# *Scanning Transmission X-Ray Microscopy meets Coherent X-Ray Diffraction: SXDM at the cSAXS beamline*

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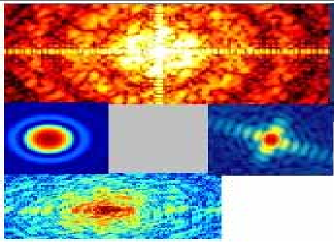
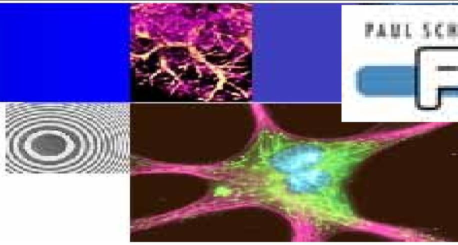
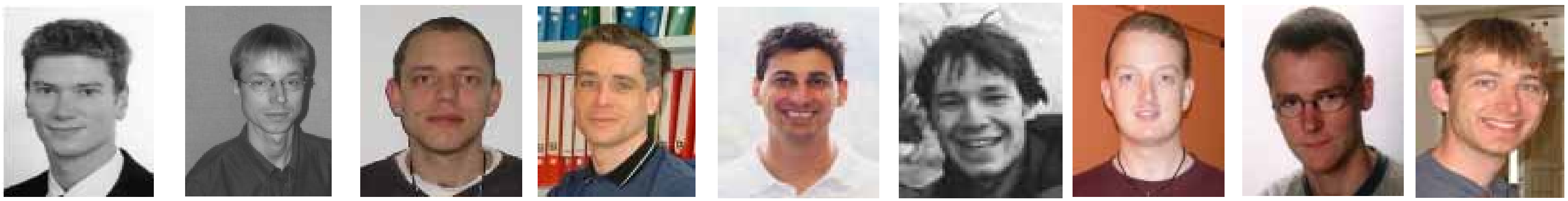


SWISS LIGHT SOURCE SLS



# Coherent X-Ray Scattering Group



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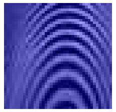
C. David, Micro- and Nanotechnology, PSI

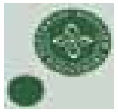
K. Ballmer, Molecular Cell Biology, PSI



J. Raabe, POLLUX, PSI

O. Marti, University Ulm

J. Rodenburg, A. Hurst, Univ. Sheffield

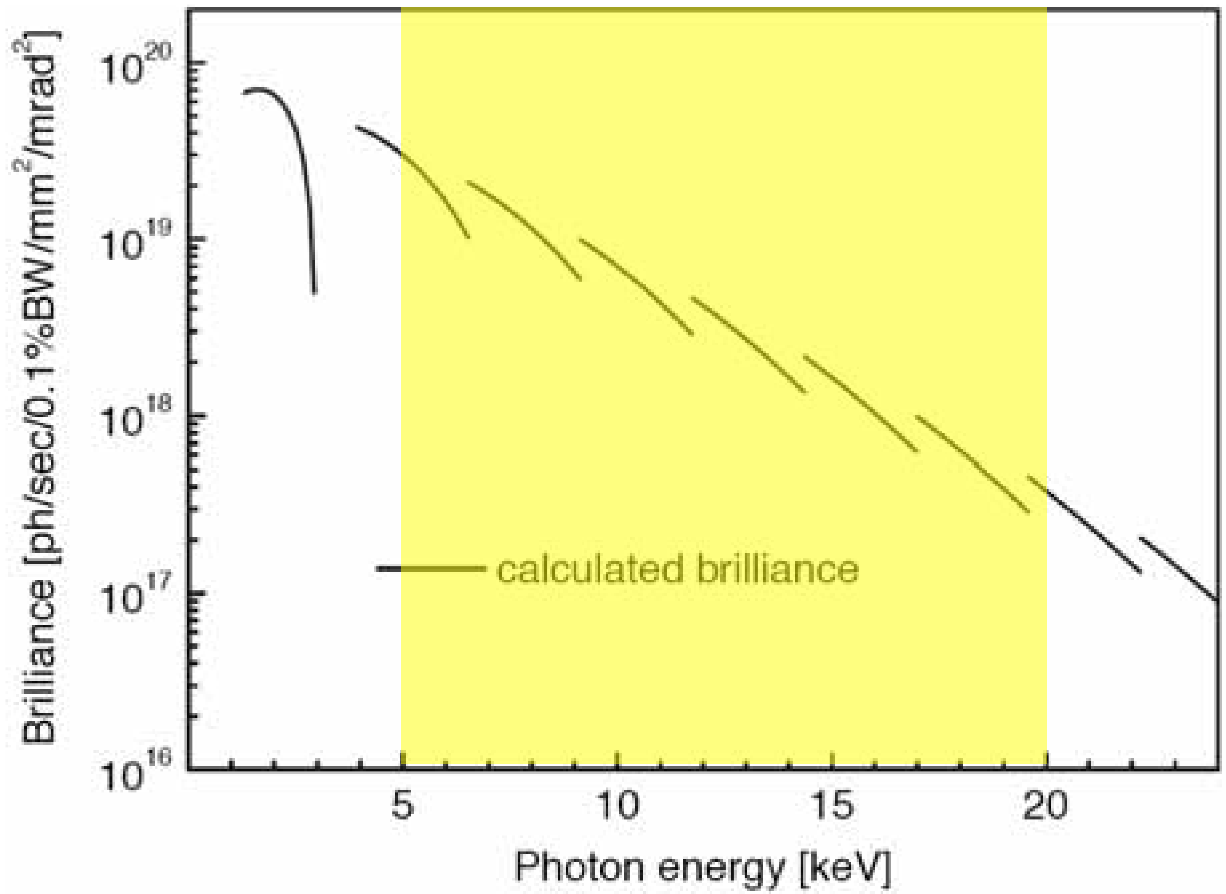


L. Sperling, S. Kynde Niels Bohr Institute

# The coherent Small Angle X-Ray Scattering beamline at the Swiss Light Source

- U19 in-vacuum undulator, $K_{max}$=2.46
  - source size approx. 200 µm x 20 µm (FWHM), divergence approx. 135 µrad x 25 µrad (FWHM)
- $lN_2$ cooled Si(111) fixed exit monochromator at 28.6 m
  - approx. 4.5 – 20 keV
  - horizontal focusing
- quartz glass mirror at 29.4 m with no, Rh and Pt coating
  - vertical focusing
- sample position at about 31m
  - focus from about 5 µm x 20 µm to 1 mm x 2mm

# U19 undulator x-ray source




calculated total flux:

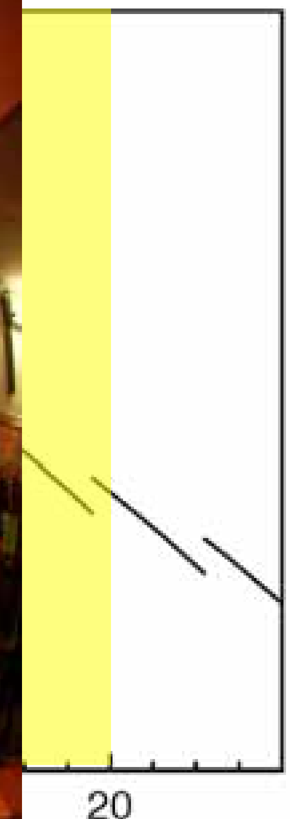
~ $10^{12}$ photons/sec

(at 12.4keV, 400mA, …)

