Scientific Trends and Opportunities from the Perspective of 8-ID

Alec Sandy
X-Ray Science Division, Argonne National Lab

Outline

- 8-ID experiment categories
- Historical trends
- Future directions
- Ancillary items

8-ID Experiment Categories

1. Noteworthy successes

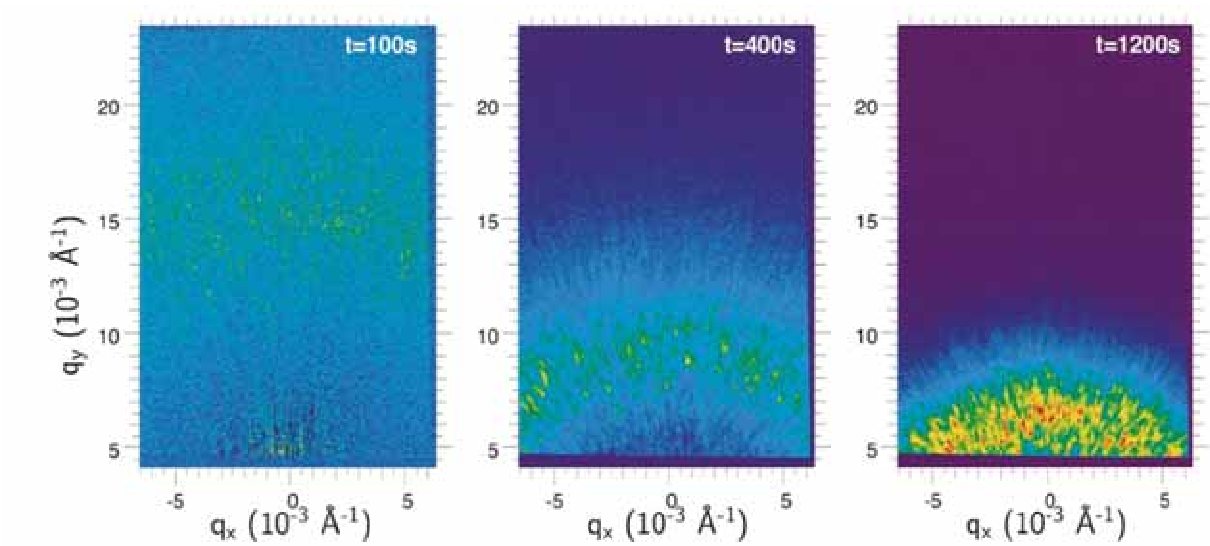
2. Bleeding-edge, marginal and jury-still-out experiments

3. Failures and too-hard and too-scary to try experiments

(2. and 3.) ERL Experiments?

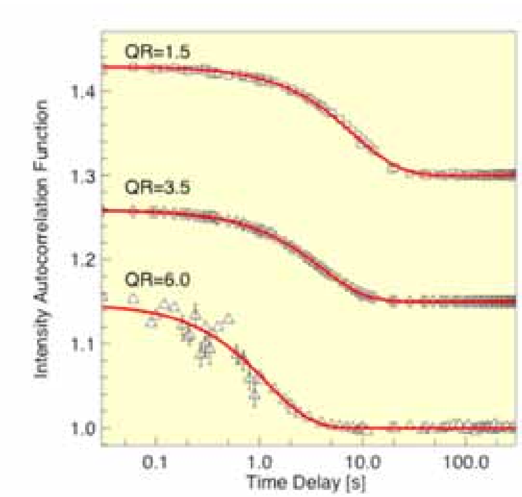
1. Noteworthy successes

- Domain coarsening in glasses
  - Fluctuations about evolution to a phase separated state in a sodium borosilicate glass
    [A. Malik et al., PRL 81, 5832 (1998)]
    - Dynamics measured in a non-equilibrium system
    - Pink-beam used in small-angle transmission geometry
      - One-and-only pink beam XPCS measurement from 8-ID
      - Time scales: > 1 s

