Shining light on matter

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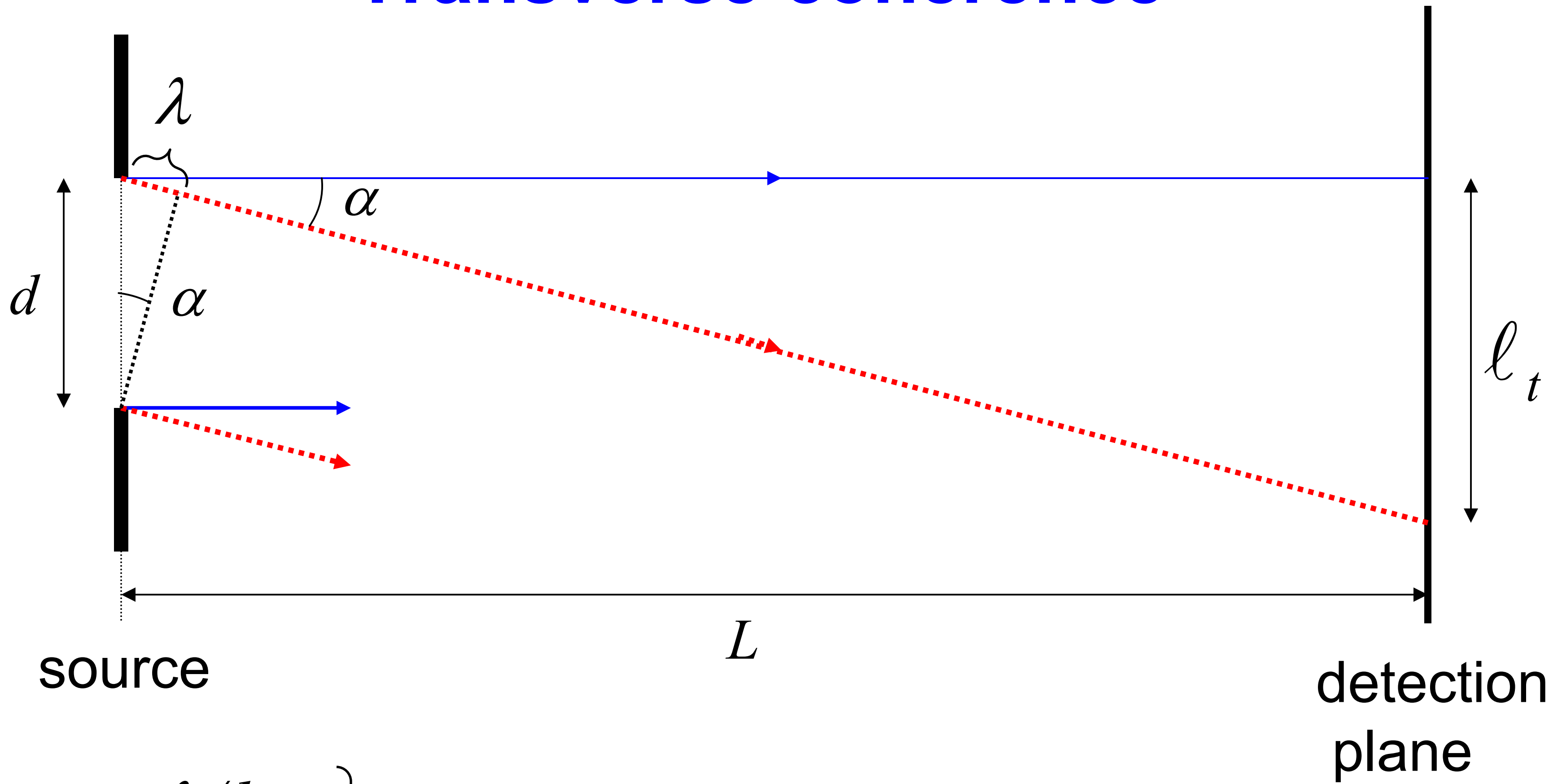
- Use of *coherence* for lensless imaging of non-crystalline objects
- *Microscopy* of magnetic domains
- Use of ultrashort *X-ray pulses* for studies of dynamical processes

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

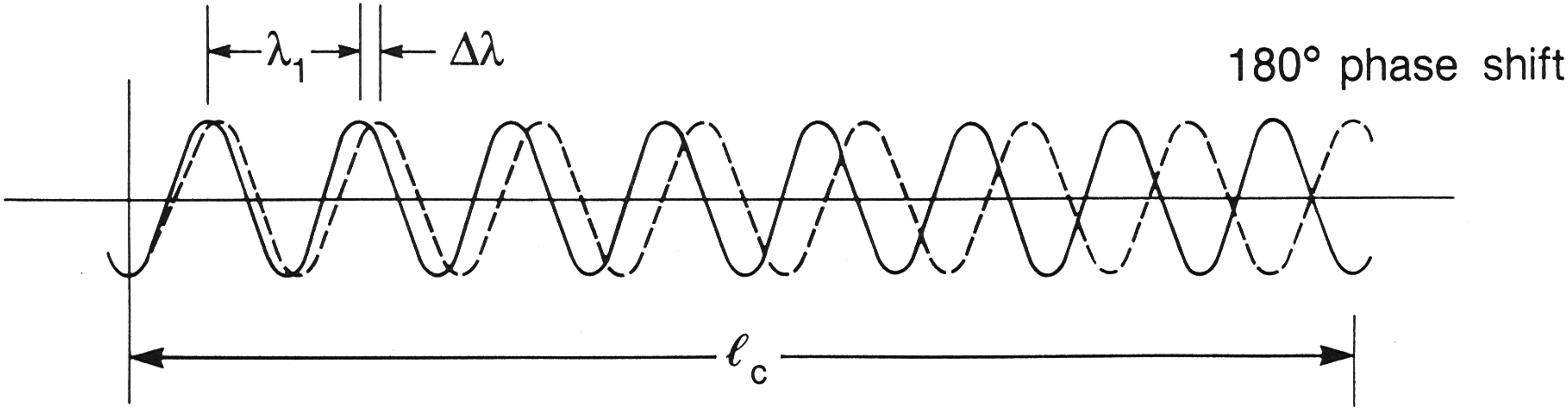
Transverse coherence



$$\left.\begin{aligned} \alpha &= \lambda/d \\ \alpha &= \ell_t / L \end{aligned}\right\} \quad \ell_t = \lambda L/d$$

with ℓ_t the transverse coherence length

Longitudinal coherence

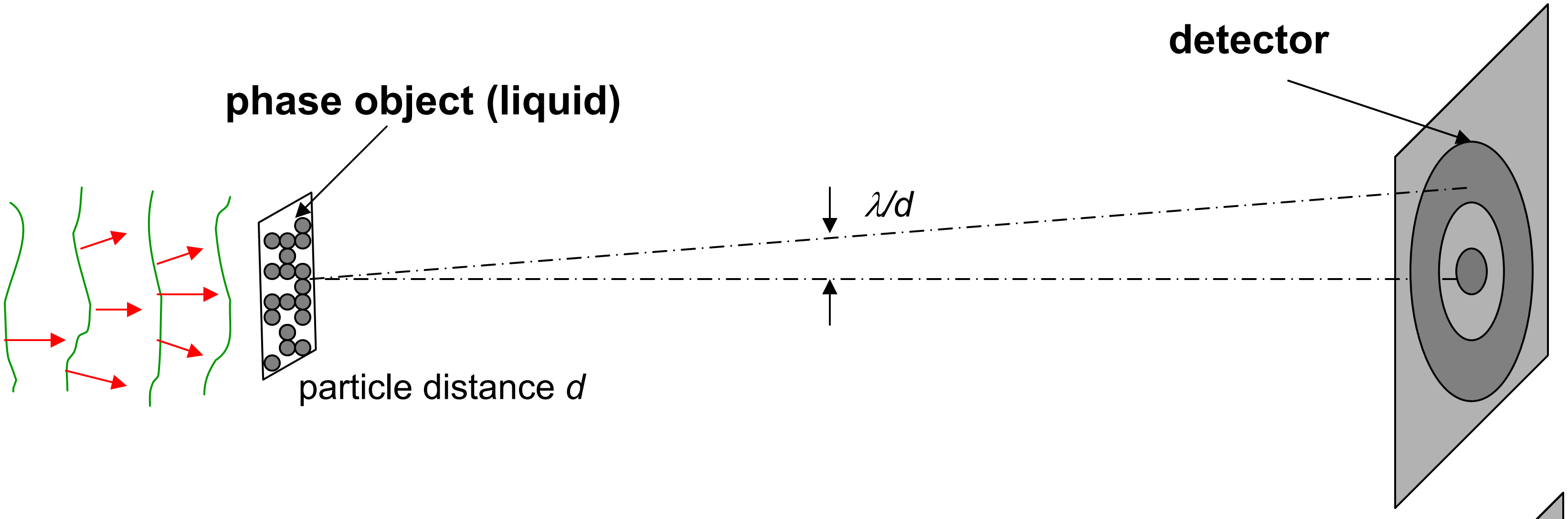


Definition: $\ell_c = N\lambda_1 = (N - \frac{1}{2})\lambda_2$

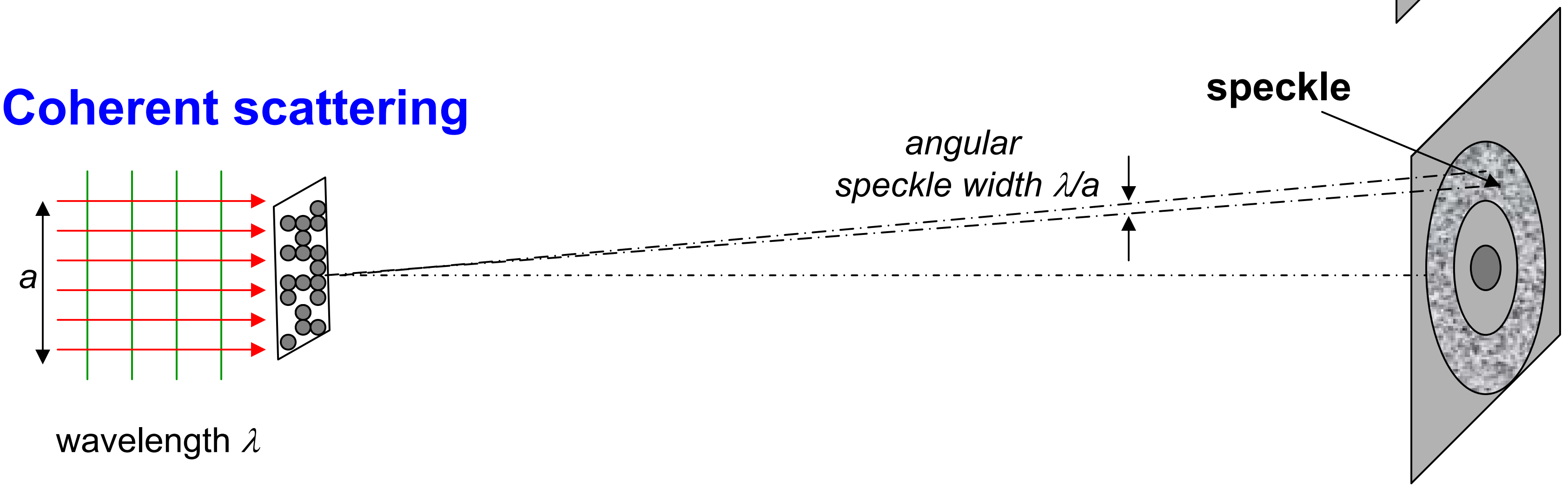
$$N = \frac{1}{2}\frac{\lambda_2}{\Delta\lambda}$$

