COHERENT HARD X-RAY (CHX)

BROOKHAVEN NATIONAL LABORATORY

NATIONAL SYNCHROTRON LIGHT SOURCE II

SCIENTIFIC SCOPE

Studies of the interplay between equilibrium and/or non-equilibrium *nano-* and *meso-scale dynamics*, *structure* and *macroscopic properties* in:

- soft matter and biological materials: colloids, polymers, nano-composites, glasses and gels, liquid crystals, liquid and polymer surfaces and interfaces, proteins
- Inorganic materials: metallic glasses, phase ordering crystals, ferroelectrics
- driven and out of equilibrium systems: complex fluids under flow/shear, polymer nano-composites under stress/strain
- heterogeneous systems: time- and space-resolved dynamical heterogeneities

Overview

PORT: 11-ID

SOURCE: undulator (IVU20)

ENERGY RANGE: 6 – 16 keV

COHERENT FLUX: 5×10^{11} ph/s @ 9.6 keV, 300mA

ENERGY RESOLUTION: $\Delta E/E = 10^{-4}$

future development: $\Delta E/E = 10^{-3}$

BEAM SIZE: 10 µm (SAXS), 2-3 µm (WAXS)

BEAMLINE STATUS: Open to users

BEAMLINE PHONE: 631.344.1411

BEAMLINE WEBSITE: https://www.bnl.gov/nsls2/beamline/11-ID

BEAMLINE CHARACTERISTICS

TECHNIQUES:

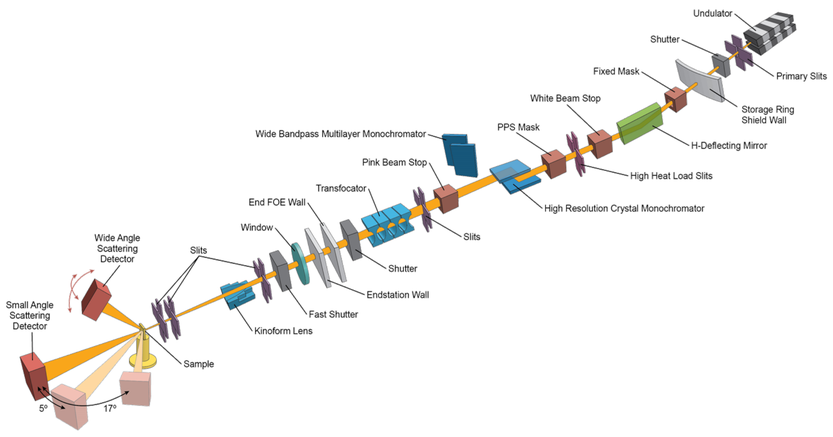
- X-ray Photon Correlation Spectroscopy (XPCS)
- X-ray Speckle Visibility Spectroscopy (XSVS)
- Coherent Scattering (SAXS, GI-SAXS, WAXS, GI-WAXS)
- Capabilities for Coherent Diffraction Imaging (CDI)

DETECTORS:

- **Eiger**: 1M (WAXS) and 4M (SAXS)
  - 75 µm pixel size
  - 1M: 3/9 kHz frame rate (12/4 – bit)
  - 4M: 0.75/2.2 kHz frame rate (12/4 – bit) possibilities for future upgrade 500k: 9 kHz (4 – bit)
- Timepix (time stamping resolution 20 ns)
- Avalanche Photo Diode

CHX at NSLS-II:

- Enables experiments with world leading coherent flux through a combination of high source brightness, wavefront preserving advanced focusing optics and state-of-the art detectors
- Signal-to-noise (SNR) in XPCS: *SNR ~ brightness x (time)$^{1/2}$*
- Hence: *10x increase* in brightness at NSLS-II enables measurement of *100x faster fluctuations* with same SNR
- Access to structural information ranging from *Ångstroms* to *microns*
- Data Analysis Tools: *https://github.com/NSLS-II-CHX*