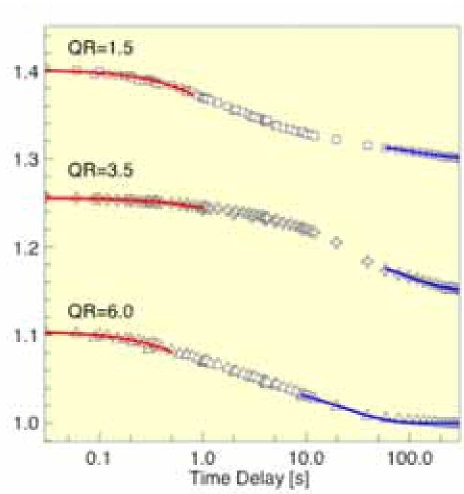


1. Noteworthy Successes

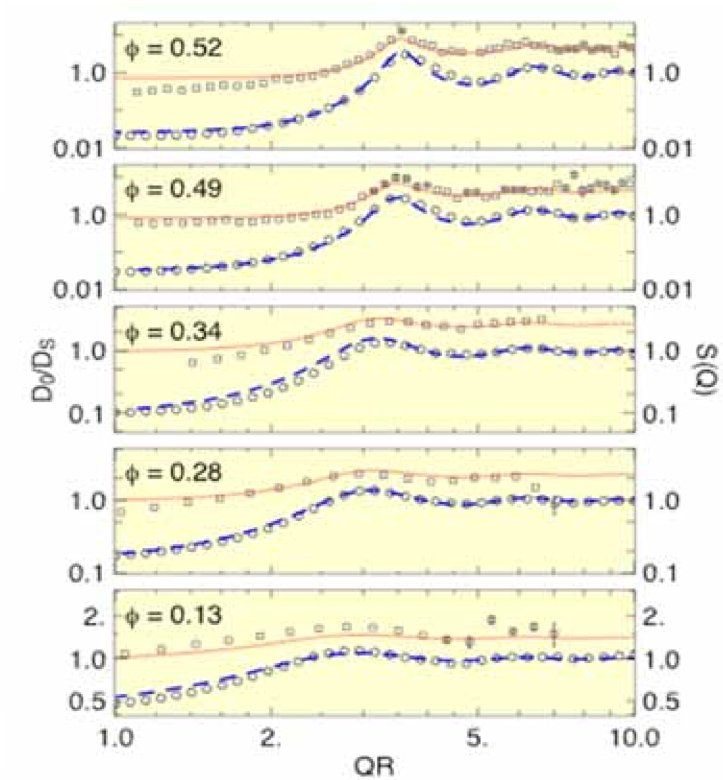
- Dynamics in concentrated hard-sphere suspensions
  - Correlation functions of sufficient quality to distinguish hydrodynamic corrections to diffusion of concentrated nanoparticles
  - [L. B. Lurio et al., PRL **84**, 785 (2000)]
    - Time scales: > 50 ms (kinetics)



