Beamline photon diagnostics
(beam position and intensity monitors)

D. Peter Siddons
Phil Yoon
Konstantine Kaznatcheev

Outline

- Scope
- Need for diagnostics
- Existing devices
- Plans

Scope

- We focus on diagnostics from shield-wall out to end-station
  - Wide range of beam sizes, energies and intensities
  - One size will not fit all!
  - Small level of effort
    - one postdoc (Phil Yoon)
    - Help from Konstantine with I0 monitors
    - few percent of me
  - Need to focus our effort on one system with wide applicability.

Existing BPM devices

- In general, NSLS-II requires an improvement of x10 in achievable position resolution over what is currently available.
- Several plausible devices exist for hard x-rays
- All rely on extracting a beam sample, so none are truly non-invasive.
- Possibly we can use the same device to give precise position and good I0 normalization.
- Very little exists at all for soft x-rays

Existing devices

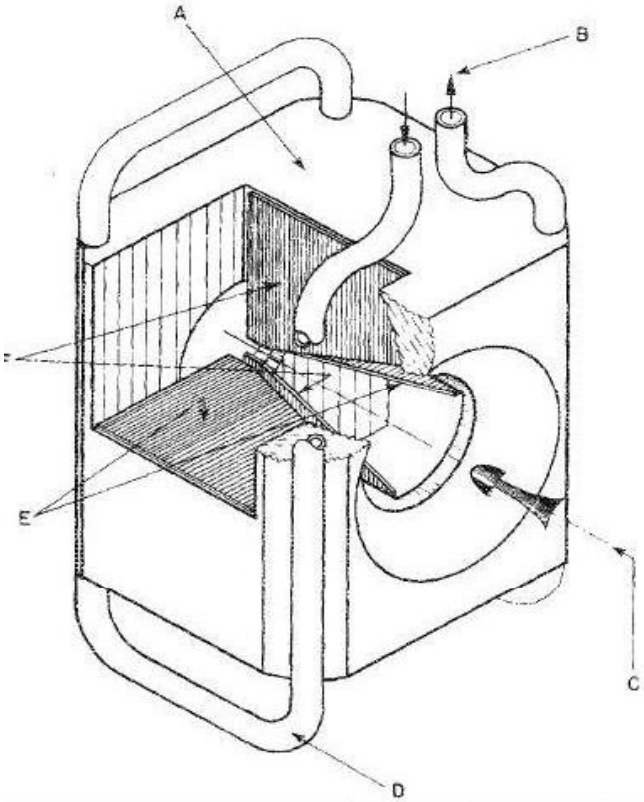
- Broad types
  - Scrapers (pick up on edges of radiation fan)
    - Scale factors depend strongly on beam size / shape
    - Often use photoemission (time-dependent response)
  - Beam dividers
    - Also scale factor is shape-dependent
  - Center-of-gravity devices
    - In principle, beam-size variation tolerant
      - devil is in the details
  - Profilers
    - Potentially a good idea if you have a signal to profile.

Physical processes

- Photoemission (typically scrapers)
  - Photo-emission yield very surface sensitive and very energy dependent.
- Gas ionization (Beam-dividers or C-of-G)
  - Significant systematic errors e.g. recombination, incomplete saturation - flux dependent
- Fluorescence + semiconductor (C-of-G)
  - This seems to be quite successful, moderately invasive.
- Thin semiconductor or photoconductor in transmission (Beam dividers)
  - radiation damage (semiconductor),
  - uniformity (photoconductor)
- Gas luminescence + CCDs (profiler)
  - ?
- Fluorescent screen + CCD (profiler)
  - invasive
  - Radiation damage?

