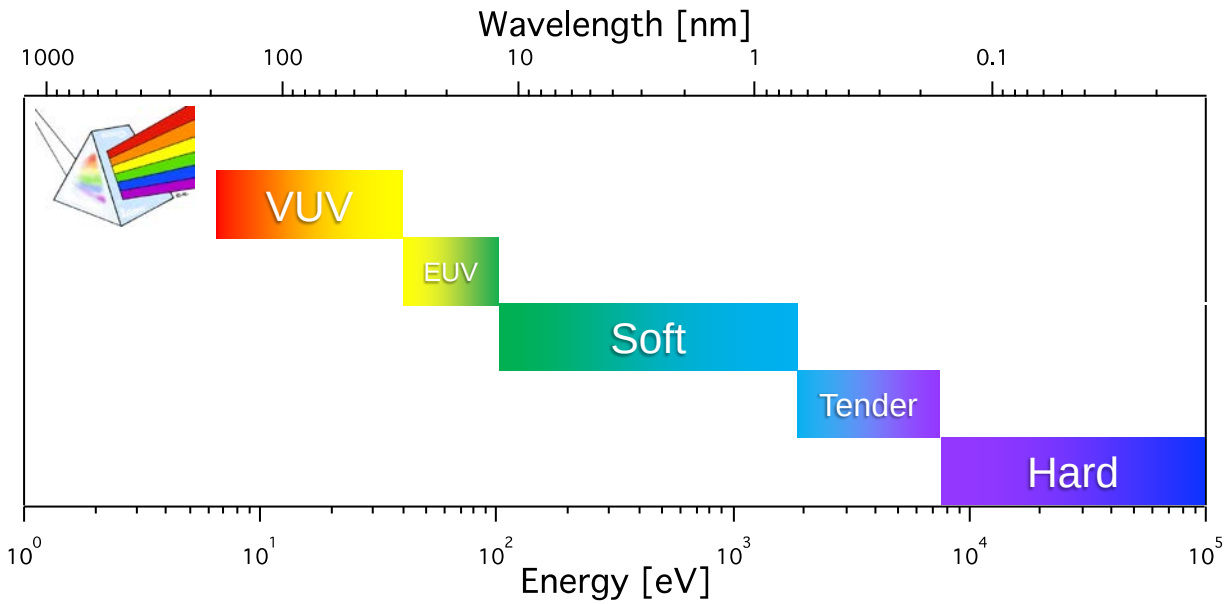
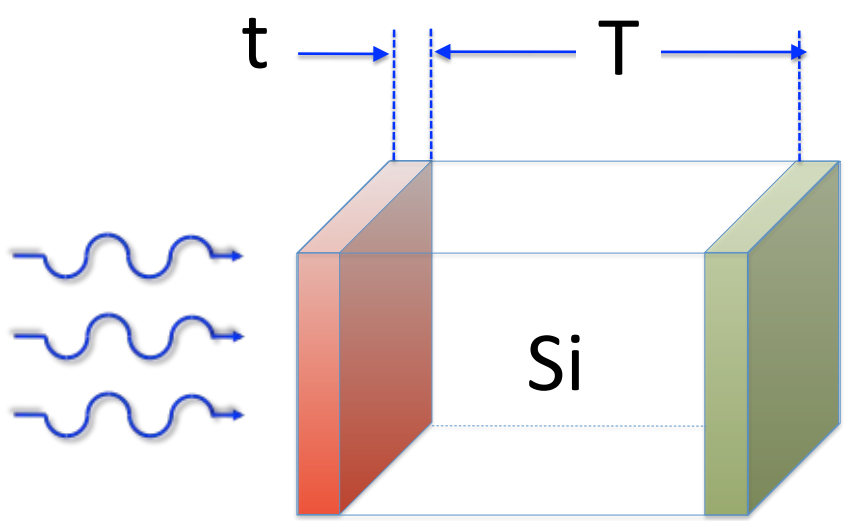
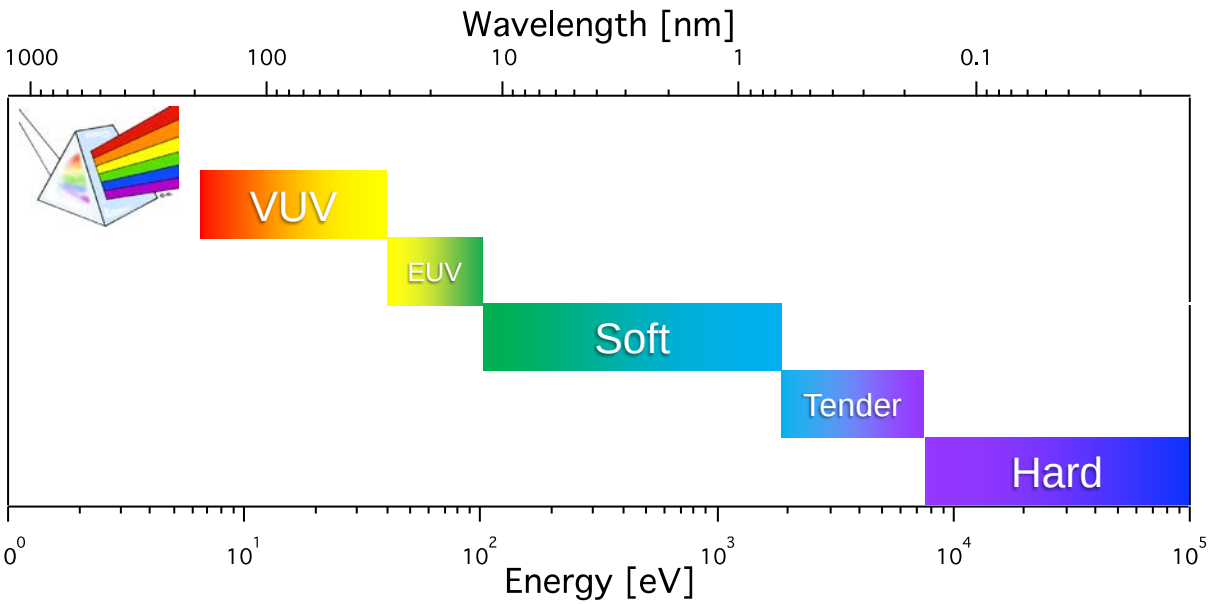
Soft X-ray Detector Development at ALS