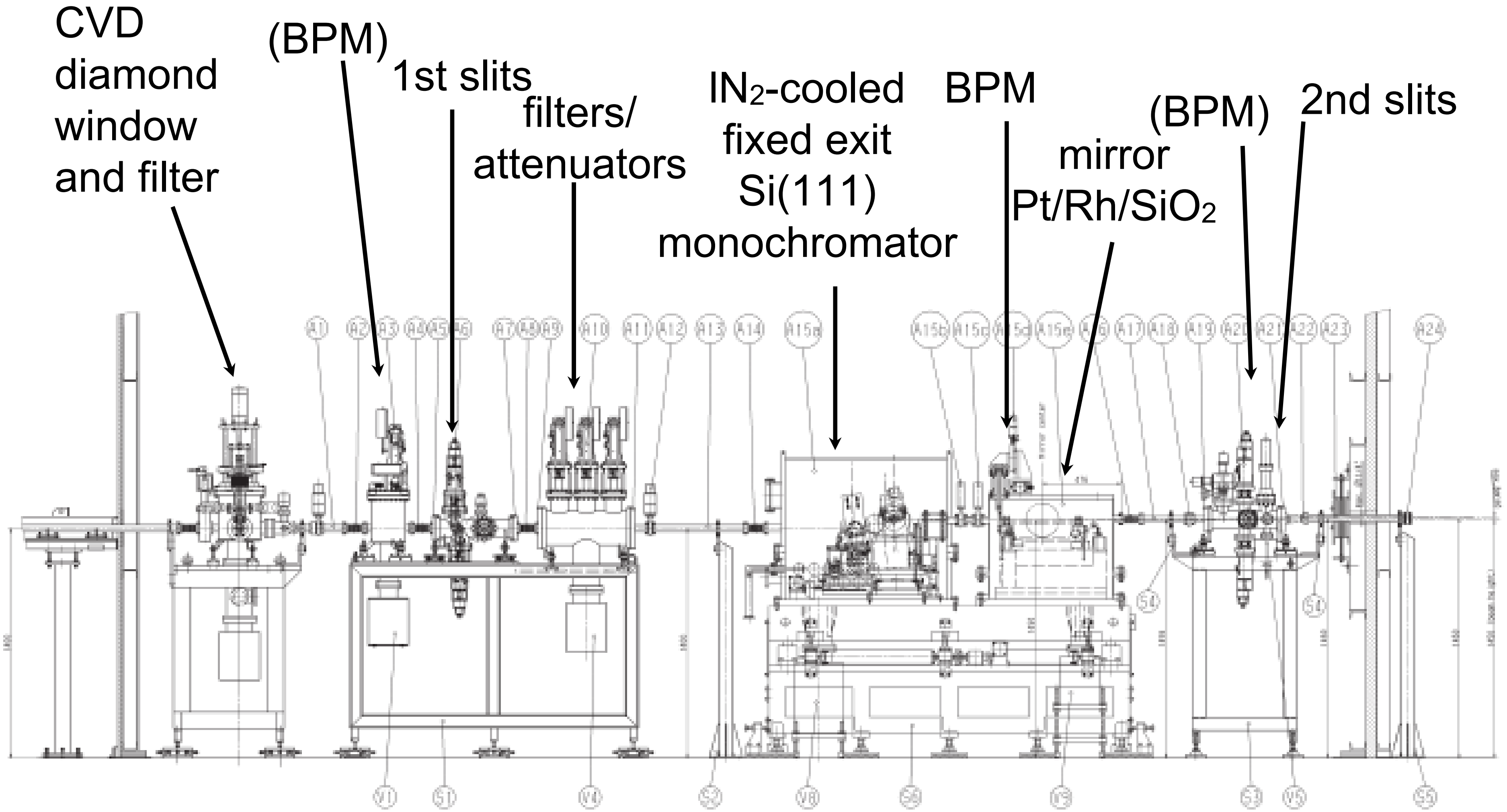
calculated coherent flux:

~ $5 \times 10^{9}$ photons/sec

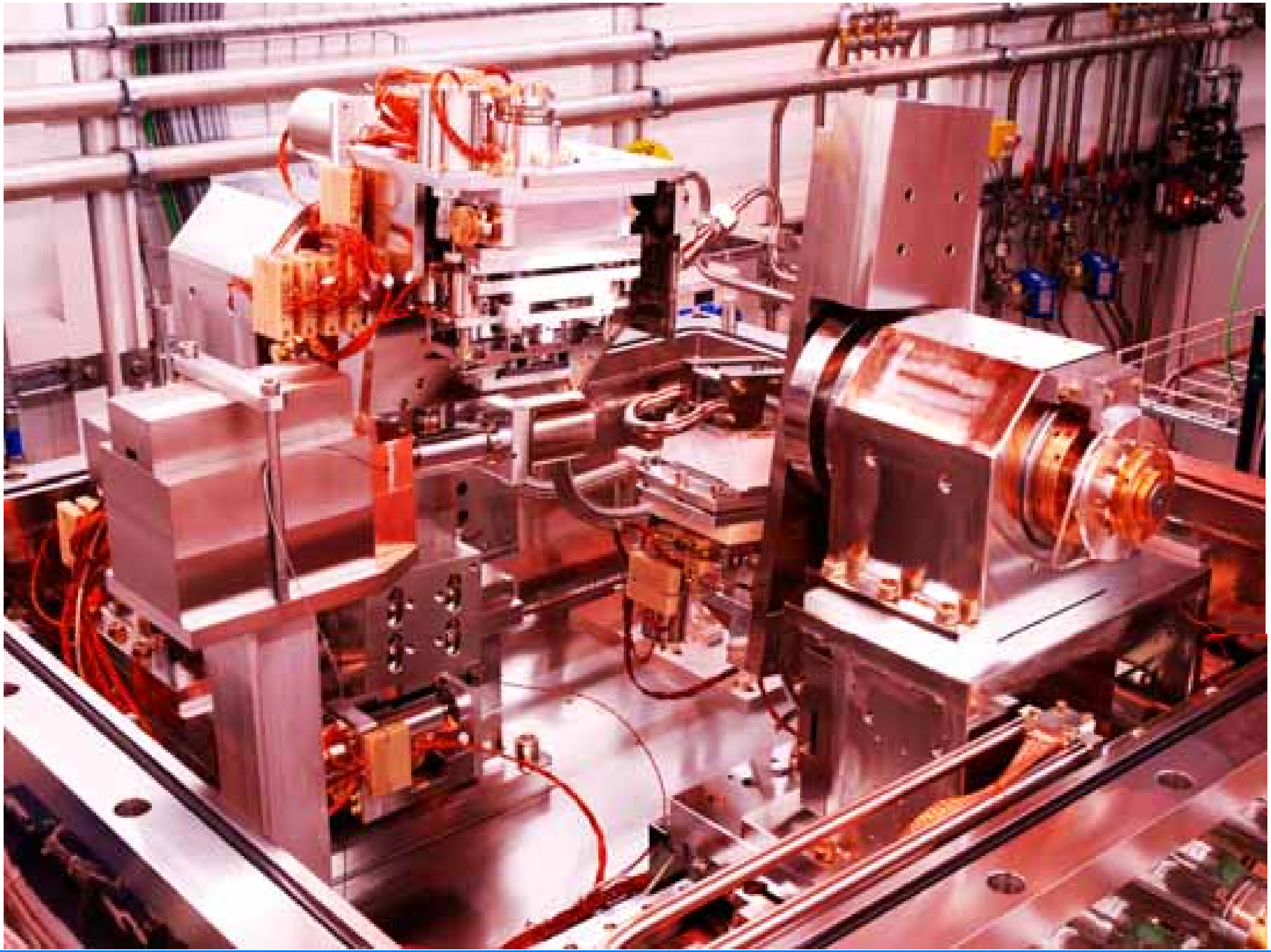
# U19 undulator x-ray source



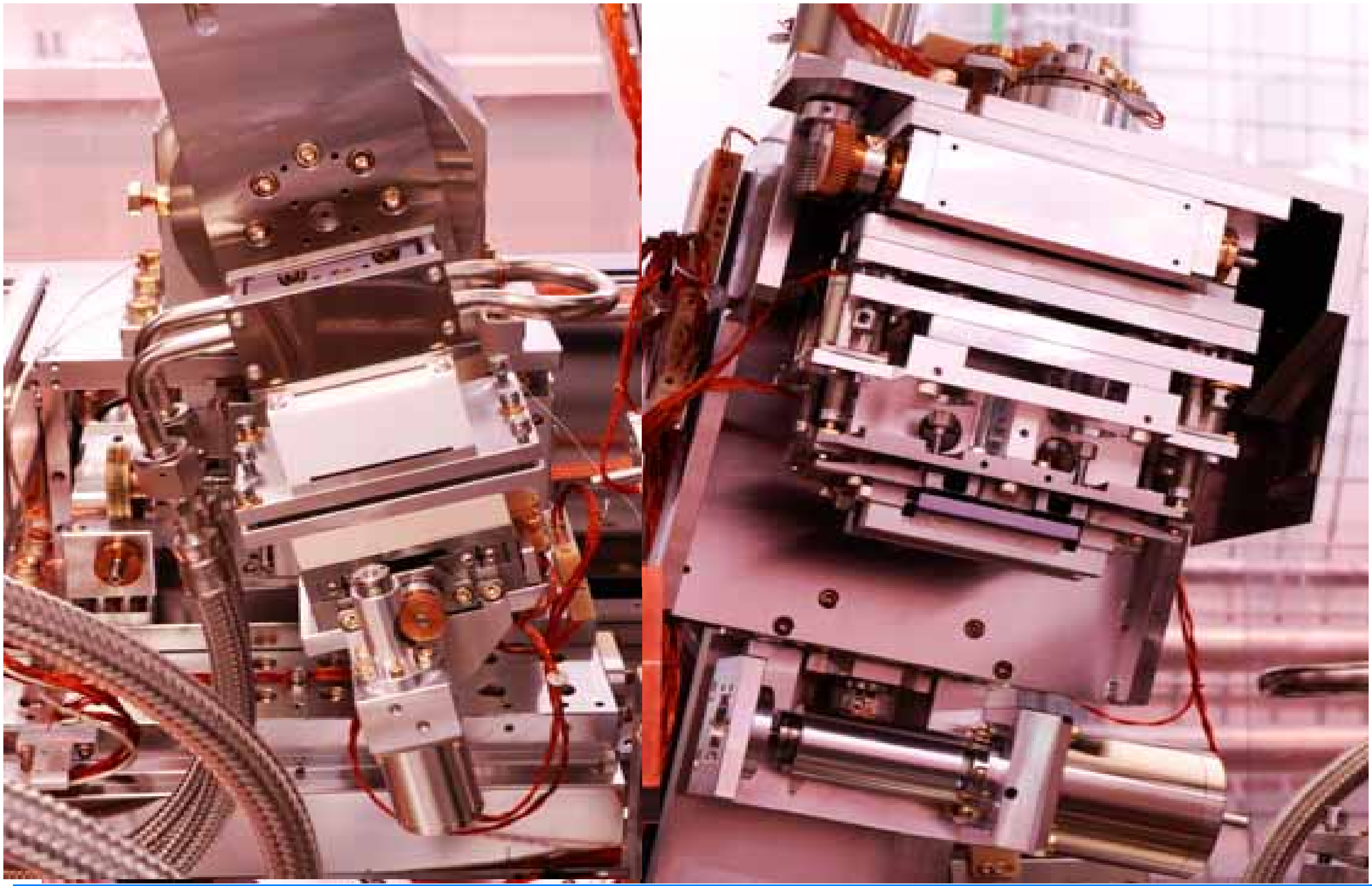
# cSAXS beamline layout: optics



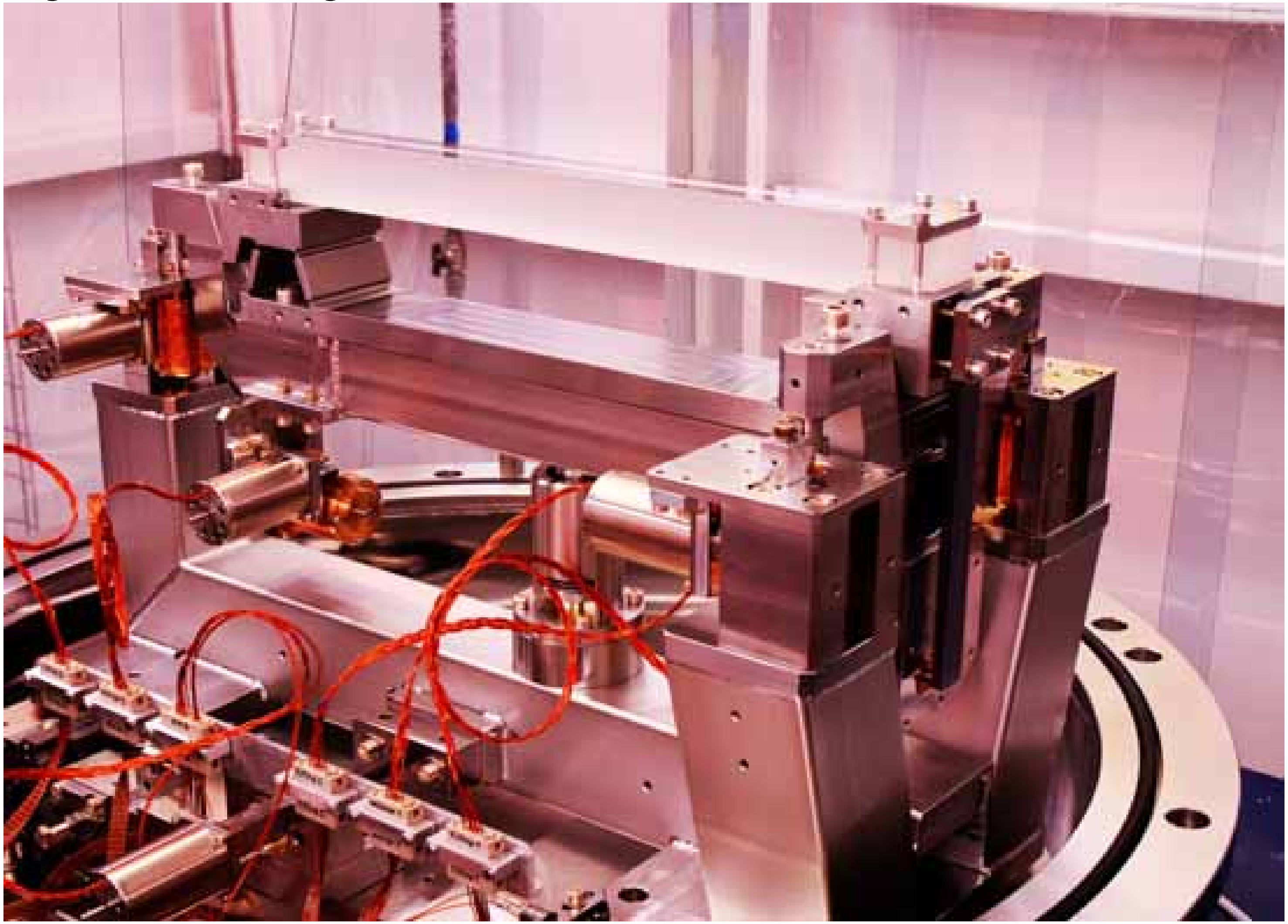
# l$N_2$ cooled Si(111) fixed exit DCM



# $IN_2$ cooled Si(111) fixed exit DCM



# Dynamically bendable mirror



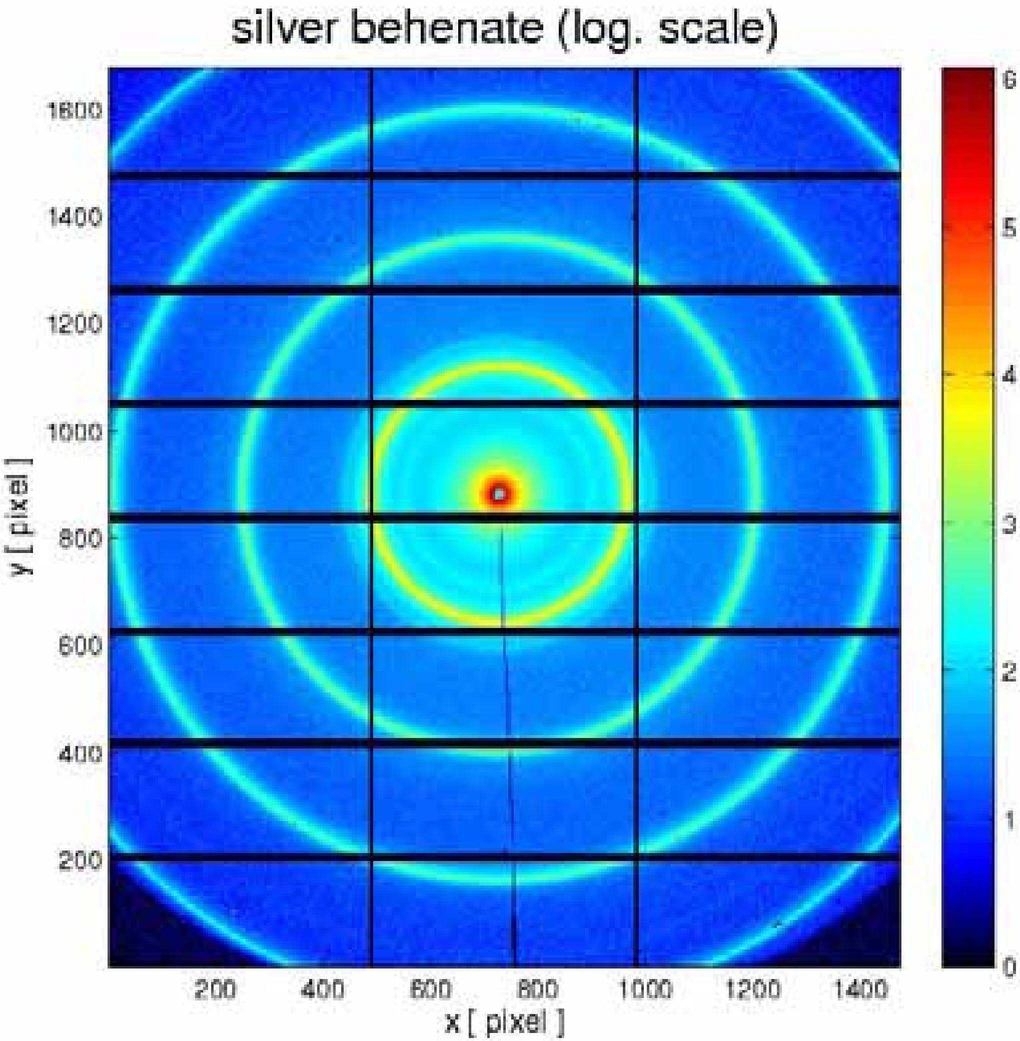
# cSAXS end station

# Pilatus 2M detector

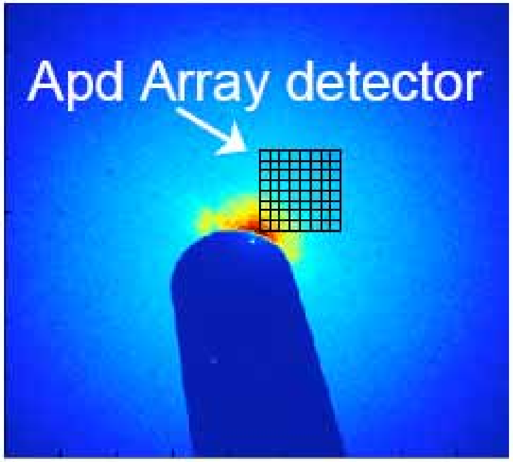
- size: 1475 x 1679 pixels
- pixel size: 172×172 μm$^2$
- total active area: 254 x 289 mm$^2$
- quantum efficiency: 100% at 8 keV,
  80% at 12 keV,
  50% at 16 keV
- readout time: < 3ms
- no readout noise
- countrate up to ~1 MHz/pixel
- 20 bit dynamic range
- point spread function limited to one pixel

