A viable near-term solution couples an existing ROIC to a relatively low-risk detector array, while an optimal solution incorporates a moderately modified ROIC with GaN

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Material	Bandgap (eV)	Pair Creation Energy (eV)	PD Thickness 50% at 22 keV	Slow Carrier Transit (ps)	K-edge X-ray Photon Range (μm)
Si	1.120	3.62	815 μm	11,640	14
GaSb	0.726	2.70	52 μm	1,733	18, 187
InAs	0.354	2.0	49 μm	980	27, 142
GaN	3.200	8.9	42 μm	156	~1, 61
Ge	0.661	2.96	37 μm	529	65
GaAs	1.424	4.4	37 μm	529	55, 17

Near-Term Solution

- Hippogriff ROIC
  - 25 μm x 25 μm Pixels
  - 512 x 1024
  - 1.5e6 e- full-well
  - ~2-ns / frame
- 37 - 50 μm (thick) GaAs Detector
  - Meets all absorption requirements except 72% at 22 keV
  - Slow carrier transit 529 - 715 ps
  - 1033, 350, 210, and 158 photons to fill well at 6.1, 18, 30, and 40 keV
- FY17 Proof-of-concept

Long-Term Solution

- "High-Energy ROIC I"
  - 50 μm x 50 μm Pixels
  - 256 x 512
  - 6e6 e- full-well
  - ~2-ns / frame
- 42 – 50 μm (thick) GaN Detector

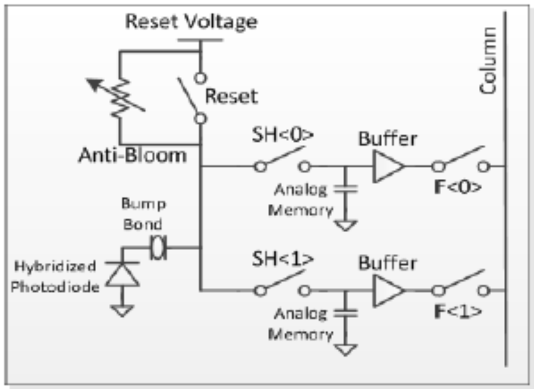
  Same benefits as GaAs except:
  1. Dramatically improved pair creation energy allows doubling of dynamic range
  2. Dramatically higher transit speed would allow a thicker detector for improvements in absorption
- FY19-20 Proof-of-concept

Gideon Robertson

- Trade study of available materials for the diode has be done
- There are a few with promise
- The inverse of the optic conversion is the issue here, to much charge for the ASIC
- Requirements need to be reviewed in light of the information from the trade study
- This looks promising but requires ($) investment in technology and time to reduce to practice

There are at least two obvious solutions to dealing with large photocurrents in the ROIC layer, both of which need further study to mitigate performance impact

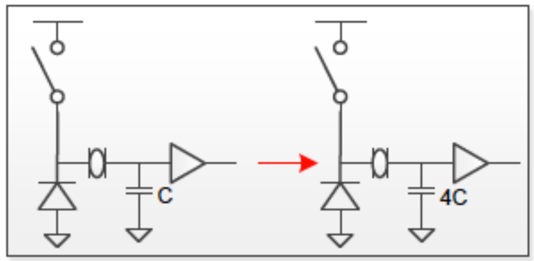
Anti-Bloom



Introduce/utilize anti-bloom transistor to compress signal at large signal levels.

(-) Might be a reasonable first candidate, however, it will induce a non-linearity, especially at upper end of signal

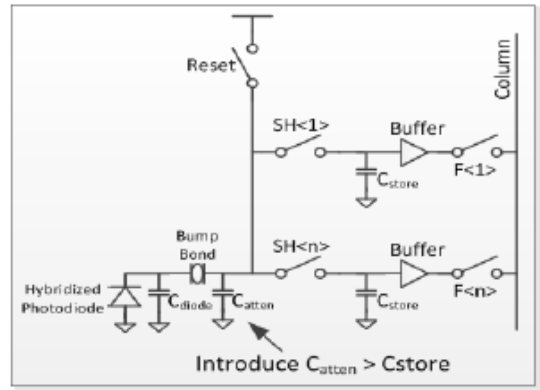
Increase Full-Well



Increase the size of the analog storage capacitor.