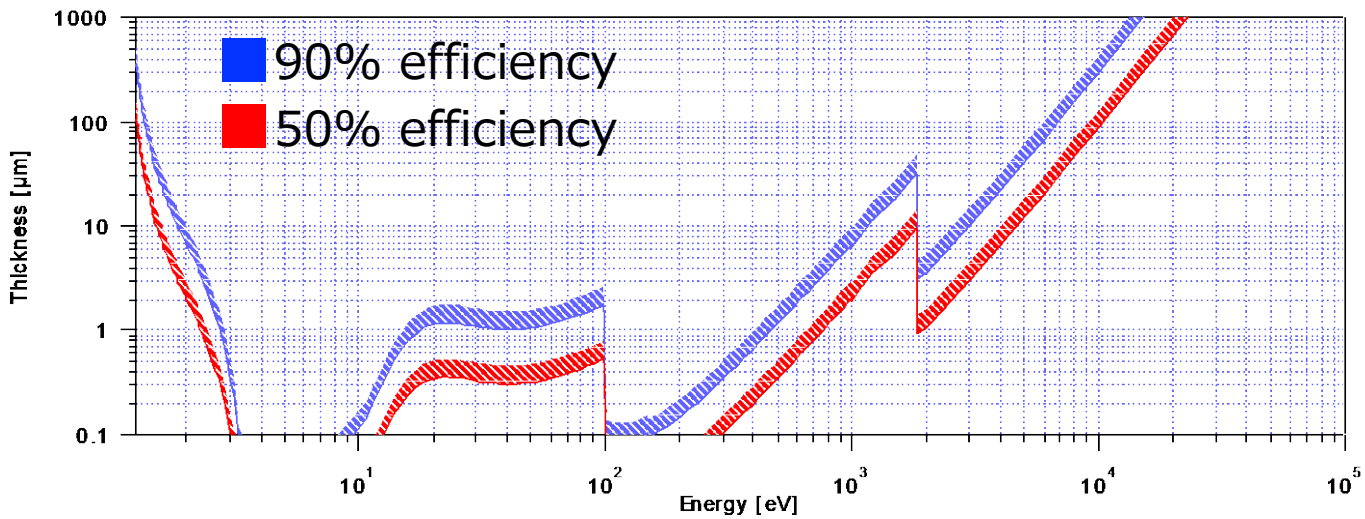
Direct detection in silicon

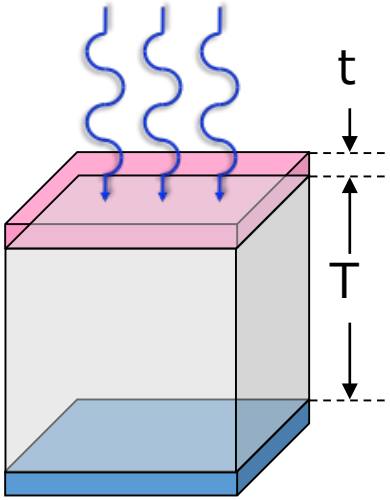


Soft X-ray Detector Development at ALS

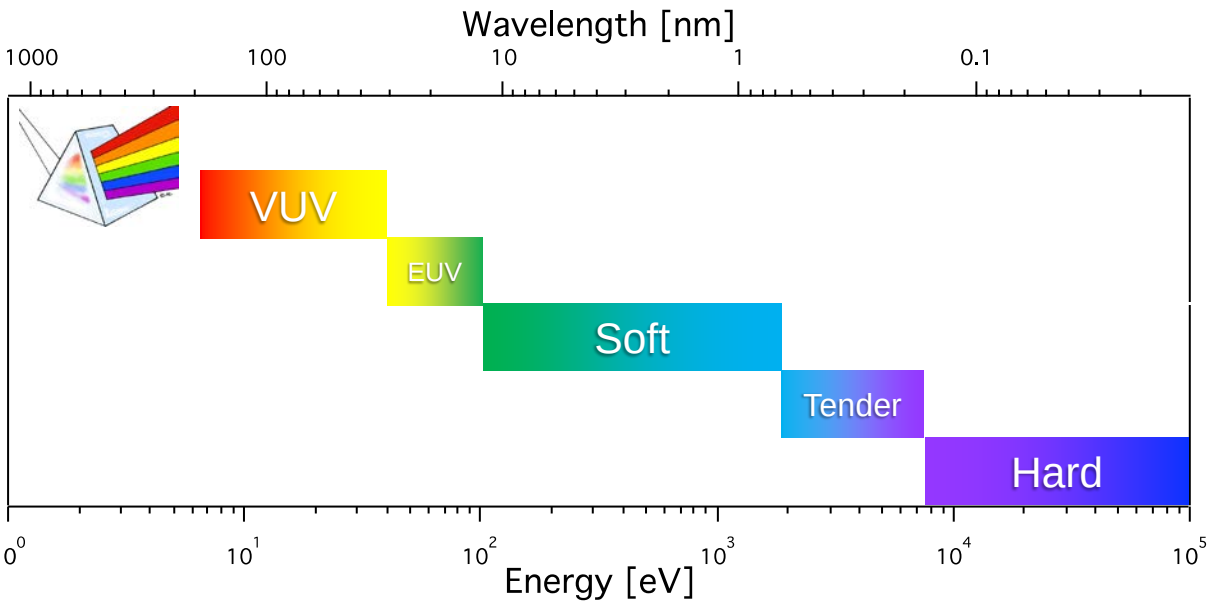


Required Thickness (T)

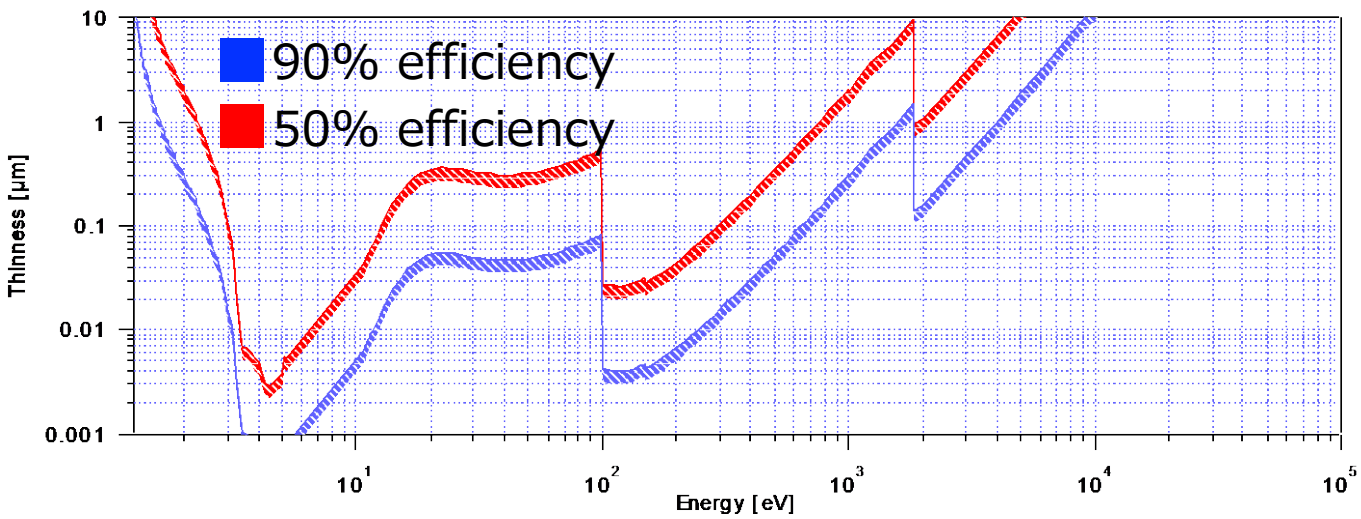


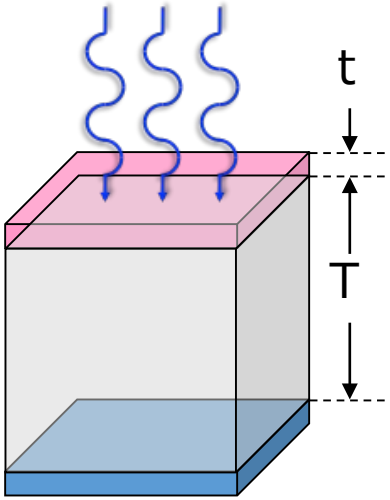


Soft X-ray Detector Development at ALS

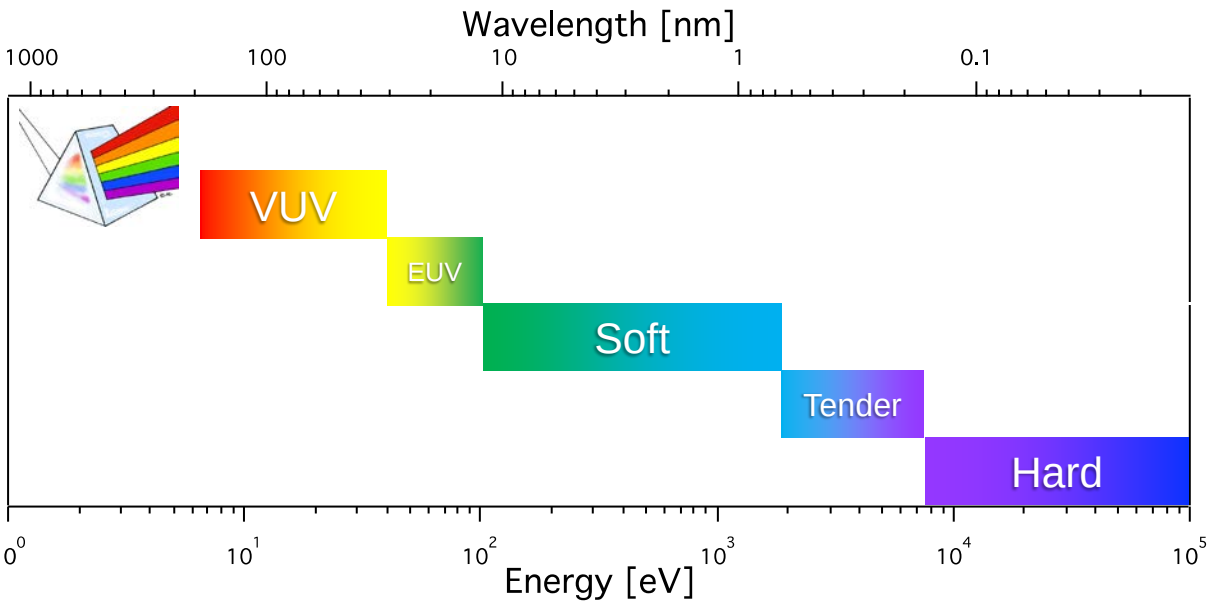


Backside Contact Thinness (t)