Types

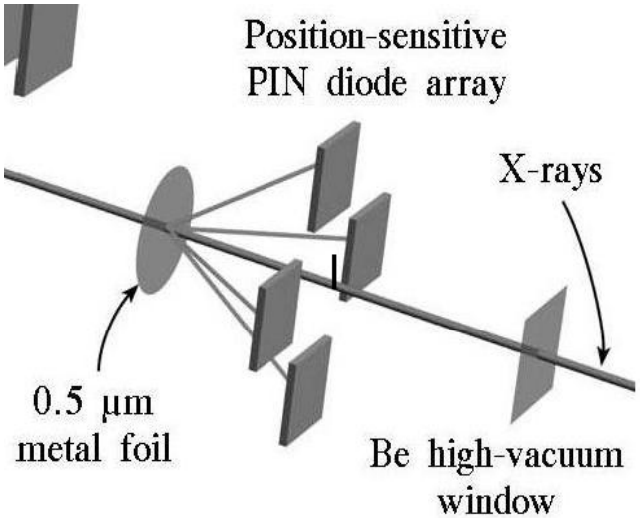
- Scraper

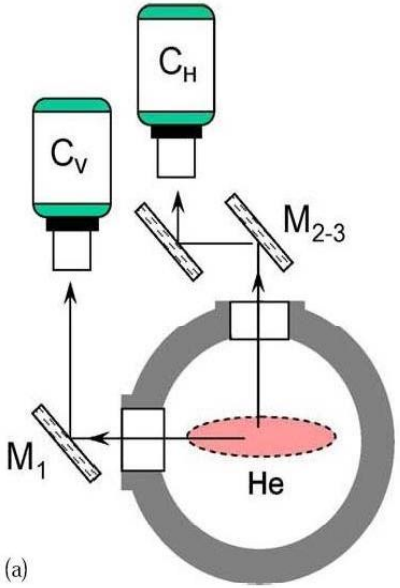


- Beam divider

- Center-of-gravity

- Profiler





Beam divider *vs* C-of-G *vs* Profilers

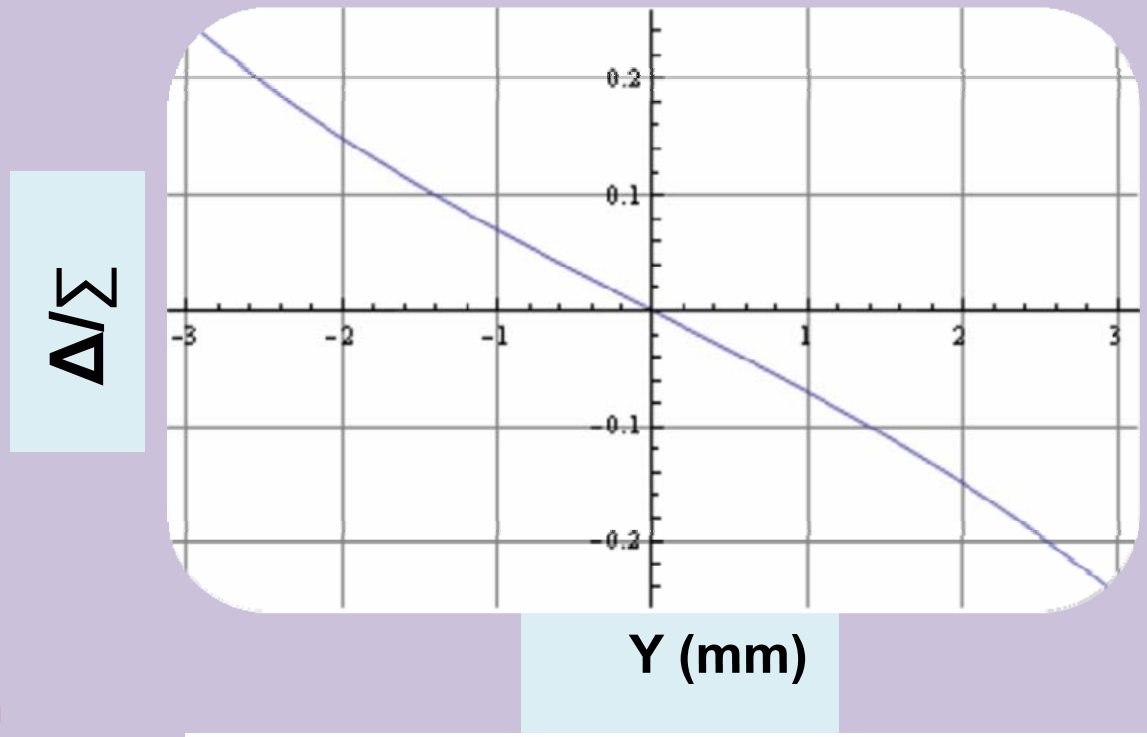
- Beam divider
  - e.g. quadrant photodiode
  - Usually near a focus
  - Detector pickup is segmented to provide differential signals
  - Resolution depends strongly on beam size / shape
  - For small focal spot, can provide high resolution
- C-of-G
  - Not necessarily near a focus
  - Each detector pickup integrates over beam profile.
  - Resolution does not depend strongly on beam size / shape, but on noise and other systematics
- Profilers generally slow
  - CCD readout (<100Hz)
  - Potential for high resolution

Plans

- Hire Postdoc (Phil Yoon; arrived Sept. 2008)
- Do literature and facility survey to establish current state-of-art (This workshop is part of that)
- Make models and tests for an existing design
  - Model of Alkyre BPM made
  - reproduces data
- Use this knowledge to design the next generation BPM.
- Search for alternative principles of operation (e.g. optical interferometry, speckle).
- Investigate BPMs and I0 monitors for soft x-rays (e.g. active OSA for STXM microscope)

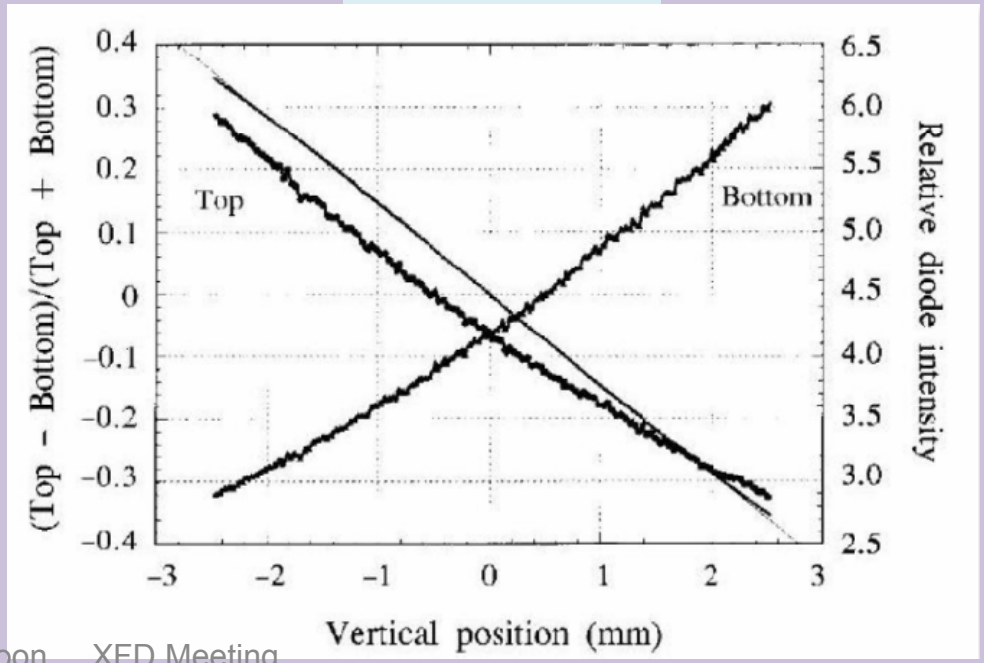
Geometrical Optimization (3)

NSLS-II analytical model
using the dimensions of APS XBPM.



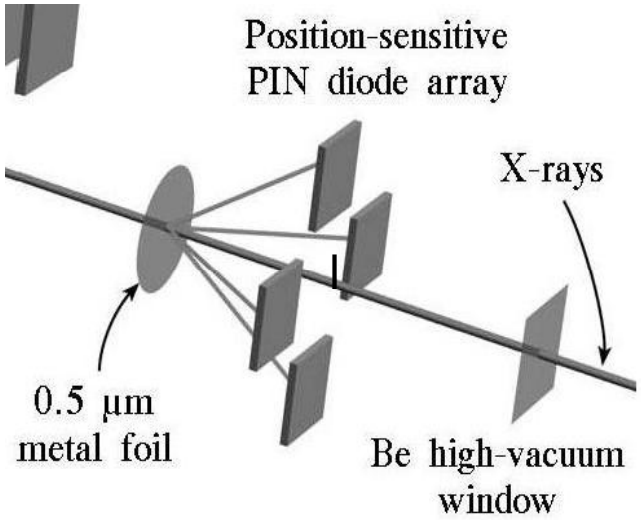
Our analytical model agrees well with APS experimental data

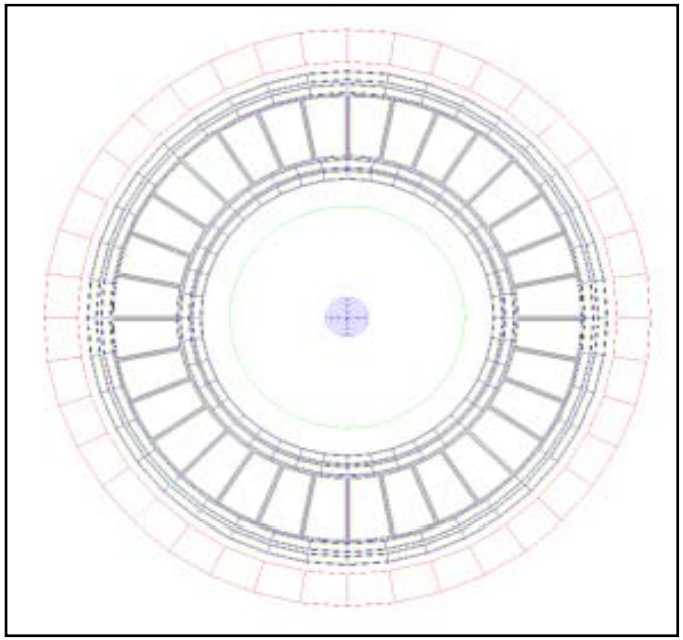
Experimental data
from Fig. 2 of R. Alkire's paper:
J. Synchrotron Rad. (2000), 7, pp. 61-68