$$\ell_c = N\lambda_1 \simeq \frac{1}{2}\frac{\lambda^2}{\Delta\lambda}$$

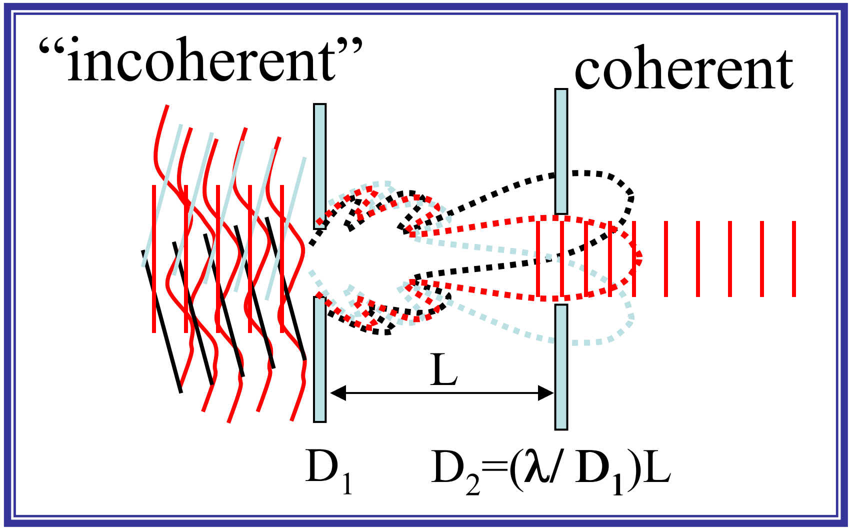
Incoherent scattering



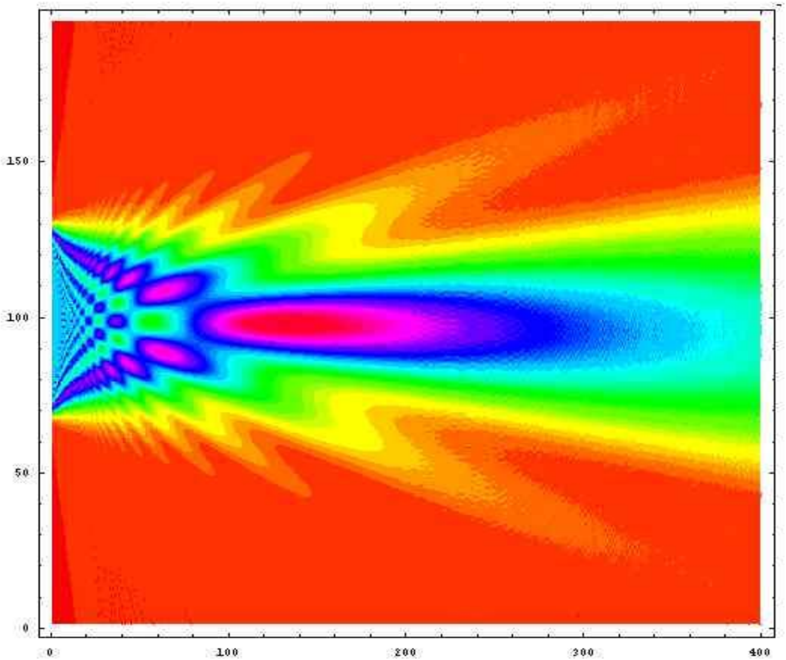
Coherent scattering



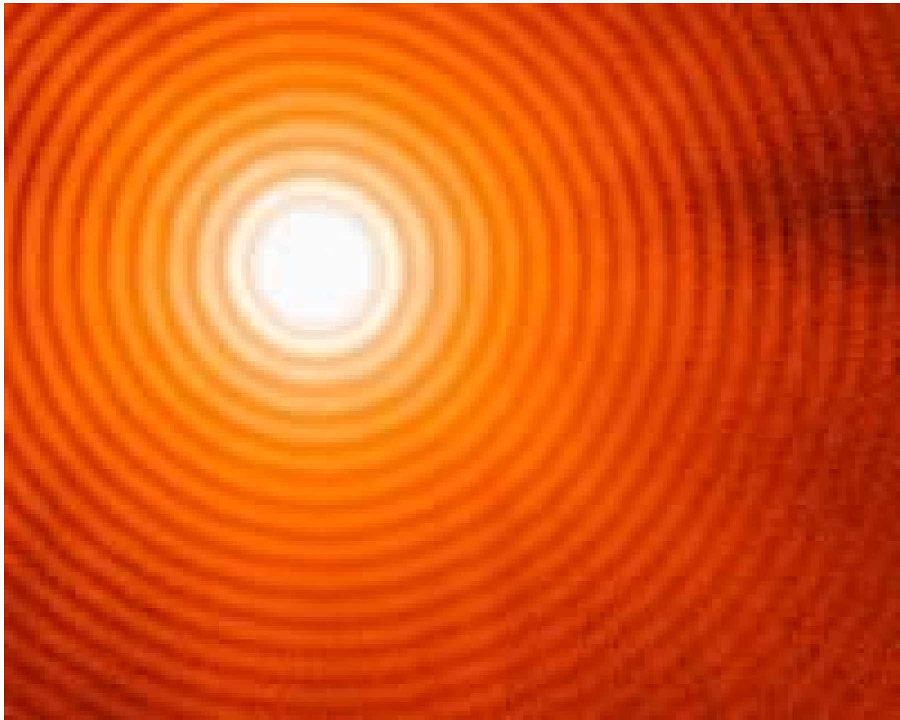
Spatial Filtering



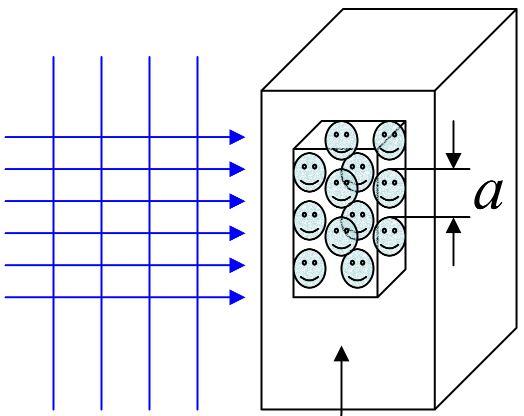
Airy pattern of 10 μm pinhole
hν = 1200 eV, 10^7 ph/s

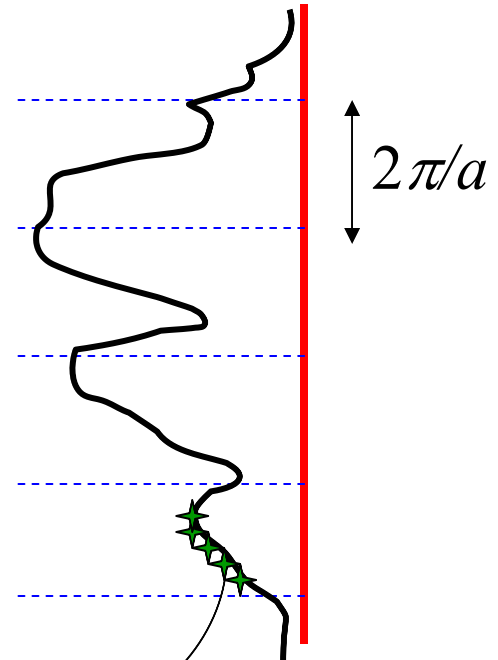


J. Peters, J.B. Goedkoop et al.



Direct inversion of diffraction patterns
or
'solving the phase problem'