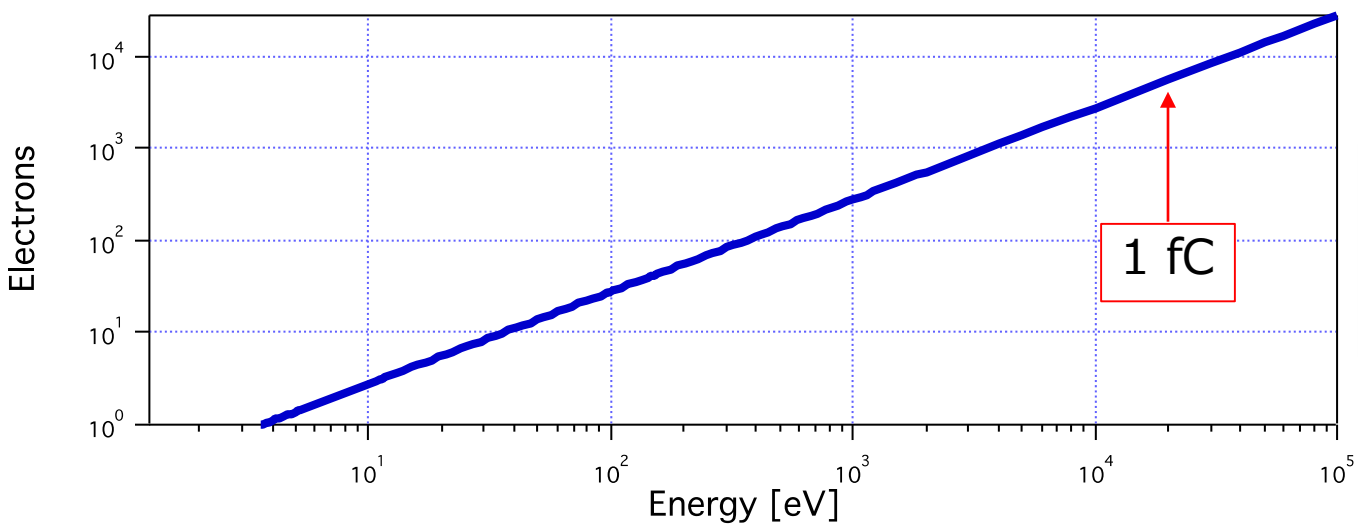




Soft X-ray Detector Development at ALS

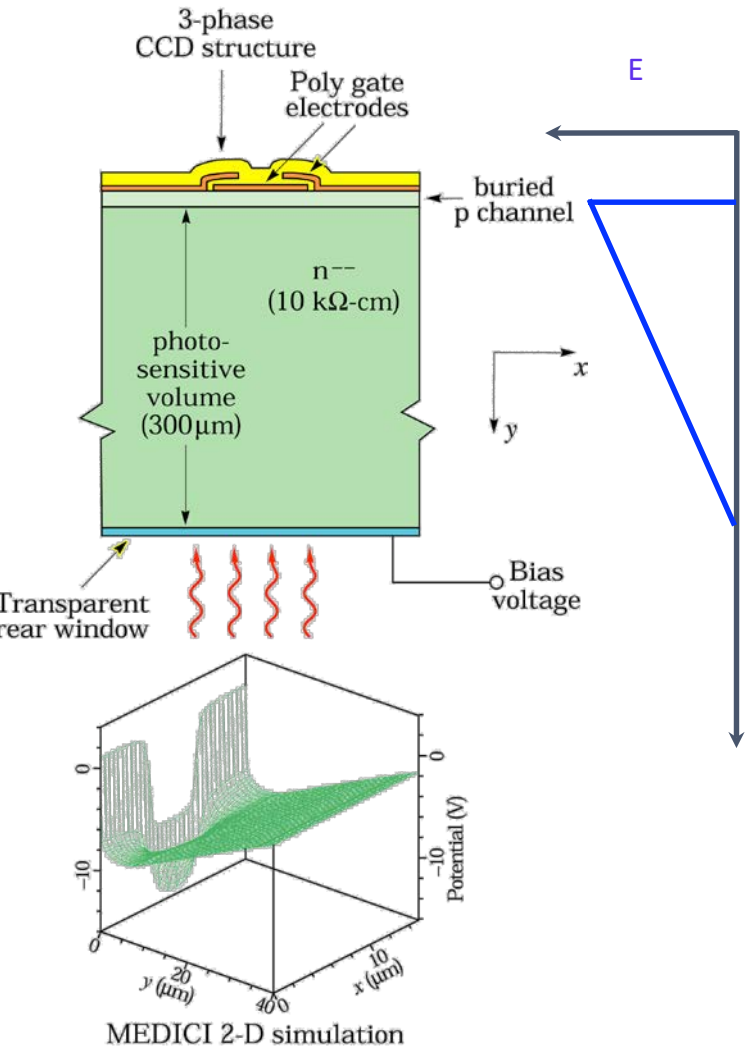


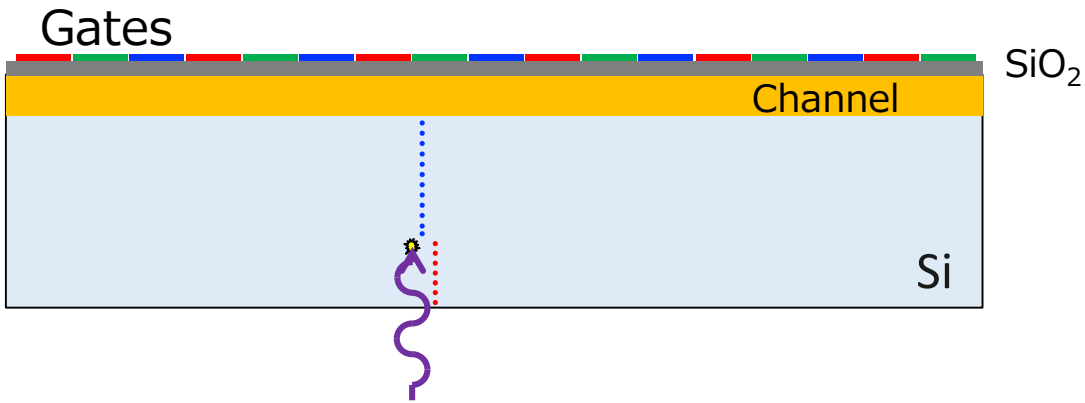
Noise:
"Soft is Hard"
H. Graafsma



Charge per Photon

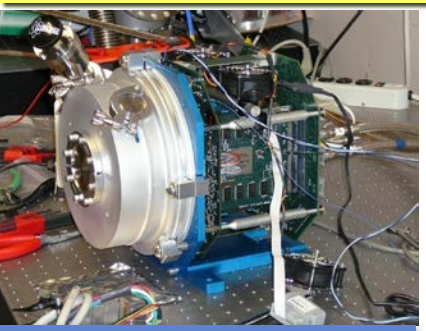
Charge Coupled Devices





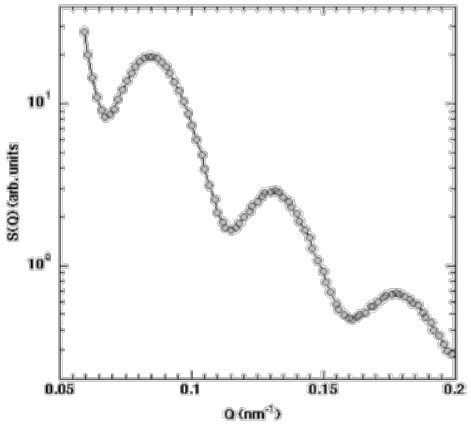
- LBNL high-resistivity CCD process
- Originally developed for astronomy (S. Holland)
- Thick (up to 650 µm) high-resistivity Si
  - Fully depleted
  - Thick for good red QE
  - Thin window for good blue QE
- n-type (p-channel) for enhanced radiation resistance (space application)
- → Direct X-ray detection

FastCCD – 200 Mpix/s

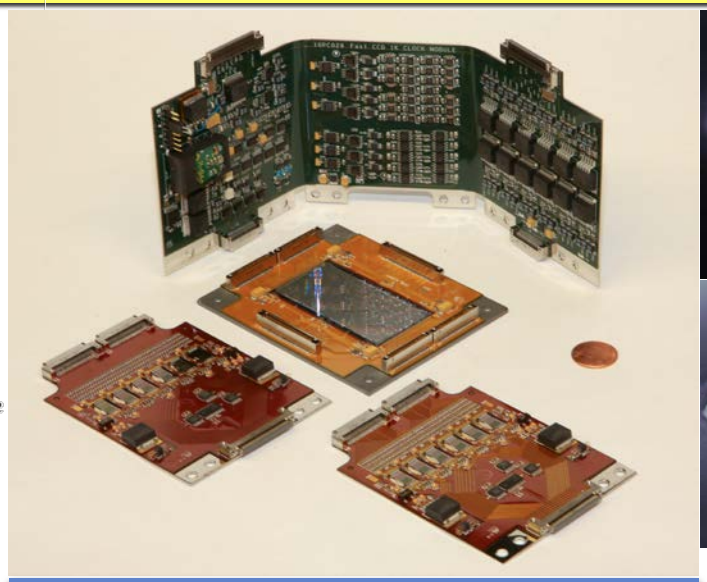


FastCCD Prototype

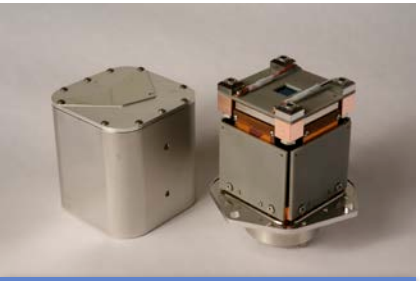
For APS, ALS Collaborative Development 2006 - …