Beamline Staff

Andrei Fluerasu
Lead Beamline Scientist
fluerasu@bnl.gov

Lutz Wiegart
Beamline Scientist
lwiegart@bnl.gov

Yugang Zhang
Scientific Associate
yuzhang@bnl.gov

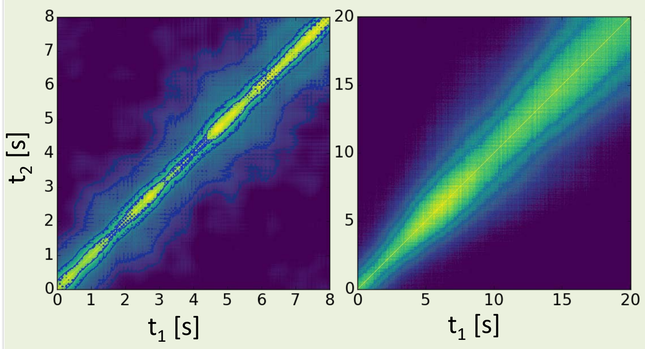
Apply for Beam Time

Beamlines at NSLS-II are available to all scientific researchers through a peer-review proposal process. For more information, see the NSLS-II Users' Guide at:

www.bnl.gov/ps/userguide/

EXAMPLES OF SCIENTIFIC APPLICATIONS

Non-equilibrium dynamics and self-organization in soft-matter systems:

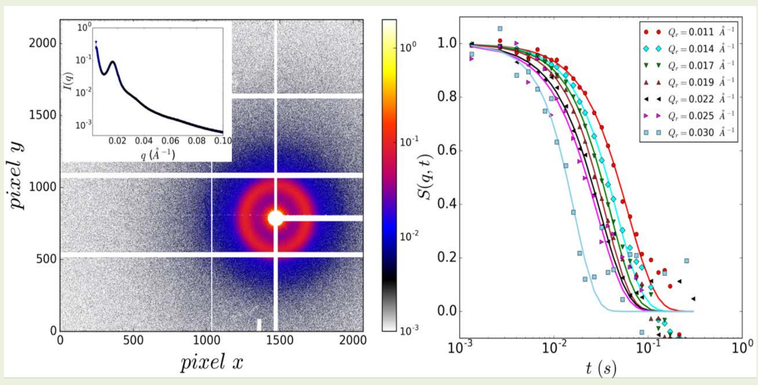


Two-time correlation functions showing heterogeneous dynamics (left) and non-equilibrium effects - "aging" (right) in colloidal systems

Studies of "Matter far beyond equilibrium" was recently identified as one of "Five challenges for science and imagination" in a report to the DOE by BESAC. The CHX instrument is ideally adapted to address this challenge. Experiments focus on understanding complex dynamics in non-equilibrium and driven (e.g. by flow/shear or strain) soft matter systems and the interplay between molecular scale structure, mesoscale dynamics, and macroscopic properties.

Revealing the Dynamics of Polymer Gels

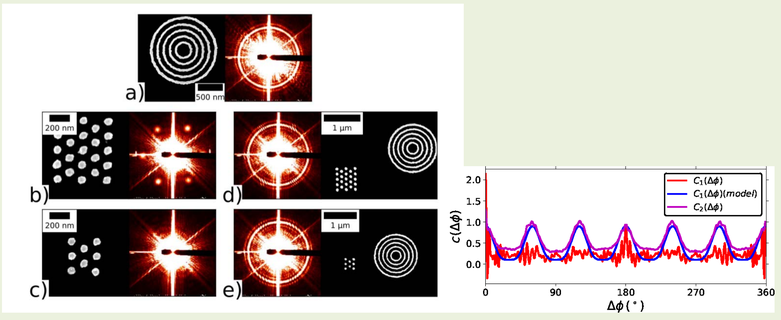
X-ray Photon Correlation Spectroscopy was used to study dynamics in transient networks of associative polymers. These materials are relevant to artificial skin and self-healing gels.



The world class coherent flux at the CHX beamline allowed the MIT-CHX team to obtain the *dynamic structure factor S(q,t)* at significantly smaller length scales ($q\sim0.03$ Å^{-1}) and shorter time scales ($t\sim10^{-2}$s) than previously recorded with similar polymers

B. Olsen *et al. (MIT, Chem. Eng.)*, unpublished (2017)

Unsolvable Structures Brought to Light: Coherent X-ray Amplification



Enables revealing structural information from week scatterers (e.g. here a lithographed 8 nano-dot mesocluster) even if the signal is below the background. The coherent interference between scattering from the sample and a reference object results in an increase in S/N. The structural information and the local (hidden) symmetries are obtained here through angular correlation functions.

J. R. Lhermitte *et al.*, *J. Appl. Cryst.* (2017) **50** *https://doi/org/10.1107/S1600576717003946*
J. R. Lhermitte *et al.*, *IUCRJ* (2017) accepted