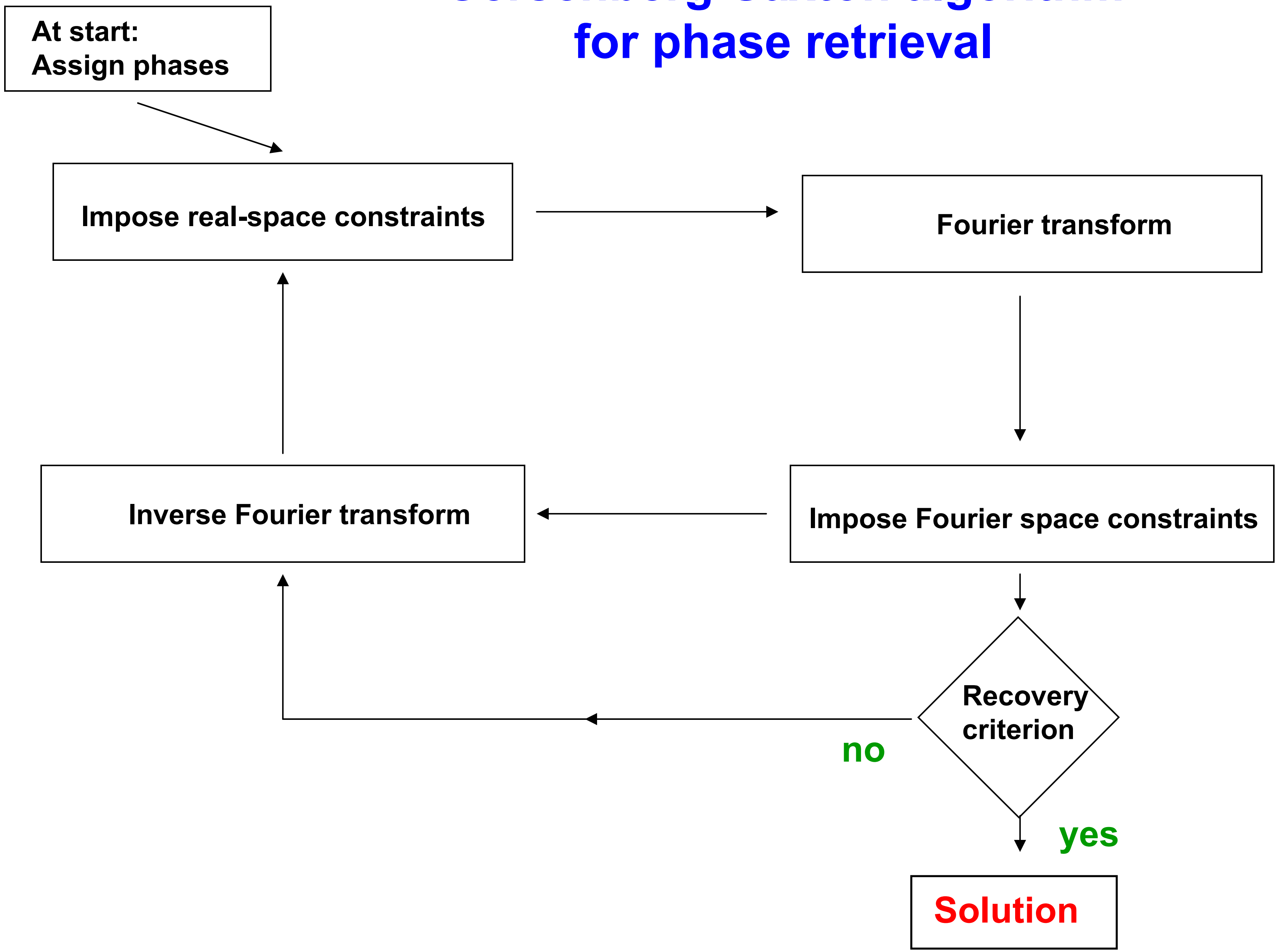




Larger no-density region

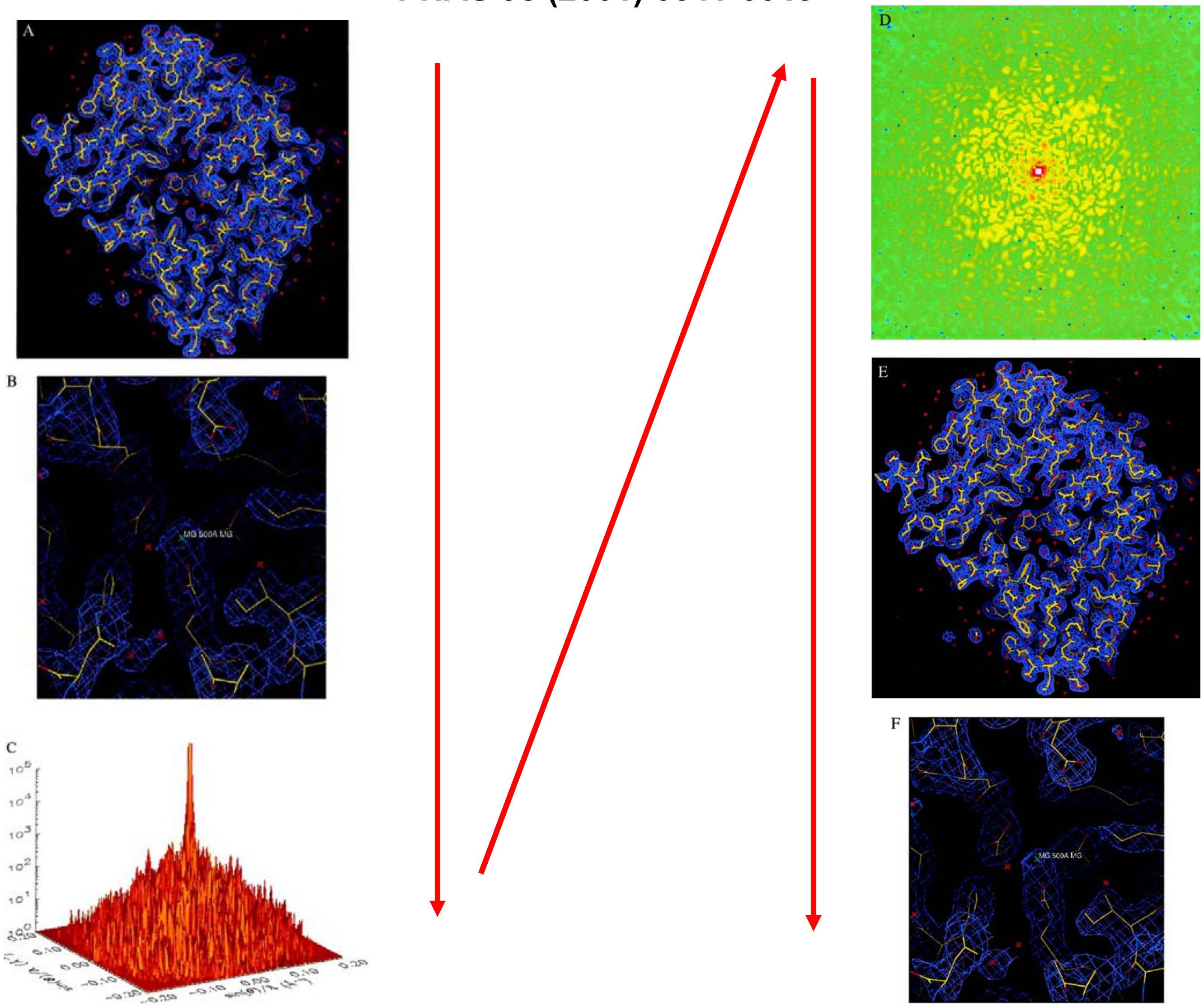
More oversampling
of the diffraction pattern

Gerschberg-Saxton algorithm for phase retrieval



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

J. Miao et al, PRL 89 (2002) 88303

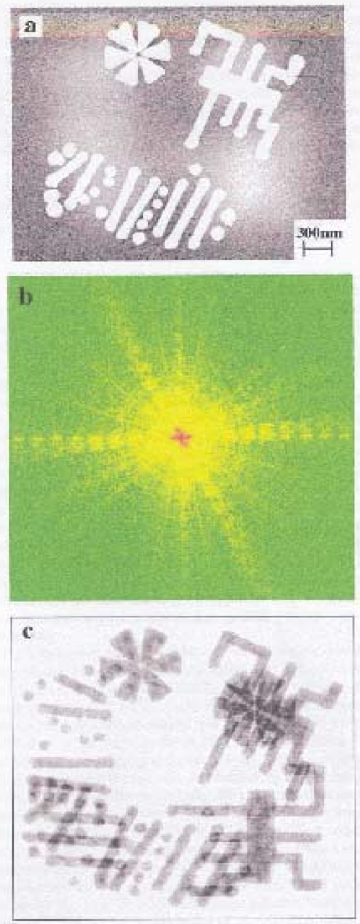


FIG. 1 (color). (a) A SEM image of a Ni sample with buried structures, (b) A high resolution diffraction pattern (a 1760 × 1760 pixel array) recorded from the sample. (c) A high-resolution image reconstructed from (b).