New fluorescence monitor

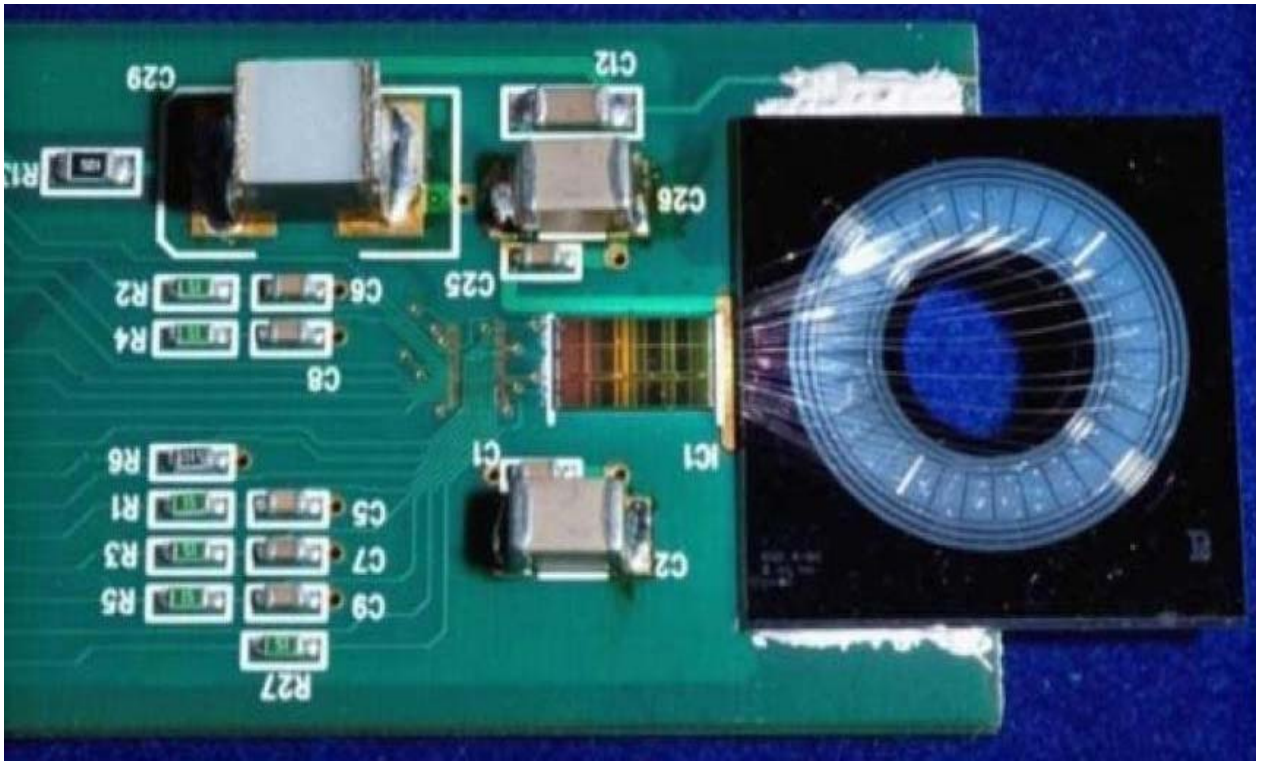
- Alkyre design uses four samples of the fluorescence radiation field to estimate position of beam on fluorescent target
- Using more independent samples of the field should provide a better estimate of the source position





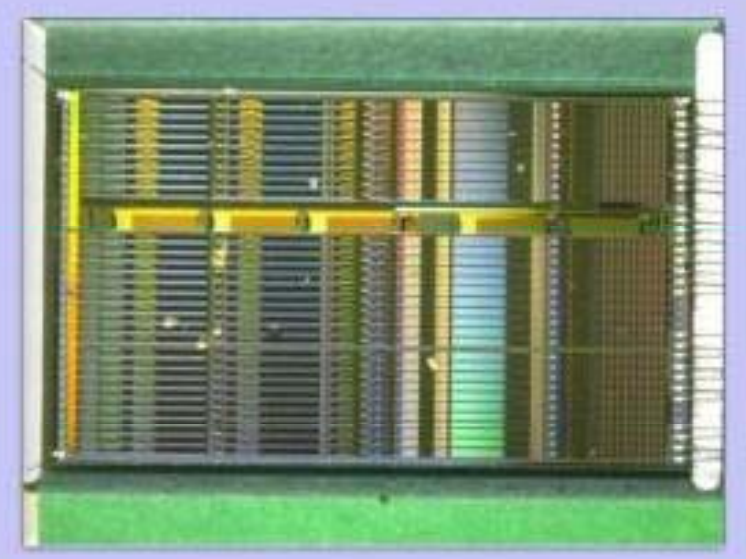
Segmented ring detector and ASIC

- We have made a 32-segment photodiode array
- It is connected to a custom integrated circuit which provides 32 channels of amplification and photon-counting.



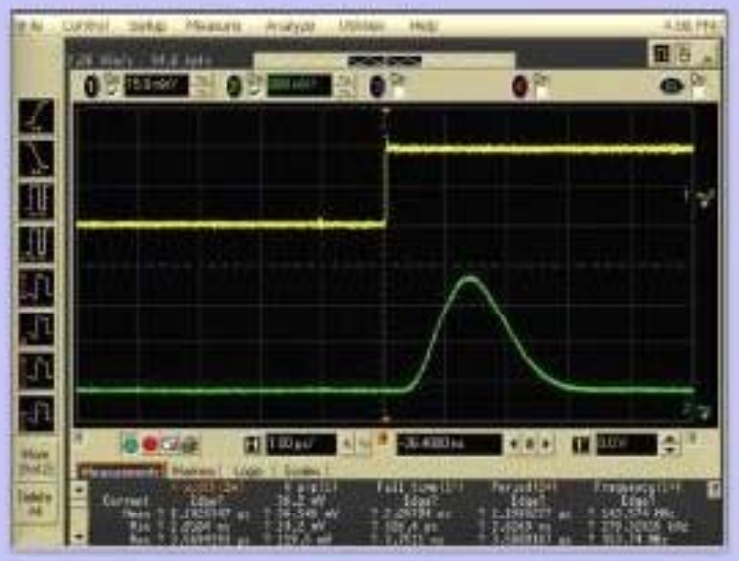
- For prototype purposes, we use wire-bonds to connect individual diode to amplifier input. This is a low-noise solution which allows us to reliably detect 6keV photons. Unfortunately, the wires block the hole
- If this idea seems promising, we will make a 64-pad array with two ASICs, avoiding the need to have bonds across central hole.