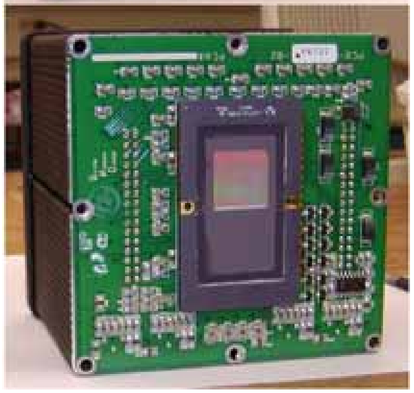
Dilute



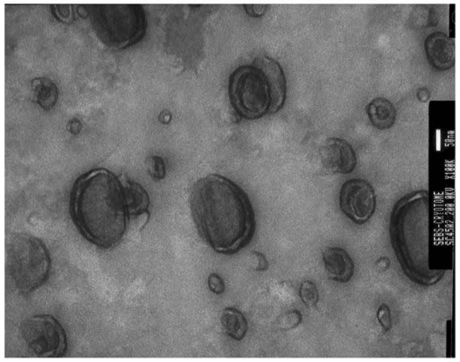
Concentrated

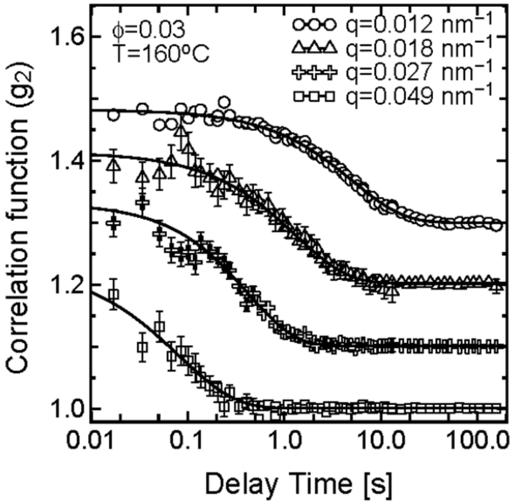


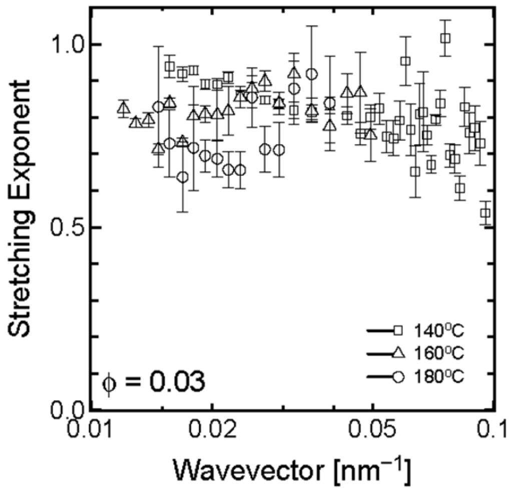
1. Noteworthy Successes



- Dynamics of block copolymer vesicles
  - Membrane fluctuations in a tri-block homopolymer mixture
    - Rapidly fluctuating speckle patterns
    - Correlation functions of sufficient quality to see stretched (2/3) exponential decays
  - Home-built SMD/Dalsa fast direct-detection detector
  - [P. Falus et al., PRL **94**, 016105 (2005) and P. Falus et al., RSI **75**, 4383 (2004)]
    - Time scales: > 10 ms







1. Noteworthy Successes

- Fluctuations about the evolution to equilibrium
  - Fluctuations in a phase ordering system [A. Fluerasu et al., PRL **94**, 055501 (2005)]
- Aging at the nanoscale
  - Nanoscale dynamics versus aging time vis-à-vis structure (Leheny et al., several publications)
- Heterodyne XPCS
  - Heterodyne methods to track flow and fluctuations within flow at the nanoscale [F. Livet et al., J. Synch. Rad **13**,453 (2006)]
- Polymer surface and interface experiments of increasing sophistication
  - Thick films, thin films, buried interfaces, wave-guide enhancements, temperature ≈ T_g (Z. Jiang, H. Kim, J. Lal, L. Lurio, S. Narayanan, S. K. Sinha)
- Re-entrant glass
  - Dynamics of repulsive and attractive glass phases and a novel "liquid" phase in between [X. Lu et al., PRL **100**, 045701 (2008)]
- Metal surface fluctuations
  - Dynamics in the reconstruction of Au(001) versus temperature [M. Pierce et al., PRL **103**, 165501 (2009)]