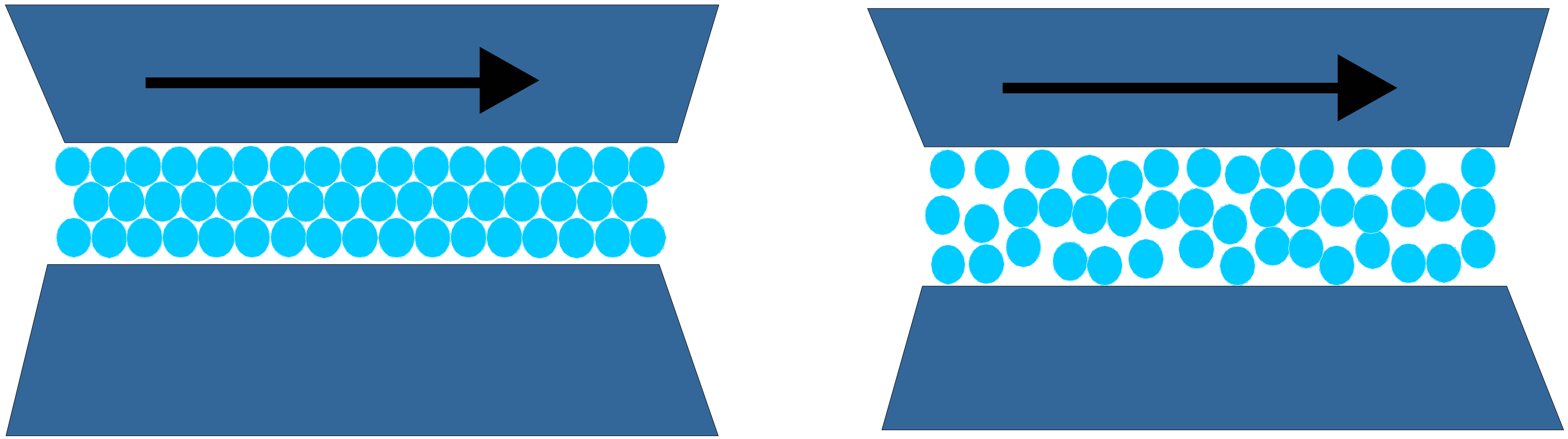
088303-2

Two buried Ni patterns separated in depth by 1 μm

Speckle pattern

Reconstructed image
Resolution ca 8 nm

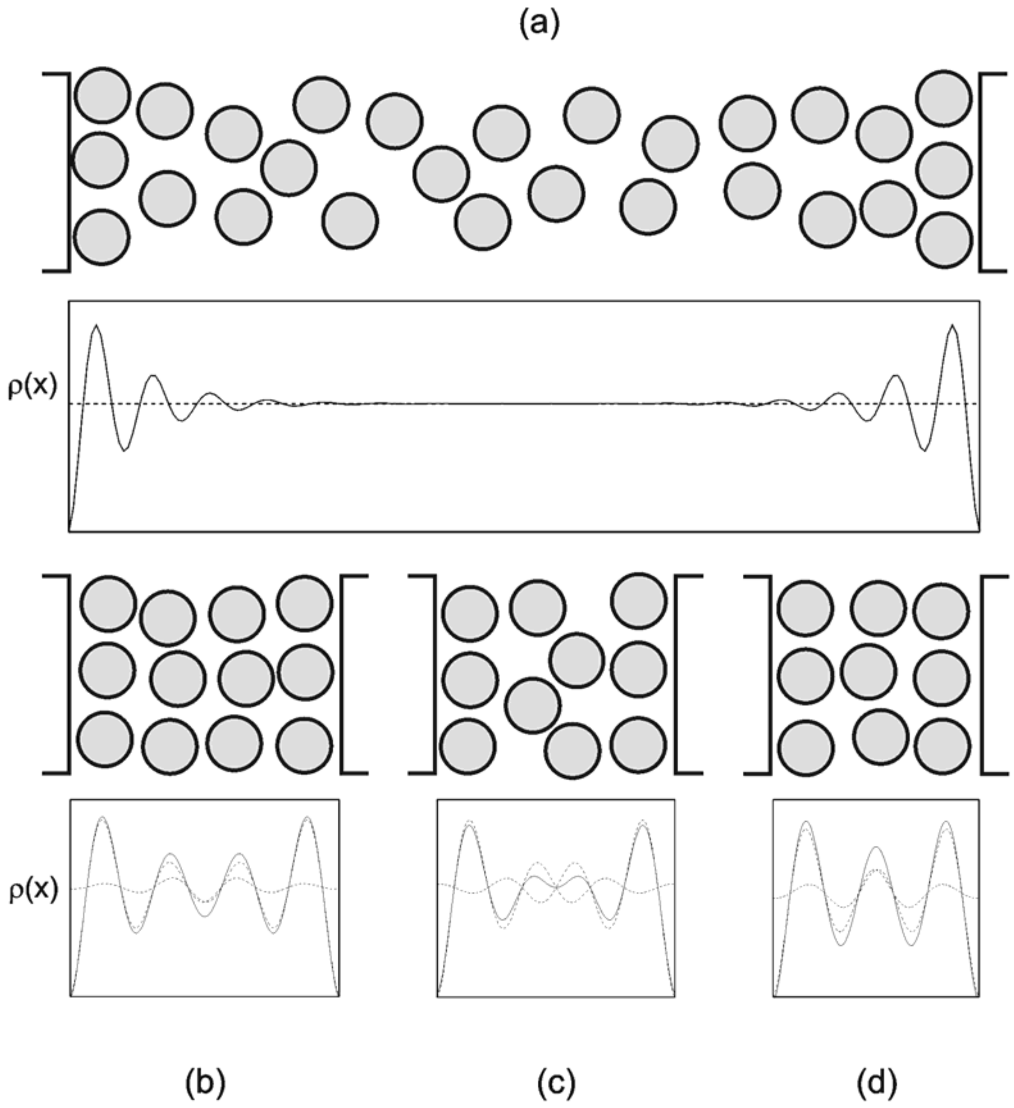
Stick-slip in boundary lubrication



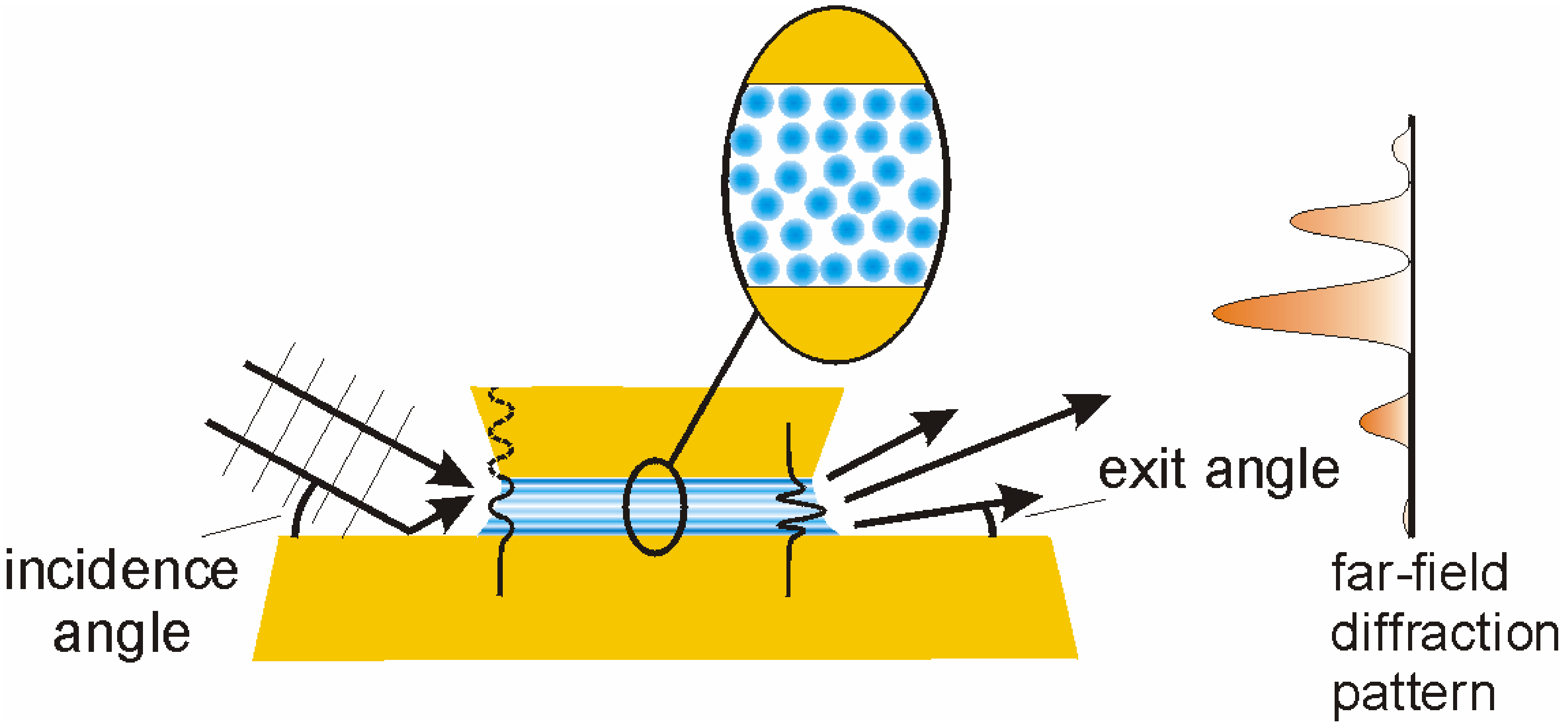
sticking

slipping,
film melts

Confinement-induced density oscillations

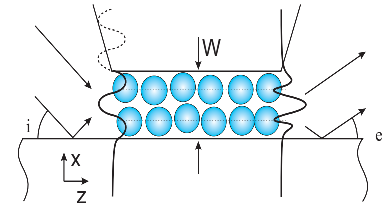


Confined colloid

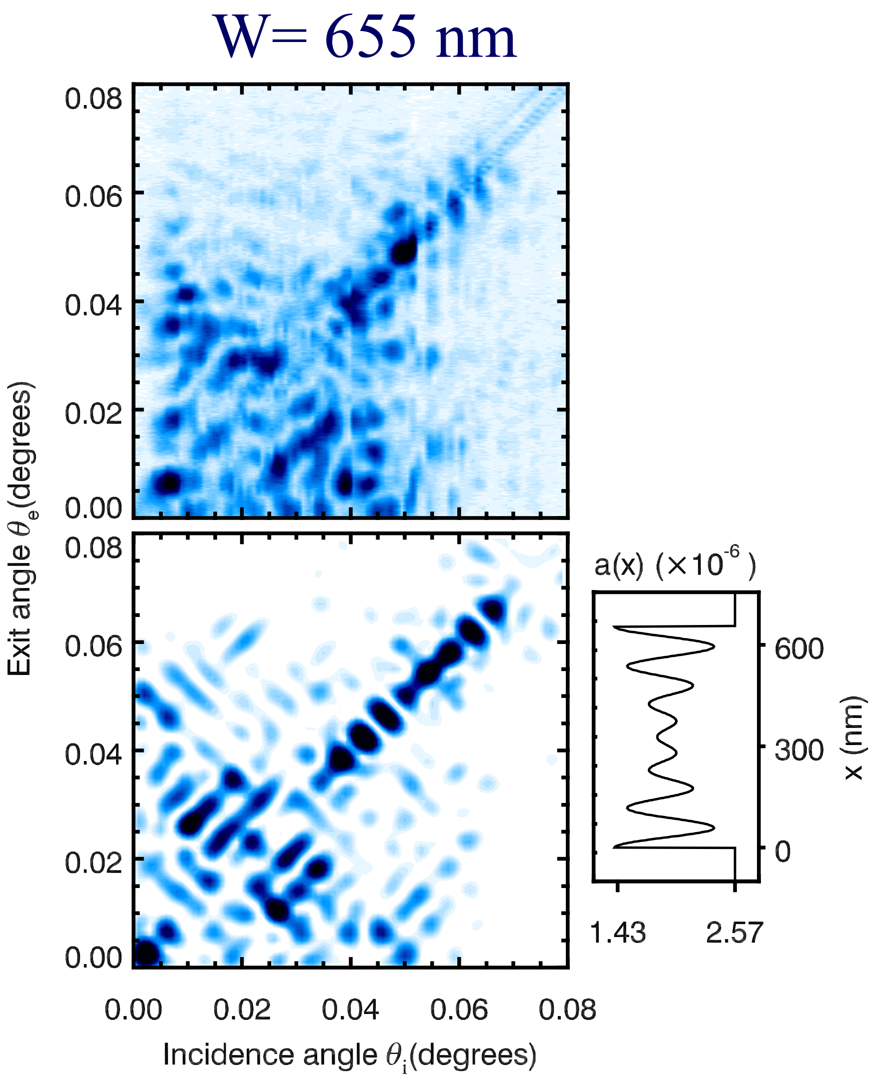


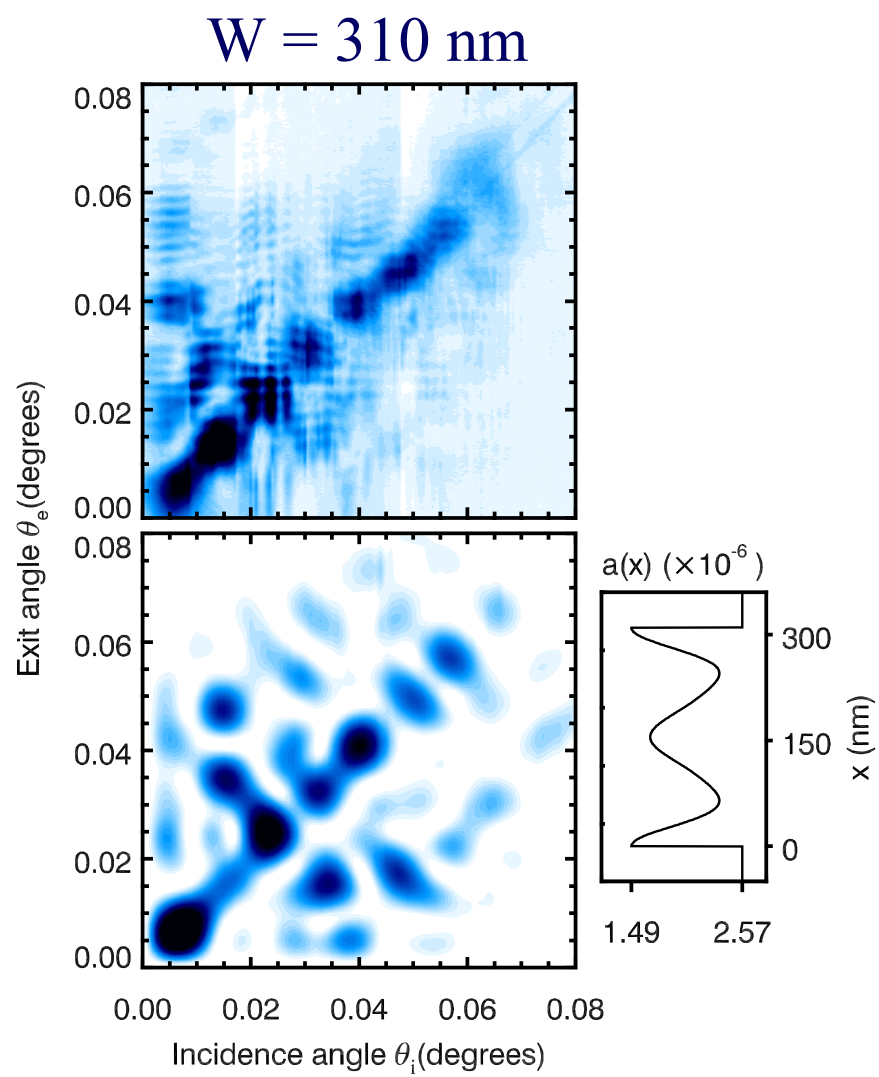
M.J. Zwanenburg et al, PRL 85 (2000) 5154