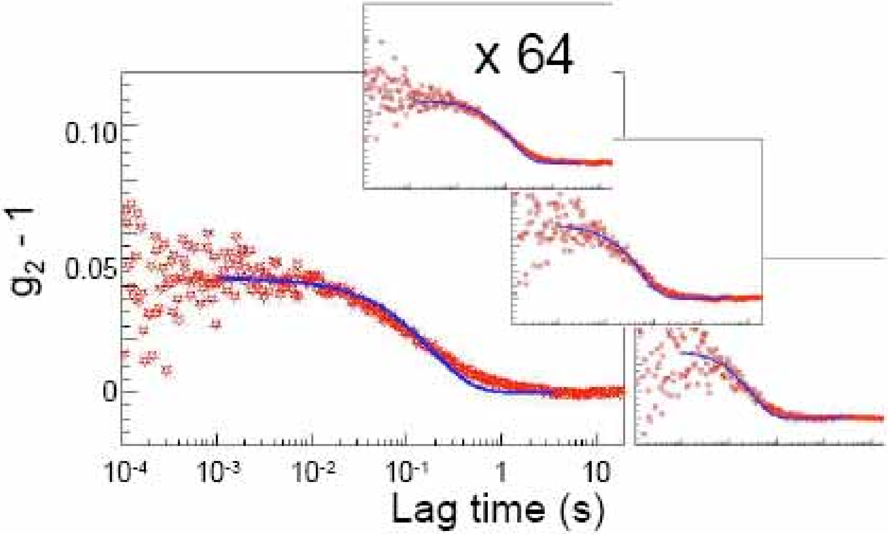
# Pilatus 2M detector

# Pilatus 2M detector



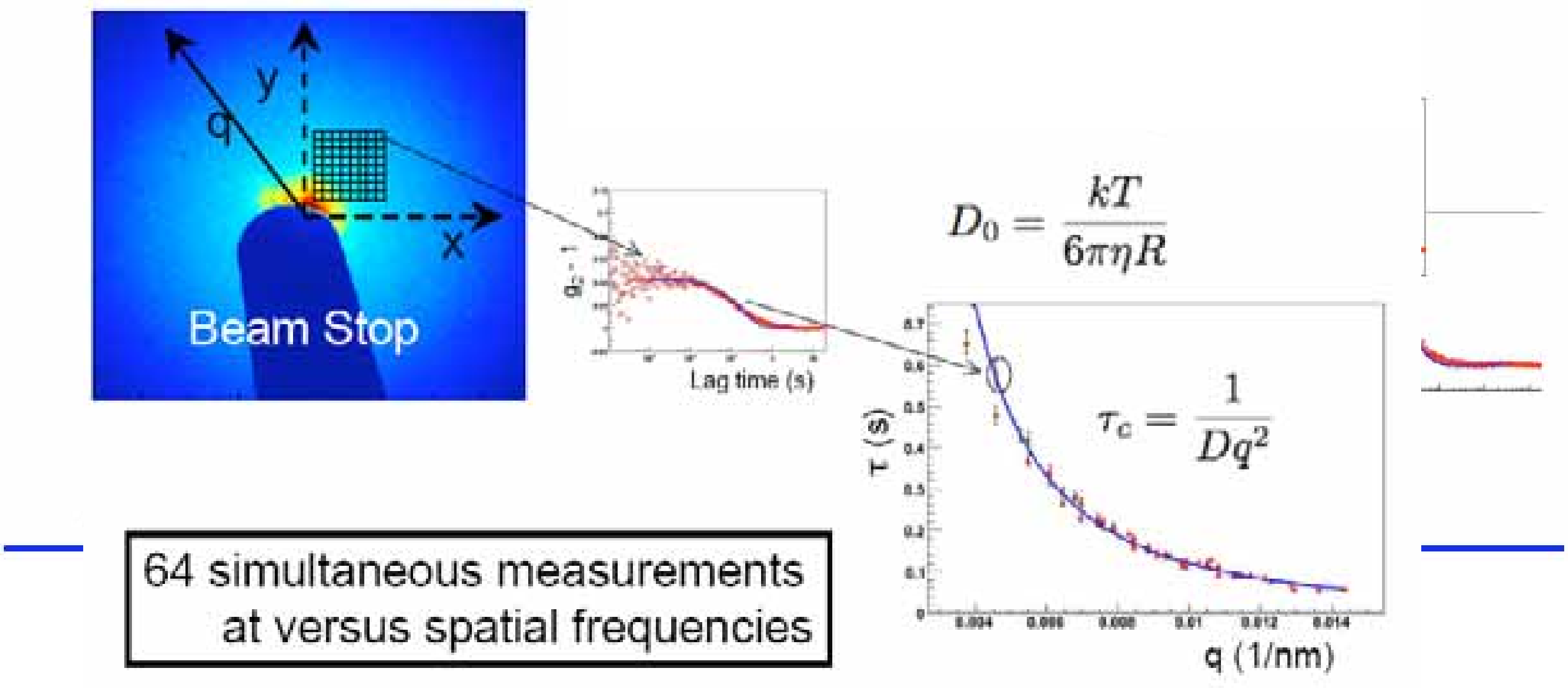
# GAPD array for XPCS measurements




$SiO_2$ Colloids (r = 112 nm) in an ethanol and benzyl alcohol solution.