Funds: LDRD, ALS/APS, ARRA

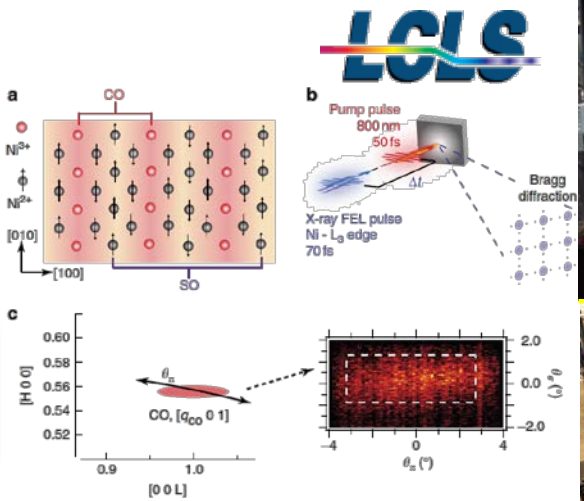


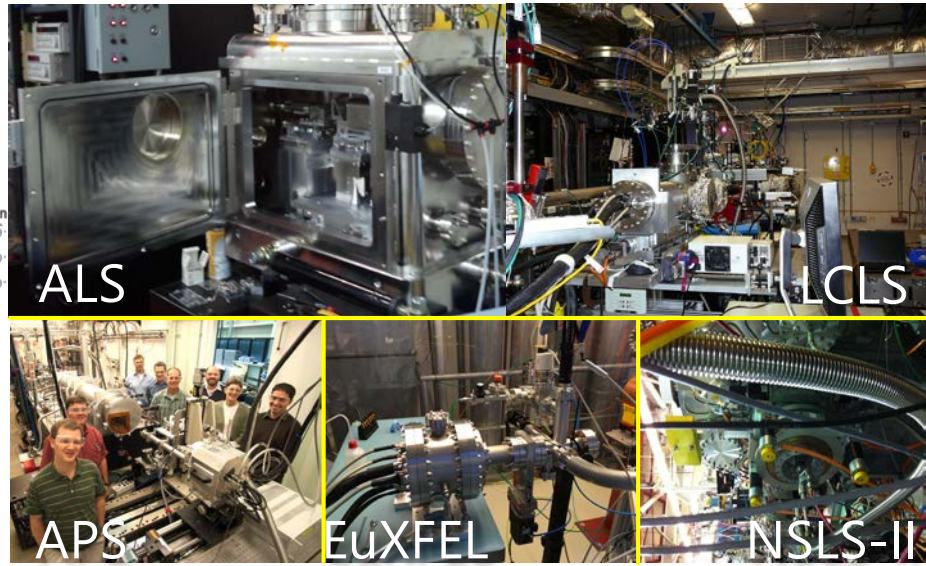
Frame-store FastCCD



Compact FastCCD

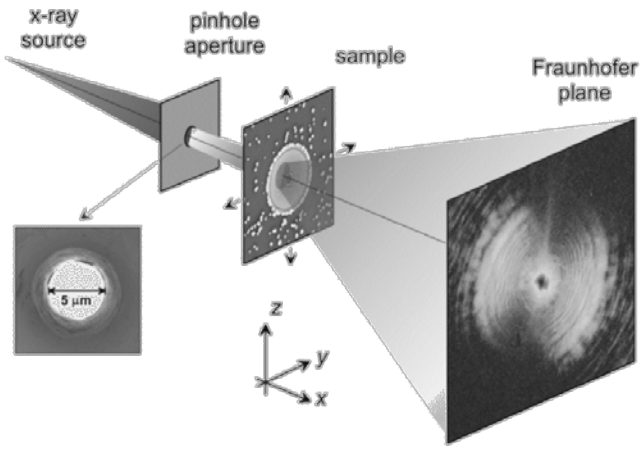
For LCLS

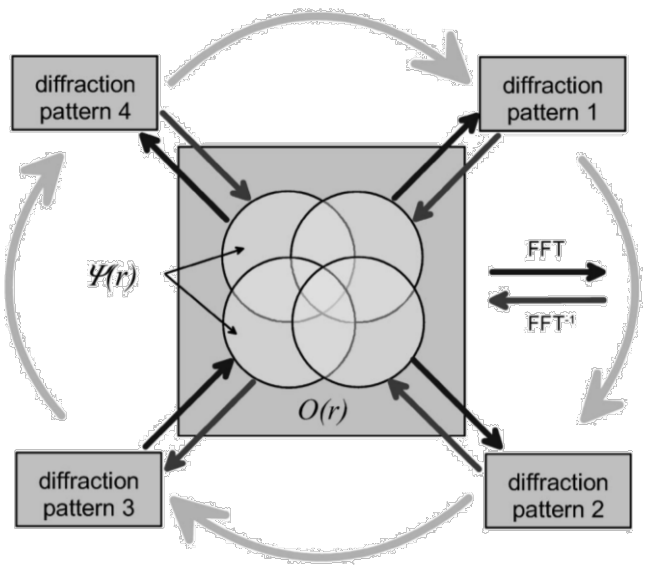




SXR Ptychography

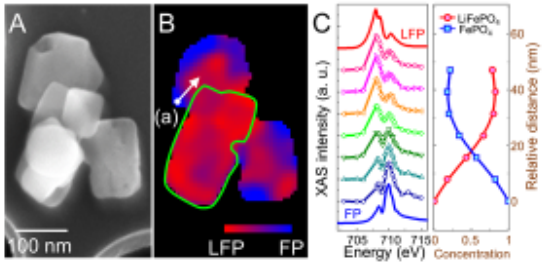
Rodenburg, *PRL* **98** (2007)



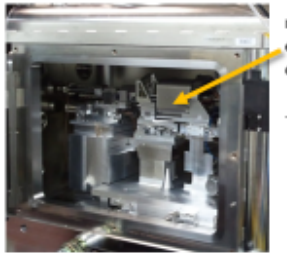


$$\psi(\boldsymbol{r},\boldsymbol{R}) = O_n(\boldsymbol{r})P(\boldsymbol{r}-\boldsymbol{R})$$

Why Is Smaller Better In Battery Cathodes?



A. Scanning electron microscopy (SEM) images of partially delithiated $LiFePO_4$ nanoplates B. Chemical phase map. C. Fe L_3 X-ray absorption spectra collected along the paths defined by (a) in B.



nm resolution soft X-ray ptychography enabled by high-speed Fast CCD detector in Nanosurveyor

- Ptychography requires diffraction patterns from tens of thousands of overlapping points. Can only be done with a CCD orders of magnitude faster than conventional CCD cameras.

Scientific Achievement

Direct visualization by x-ray ptychography of correlations between chemical phase changes and their mechanical consequences in a range of cathode particle sizes.

Significance and Impact

Establishes mechanics as a primary driver in the superior performance of nanoscale cathode particles and informs the design of ultimate devices

Research Details

-Irregular distribution of chemical phases observed in micron-, sub-micron-, and nano-sized $LiFePO_4$ plates.
-Only the smallest particles can support the resulting strain and do not crack
-The size dependence of electrochemical performance is closely related to fatigue at the electrodes

Y.-S. Yu, et al., *Nano Letters* DOI:10.1021/acs.nanolett.5b01314 (2015)

Work was performed at Lawrence Berkeley National Laboratory

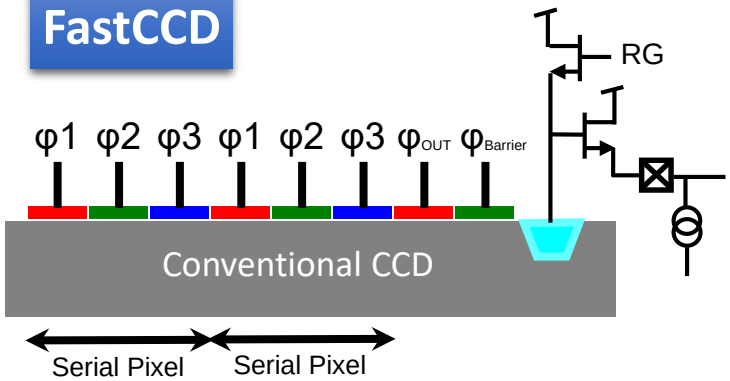
U.S. DEPARTMENT OF ENERGY | Office of Science

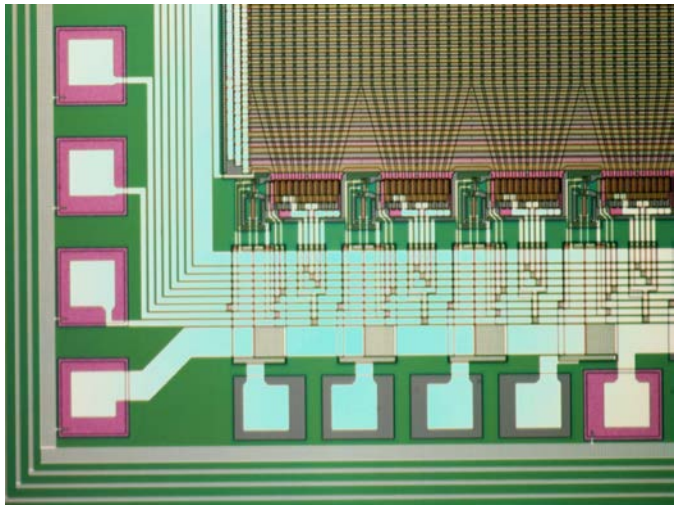
Wavelength-limited (few nm) SXR ptychography

- Spectro-ptychography
- Spectro-tomo-ptychography

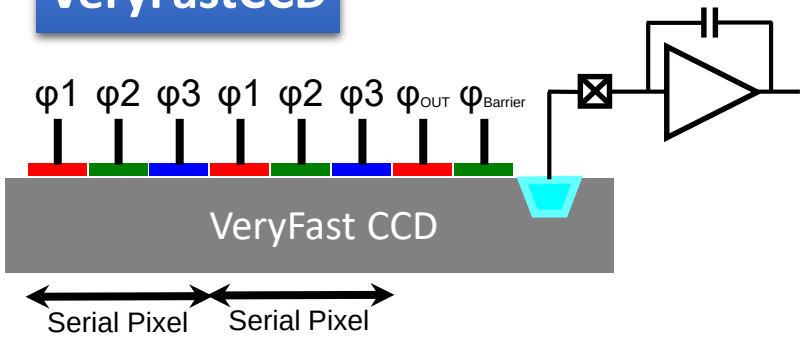
VeryFastCCD

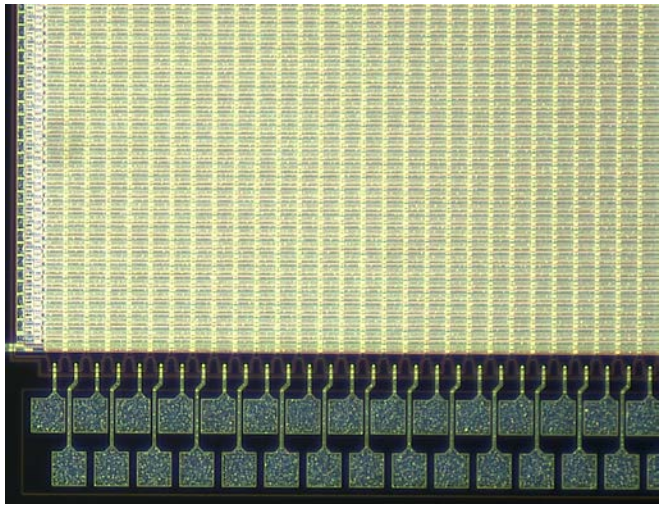
FastCCD





VeryFastCCD





200 Mpix/s	10,000 Mpix/s
(almost) Column Parallel	(fully) Column Parallel
Voltage output	Charge output

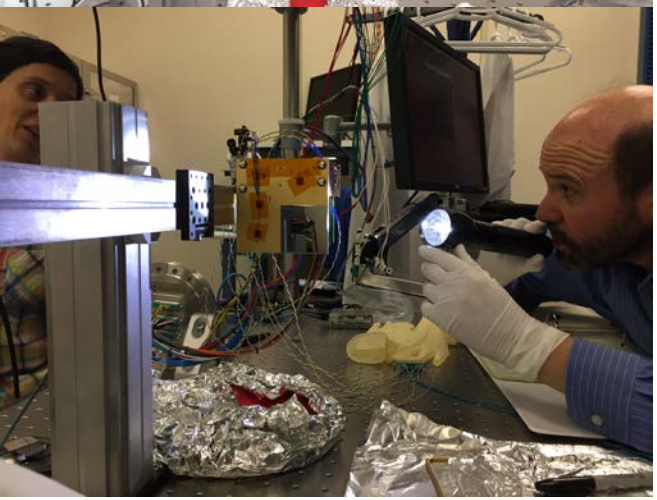
VeryFastCCD – 10,000 Mpix/s

Collaborative development with LCLS

Initial funding from BES-ADR

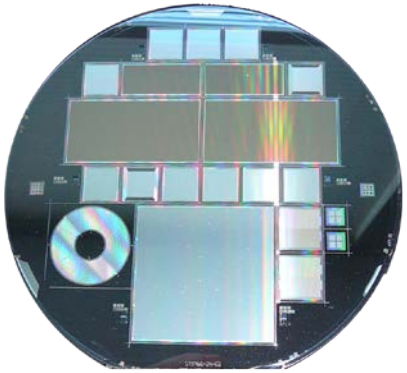
"t=0" LCLS-II detector

(+upgrade of FastCCD)