Colloids in waveguide

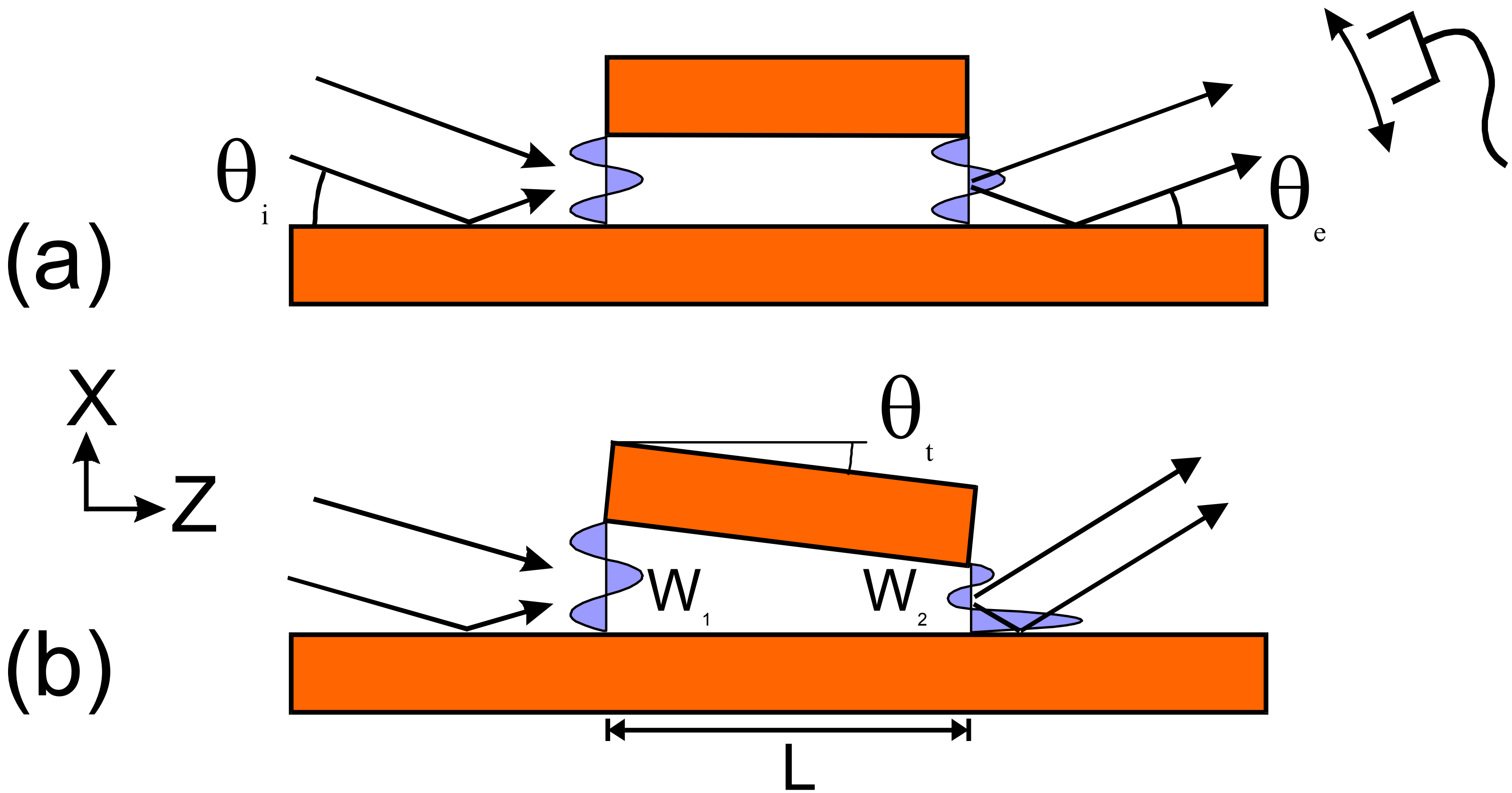


Particle radius 110 nm

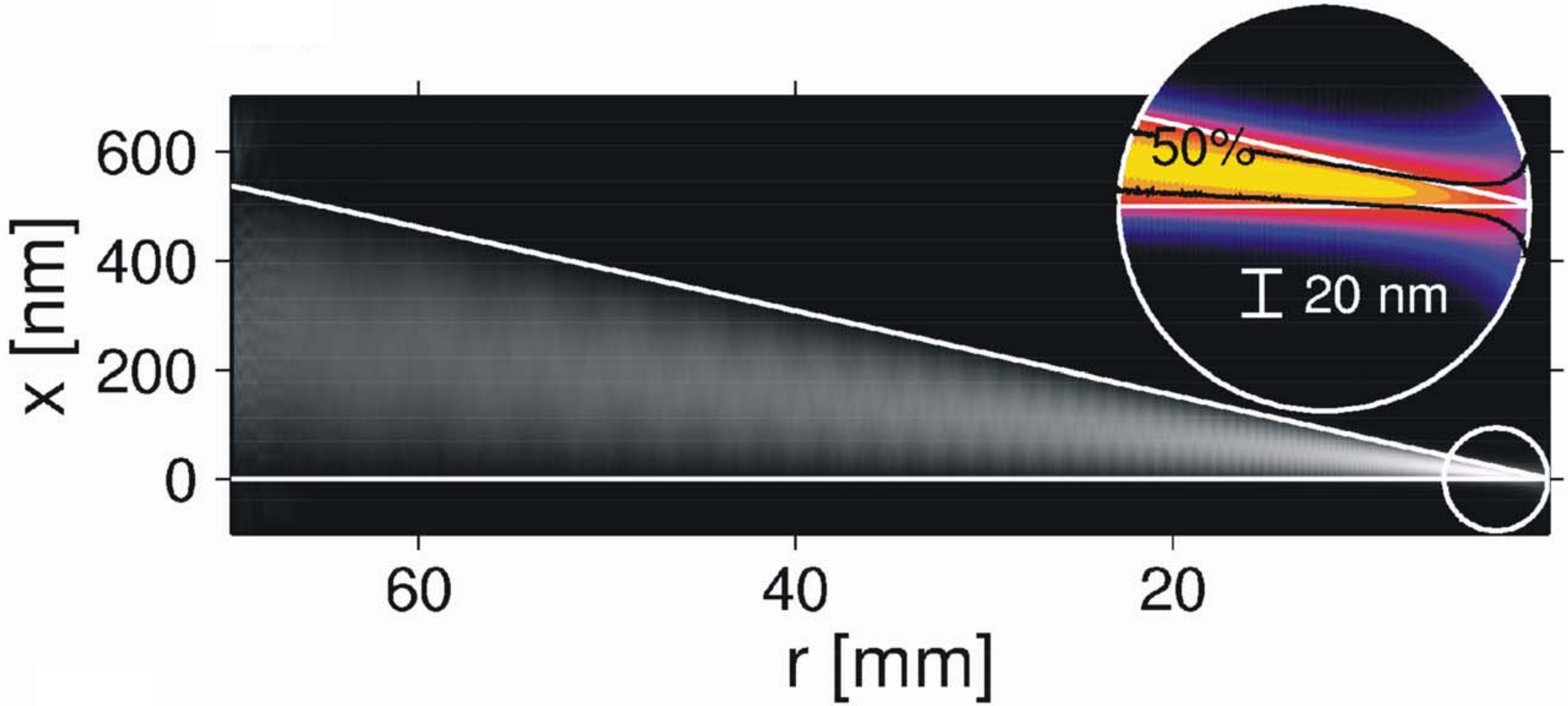




Focusing X-ray beams to nanometer dimensions



What is the smallest spot size ?