(+) This solution is a good candidate, however, speed and area impacts need further study

Capacitive Charge Division



Introduce a charge dividing capacitor on the front-end of the ROIC.

(+) This solution is a good candidate, however, will need to look at impacts to reset and analog signal levels.

Gideon Robertson

- Circuit designs have been evaluated
- There is one with promise
- Needs carful thought about the real feasibility, as high energy photon count goes up so does charge requiring dumping
- Test structure should be included in diode design plan for proof of principle
- Engage Jonathon Hares in this problem

Andrew MacPhee

Conclusion

- Currently there is no identified scintillator solution for SLOS
  - Noise floor corresponds to ~600 optical photons, we can get ~12 / x-ray
- Way forward:
  - reduced noise floor for gated CMOS camera ~30x from 600 -> 20e$^-$ combined with:

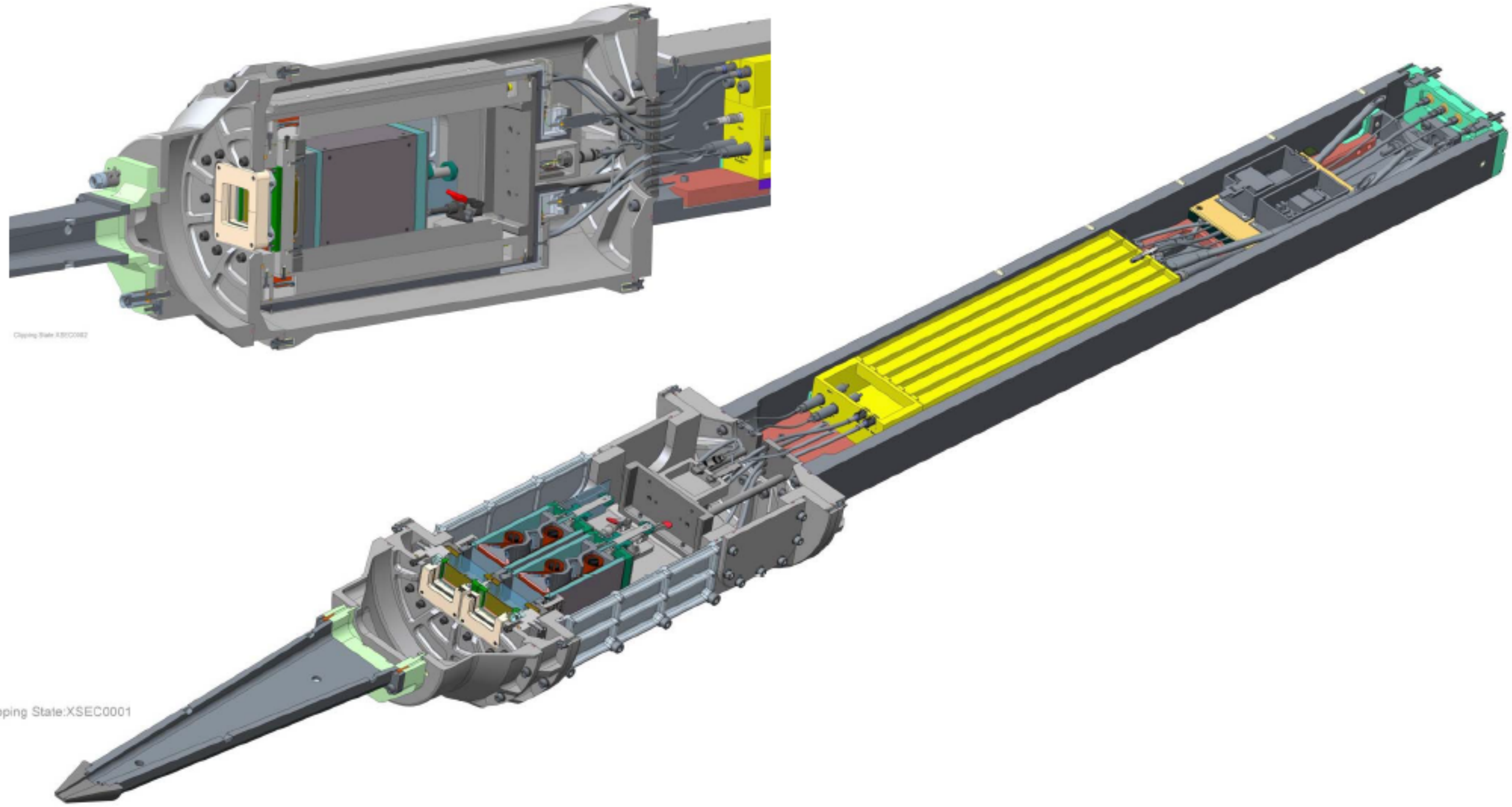
i) ZnO:Ga scintillator (if it can be made large and uniform enough)

