Shining light on matter

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- Use of coherence for lensless imaging of non-crystalline objects
- Microscopy of magnetic domains
- Use of ultrashort X-ray pulses for studies of dynamical processes

One exploits the high brilliance of 3rd generation synchrotron radiation sources
Transverse coherence

\[ \alpha = \frac{\lambda}{d} \]
\[ \alpha = \frac{\ell_t}{L} \]
\[ \ell_t = \frac{\lambda L}{d} \]

with \( \ell_t \) the transverse coherence length
Longitudinal coherence

\[ \ell_c = N\lambda_1 = (N - \frac{1}{2})\lambda_2 \]

\[ N = \frac{1}{2} \frac{\lambda_2}{\Delta\lambda} \]

\[ \ell_c = N\lambda_1 \approx \frac{1}{2} \frac{\lambda^2}{\Delta\lambda} \]
Incoherent scattering

Coherent scattering
Spatial Filtering

Airy pattern of 10 \( \mu \text{m} \) pinhole
\( h \nu = 1200 \text{ eV}, 10^7 \text{ ph/s} \)

J. Peters, J.B. Goedkoop et al.
Direct inversion of diffraction patterns
or
'solving the phase problem'

Larger no-density region

More oversampling of the diffraction pattern

$2\pi/a$
Gerschberg-Saxton algorithm for phase retrieval

At start: Assign phases

Impose real-space constraints → Fourier transform

Inverse Fourier transform ← Impose Fourier space constraints

Recovery criterion

yes

no

Solution
Simulated single-molecule diffraction images and their inversion

J. Miao, K.O. Hodgon and D. Sayre,
PNAS 98 (2001) 6641-6645
3D X-ray diffraction microscopy


Two buried Ni patterns separated in depth by 1 µm

Speckle pattern

Reconstructed image
Resolution ca 8 nm
Stick-slip in boundary lubrication

sticking

slipping, film melts
Confinement-induced density oscillations

\[ \rho(x) \]
Confined colloid

M.J. Zwanenburg et al, PRL 85 (2000) 5154
Colloids in waveguide

Particle radius 110 nm

W = 655 nm

W = 310 nm
Focusing X-ray beams to nanometer dimensions
What is the smallest spot size?

Spot size $\sim 0.64 \lambda/2\theta_c$

With $\theta_c$ critical angle for total reflection

C. Bergemann et al
Make small line focus by using mode mixing and interference
Focus in 2D by use of hollow capillary
Photoemission electron microscopy (PEEM)

- Elemental composition
- Chemical bonds
- Structural parameters
- Electronic structure
- Magnetic properties

Schematic layout of the PEEM

- Circularly polarized X-ray beam
- Helicity + or -
- Electrostatic lenses
- High voltage
- CCD
GMR effect - tunnel junction

Magnetization in applied external field (hysteresis loop)
Imaging of magnetic domains on both sides of interface

1:1 correlation of domain structure

LaFeO$_3$ layer

XMLD
Fe L$_3$

Co layer

XMCD
Co L$_3$/L$_2$

Exchange bias systems

Current

FM free layer
PM spacer
FM pinned layer
AFM layer

XMCD image (L3/L2)
FOV = 20 micron

210 nm dots

L. Heyderman, F. Nolting, P. Fischer (MPI-MF, Stuttgart)

20 µm
Nanomagnetism and dynamics

Smaller dimensions
(500 – 2) nm

Dynamics
1 s – 100 ps
pump-probe technique

time-resolved studies of micro- and nano-sized magnetic systems
Time resolved studies in the ps and fs domain

- Ultrafast photochemical reactions
- Solvent-solute structural dynamics
- Structural dynamics in biological systems
- Order-disorder phenomena in condensed matter
- Magnetisation dynamics in microdomains
Generating 50-100 fs pulses by electron beam slicing

30-ps Electron Bunch

Electron-Photon Interaction in Wiggler

Femtosecond Laser Pulse

Femtosecond Electron bunch

Femtosecond X-Rays

Spatial Separation Dispersive Bend

Bend-Magnet Beamline

R.W.Schoenlein et al.
Science 287 (2000), 2237

Projects at ALS, SLS, BESSY, SOLEIL
Electron beam slicing at the SLS

G. Ingold et al
Have we got any intensity left?