Soft X-ray Lensless Imaging and Resonant Imaging Endstation
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Outline

- study of phase transitions – single shot experiments
- study of ultrafast electronic and spin dynamics – pump-probe experiments
- soft x-ray resonant imaging endstation (low fluence)
- plans for high fluence or single shot experiments
Solid state and its excitations

Electron-Lattice Dynamics
- Electron-phonon relaxation time
  \( \tau_{\text{cl}} \)
- Electron-spin relaxation time
  \( \tau_{\text{es}} \)
- Spin-lattice relaxation time
  \( \tau_{\text{sl}} \)

Magnetization Dynamics

E. Beaurepaire, et al.,
*PRL* 76, p4250 (1996)
X-rays see them all
Soft X-ray Fourier Transform Holography

Absorption Hologram
absorption reduced by order of magnitude for comparable image quality
Refractive Index
\[ n = 1 + i \pm + i \bar{n} \]

weak contrast
\[ t = 1 + i \bar{t} + i \bar{\Delta} \]
from pump – probe where time resolution is essential to imaging of critical fluctuations where number of photons is essential
FM - PM phase transition

\[ \hat{A} = \frac{1}{kT} P \ \pm^3 \pm^3 \]

Single shot at instant of time

\[ T_C = RT \]

\[ 5 \mu m \ 2.5 \text{ ML Co} \]
critical opalescence

\[ G(r) = kTc \langle(r) \rangle \cdot 10^{-2} \]

\[ \sim \frac{1}{|r|} e^{-|r|/\xi} \]

\[ T = 1.05T_c \quad T = 1.01T_c \]

\[ \frac{r}{\xi_0} \]

\[ kTc\chi(q) \]

\[ \chi(q) \propto \frac{1}{q^2 + \xi^{-2}} \]

\[ q \]

real space

reciprocal space
2D Ising Model

\((T_i - T_c) = T_c / 4 \times 10^3\)

\[
\chi(T) = \left( \frac{\xi(T)}{\xi_0} \right)^{\gamma/\nu}
\]

\(\langle T_c \rangle \approx 0.1 \times m\)

\[
\frac{\dot{\xi}(T_c)}{\dot{\xi}_0} = \left( \frac{\langle T_c \rangle}{\langle T_c \rangle_0} \right)^3, \quad z = 2
\]

\(\dot{\xi}(T_c) \approx 80 \times s\)
- Imaging magnetic fluctuations – need the full pulse intensity
- No “movie” possible, since the pulse drives the system out of equilibrium
- XPCS may then be possible using (cw) source with average high brightness
Correlated Materials

Electrons $\leftrightarrow \tau_{cl}$ Phonons

$\tau_{es}$ Magnetization $\tau_{sl}$
High-Tc superconductor


Electronic liquid crystal:
BL13-3 Coherent X-ray Scattering

Sample Environment

- a. Cryostat and sample holder
- b. in-vacuum CCD on linear stage
- c. Guard Apertures and magnet
- d. Coherence apertures / filters

Experiments

Soft X-ray coherent Scattering
- resonant, polarization dependent
- X-ray Holography, MAD Imaging
- X-ray Photon Correlation Spectroscopy

Specs:
- Energy range 200-1200 eV
- CCD N.A. = 0.031 - 0.545
- max. q at 800eV: 2.3 nm\(^{-1}\)
- 30nm resolution demonstrated at cryogenic temperatures

Covers important K and L edges for
- Polymers, Magnetic Nanostructures, Correlated Materials, Nanocrystals, Biominerals

SEM

FTH

superparamagnetic array of 18nm Fe/FeO nanocubes
Cryostat
15-350K

magnet
.1 T

beamstop

apertures/filters

CCD

Al
Commercial CCD
- 13.5um pixel size
- 2048x2048 pixels
- 2MHz pixel readout

for 850eV (1.46nm)
- 1.7nm image pixel size @ 30mm
- 18.5nm image pixel size @ 350mm

extras
- 1um Al cover (optical filter)
- movable beamstop
unfocused KB system
- <10uJ/cm²

focused KB system
- >10uJ/cm²
- reflecting beamstop
Timeline

- System using unfocused LCLS beam ready in July ‘09
- Testing at BL 13, SSRL before summer shutdown
The End