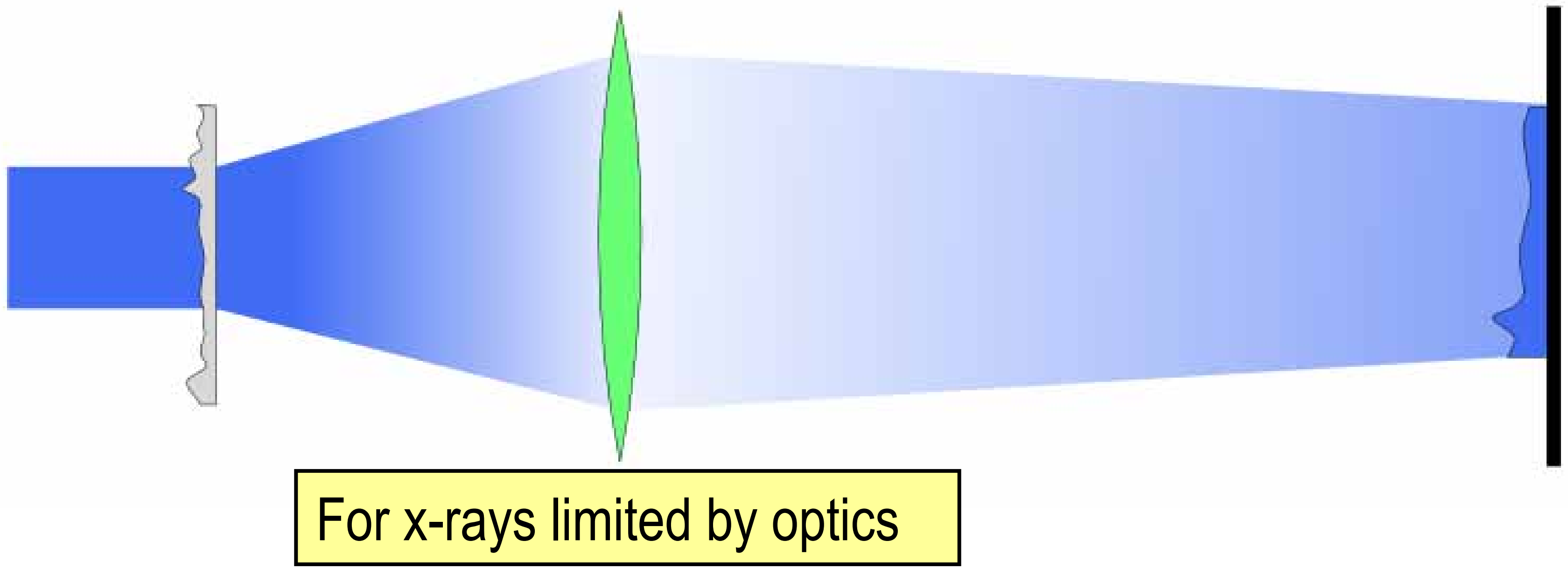
# GAPD array for XPCS measurements



# Infrastructure:

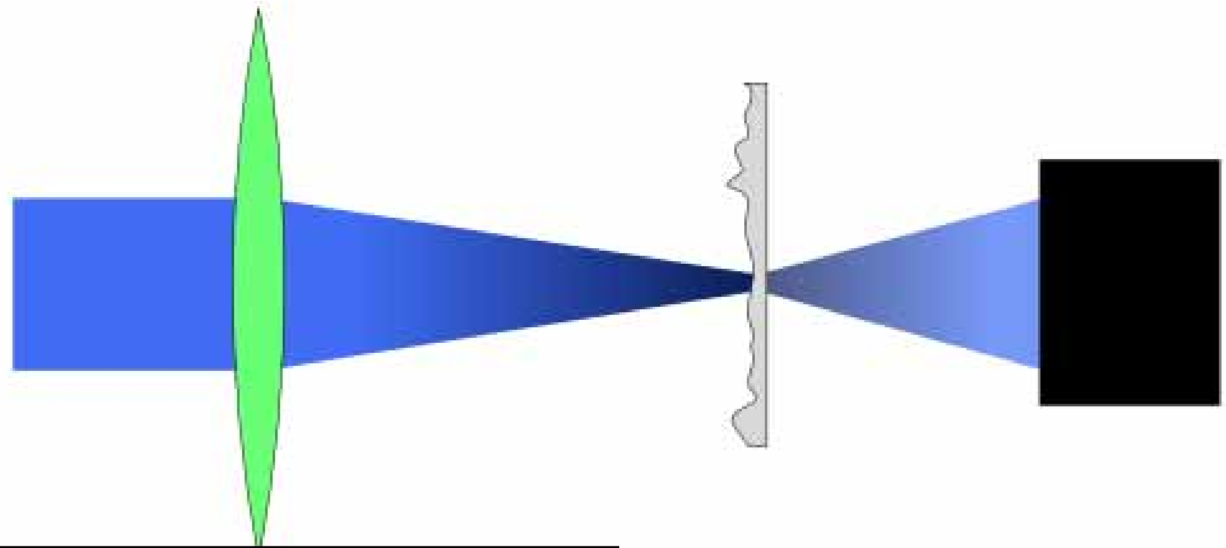
- Chemistry lab.
- Data storage
- Computing
- ...

# High resolution imaging: 1) Full field




Traditional (x-ray, bright field) microscopy

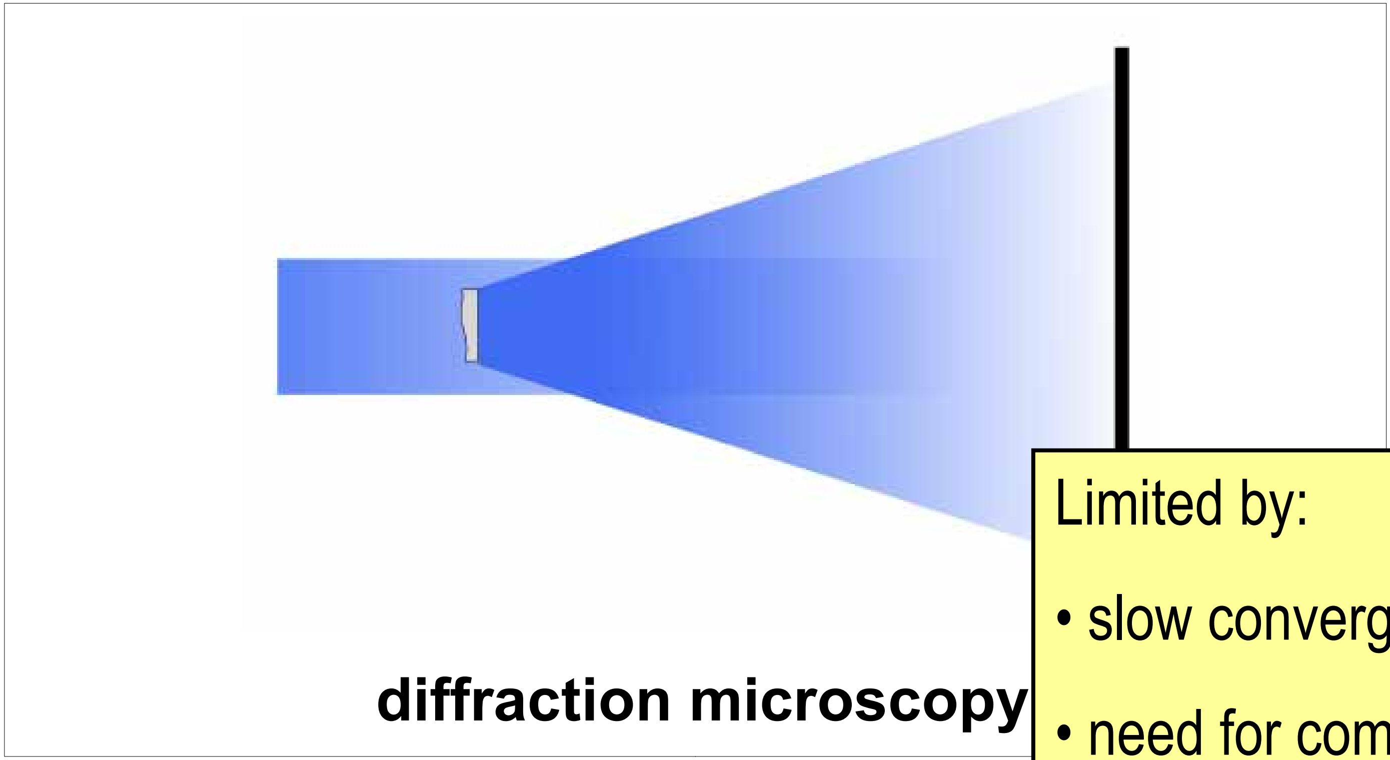
# High resolution imaging: 2) Scanning microscopy