ii) Optimized dopant for the new LBL scintillator (~40x)

- To maximize efficiency whilst maintaining spatial resolution at higher energy ~60keV the scintillator should be in the form of a fiber optic faceplate
- The scintillator material needs to be drawable into fibers, fused and polished (new LBL can), or growable in an MCP like structure
- ZnO:Ga cannot be drawn, but maybe can grown or annealed in an MCP?

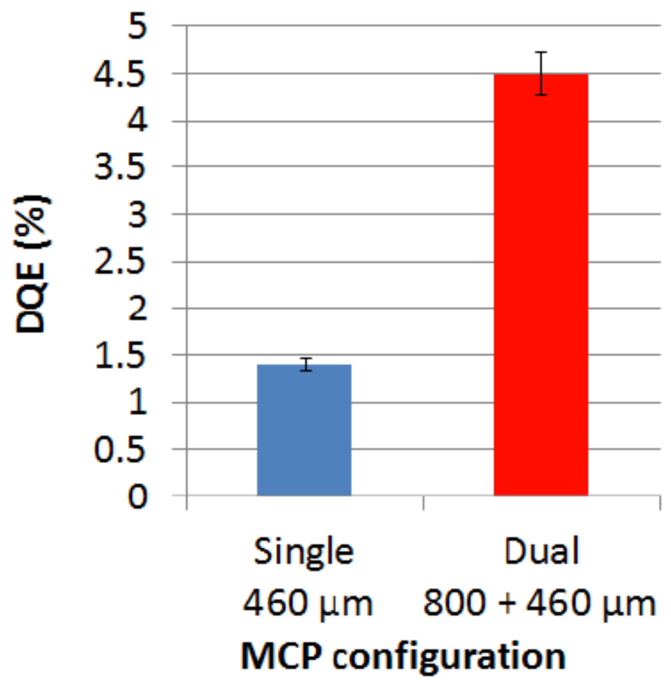
- Andrew MacPhee
- Trade offs between spatial resolution, temporal response and light output limit useful applications
- A few materials show promise for slower time scales (HED applications)
- Need to fund R & D with LBL to meet short time scale application requirements
- Source of noise in SNL devices needs to be better understood

AXIS is DIM based x-ray framing camera with two 40 mm x 40 mm frames



Summary

Using a novel dual MCP, we have demonstrated an imaging detector with 3.2x higher DQE @ 59 keV



MCP thickness	Bias (V)	DQE (%)	QE (%)
Single 460 µm	775	1.4	8.1
Dual 800 + 460 µm	625 + 600	4.5	13.3

(1) Compton radiography requires gated x-ray imager with DQE > 4%

(2) Single MCP camera becomes noisy over 30 keV due to depth dependent electron gain of MCP

(3) With using dual MCP, it is possible to suppress the noise due to depth dependent gain

(4) With using with dual MCP, DQE = 4.5% was achieved

(5) The 1st dual MCP camera AXIS is in its production phase

- Niko Izumi
- Old technology prevails (More MCP’s)
- Requirements are much different from other talks 4% DQE
- Detector Quantum Efficiency was explained (DQE)
- A proof of principle system has demonstrated requirement can be met
- Final system has been built and is in calibration now
- First use in the spring