ASIC Design/Tests

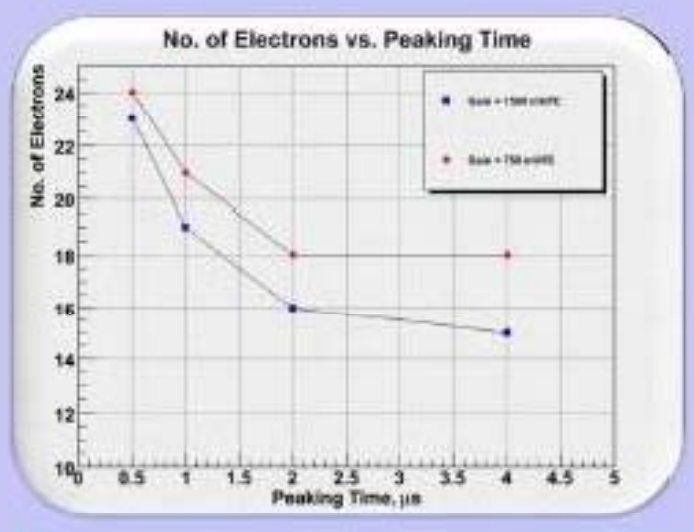


a new HERMES ASIC die

ASIC-test station



Signal response from channel 0 of HERMES4;
All of 32 channels show consistent response output.

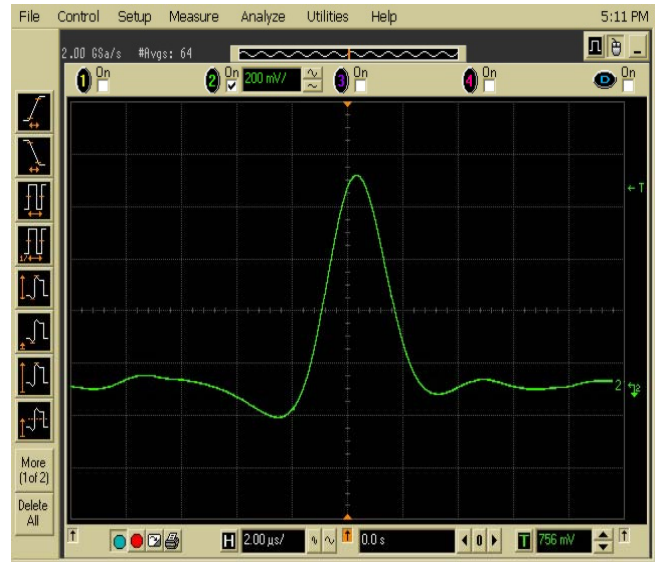


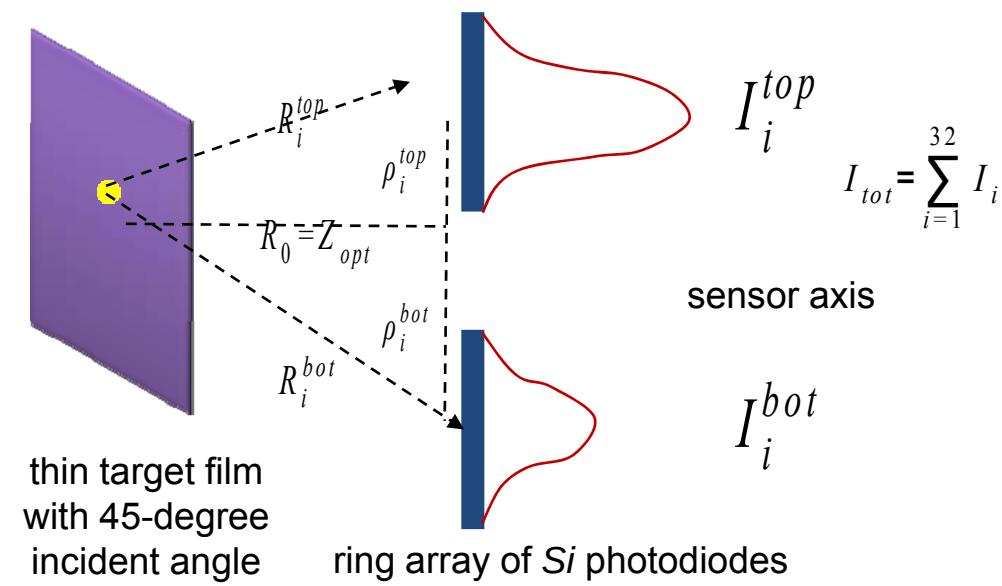
RMS noise electron vs.
peaking time in microsecond.

Fluorescence BPM testing

- Detector has been tested with a 55Fe radiation source (6keV)

- Since we can't send beam through central hole for this prototype, we will place fluorescent sample at an angle to detector face and pass beam parallel to detector face. Result should tell us if idea shows promise.