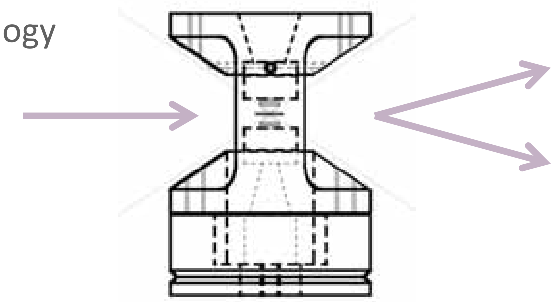
Trends and Future Directions

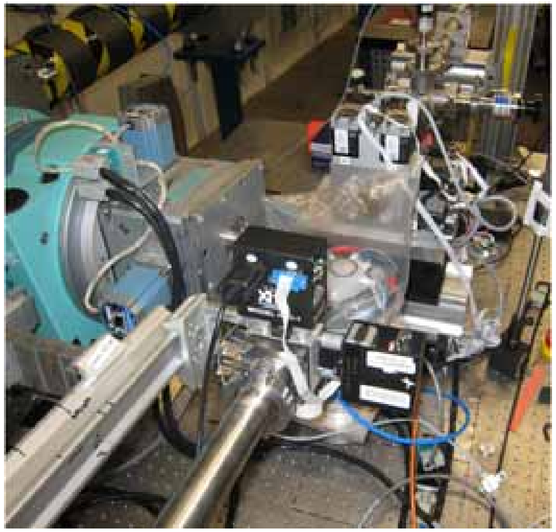
- Observations
  - Temperature and sample composition have been the main independent variables
  - Area detectors have enabled quantitative g_2 measurements
    - Non-equilibrium
    - Aging, jamming
  - Results to-date have been achieved with
    - Essentially no increase in effective brilliance (no focusing)
    - Little change in detector throughput
      - SMD/Dalsa detector is an exception
  - 8-ID science cases have largely been ignored

- For the future examine
  - Variables other than temperature and sample composition
  - Bleeding-edge experiments
  - Too-hard or too-scary experiments
  - 8-ID sciences cases
  - Large wave-vector transfer XPCS
    - Largely untapped - over last 12 years: 3 publications, 1 in press and 2 under review
      - Flux levels make for very challenging experiments
      - High resolution (coherent) beam reveals new features in the diffraction pattern

Future Directions: Bleeding Edge and Too-Hard

- Variables other than temperature or composition
  - Shear
    - Connection between nanoscale dynamics and bulk rheology
      - W. Burghardt, S. Narayanan, M. Sikorski, …
  - Pressure
    - Pressure-driven structure fluctuations
      - W. Yang
  - Environment
    - Electrochemistry, catalysis
      - M. Pierce, H. You
  - Confinement
  - Biophysics
    - A. Fluerasu, L. Lurio, S. G. J. Mochrie

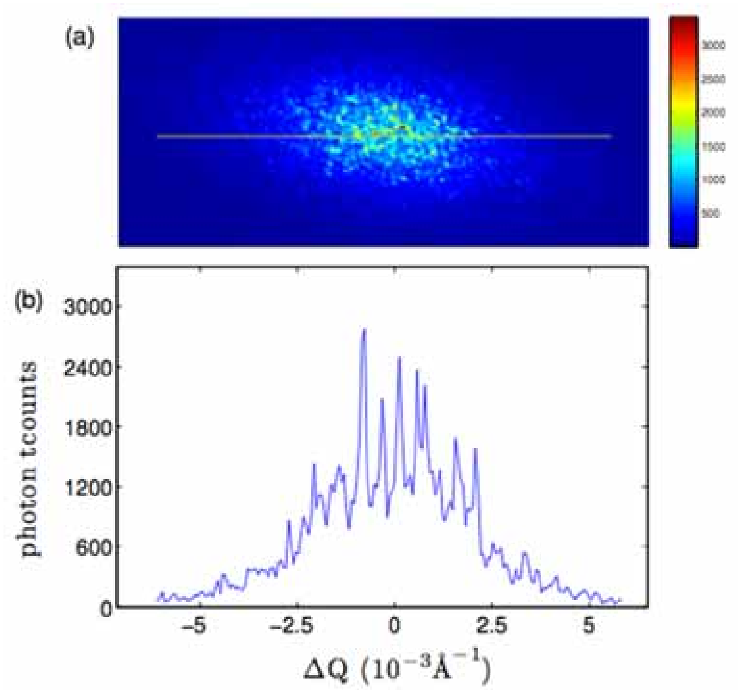




- Above experiments benefit from higher x-ray energies and require considerably more brilliant sources: $F_c = B(\lambda/2)^2$

