NANOSCIENCE CRYSTALLOGRAPHY AT A HIGH BRILLIANCE LABORATORY X-RAY DIFFRACTOMETER:

FROM MESOSCOPIC TO INTERATOMIC LENGTH SCALES

26 NOVEMBER 2020 I E. KENTZINGER, U. RÜCKER, A. QDEMAT, T. BRÜCKEL

JÜLICH CENTRE FOR NEUTRON SCIENCE & PETER GRÜNBERG INSTITUT

Mitglied der Helmholtz-Gemeinschaft

JÜLICH
Forschungszentrum

MOTIVATIONS: MAGNETIC NANOPARTICLES

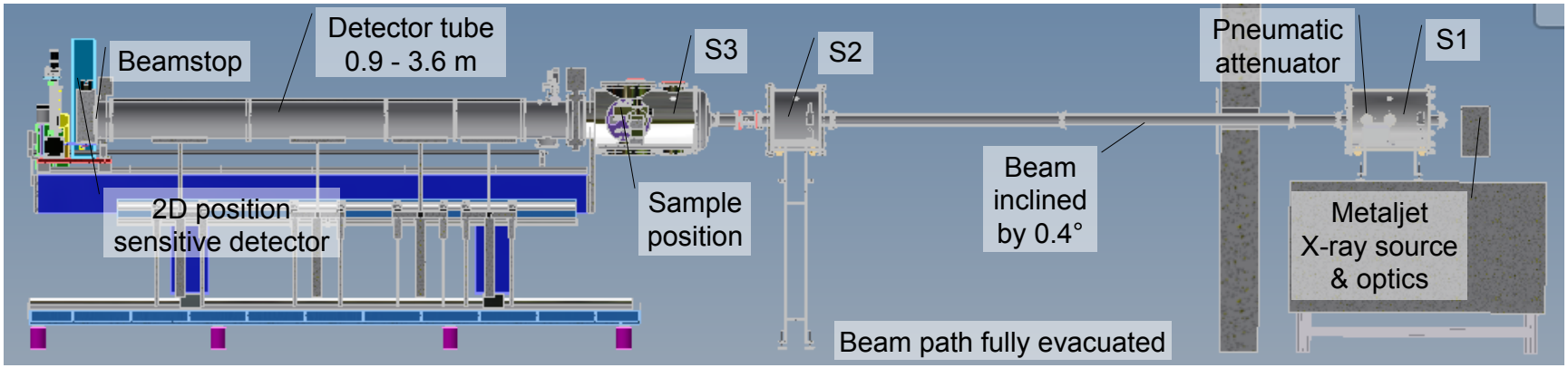
- Core-shell structure: SAXS
- 2D and 3D arrangements on a surface: Grazing Incidence SAXS (GISAXS)
- Structural characterisation complementary to magnetic investigation by neutron scattering

- Applications: sensing, data storage, biomedicine:

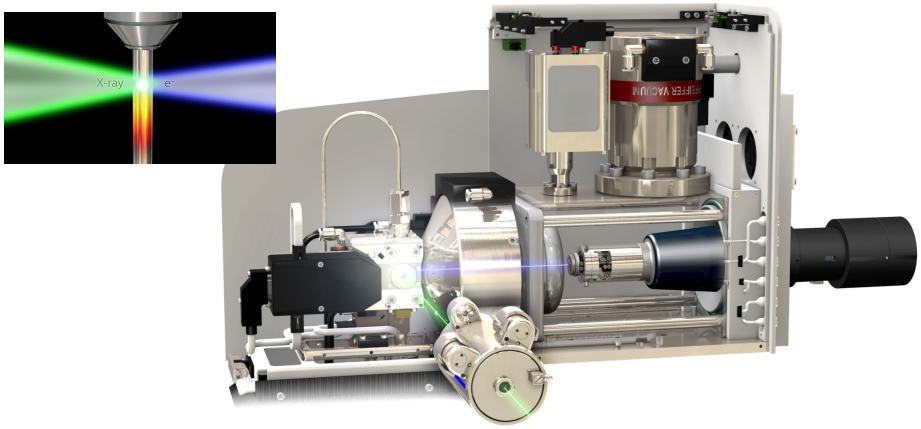
  A. Fernández-Pacheco, Nat. Comm. **8** 15756 (2017)

GALAXI

Gallium Anode Low Angle X-ray Instrument



X-ray source: MetalJet (Excillum) + Optics (Incoatec)



MetalJet: 400 µm thick liquid metal jet (GaInSn alloy) anode
20 x 80 µm^2 electron beam
20 µm ø X-ray focus
70 kV, 200W, Ga K_α 9240 eV, λ = 1.34 Å
Power density 10 * higher than Cu anode