Axial view of forward scattering

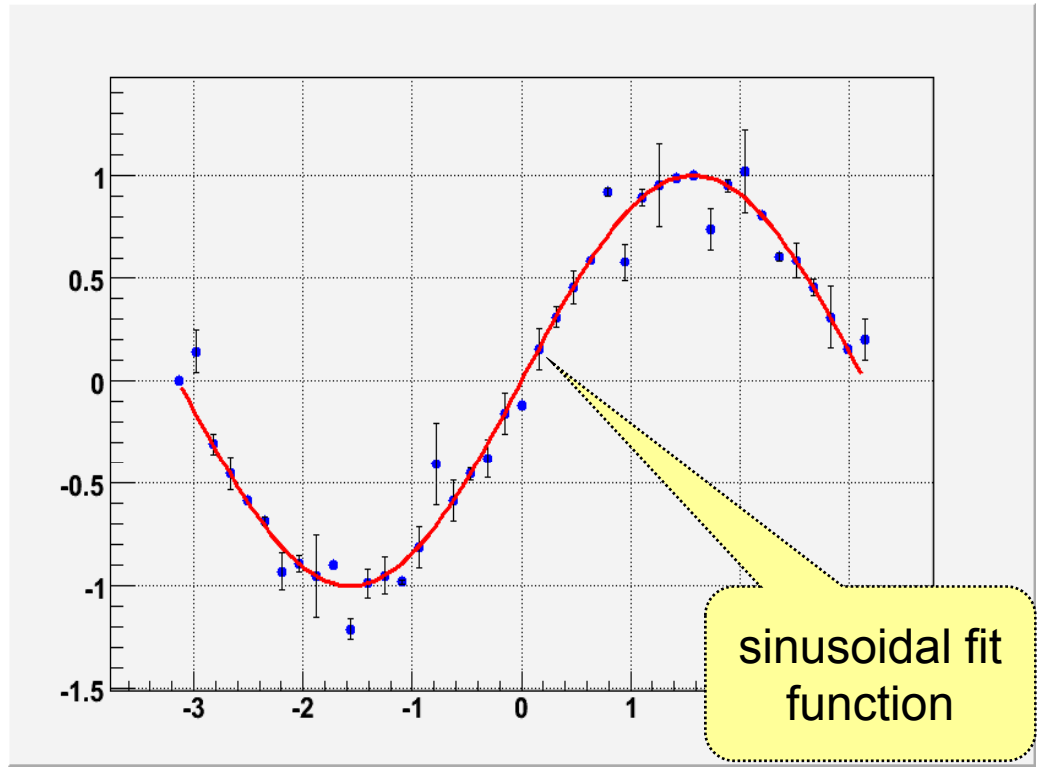
Simulated data

- Intensities recorded in the 32 diodes can be fit to a sinusoid.
- The amplitude will give the radial offset
- The phase will give the polar angle
- This can be converted into X-Y

$\rho \sin \varphi$

or

$\rho \cos \varphi$

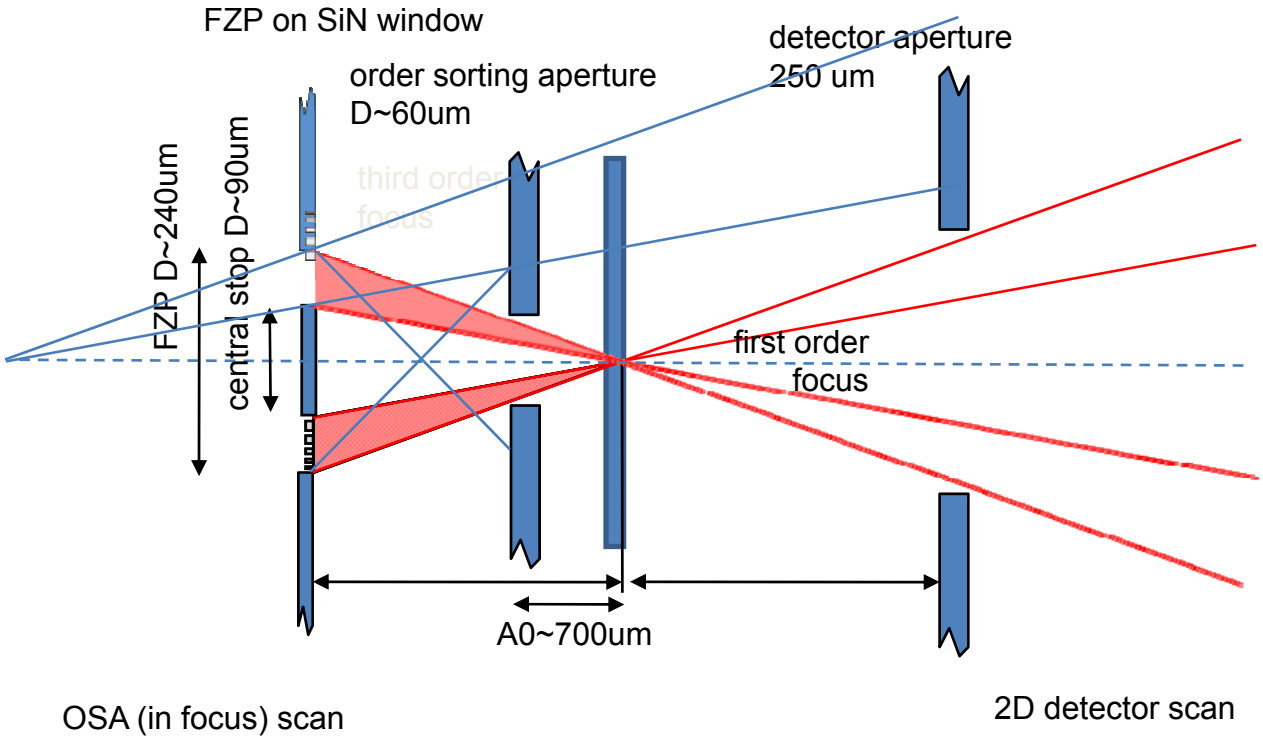


φ [rad]

Intensity monitors

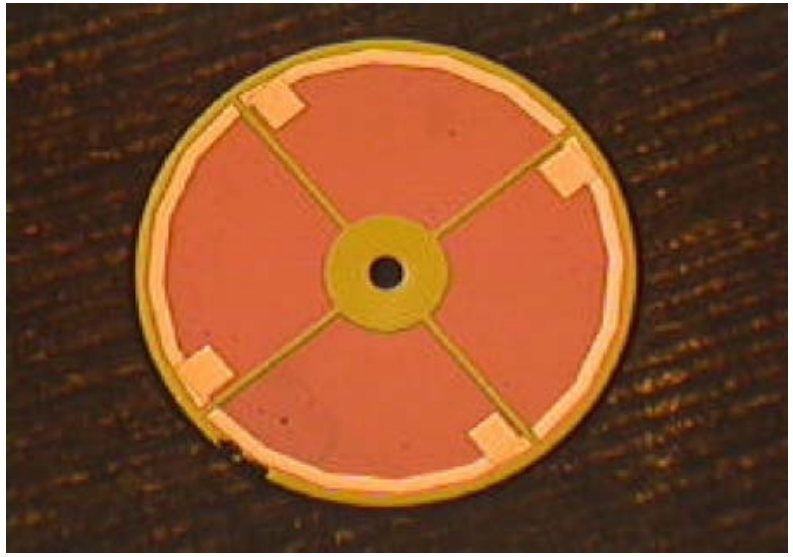
- Hard x-rays not really a problem:
  - ion chambers
  - thin photodiodes (radiation damage?)
  - diamond photoconductors?
- Soft x-rays very difficult, since nothing is transparent to soft x-rays.
  - photoemission from semi-transparent wire mesh
    - Difficult for small beam