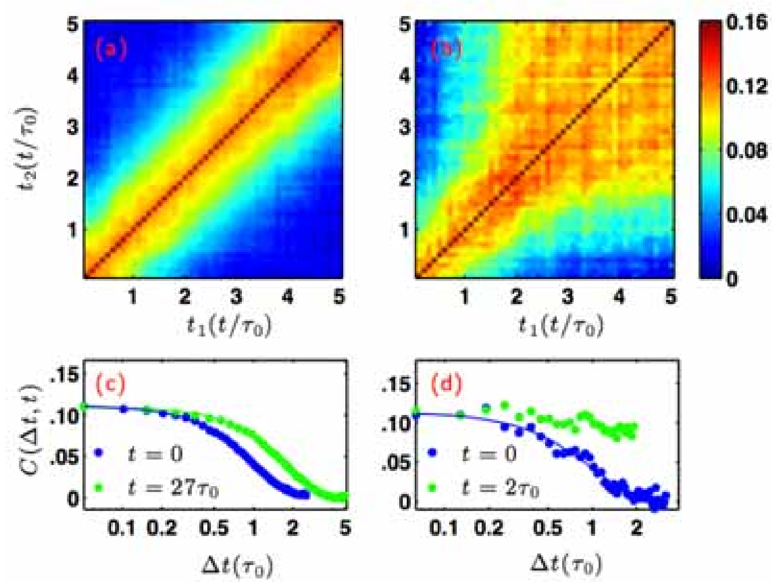
Future Directions: Bleeding Edge and Too-Hard

- Large wave-vector XPCS
  - Charge-density waves
    - Charge-density wave peak studied in incommensurate phase of 1*T*-TaS_2 in pure and Ti doped samples [J. Su, A. Sandy (ANL), M. Sutton (McGill)]
      - CDW speckle patterns from properly annealed samples are static meaning no spontaneous phase fluctuations (phasons)

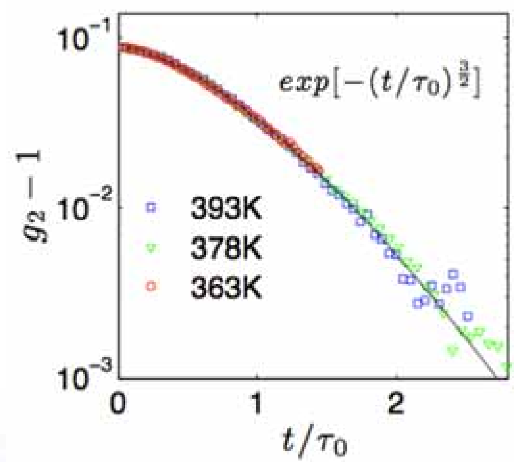


Future Directions: Bleeding Edge and Too-Hard

- Charge-density waves
  - Charge-density wave peak studied in incommensurate phase of 1*T*-TaS_2 in pure and Ti doped samples …
    - Annealing deeply-quenched (freshly-prepared) samples yields transient dynamic speckle patterns
    - Transient effects are damped out more rapidly in more strongly doped samples

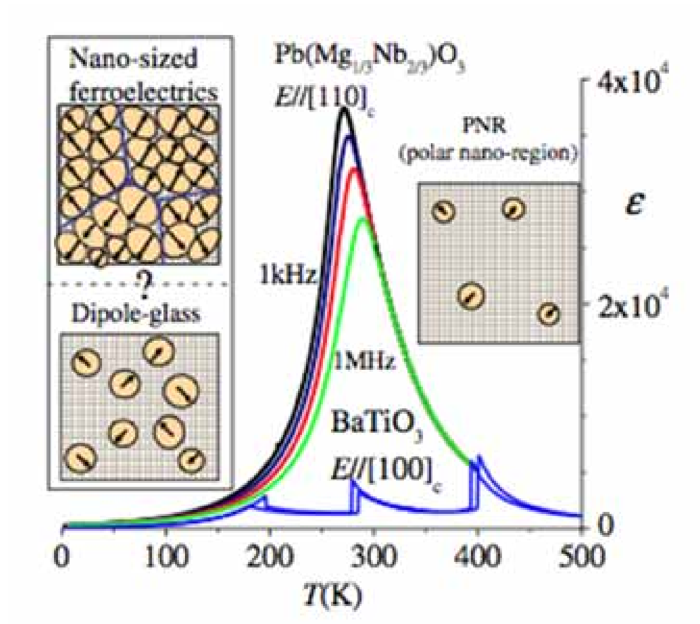


- Correlation functions are compressed exponentials suggestive of collective re-arrangement of CDW phase domain walls
- ERL would enable
  - » Wave-vector- and spatially-resolved motion of phase domains
  - » Other CDW's