Outline

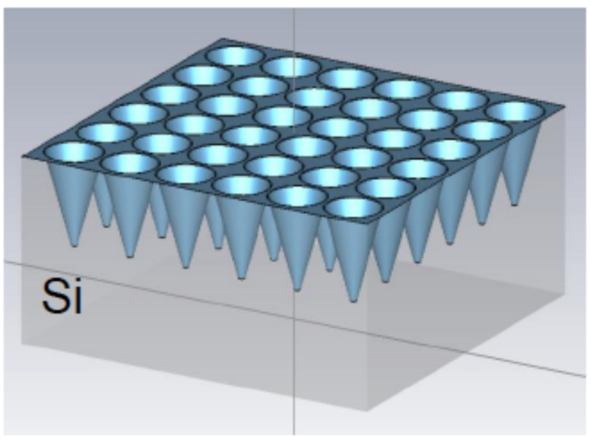
- **Overview**
  - Motivation for the project.
  - Yield enhancement at grazing incidence.
  - Utilization of 3-D structures.

- **Photocathode Design and Fabrication Details**
  - Photocathode design considerations and requirements for X-ray imagers.
  - Recessed cavity design and expected yield.
  - Fabrication details and results.
- **Recent measurements show an increase in yield**
- **Project Accomplishments**
- **Future work**

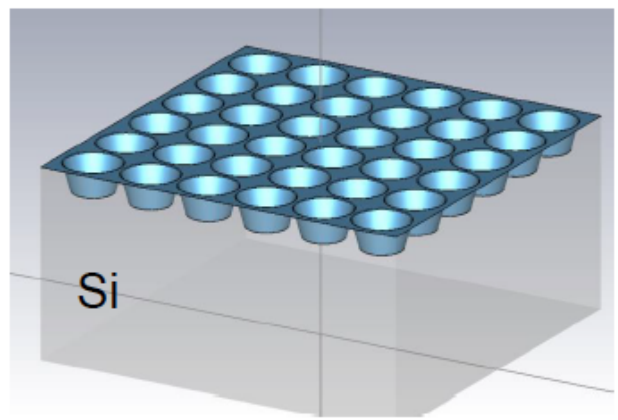
Total yield enhancement expected to be 1.2-3 times at 10 keV

Energy (keV)	Recessed Geometry	Incidence Angle	Diameter (μm)	Depth (μm)	Δt (psec)	Au Rel. Increase
10	Cone	10 - 15	9	3	1	1.6
10	Cone	10 - 15	9	8.4	~10	2.36
10	Cone	10 - 15	9	16.8	~200	2.81