In "proof-of-concept" phase

- Have a variety of CCDs (different sizes/flavors)



- Have v1 of readout ASIC ("VASE")
- **Test on COSMIC BL this summer**
  - "forget to take back" if it works
- Designs for LCLS-II in evolution

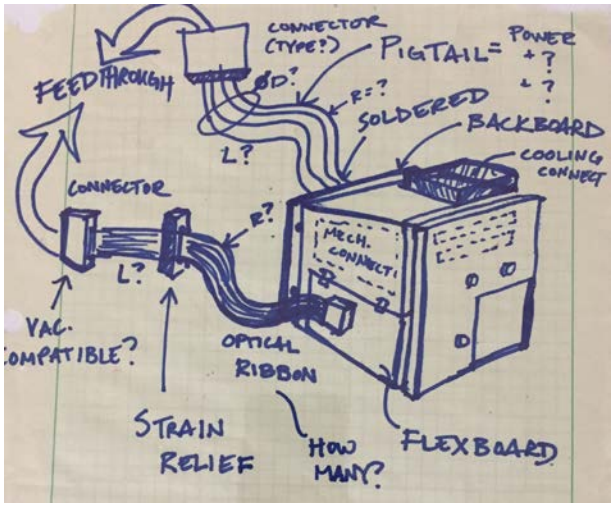
LCLS production systems funded by LCLS

So far, so good:

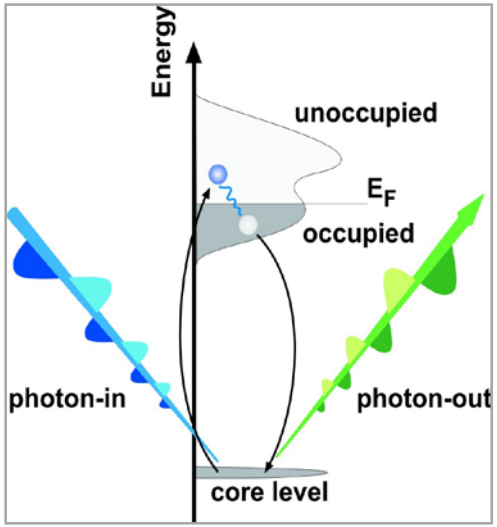
- CCDs work
- VASE works

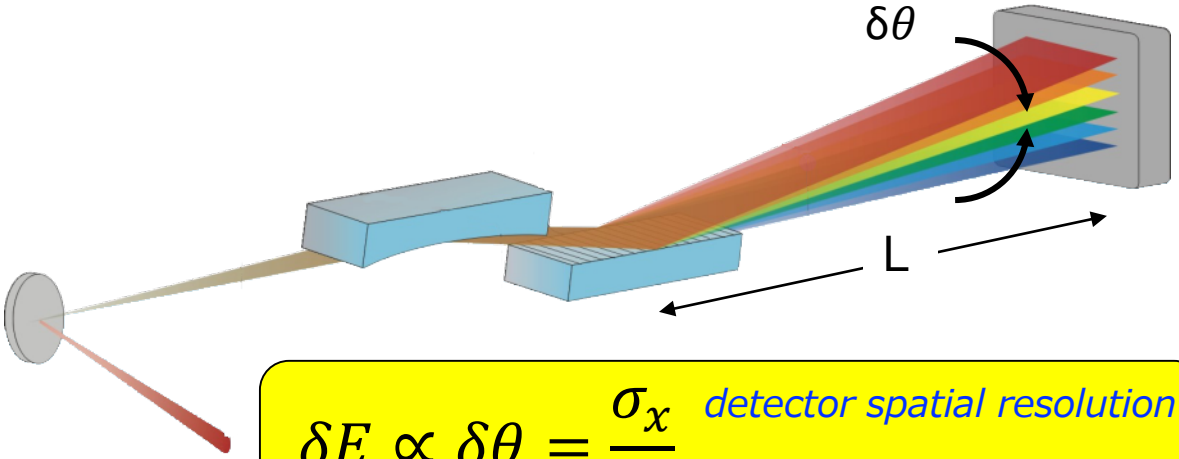
Prototype will use FCCD mechanics, (but fiber-optic readout)

- ~50 Gb/s



RIXS



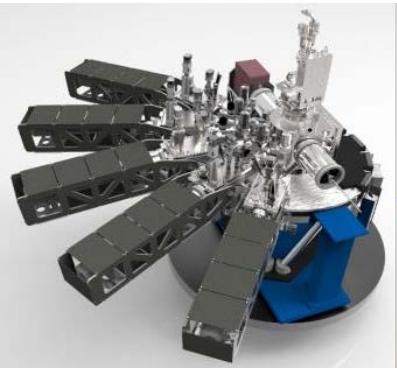


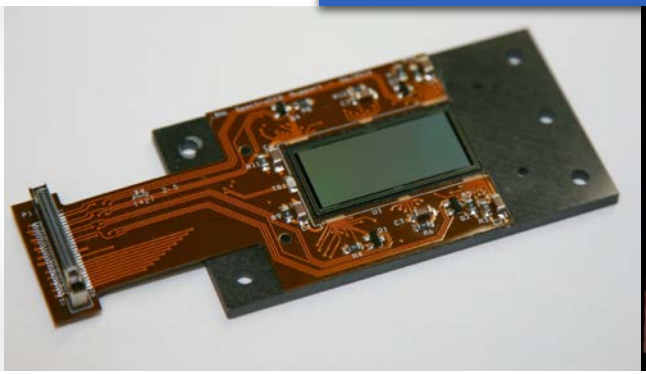
$$\delta E \propto \delta\theta = \frac{\sigma_x}{L}$$

detector spatial resolution

beamline length

SpectroCCD for qRIXS





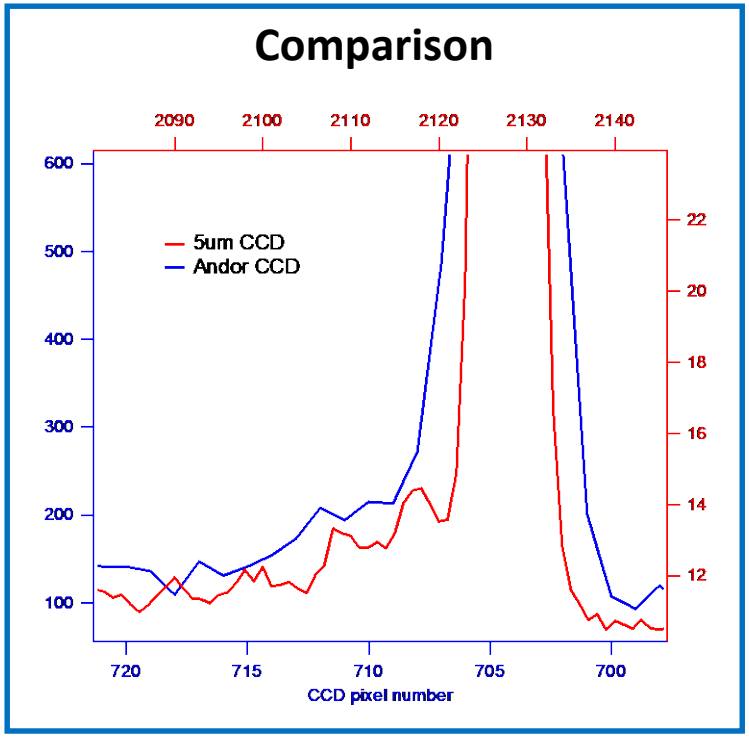
A. Goldschmidt

SpectroCCD

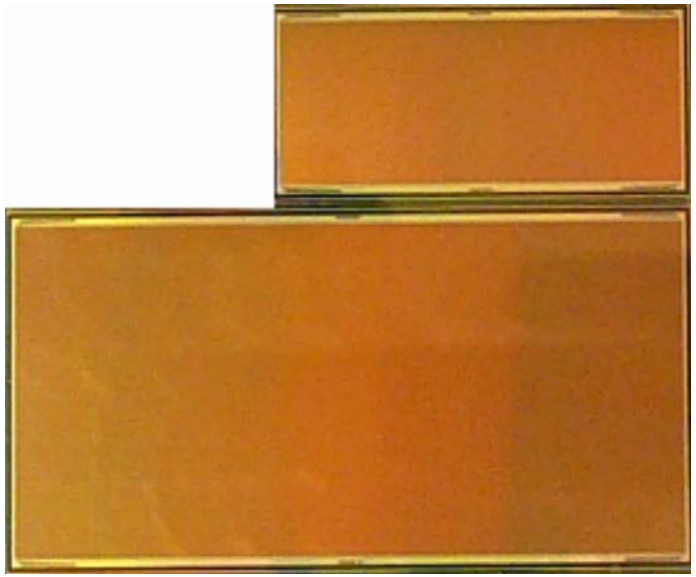
- Intrinsic spatial resolution, rather than centroiding
  - No rate limitation
  - Centroiding also possible, of course