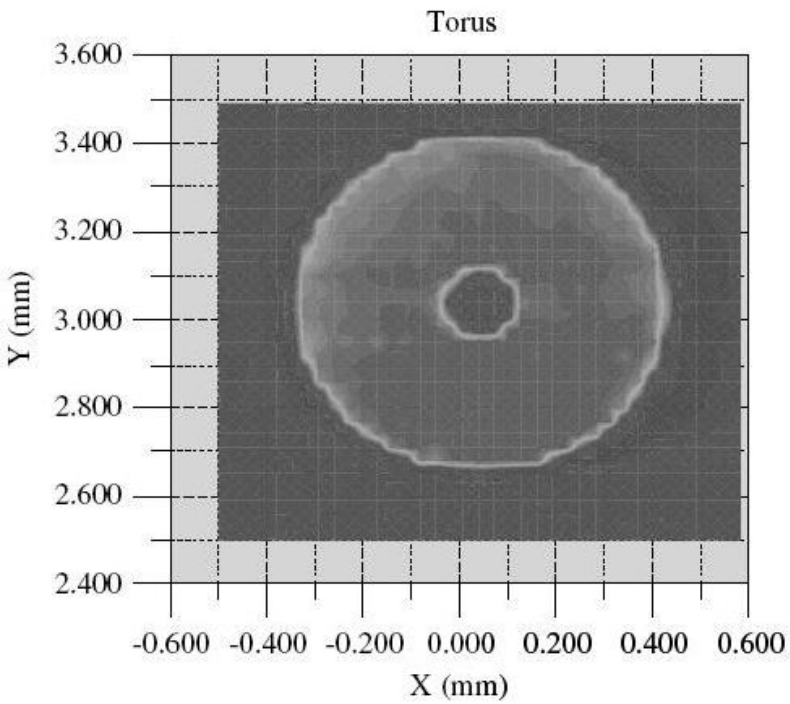
Zone-plate STXM

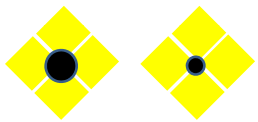


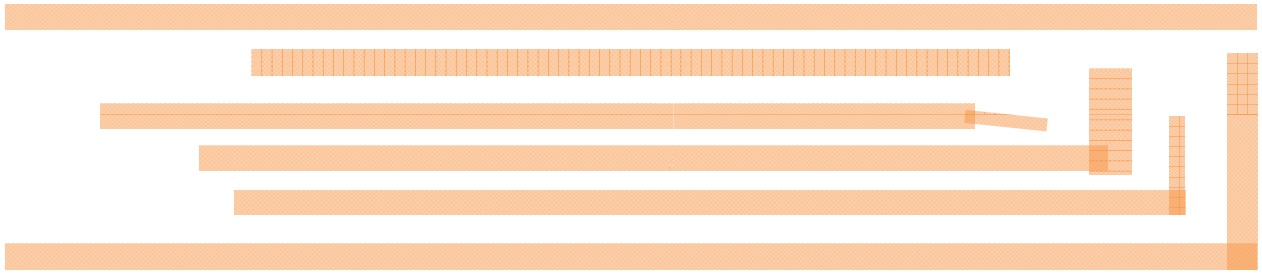
'Edgeless' detector technology

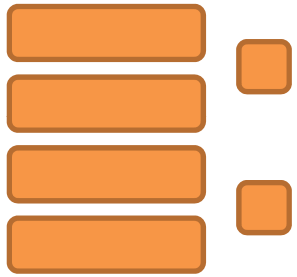
- “Use of active-edge silicon detectors as X-ray beam monitors”. C.J. Kenney, J. Hasi, Sherwood Parker, A.C. Thompson, E. Westbrook. NIM A 582 (2007) 178–181
- Ideal for STXM, where focus is surrounded by a halo of radiation which is a good measure of intensity in focused beam.
- Konstantine Kaznatcheev is working with Kenney to make prototypes suitable for tests at X1A.











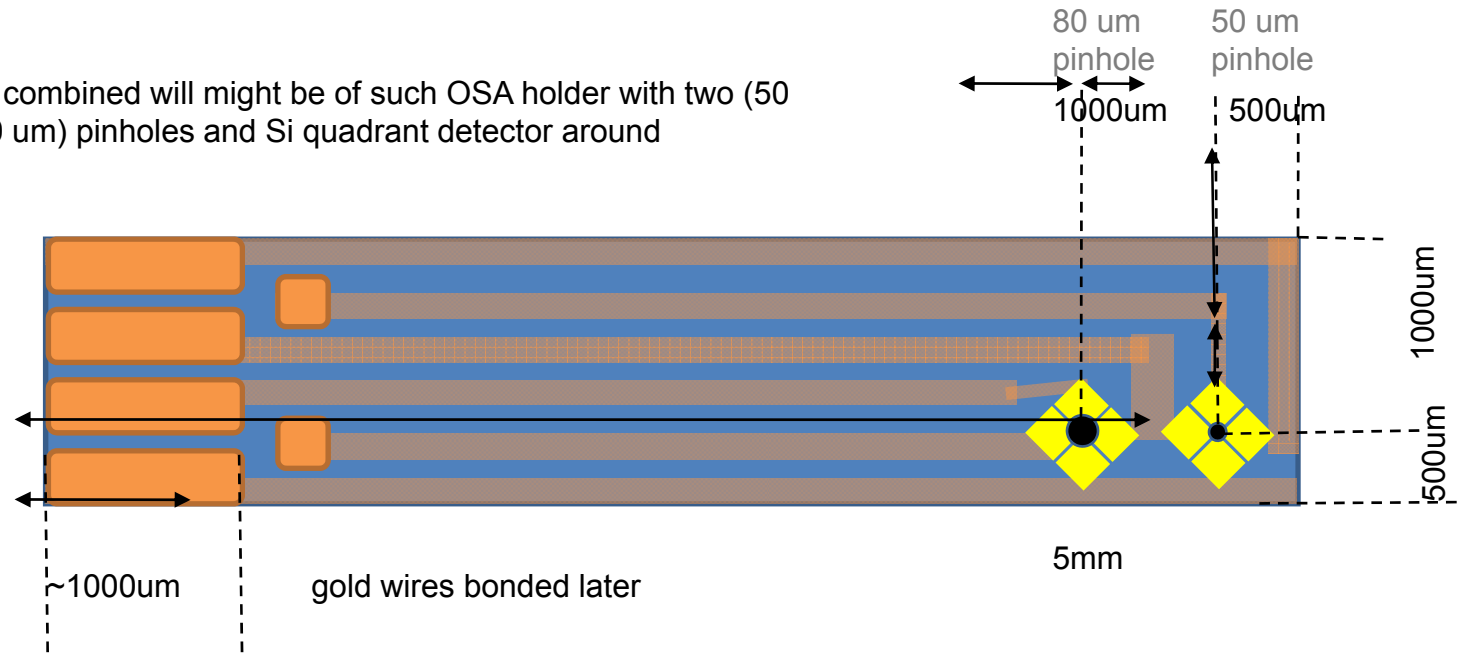
Mask 1…x: Doping/ etching of the active Si diode area: ~4*250um squares + hole (50 or 80um)