Full Depth



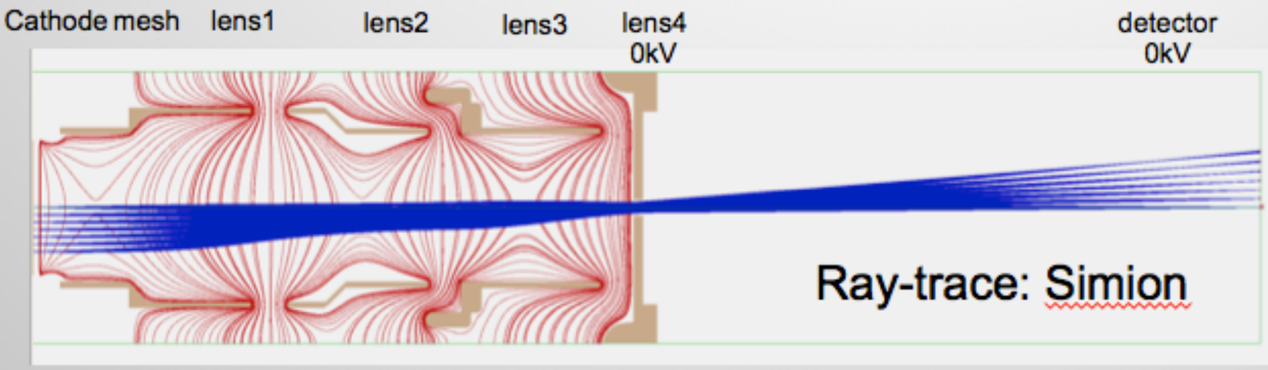
Shallow Depth



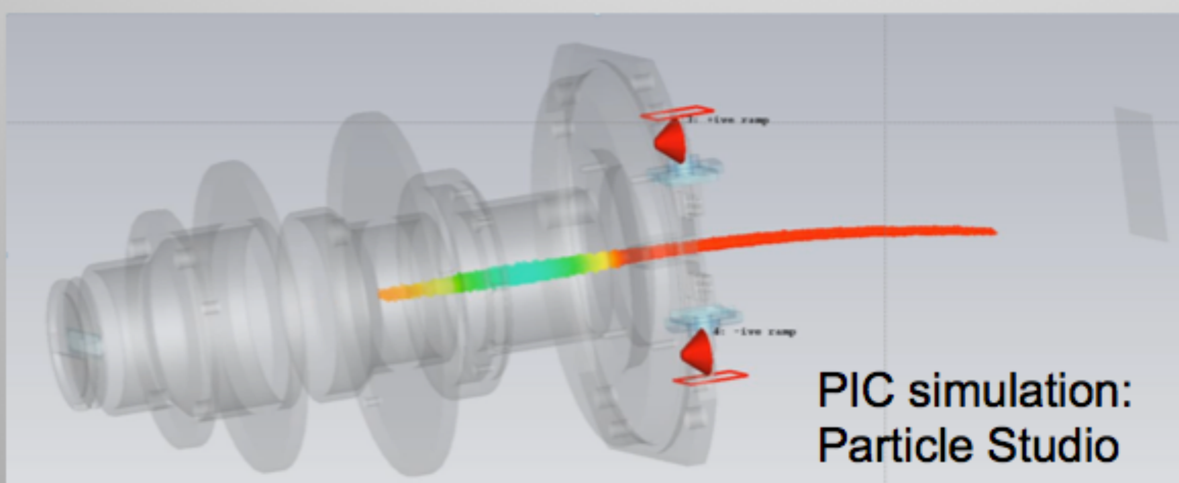
- 9 μm diameter chosen for ease of fabrication
- 10 - 15 degree wall angle chosen to increase enhanced surface area

- Kathy Opachich
- Addressing the need for better QE at high photon energies for transmission photocathodes
- Model of structured photocathodes was done last year
- Prototype has been built and tested
- A improvements in QE has been observed
- Full scale part will be made for DIC and tested
- More work to be done in the future

We model the streak tubes using ray-tracing for fast tuning and PIC simulations to include dynamic fields and space-charge effects



SIMION (ray-tracing) Solves Laplace's equation for the applied potentials in 3D throughout a uniform grid then solves the trajectories for the rays. Quick, ~few mins 100k rays ~1M mesh cells



CST Particle Studio is a commercial time domain PIC solver for designing particle accelerators etc. Uses finite integration technique and includes relativistic equations of motion, space-charge effects and dynamic fields (sweep). 20M cells 10M particles 9ns ~8hrs on 12 cores + Fermi GPU. LC libraries next year

- Andrew MacPhee
- Spoke about the use of modern modeling tools for improvements to existing hardware
- Next is to reduce to practice the modeling presented on the Kentech low mag camera
- Need to complete the modeling of other tubes and present results
- Dynamic range issues still need to be addressed for x-ray streak camera needs
- Andrew reminds us, the pipeline of young people needs to be nurtured if we want to continue to make advancements in these technologies

Goals and results of the SNL crystal calibration work

Sandia National Laboratories

Goals

1) Measure accurate rocking curve of bent crystals to help the understanding of measurements taken on Z (opacity, photoionized plasmas, non-thermal emission, liner spectra…)
   e.g The iron opacity measurements on Z require integrated reflectivity, crystal resolution, and 2^{nd} to 1^{st} order reflectivity ratio (2^{nd} order correction below 950eV)

2) Evaluating absolute source intensities, instrumental broadening, plasma line-widths.

