9$



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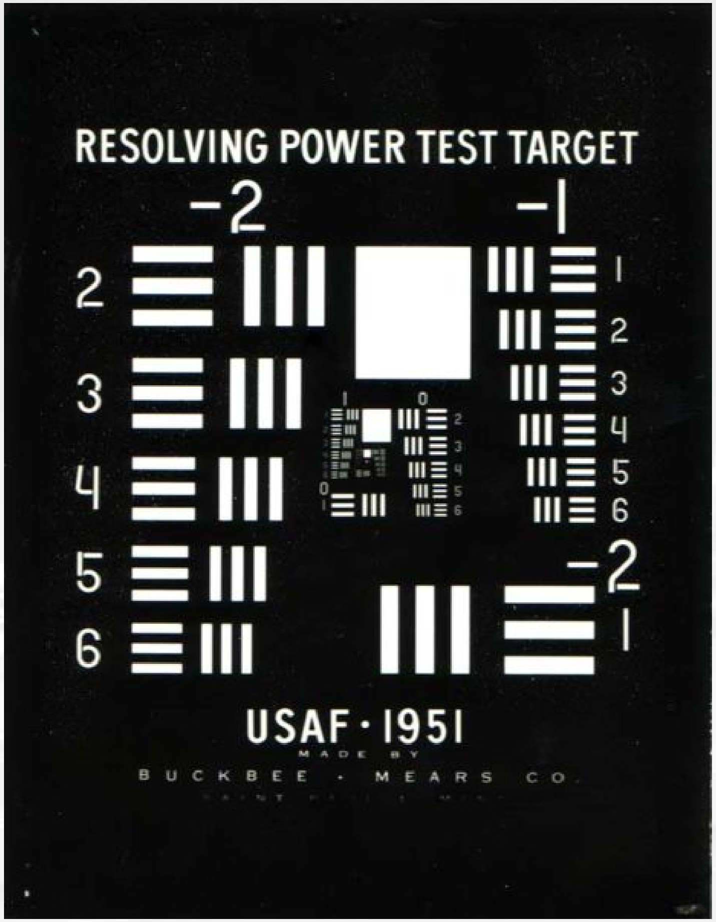
Surveying & Calibration

- Calibration
  - Size
    - Use USAF-1951 standard resolution test pattern
    - Put fiducials on YAG:Ce back side, i.e., Al patterns of known dimensions
  - Resolution
    - Use USAF-1951 standard



Summary

- Optics design
  - Commercial systems w/ proven performance
  - Flexible to meet changing requirements in future
  - Performance well understood
    - Resolution
    - Signal level
      - Attenuation requirement
- Will meet physics specifications for LUSI instruments
  - FOV, resolution, and readout speed

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PHOTON SCIENCE at STANFORD LINEAR ACCELERATOR CENTER

LUSI LCLS Ultrafast Science Instruments

DESIGN REVIEW REPORT	Report No. TR-391-003-21-0

The Design Review Report Shall include at a minimum:

- The title of the item or system;
- A description of the item;
- Design Review Report Number;
- The type of design review;
- The date of the review;
- The names of the presenters
- The names, institutions and department of the reviewers
- The names of all the attendees (attach sign-in sheet)
- Completed Design Checklist.
- Findings/List of Action Items – these are items that require formal action and closure in writing for the review to be approved. See SLAC Document AP-391-000-59 for LUSI Design Review Guidelines.
- Concerns – these are comments that require action by the design/engineering team, but a response is not required to approve the review
- Observations – these are general comments and require no response

TYPE OF REVIEW: Preliminary Design Review

WBS: 1.5 Diagnostics Common Optics

Title of the Review	Profile Monitor and Wavefront Monitor, Optics Preliminary Design Review	
Presented By:	Yiping Feng,	
Report Prepared By:	Sebastien Boutet	**Date:**02-10-09
Reviewers/Lab :	Bill White – SLAC Sebastien Boutet – SLAC	
Distribution:		
Attachments:	☐Review Slides ☐Design Checklist ☐Calculations ☐Other	

Purpose/Goal of the Review:

Assess the validity of the optical components to be used in the LUSI diagnostics devices

Introduction and outcome summary of the review:
The optical components of the LUSI diagnostics were presented with calculations validating the technical choices. All the options chosen by the LUSI group seemed valid and the committee recommends continuing to the final design.

Findings/Action Items:
The LUSI group should communicate with the in-vacuum mirror vendor to determine if the proposed mirror is vacuum compatible and can be delivered clean and ready for vacuum.

The LUSI group should determine whether a high quality vacuum window is truly necessary. It is unclear if one truly needs such a window for which design work and fabrication would be required to mount the window in a flange. The LUSI group should investigate the use of standard pre-mounted window flanges available commercially.

The LUSI group should communicate with the vacuum window vendor to determine if they can be provided with coating,

Concerns:

The vacuum window will bow under vacuum forces. It should be determined whether such bowing will cause image distortions that will prevent the specifications from being met.

Observations:
Except for the profile monitor, the 120 Hz readout rate of the CCD camera is not necessary. However, using a common camera for every device is a valid option to simplify the controls requirements.

The cable length on Cameralink devices is limited. It should be verified that is can be long enough for the LUSI needs without the need to use a fiber.

Placing a resolution test pattern on the YAG screen is a good idea and can be achieved using a FIB. Alternatively, one could mount a standard military test pattern next to the YAG. However, this brings some depth of field issues and the YAG screen and test patterns would have to be well-aligned.

The concept presented, a YAG screen at normal incidence with a 45 degree mirror is valid and the committee recommends using this design. However, it may be possible to improve the resolution with a thinner scintillator, possibly coating a surface placed at 45 degrees in the beam. The committee recommends pursing this option in parallel for possible future improvements of the system.

Response to Findings/Action Items:

The LUSI group should communicate with the in-vacuum mirror vendor to determine if the proposed mirror is vacuum compatible and can be delivered clean and ready for vacuum.
Response: DCO will confirm with the mirror vendor for vacuum compatibility issues.

The LUSI group should determine whether a high quality vacuum window is truly necessary. It is unclear if one truly needs such a window for which design work and fabrication would be required to mount the window in a flange. The LUSI group should investigate the use of standard pre-mounted window flanges available commercially.
Response: DCO will confirm the requirements by simulation. XTOD group responsible for the LCLS FEE also specified similar windows for their direct imager based on their simulations. We'll compare our findings with them.

The LUSI group should communicate with the vacuum window vendor to determine if they can be provided with coating.
Response: DCO will communicate with the window vendor to address any coating issues. Antireflective coatings are available in the ADC and VG Scienta viewport product line.