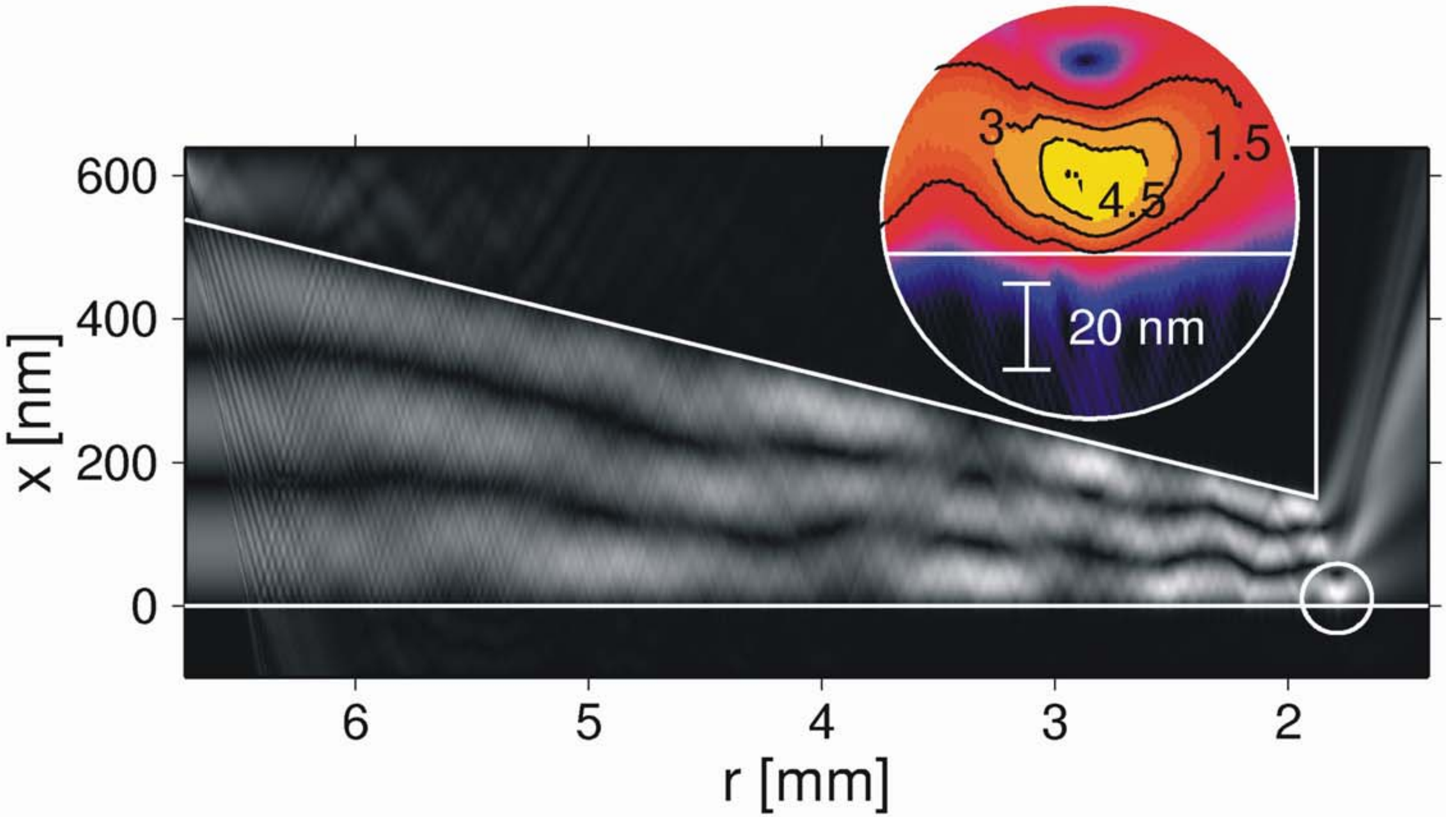


Spot size ~ $0.64\lambda/2\theta_c$

With θ_c critical angle for total reflection

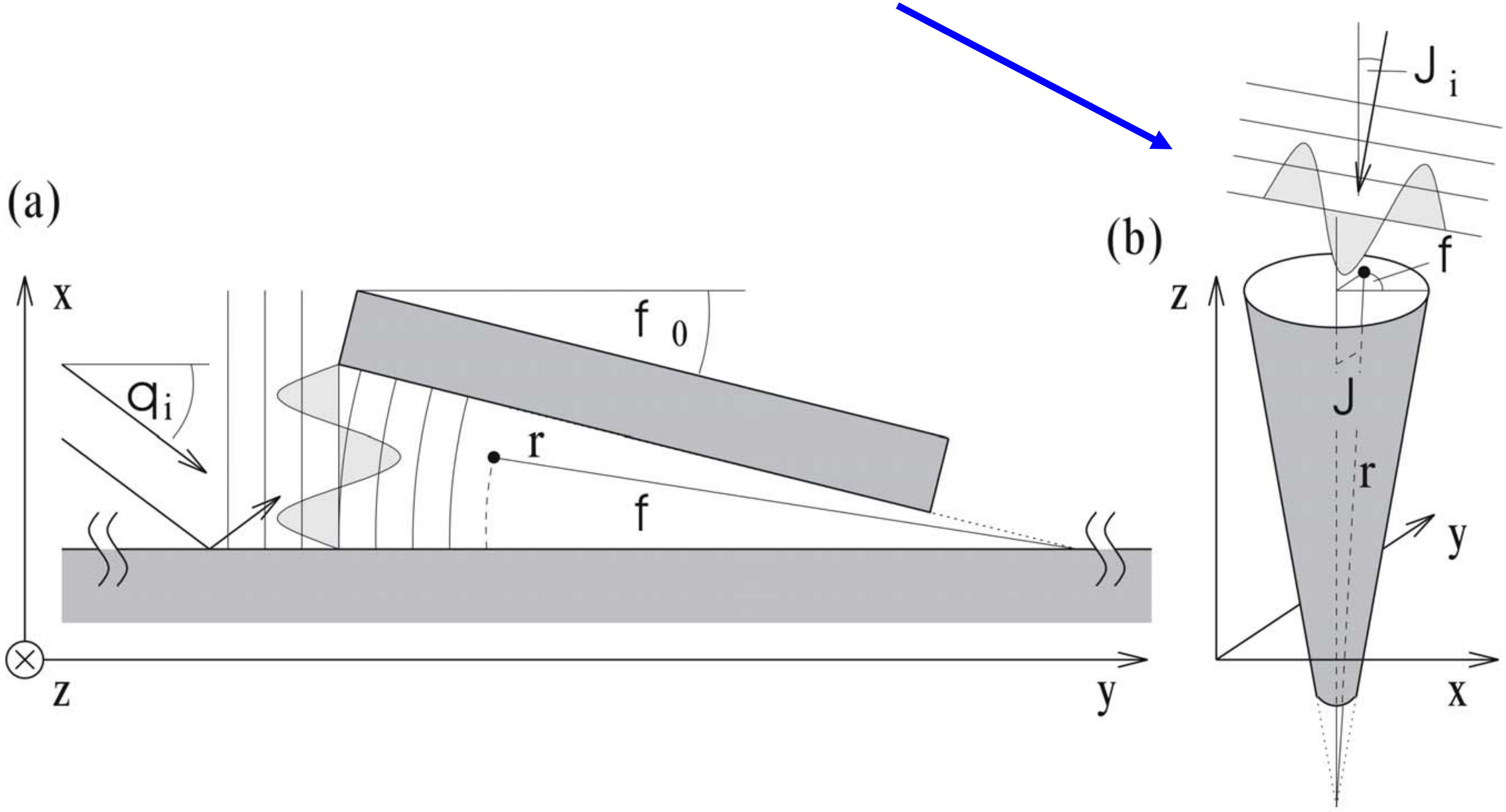
C. Bergemann et al

Make small line focus by using mode mixing and interference

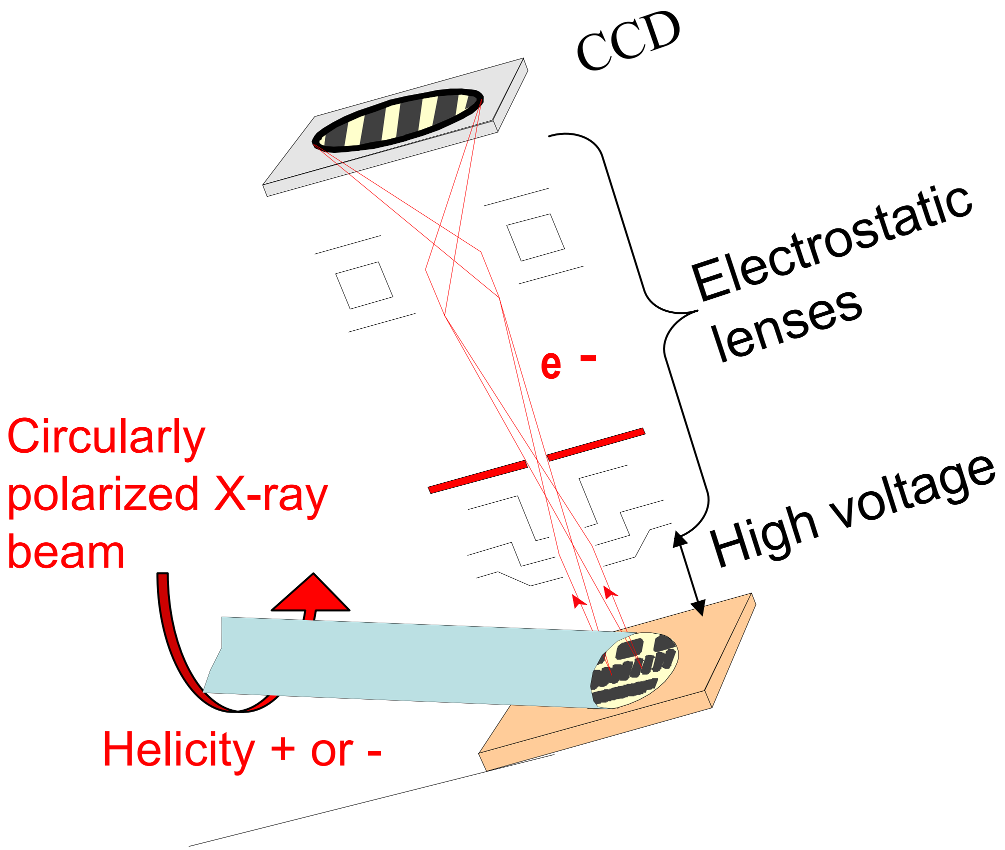


C. Bergemann et al

Focus in 2D by use of hollow capillary

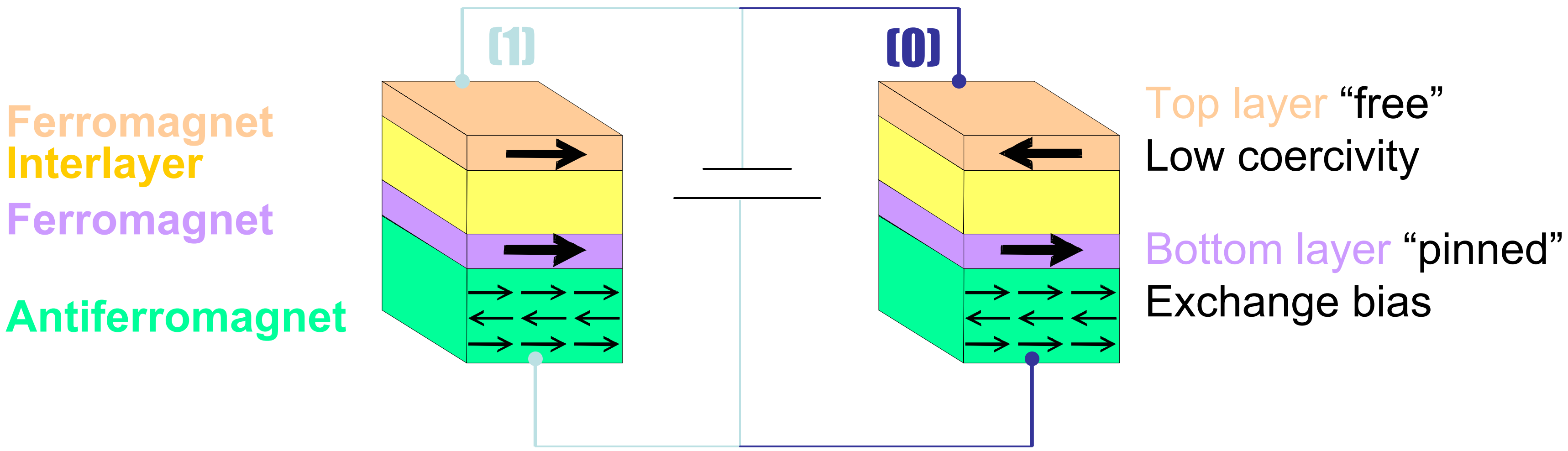


Photoemission electron microscopy (PEEM)