3) Develop intuition and a path to model crystal performance that could be used in a larger parameter space (various crystal curvatures, geometries, orders, photon energy…)

Results

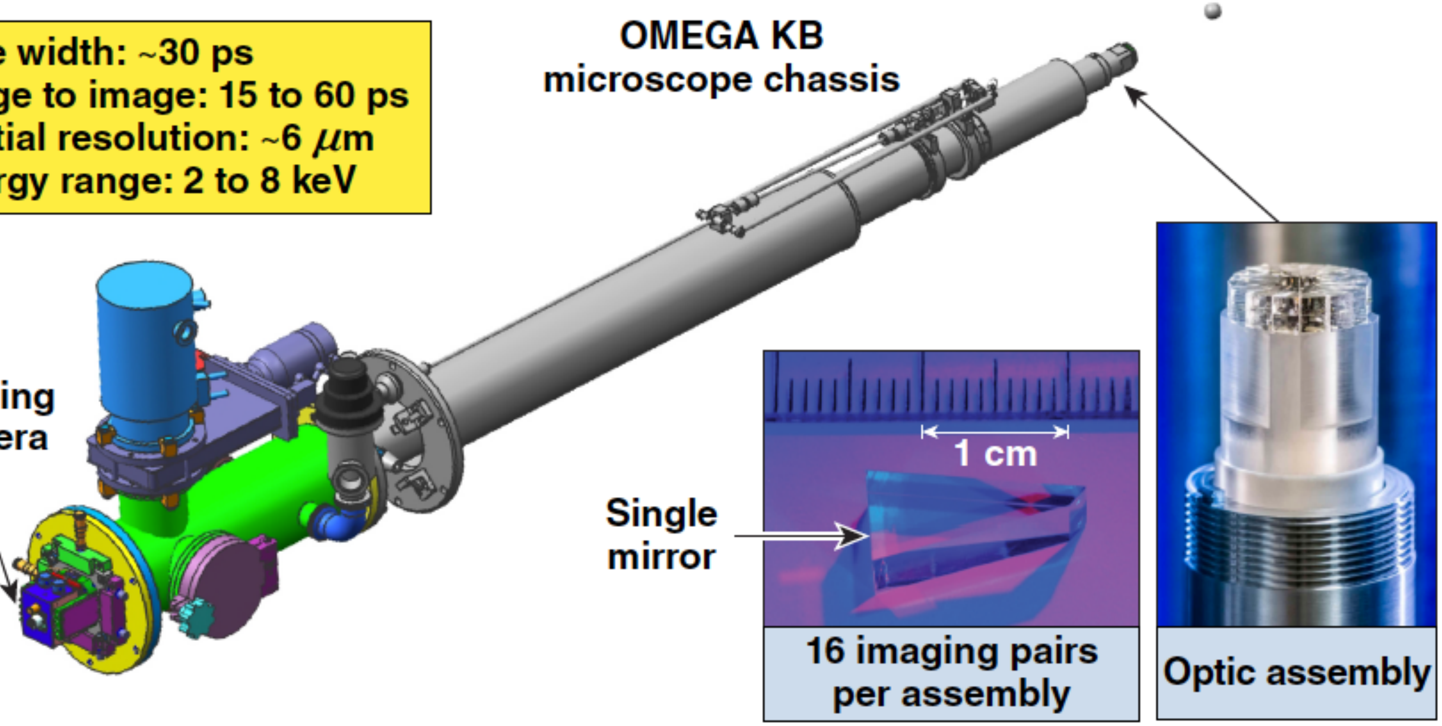
1) We accurately measured integrated reflectivities for a set of KAP crystal curvatures (flat, 2,4, 6 and 9in) and diffraction orders (1^{st}, 2^{nd} and 3^{rd})
2) Integrated reflectivities show good agreement with XOP multilamellar model with a set of Debye-Waller factors (temperature factors) depending on crystal curvature and order of diffraction. It is possible that they could also depend on photon energy but the present data is too limited to be conclusive.
4) Width for 2^{nd} and 3^{rd} order agree relatively well with XOP multilamellar model
5) Widths in 1^{st} order are systematically measured higher than any calculation due to extra instrumental broadenings, this might be solved through deconvolution.
6) Width and spectral shape in 1^{st} order are measured with a conventional x-ray source
7) Crystal efficiencies were measured to high accuracy using NIST calibrated KERMA source

- Loisel
- Calibrations data were present
- Several systems at various location have been utilized
- Modeling tools are being developed
- Results are compared to modeling with agreement in most areas
- Absolute calibrations are challenging to make as well as time consuming
- Z uses many crystals, can we automate in some way?