5 µm x 45 µm pixel

HOPG@285 eV – BL 8.0



Prototype 2496 5 µm x 750 45 µm pixel



Production 6000 5 µm x 1450 45 µm pixel

- Multiple detectors for qRIXS@ALS
- Plan to try on SIX@NSLS-II

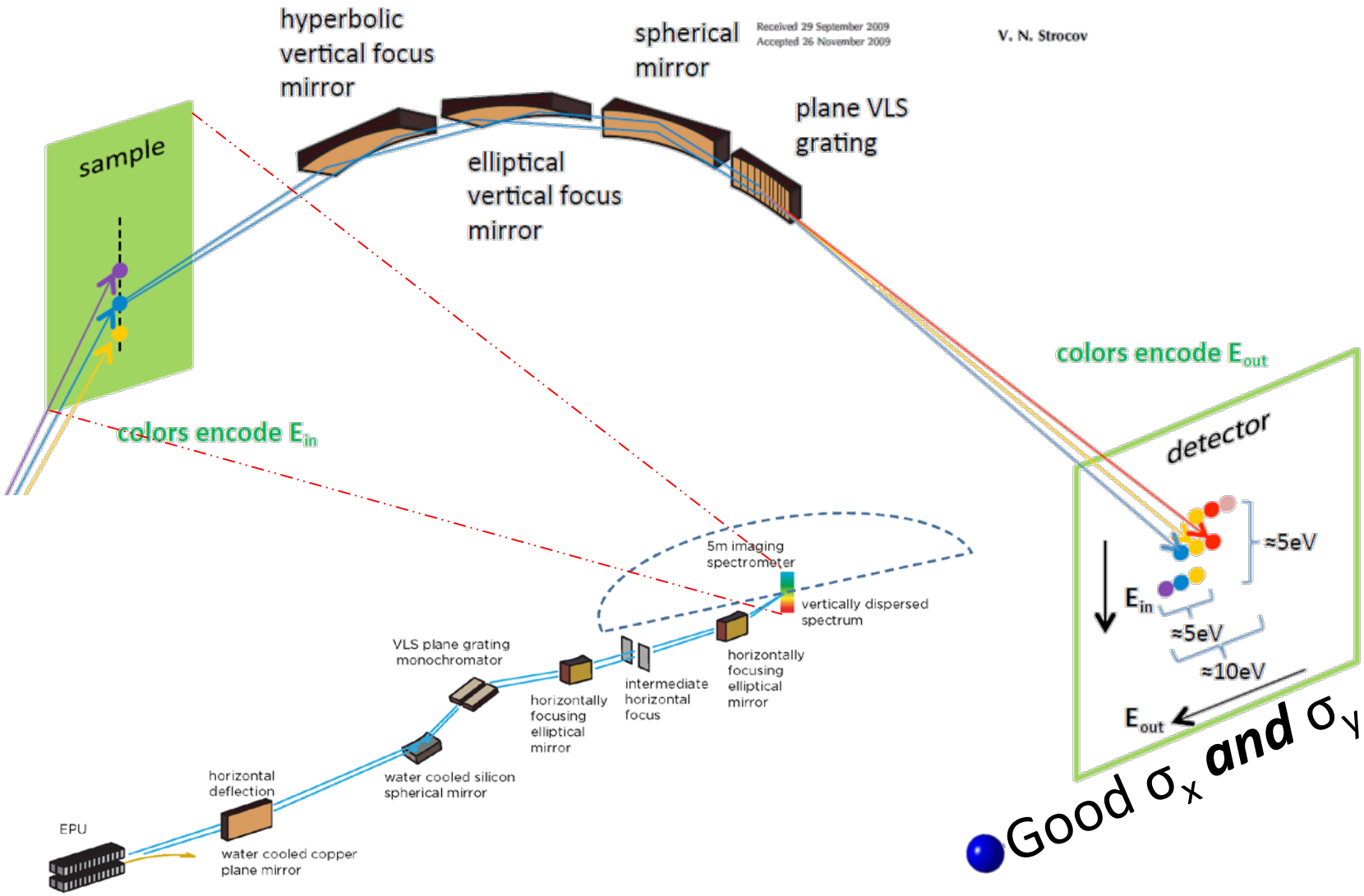
Funds: BES-ADR, ALS, SBIR

QERLIN (2D RIXS)

Journal of Synchrotron Radiation
ISSN 0909-0495
Received 29 September 2009
Accepted 26 November 2009

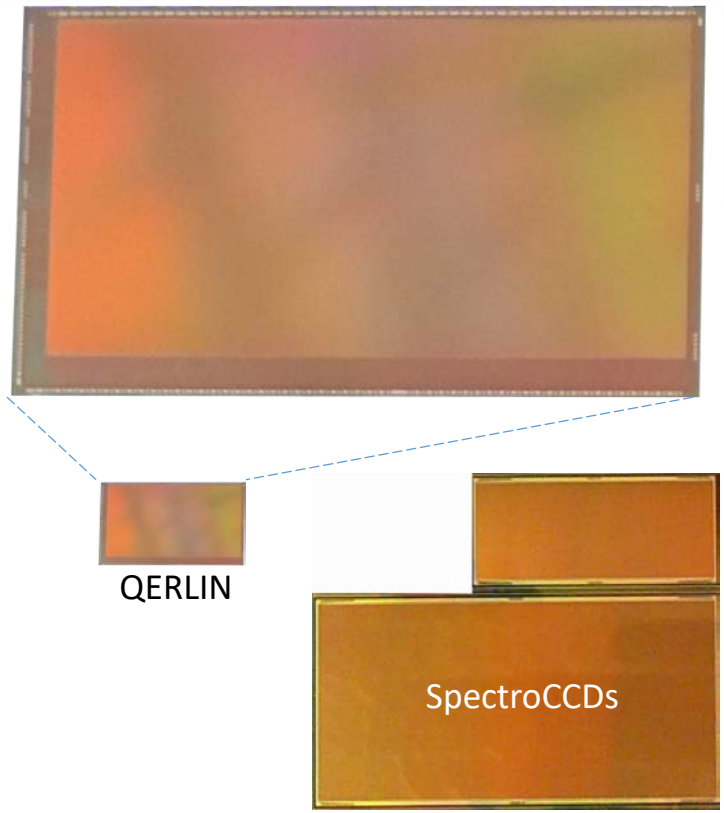
Concept of a spectrometer for resonant inelastic X-ray scattering with parallel detection in incoming and outgoing photon energies