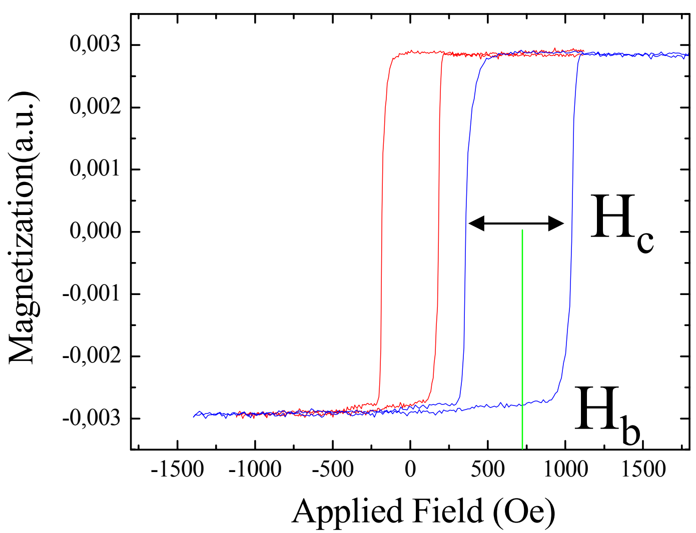


- elemental composition
- chemical bonds
- structural parameters
- electronic structure
- magnetic properties

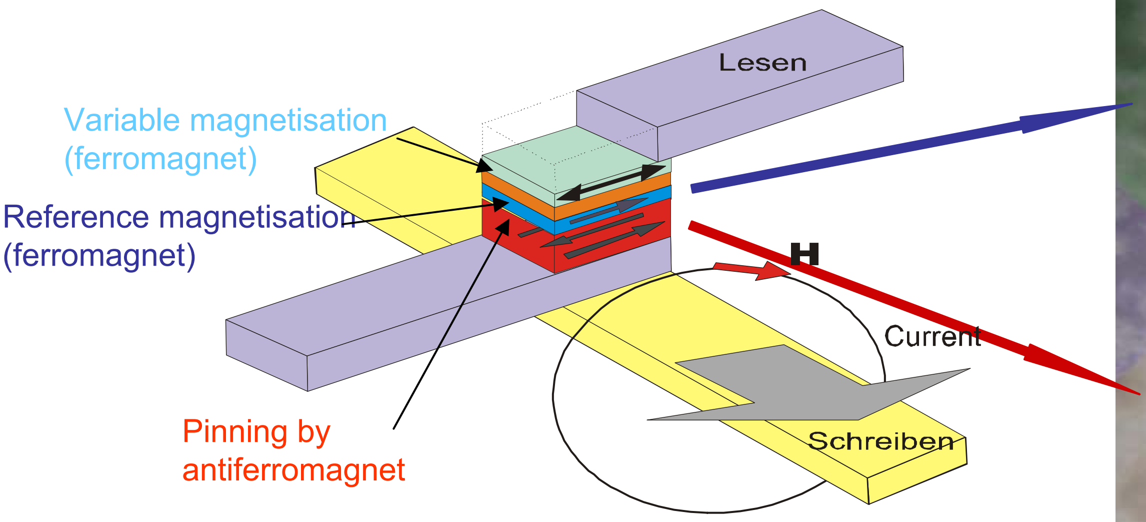
GMR effect - tunnel junction

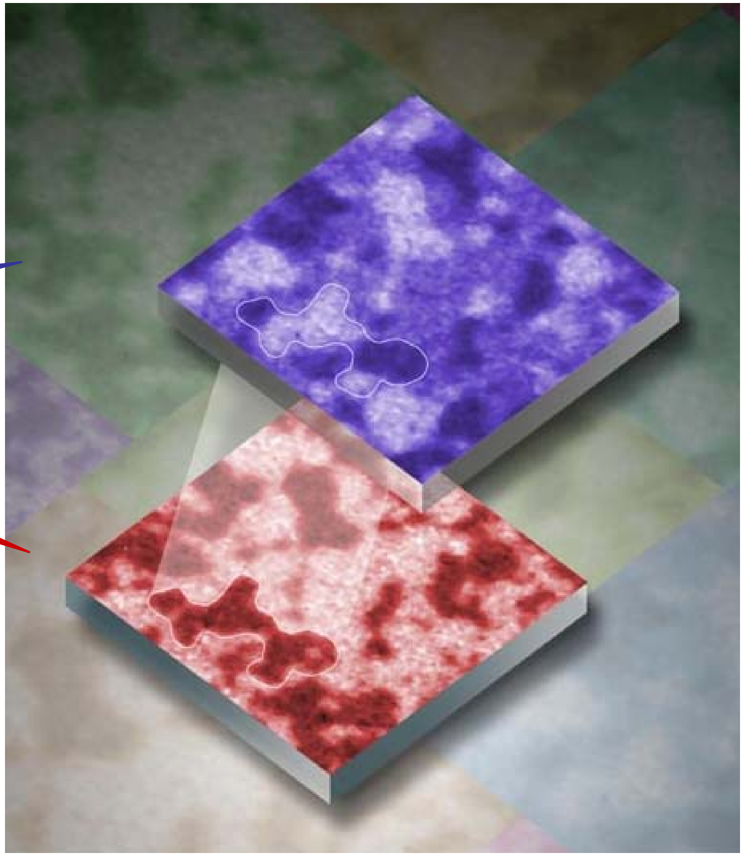


Magnetization in applied external field (hysteresis loop)



Magnetic storage cell

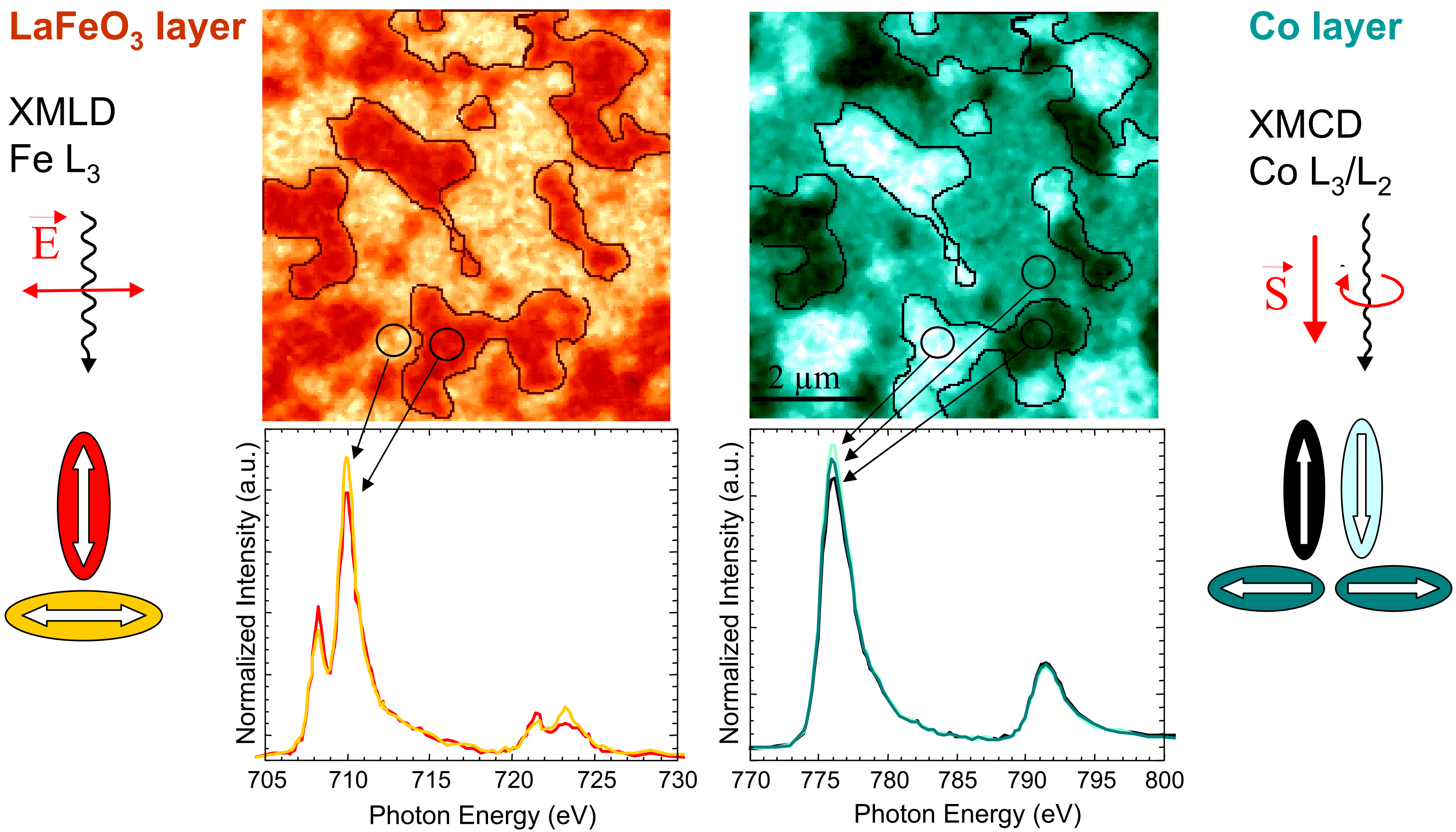




F. Nolting et al.

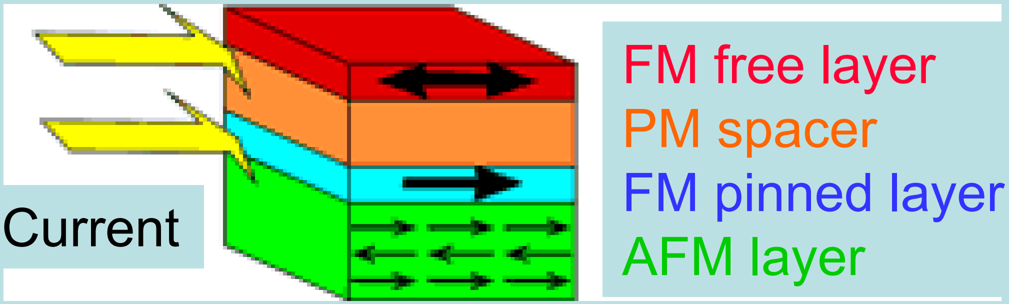
Imaging of magnetic domains on both sides of interface