KBFRAMED is a 16-channel Kirkpatrick–Baez (KB) x-ray microscope that provides time-resolved images of the core around stagnation

UR LLE

Gate width: ~30 ps
Image to image: 15 to 60 ps
Spatial resolution: ~6 μm
Energy range: 2 to 8 keV



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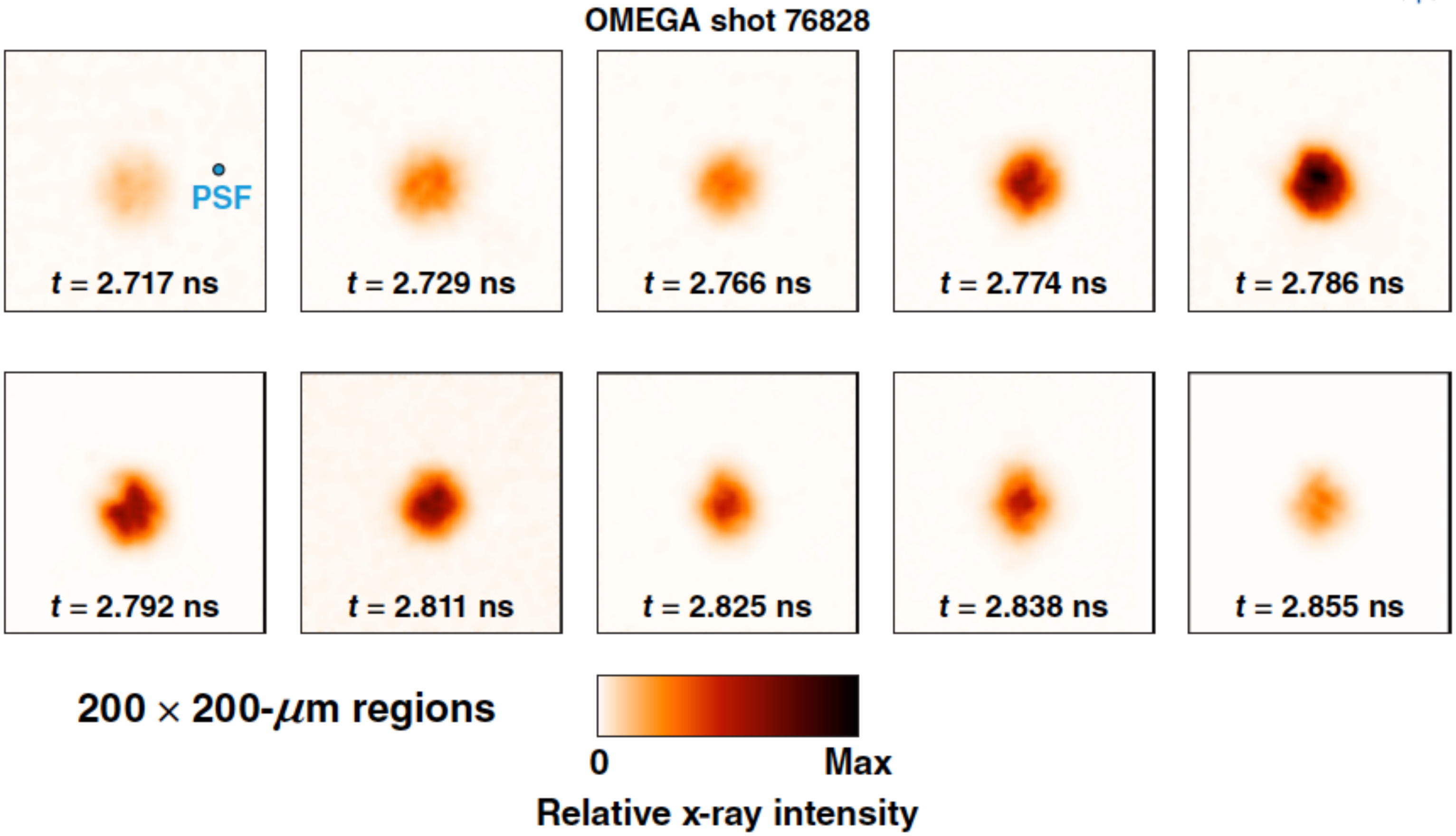
F. J. Marshall, J. A. Oertel, and P. J. Walsh, Rev. Sci. Instrum. 75, 4045 (2004).