?gold connectors: ~25um lines ~50nm thick

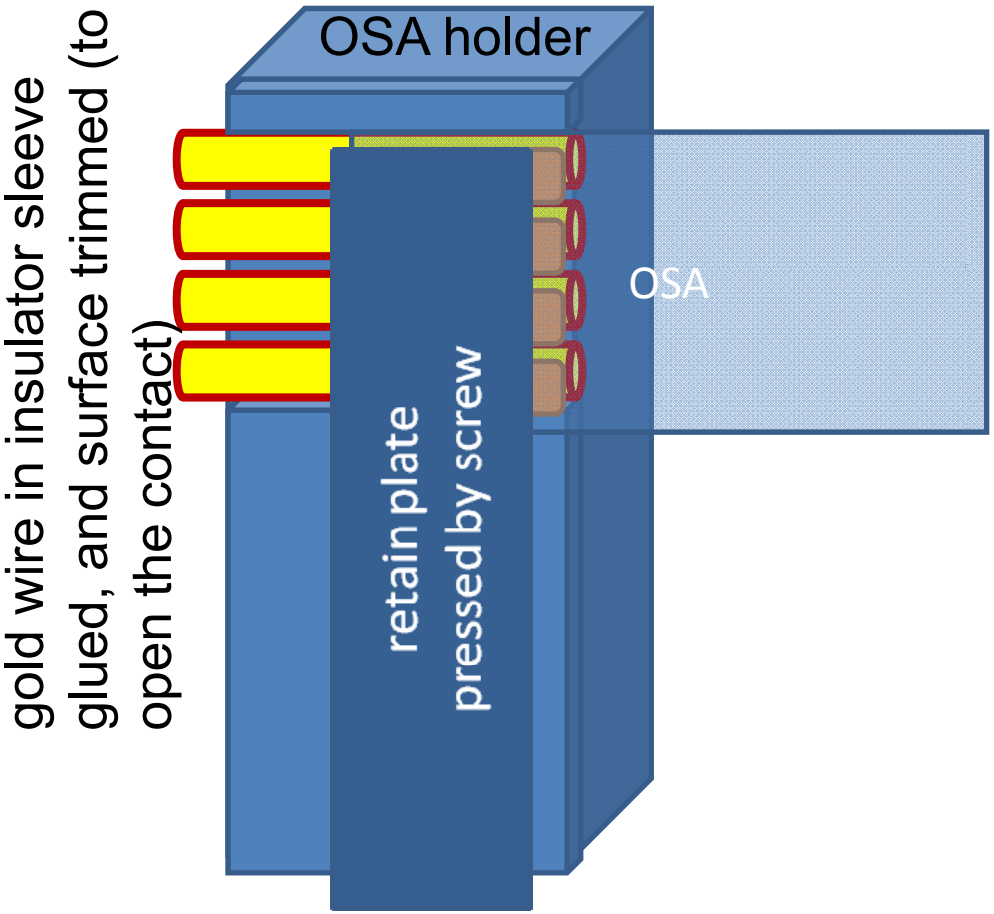
Typical ZP we have now is 240um diam. with 90um diam. central stop, but we still occasionally use old 160/60um ZP

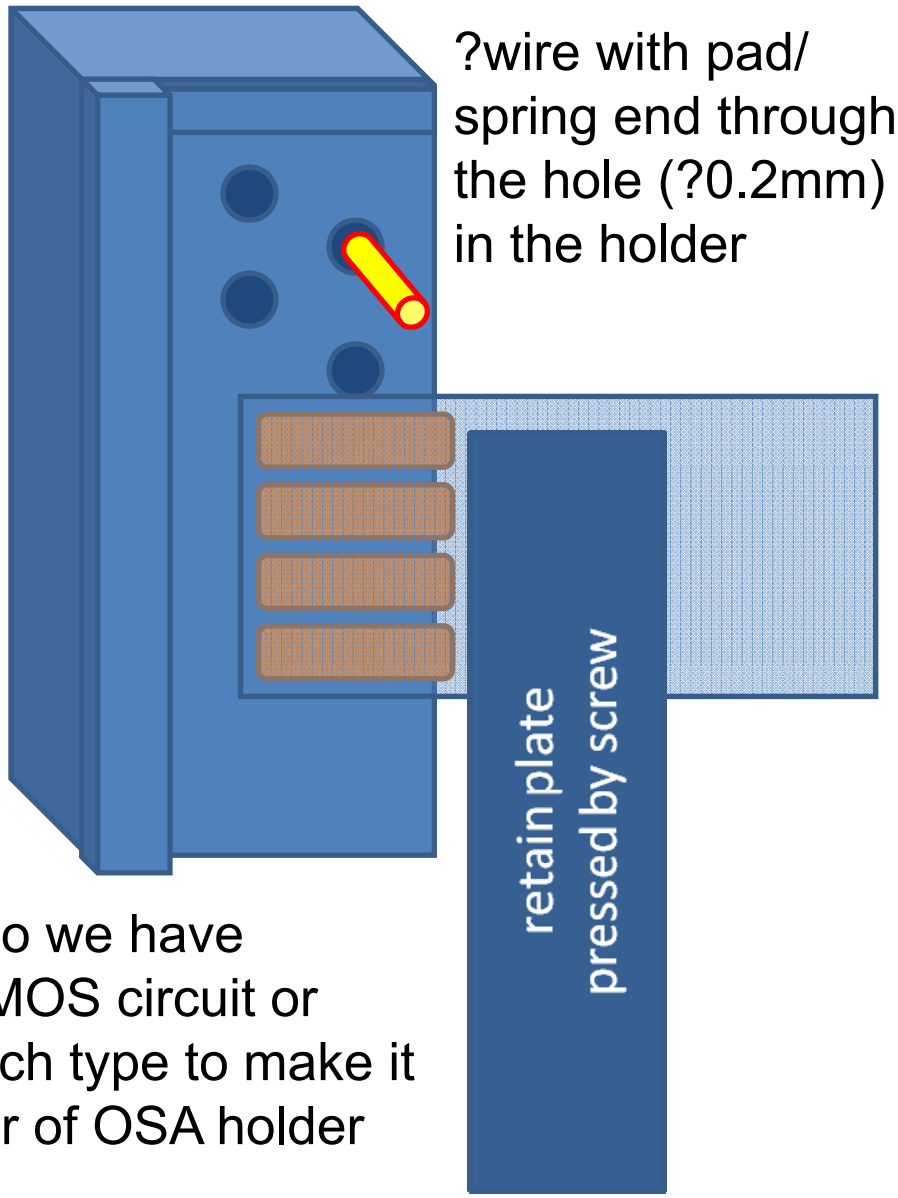
?last mask: thick gold pads/ contact area: x4: 1.0 *0.25mm + x2 0.25*0.25/ ~500nm thick

So, all combined will might be of such OSA holder with two (50 and 80 um) pinholes and Si quadrant detector around