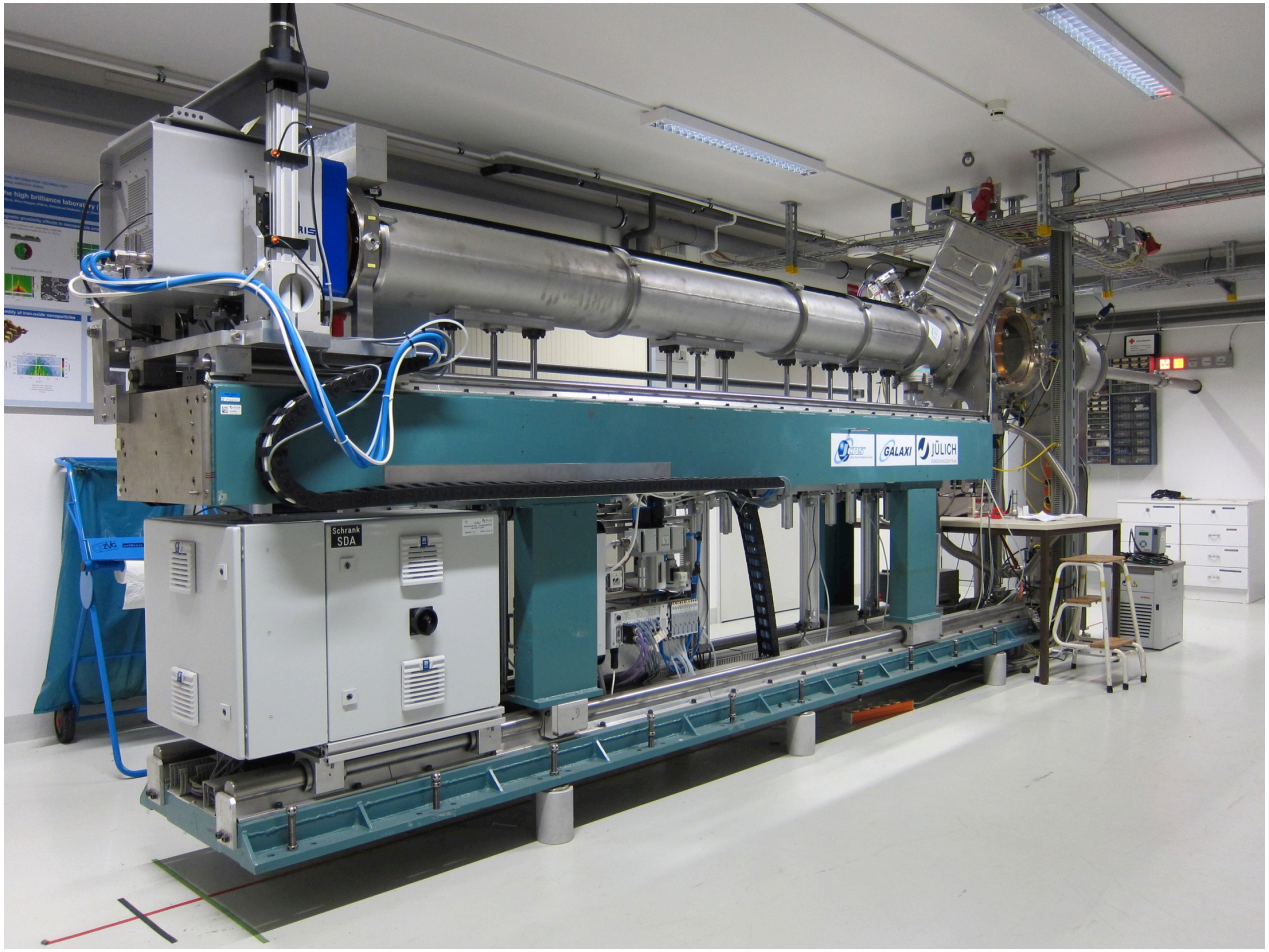
Optics: parabolic Montel mirrors, synchrotron grade quality

X-ray beam: 2.4 x 2.4 mm^2, divergence < 0.3 mrad (fwhm)
Current > 4 * 10^9 photons /s