Future Directions: Bleeding Edge and Too-Hard

- Large wave-vector XPCS
  - Relaxor Dynamics
    - Ferroelectric material that displays a large dielectric response to an applied field
      - Response to driving fields is large and temperature and frequency dependent
      - Origin of response has been studied for decades but remains controversial
      - $Pb(Mg_{1/3}Nb_{2/3})O_3$ (PMN) is a prototypical example
        - » Polar nano-regions (PNR's) believed to exhibit either a static dipole glass at low temperature or nano-sized ferroelectric domains



Fu et al., PRL **103**, 207601 (2009)

Future Directions: Bleeding Edge and Too-Hard

- Additional large Q possibilities
  - Glassy condensed matter
    - Spin ice (S. K. Sinha)
      - Frustrated ferromagnetic state with glassy behavior at low temperatures
  - Orientational glasses
    - I.e., $(KBr)_{1-x}(KCN)_x$ or $(KCl)_{1-x}(KCN)_x$
      - KCN molecules orient locally and freeze their orientations low temperatures
        - » Use XPCS to examine this transition

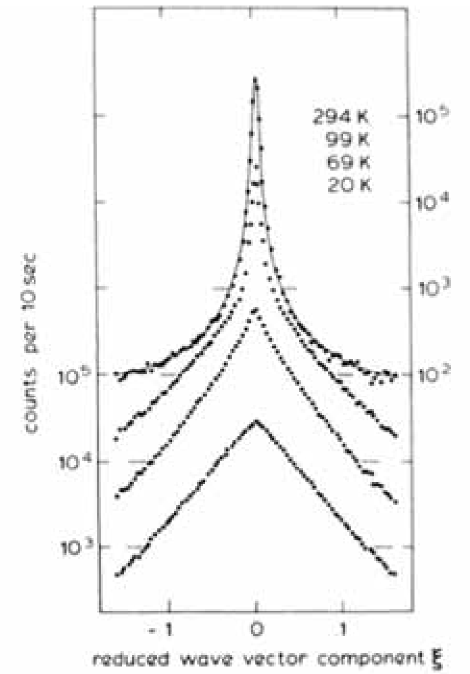
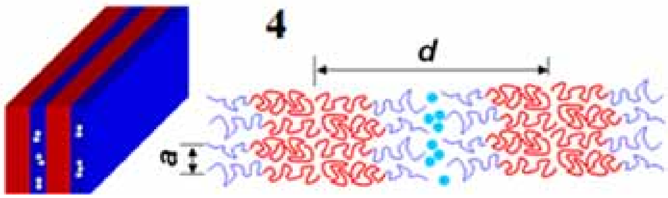


FIG. 1. The (2ξ0) profiles of $(KCl)_{0.2}(KCN)_{0.8}$ shown on a logarithmic intensity scale. The left scale refers to the 20-K data, and the right one to the 294-K data. The profiles are shifted by one order of magnitude with respect to each other. The ticks mark the 10^3 level for each run. The solid line of the high-temperature profile results from the superposition of a δ-like Bragg spike and diffuse intensity $I \sim \xi^{-2}$, folded with the experimental resolution and fitted to the data. The linewidth at 294 K is 0.0057 in ξ or 0.17° in the rocking angle (FWHM).

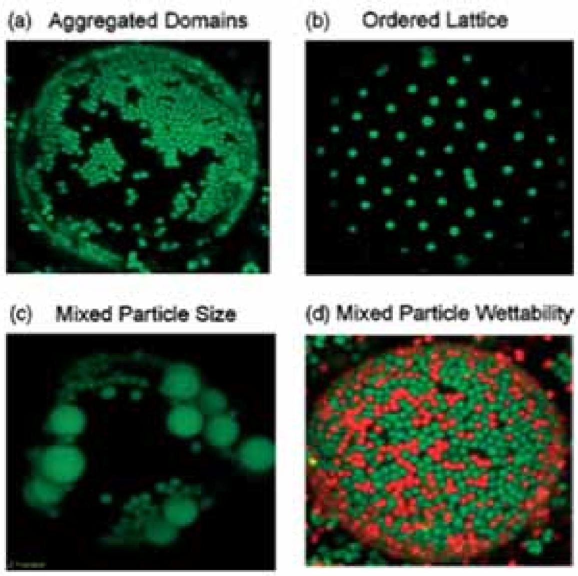
K. Knorr and A. Loidl, PRL **57**, 460 (1986)