V. N. Strocov

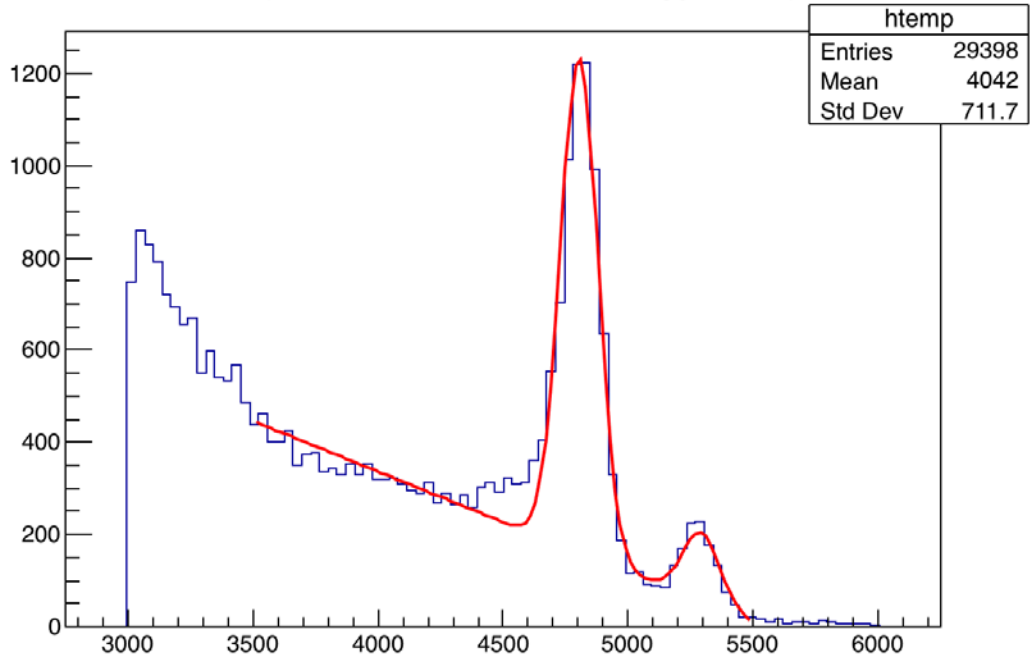


- Good σ_x **and** σ_y needed

CMOS Detector for QERLIN



8 Mpix
5 x 5 μm^2 pixels
Thinned, back-illuminated, ultra-thin contact



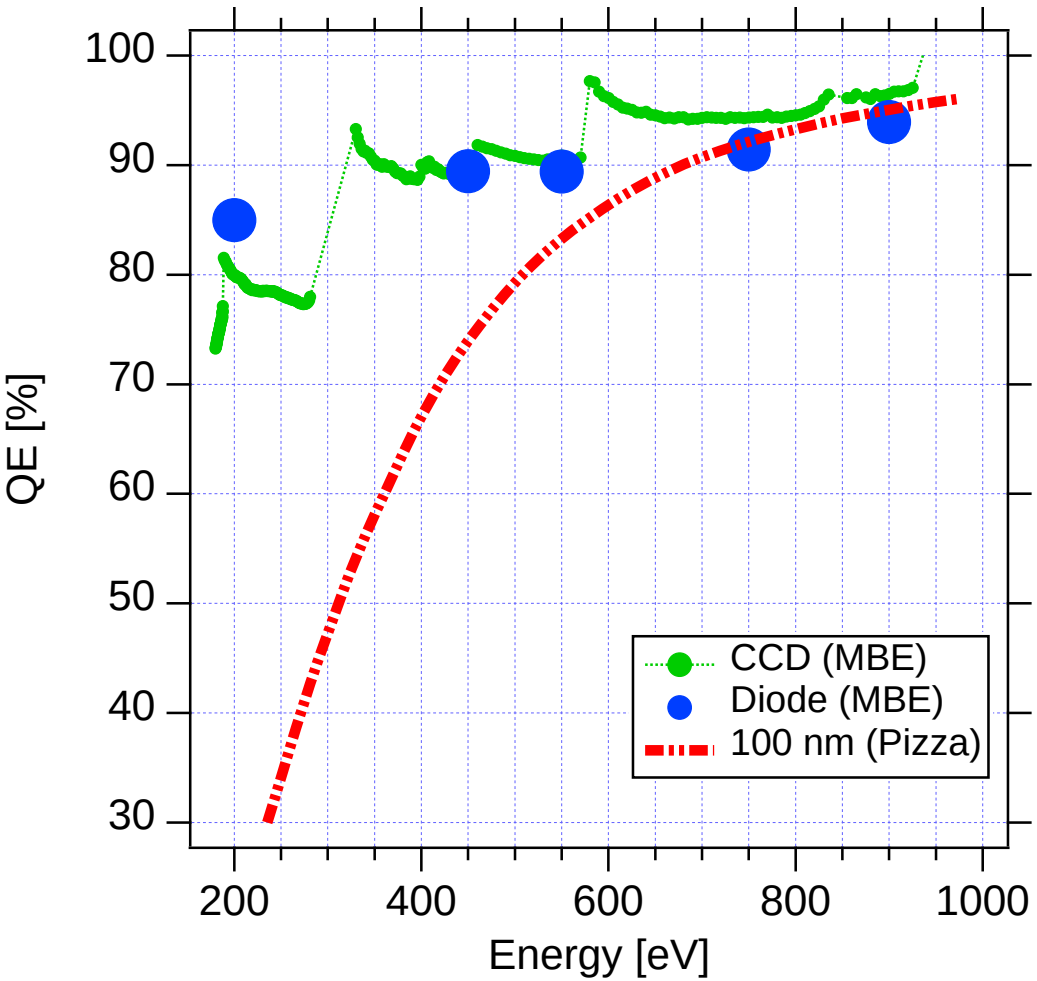
^{55}Fe spectrum in lab showing good K_α-K_β separation

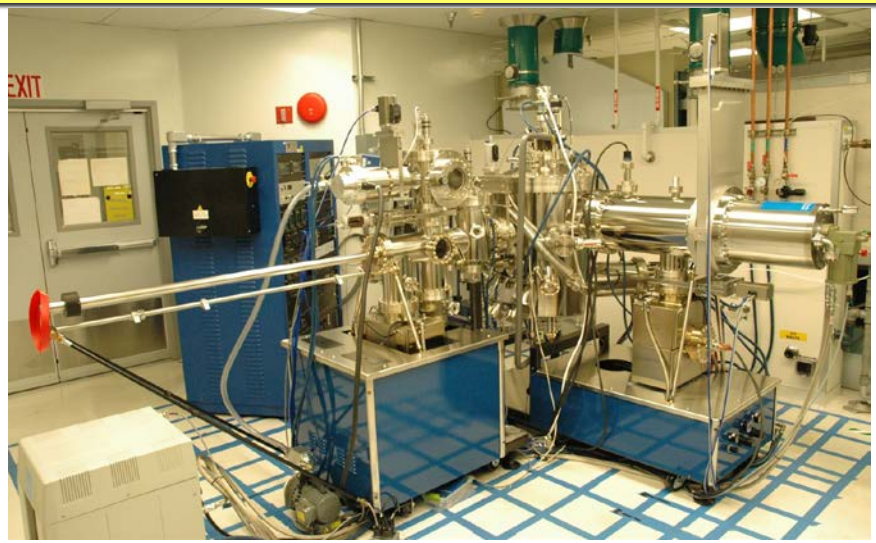
- On QERLIN ES ~1 yr
- Test at ALS this fall
- (re-use FCCD mechanics)