For x-rays limited by optics

**scanning X-ray transmission microscopy**

# High resolution imaging: 3) Diffraction microscopy

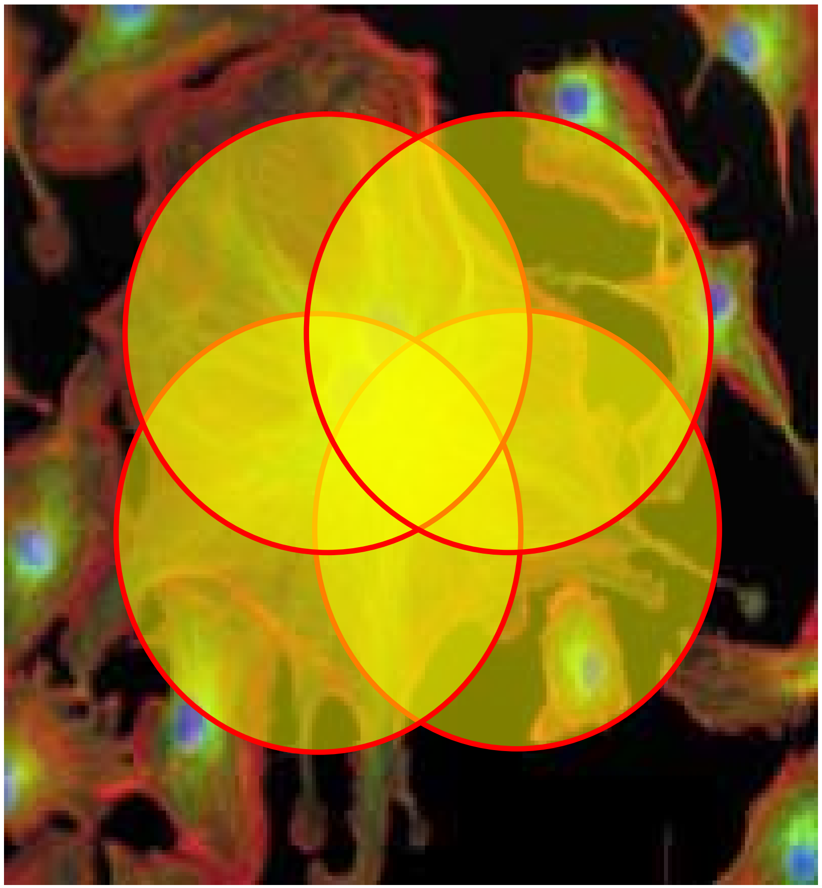


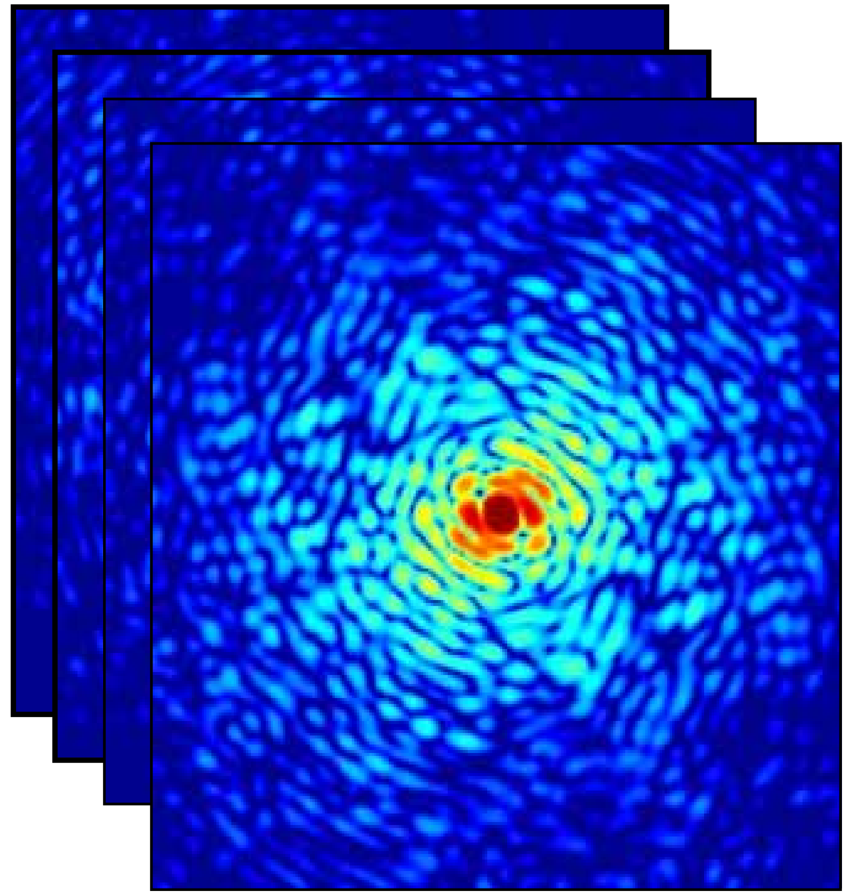

Limited by:

- slow convergence
- need for compact objects
- difficulties for complex objects

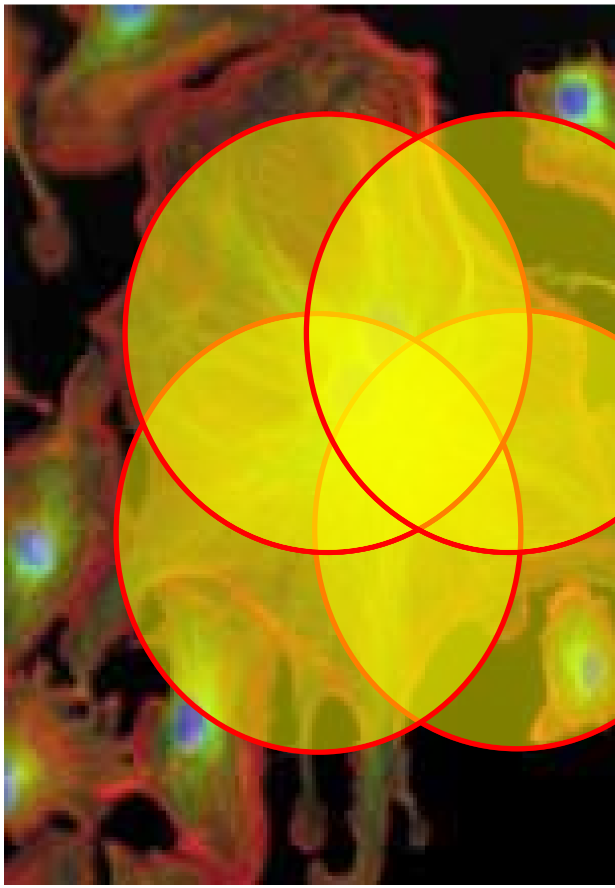
# Combination 1:
# STXM with a 2D detector for phase contrast

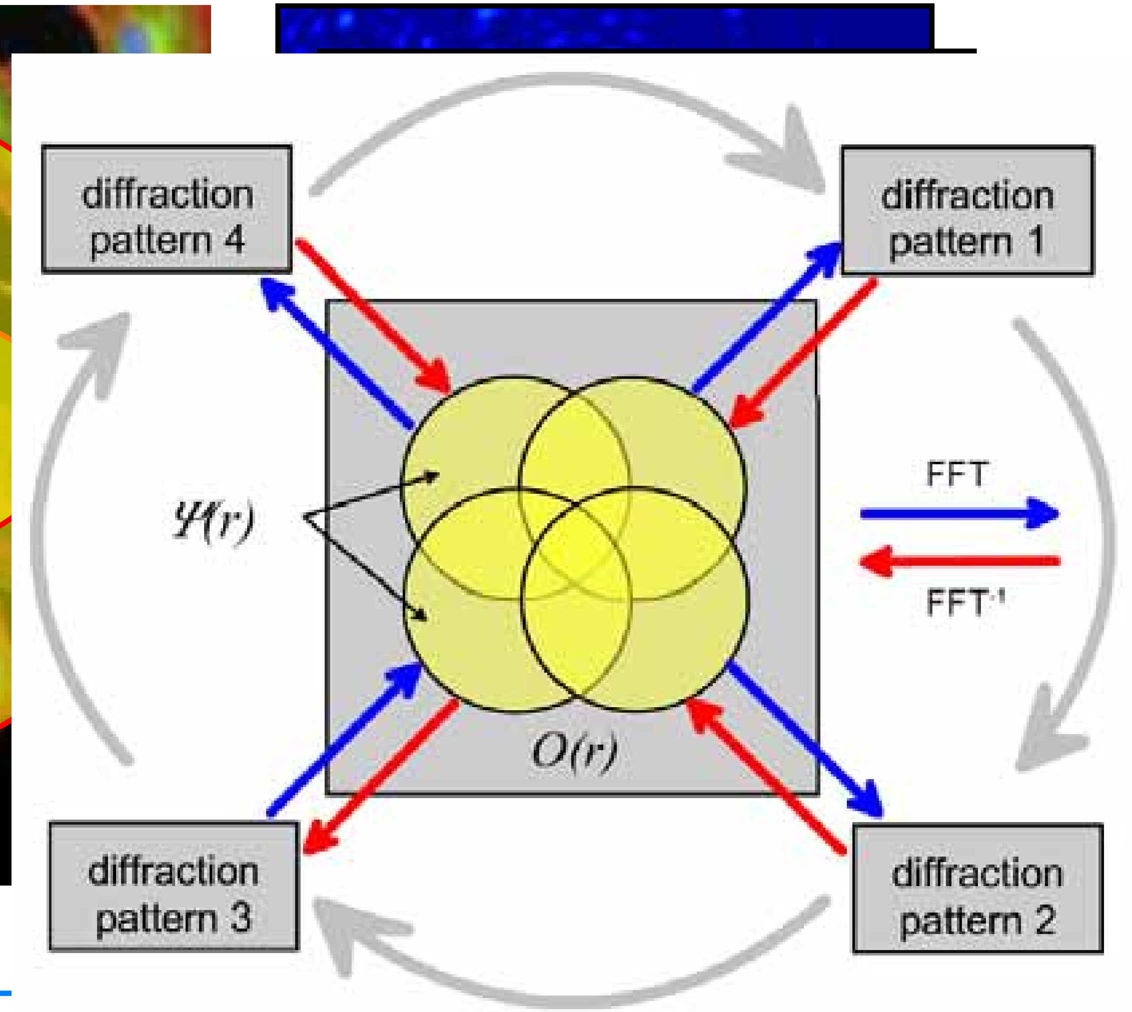
# Combination 2:
# Scanning X-Ray Diffraction Microscopy (SXDM)