KBFRAMED records an image (Δt = 30 ps) of the stagnating core every ~15 ps in the 4- to 8-keV photon-energy range



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Fred Marshall

- A Kirkpatrick-Baez (KB) microscope has been built
- Data shown indicates similar performance to the NIF KB
- Calibration data was presented that showed challenges in alignment
- Experimental data was presented

Observations

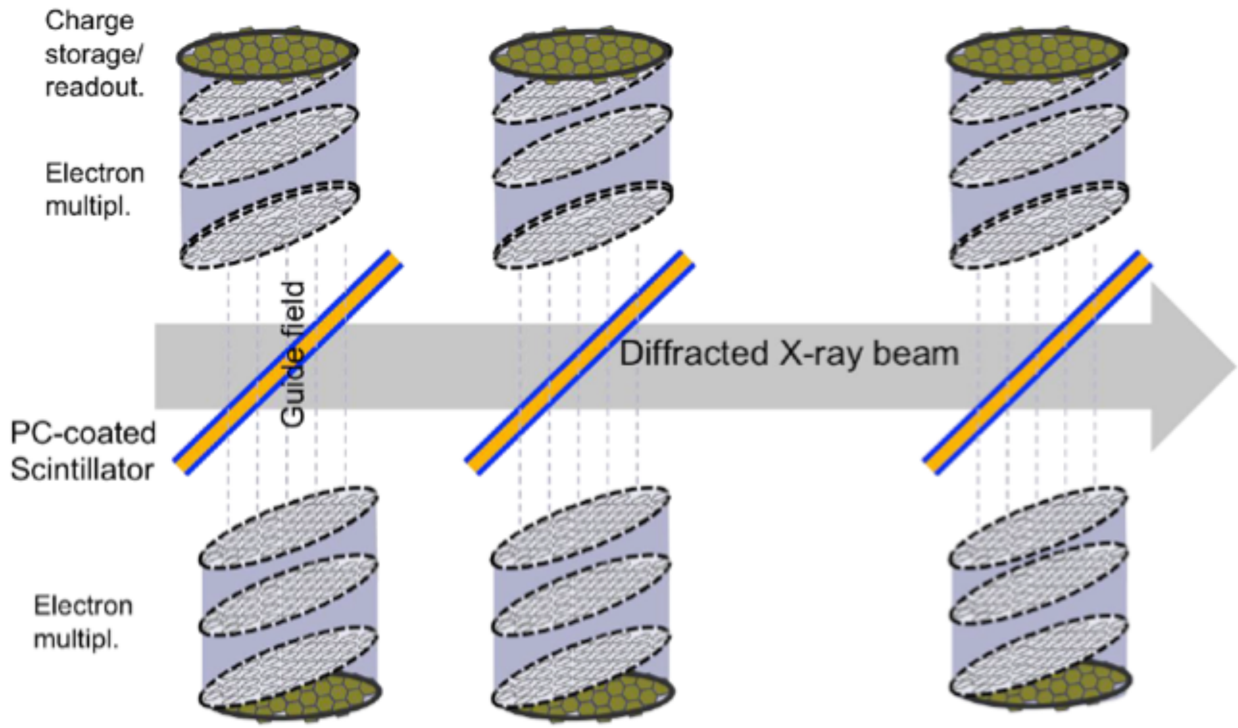
- To much content in the workshop
  - Much of it present in other venues
  - New ideas need to be brought forward
  - Can we run next year as a call for solutions to problems more broadly (DARP calls)
- No time for real discussion of the real challenges

- To few people cross coupling into technology development

- Calibrations facilities needs are under represented, instruments need characterization and calibrated to be highly accurate and more useful

Andrew MacPhee Versions of this idea have been kicked around in past

Zhehui Wang *et al*. (LANL), "Thin scintillators for ultrafast hard X-ray imaging" Proc. SPIE Vol. 9504 (2015)



X-ray -> optical -> electrons -> gain -> detection

Promising route for gated hard x-ray detection. Sensitivity and resolution still governed by scintillator thickness, but here the low optical signal can be boosted