Funds: ALS

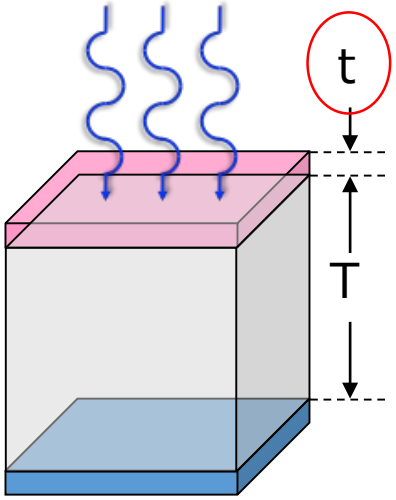
Thin Contact Development

Quantum Efficiency measurements at ALS metrology beamline 6.3.2





- "Pizza" process
  - 100 nm
  - ≥500 eV
- MBE
  - 10 nm

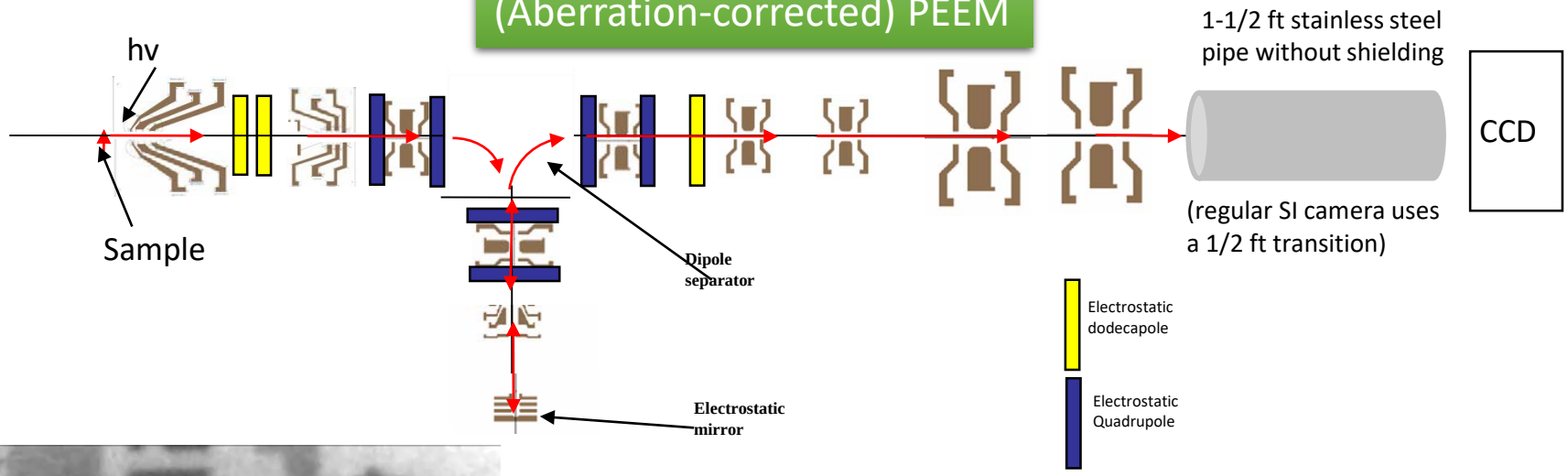


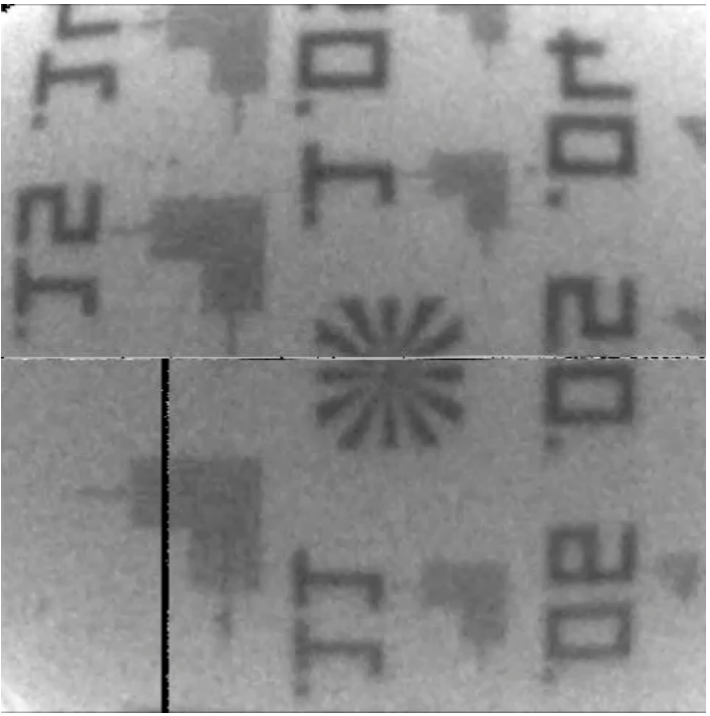
C. Tindall

Funds: BES-ADR, LBNL

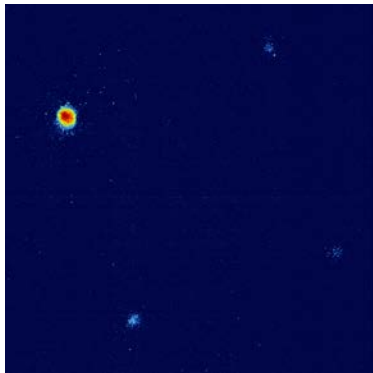
Other Activities

(Aberration-corrected) PEEM

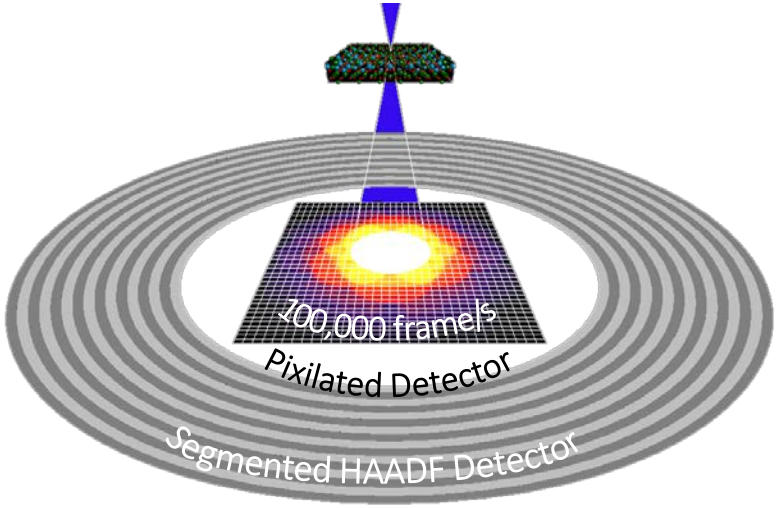


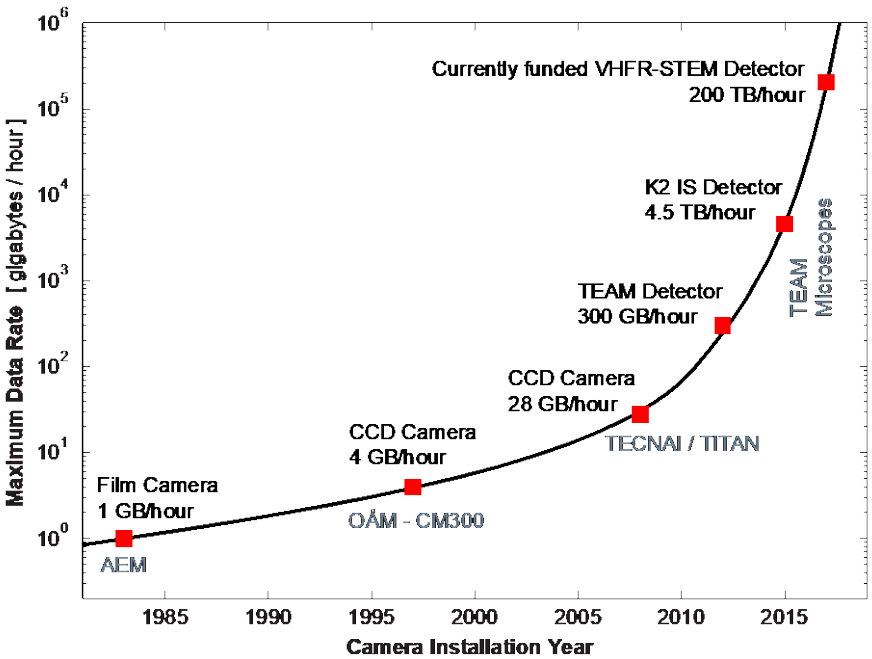


- Electron detection (a group activity)
- PEEM
  - 1st attempt (proof-of-concept)
  - Try again, both with CCD and CMOS
  - Leverage CMOS activity for UED@SLAC based on *TEAM* detector

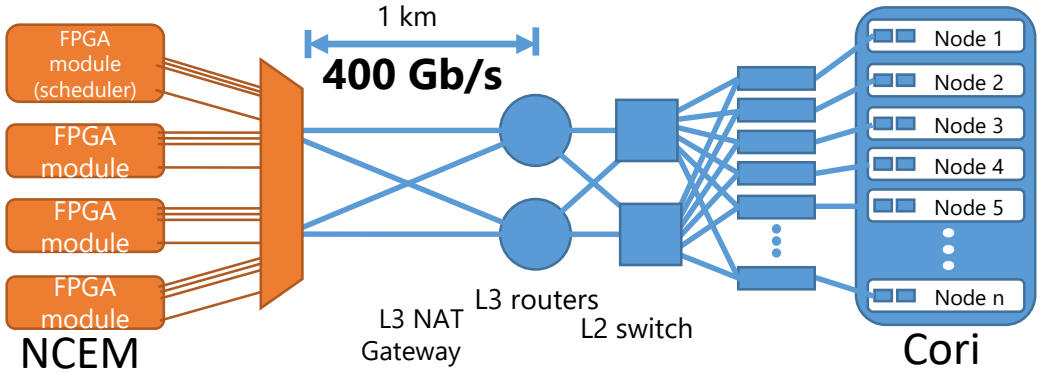


Other Activities





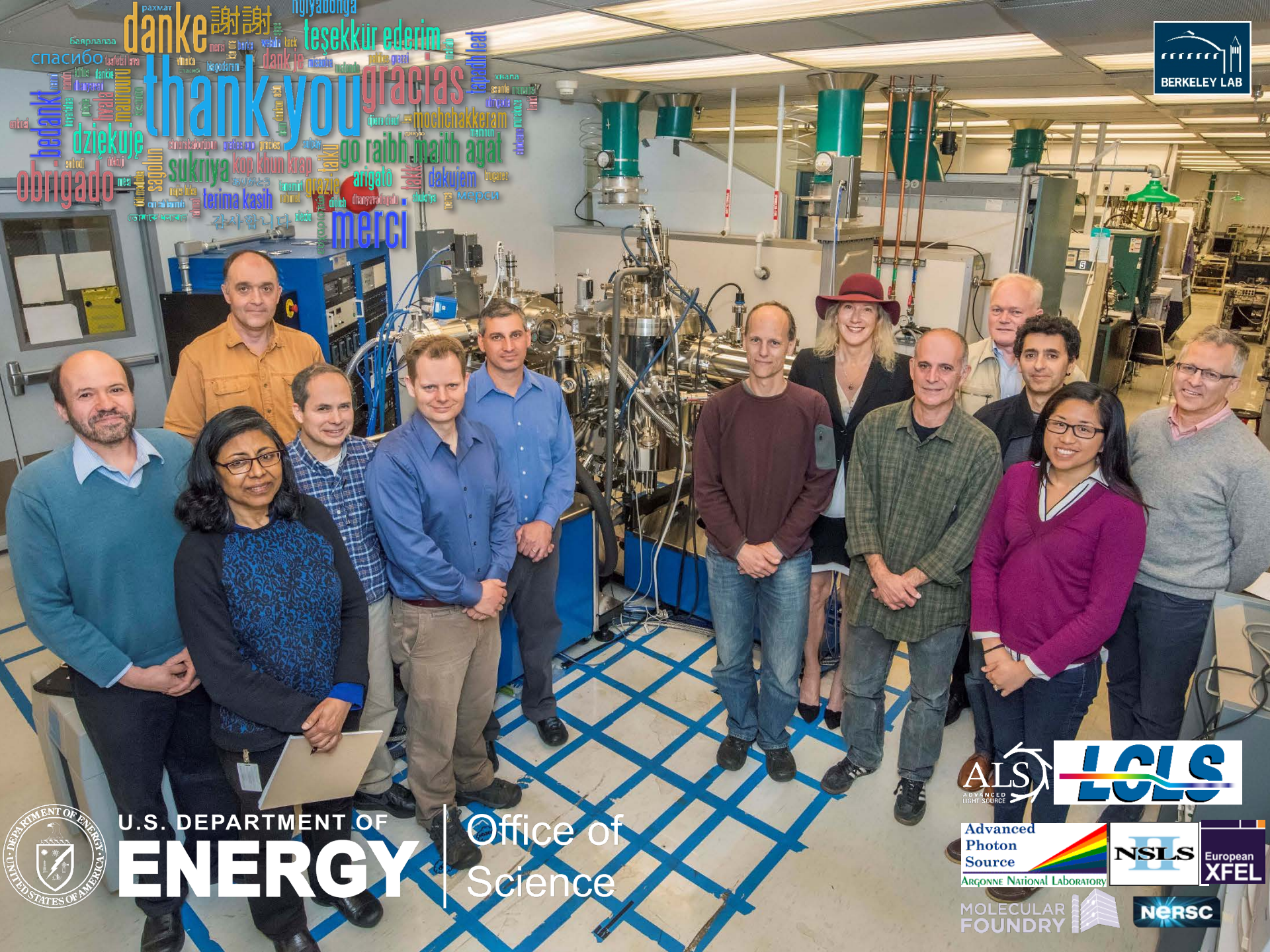
- Data
  - 100,000 fps STEM
  - EM Data → NERSC
- How to move it
- Analysis/pre-analysis



- 93 eV – detectors for EUV

Summary

- Monolithic silicon detectors for soft X-rays
  - CCDs – benefit from efforts for cosmology
  - CMOS – benefit from efforts for electron microscopy
- Enabling technologies
  - Ultrathin contacts
  - Device thinning and processing
- Heterogeneous funding model
  - Highly leveraged
    - ~14 people directly involved, others peripherally– $\sum \$ \ll 14$
- Commercialization always a challenge
  - Small market
  - SBIR – can be helpful, but not particularly fast


danke
謝謝
teşekkür ederim
thank you
gracias
спасибо
mochchakkeram
dziękuję
obrigado
go raibh maith agat
sukriya
kop khun krap
terima kasih
arigato
dakujem
merci
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Science
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LCLS
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Photon
Source
ARGONNE NATIONAL LABORATORY
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XFEL
MOLECULAR
FOUNDRY
NERSC