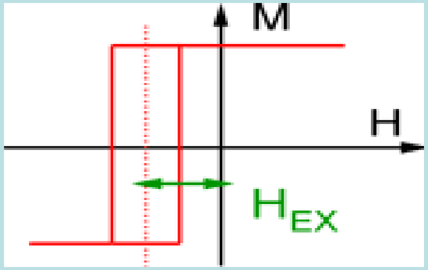
1:1 correlation of domain structure

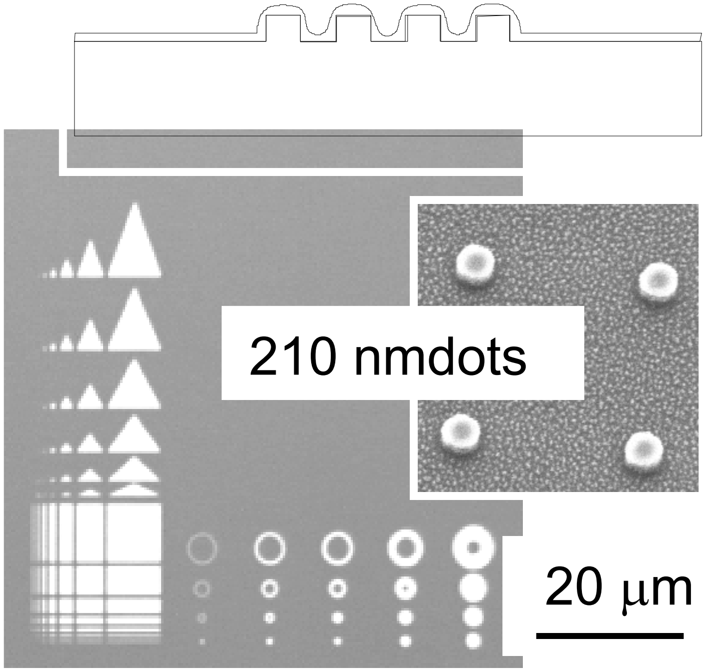


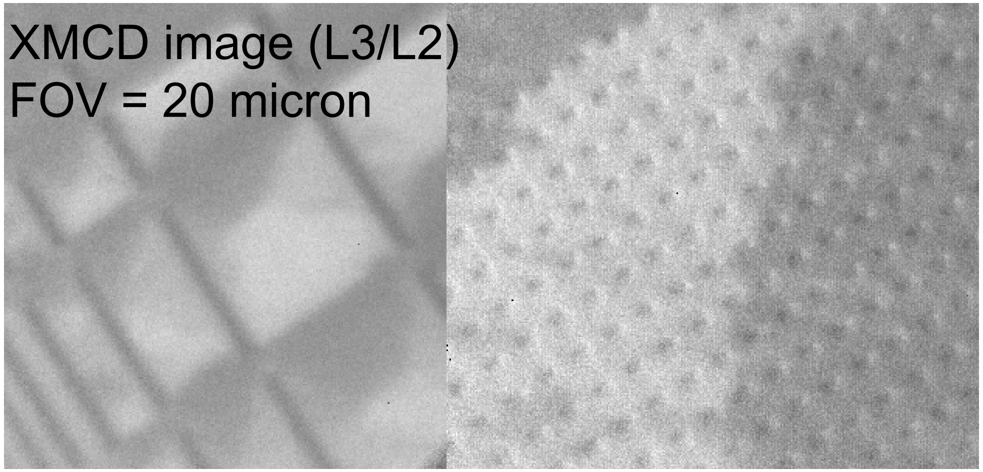
F. Nolting et al, Nature, 405 (2000) 767

Exchange bias systems





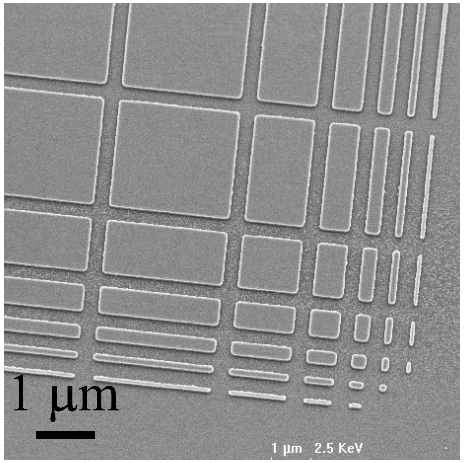




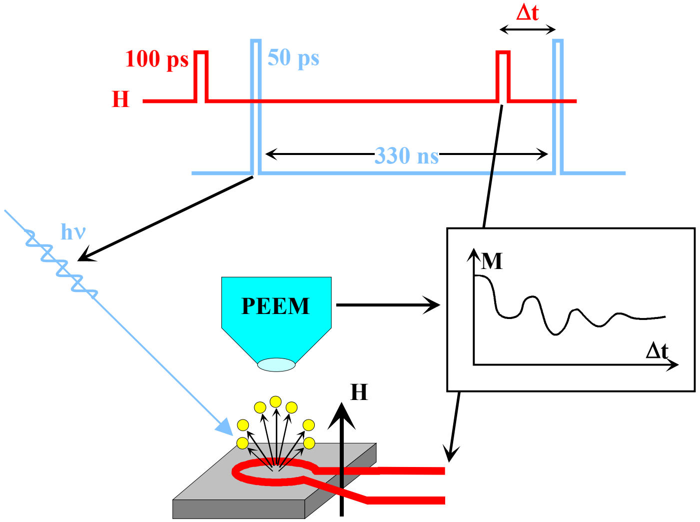
L. Heyderman, F. Nolting,
P. Fischer (MPI-MF, Stuttgart)

Nanomagnetism and dynamics

Smaller dimensions
(500 – 2) nm



Dynamics
1 s – 100 ps
pump-probe technique

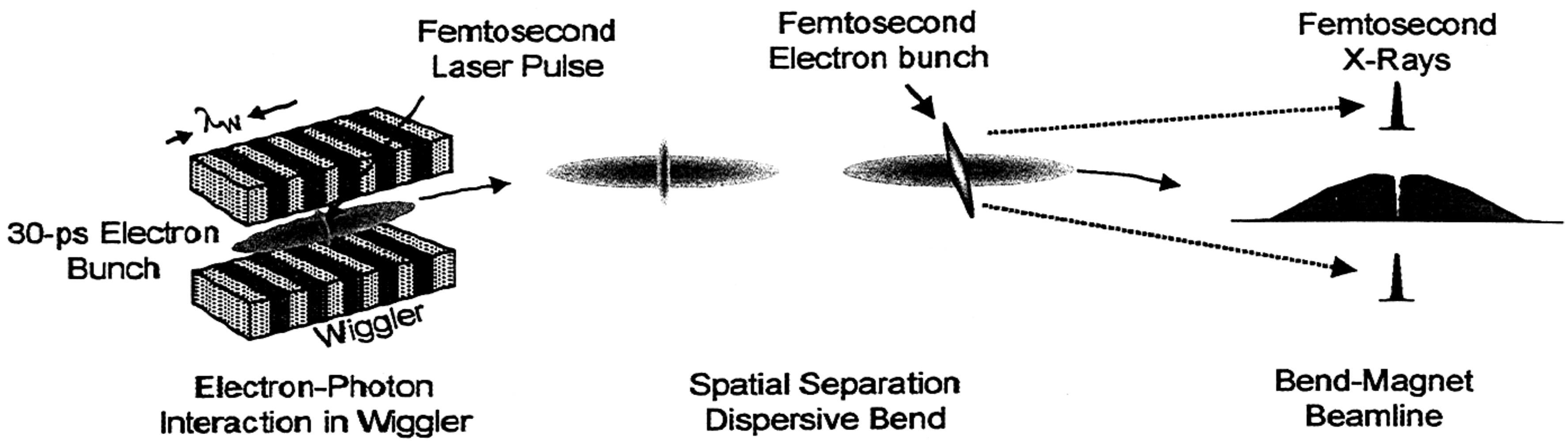


time-resolved studies of micro- and nano-sized magnetic systems

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

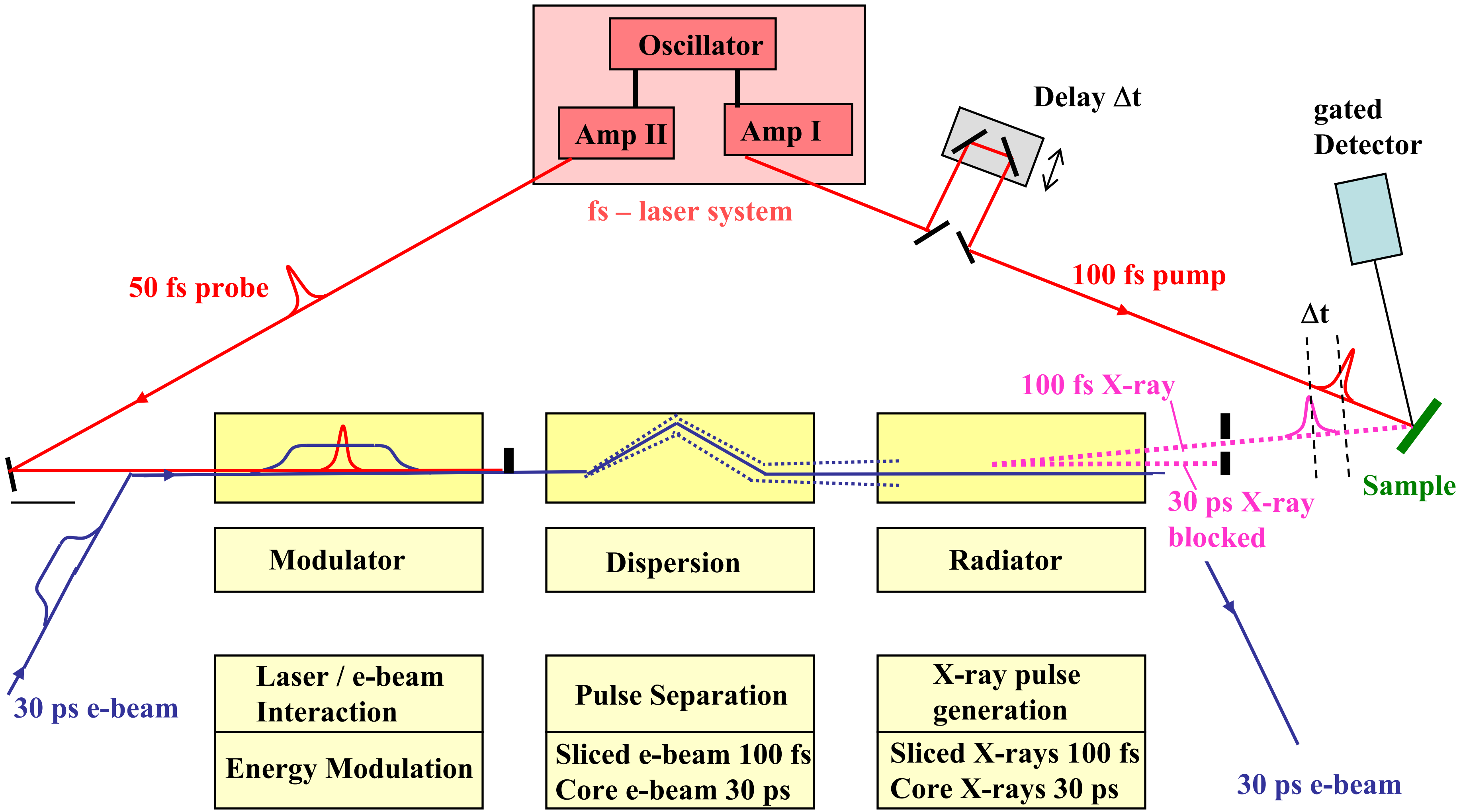


R.W.Schoenlein et al.
Science 287 (2000), 2237

Projects at ALS, SLS, BESSY, SOLEIL

G. Ingold et al

Electron beam slicing at the SLS



Have we got any intensity left?