(A) or (B)





?do we have CMOS circuit or such type to make it par of OSA holder

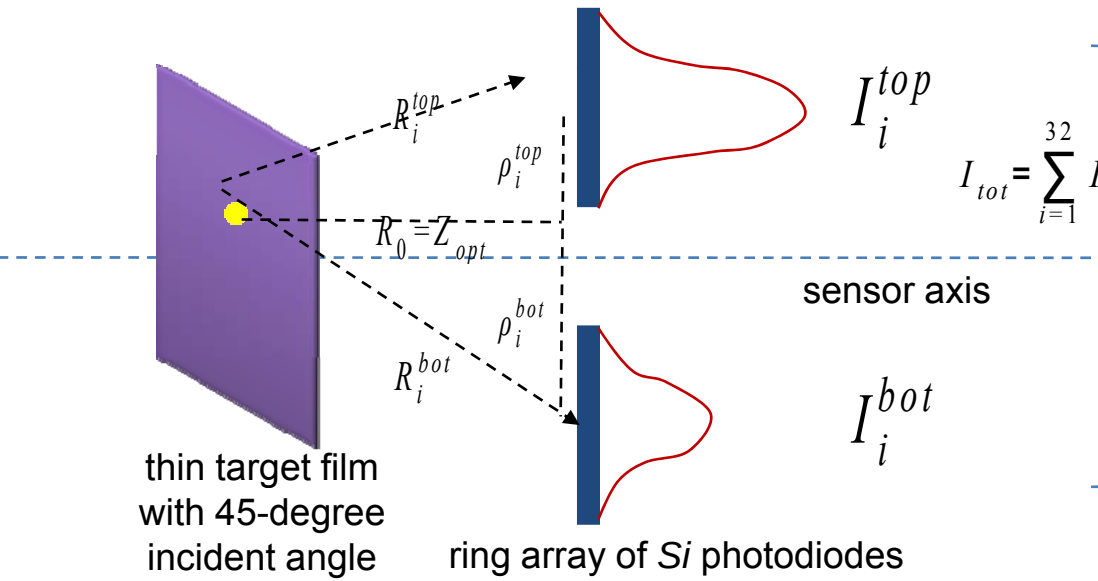
Conclusions

- A modest effort has been started (September 2008)
- Good progress in making and testing a new fluorescence BPM (Phil Yoon)
- A start made on making an 'Active OSA' beam intensity monitor for soft x-rays (Konstantine Kaznatcheev).

Thanks

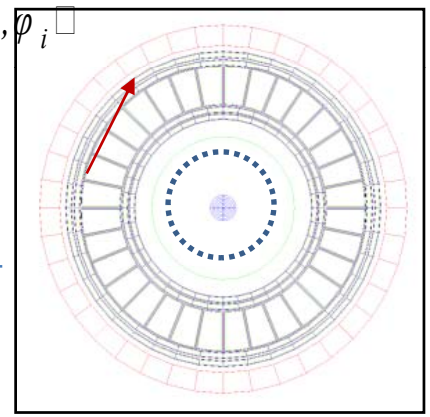
- Gianluigi DeGeronimo (ASIC design & testing)
- Zheng Li & Rolf Beuttenmuller (diode array)
- Gabriella Carini (diode testing)

Method of Finding X-ray Beam Positions



Axial view of forward scattering

$$I_{tot} = \sum_{i=1}^{32} I_i$$



Front view of ring-array photodiodes

$$R_i^{top} + R_i^{bot} = D_{sensor} = 2\rho_0$$

$$\frac{I_0}{I_i} = \frac{R_i^2}{R_0^2}$$

$$R_i = R_0 \sqrt{\frac{I_0}{I_i}}$$

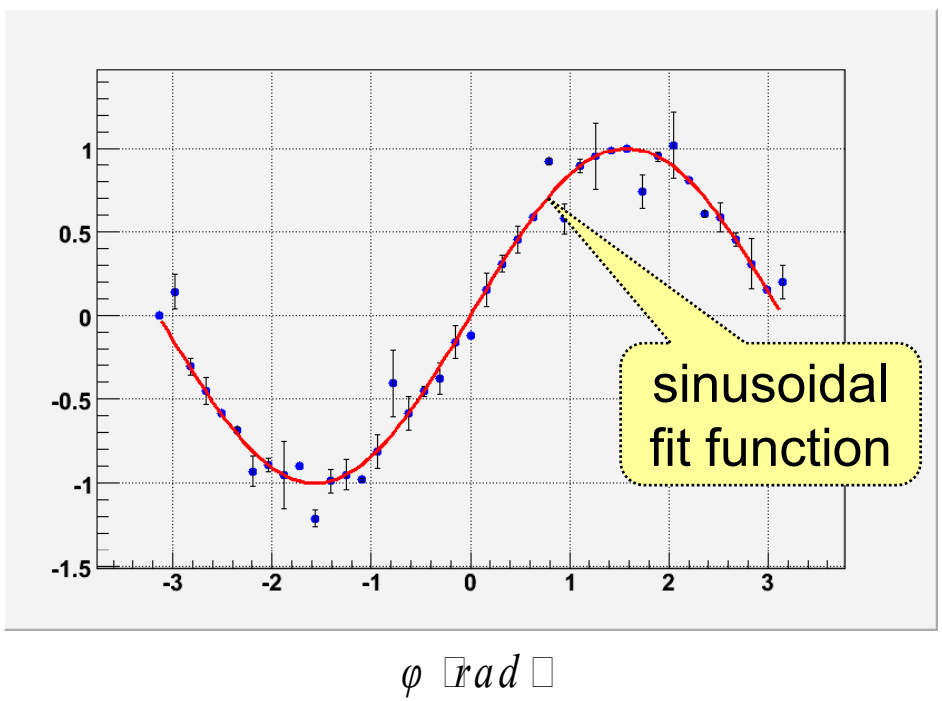
$$\rho = \rho_0 - \rho_i = \rho_0 - \sqrt{R_0^2 + R_i^2}$$

The maximum beam intensity I_{max} is acquired when an x-ray beam centroid is positioned on the *sensor axis* at the distance of Z_{opt}^* from the sensor. When a beam is off axis, from beam intensities (I_i^{top} and I_i^{bot}) that are registered at diametrically opposite diode segments, one can deduce radial distances (R_i^{top} and R_i^{bot}) by means of scaling down I_{max}. Thereby, polar coordinates (ρ_i, ϕ_i) of the forward-scattered x-ray beam on the sensor plane can be extracted. Once a beam centroid is determined, the polar coordinates can be transformed to Cartesian coordinates, if necessary.

$\rho \sin\varphi$

or

$\rho \cos\varphi$



Utilizing polar coordinates associated with each of 32 photodiode segments, we can fit them to a sinusoidal function as shown to the left.

Phil Yoon