Future Directions: Bleeding Edge and Too-Hard

- "Nanoparticle" dynamics
  - Confinement
    - Nanoparticles segregated at interfaces
      - Block copolymers
      - Pickering emulsions
      - Liquid surfaces or interfaces (doped lamellar phases)
    - ERL high brilliance to overcome weak scattering contrast
  - Biophysics
    - Protein solutions
      - Eye-lens protein (L.B. Lurio and G. Thurston)
      - Protein gelation
    - ERL high brilliance extended to higher energies mitigates damage and probes fast dynamics

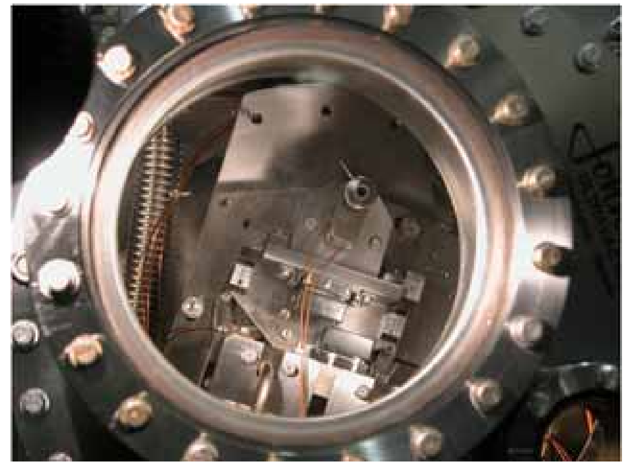


B. Lee et al., unpublished



L. Dai et al., Scanning **30**, 87 (2008)

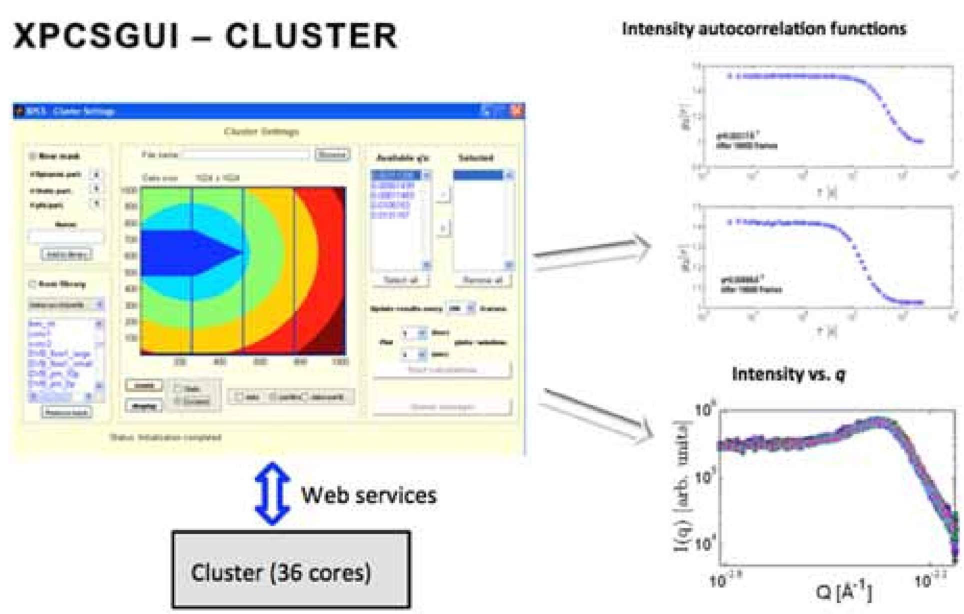
Ancillary Items



- Stable, brilliance-preserving beamline optics
  - APS ➔ LCLS ➔ ERL

  (S. Narayanan et al., J. Synch Rad. **15**, 12 (2008).