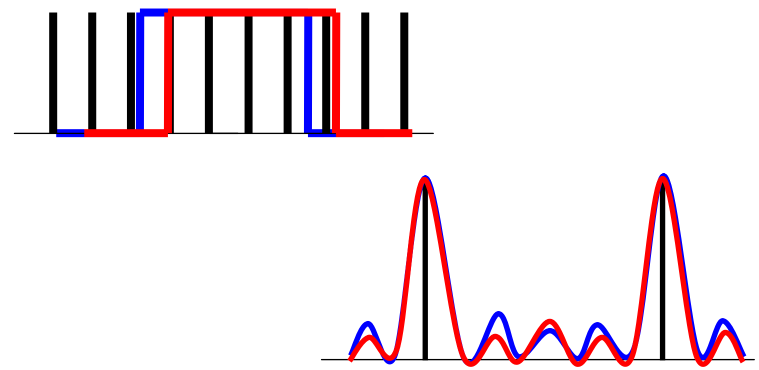
# Combination 2:
# Scanning X-Ray Diffraction Microscopy (SXDM)





# Ptychography & Iterative Phase Retrieval

- *W. Hoppe, Acta Cryst. A 25, 508 (1969).*
- *R. Hegerl, W. Hoppe, Ber. Bunsen-Ges.* Phys. *Chemie 74, 1148 (1970).*



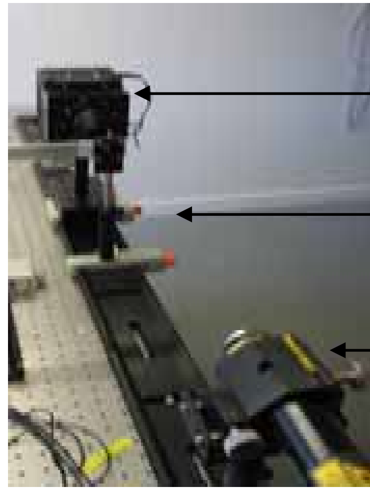


## Dynamische Theorie der Kristallstrukturanalyse durch Elektronenbeugung im inhomogenen Primärstrahlwellenfeld

Von R. Hegerl und W. Hoppe

Some time ago a new principle was proposed for the registration of the complete information (amplitudes and phases) in a diffraction diagram, which does not – as does Holography – require the interference of the scattered waves with a single reference wave. The basis of the principle lies in the interference of neighbouring scattered waves which result when the object function $\varrho(x, y)$ is multiplied by a generalized primary wave function $p(x, y)$ in Fourier space (diffraction diagram) this is a convolution of the Fourier transforms of these functions. The above mentioned interferences necessary for the phase determination can be obtained by suitable choice of the shape of $p(x, y)$. To distinguish it from holography this procedure is designated "ptychography" ($\pi\tau\upsilon\xi$ = fold). The procedure is applicable to periodic and aperiodic structures. The relationships are simplest for plane lattices. In this paper the theory is extended to space lattices both with and without consideration of the dynamic theory. The resulting effects are demonstrated using a practical example.

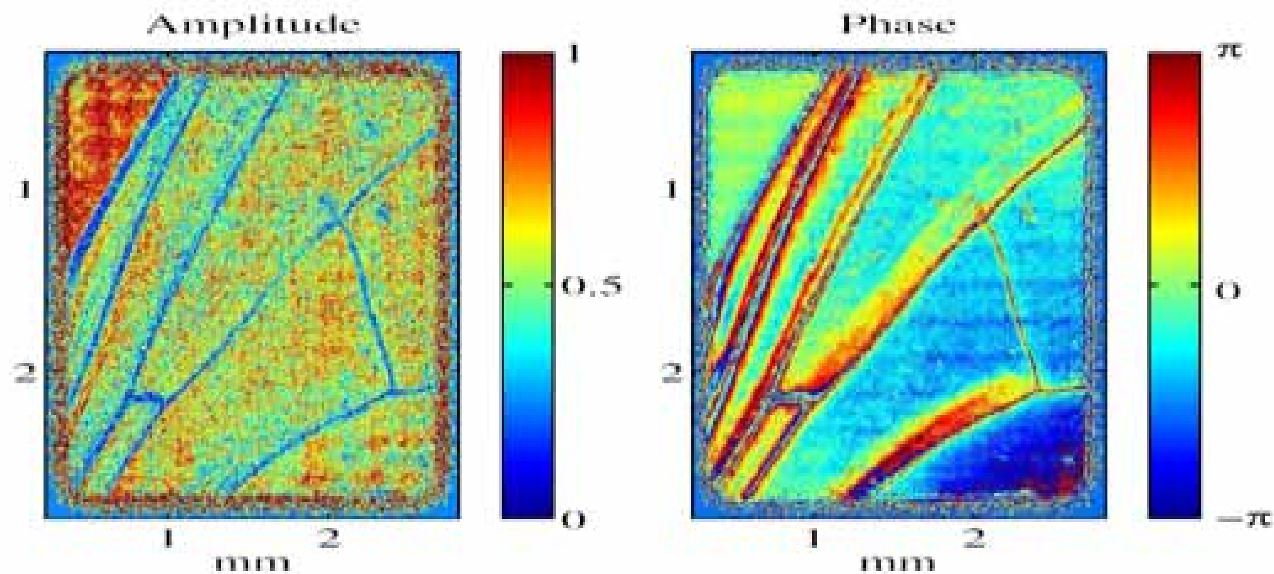
# Scanning Diffraction Microscopy with visible laser light



*cooled CCD, 16 bit*

*object on xy translation stage*

*HeNe laser, 15 mW, continuous*



# SXDM with a test sample

# First STXM data analysis (online)

# Reconstruction of a selected region

# Simultaneous reconstruction of the probe

# Summary

- STXM with 2D detector:
  - fast online feedback
  - absorption, phase contrast and dark field information
  - initial guess for the high resolution reconstruction
- SXDM:
  - overlapping illuminations lead to overdetermination
  - curved wave front helps additionally (+ no beam stop)
  - the not precisely known illumination is reconstructed with the object

→ Combine the best of both worlds (STXM and CXD/CDI) to SXDM