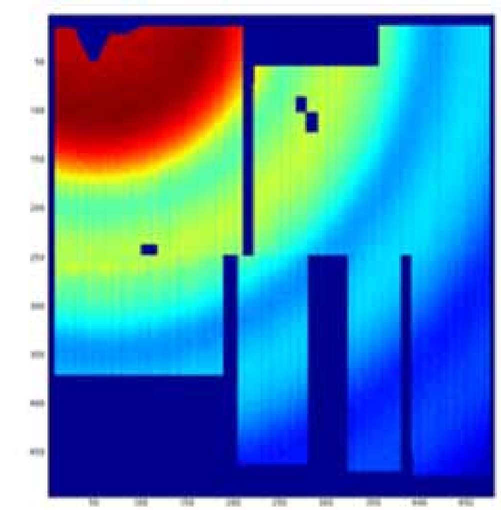
- User-friendly and powerful XPCS data discrimination and reduction tools
  - Makes XPCS facilities accessible to users

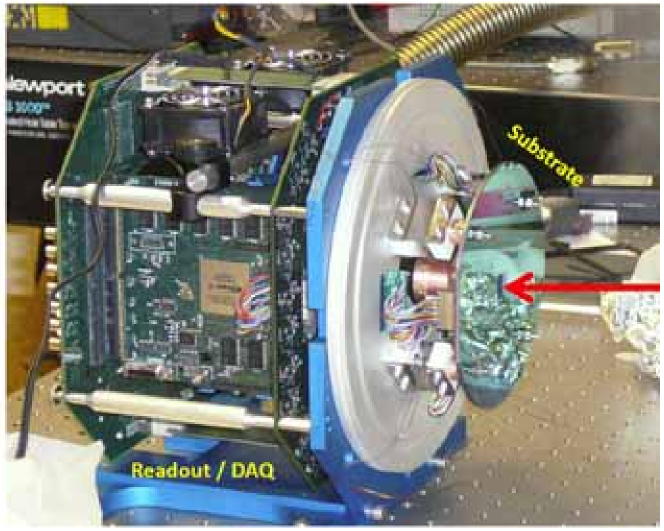


M. Sikorski, Z. Jiang, M. Sprung, S. Narayanan, A. R. Sandy, and B. Tieman, *"A graphical user interface for real-time analysis of XPCS using HPC", Nucl. Instr. And Meth. A (in press).*

Ancillary Items

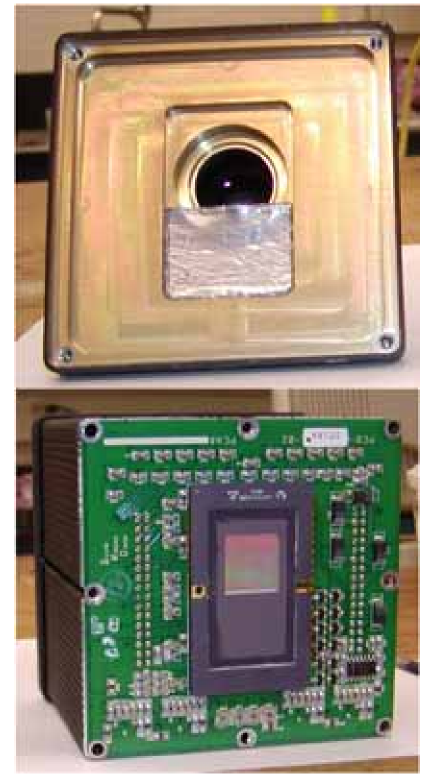
- Stable and long-term support for detector development to support advanced x-ray sources (and XPCS) is a critical need!





LBL-ANL Fast CCD v. 1.0 (2004-2010)
- 140 (0.25 Mpix) fps digitization
- (v2.0 soon? – 200 (1 Mpix) fps

Maxipix (2010)
- 1400 (0.06 Mpix) fps digitization



SMD (2004)
- 60 (1 Mpix) fps digitization

Acknowledgements

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  - Zhang Jiang
  - Suresh Narayanan
  - Marcin Sikorski
  - Joe Strzalka
  - J.-D. Su

- The many 8-ID Users