GALAXI

Gallium Anode Low Angle X-ray Instrument

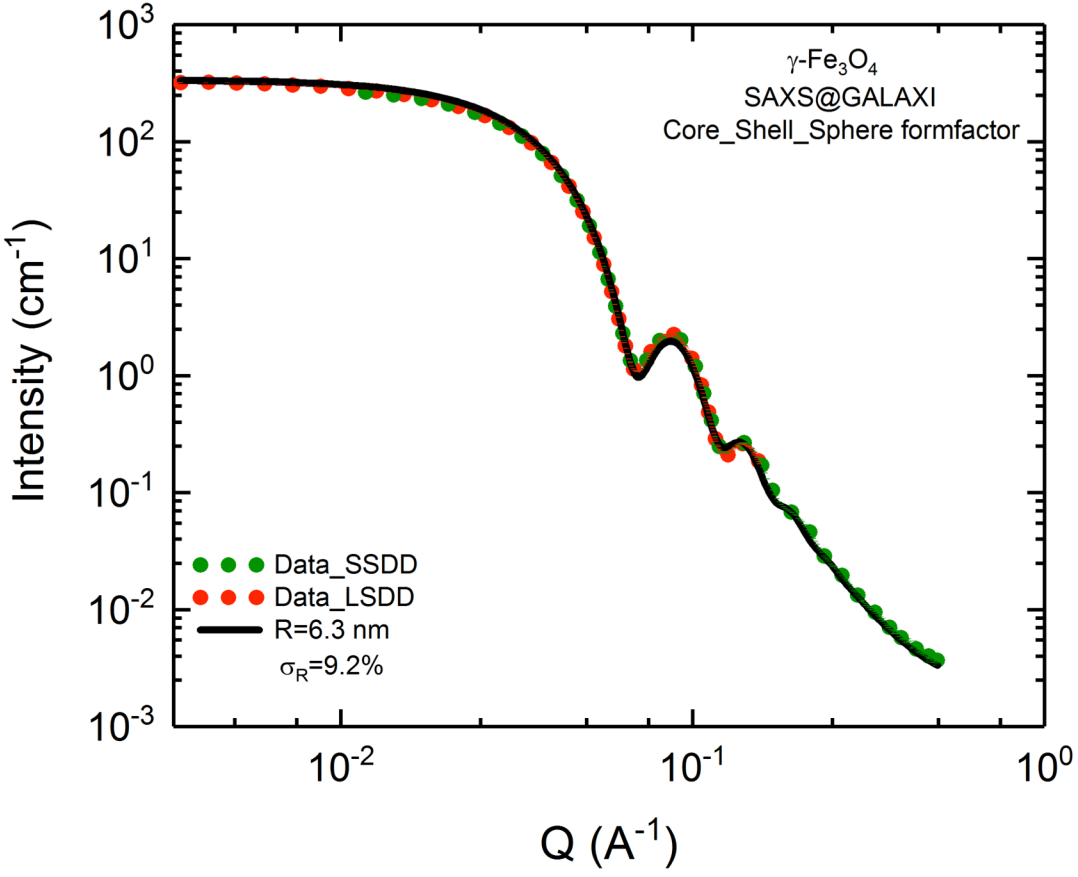
Detector:
Pilatus 1M



Journal of large-scale research facilities, **2** A61 (2016)

MODES OF OPERATION

SAXS from magnetic nanoparticles of cubic shape

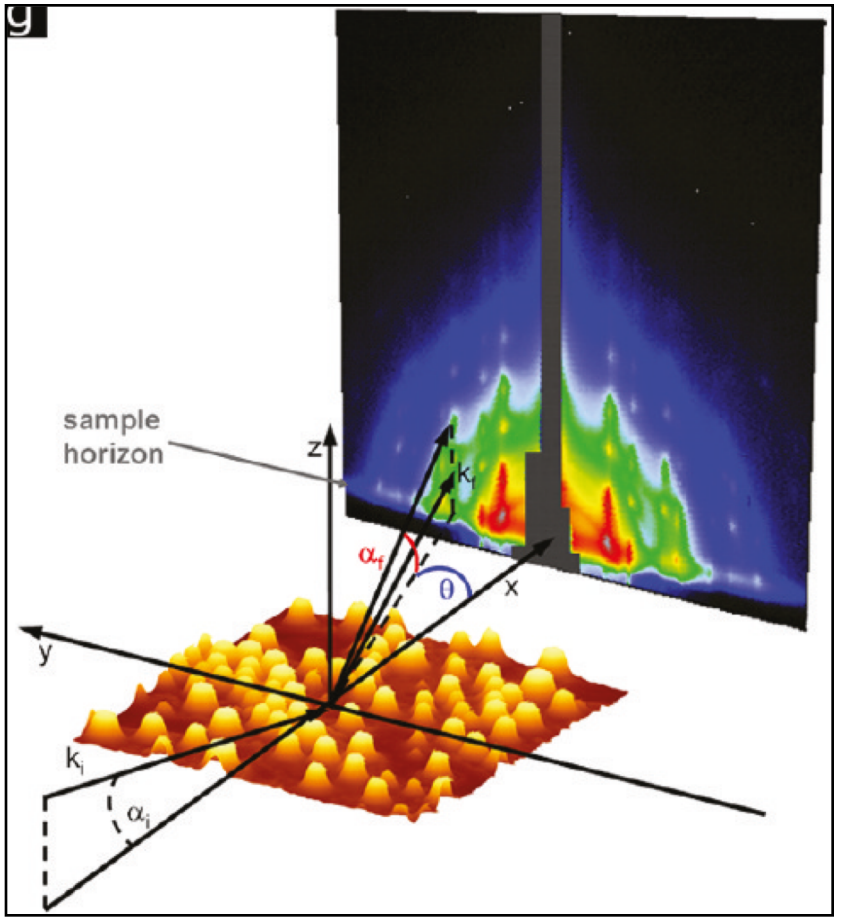


- Collaboration with Dominique Dresen and Sabrina Disch (University of Cologne)

MODES OF OPERATION

Reflectometry and GISAXS:

- In plane structure by surface sensitive techniques: SEM, AFM
- Full 3D structure by GISAXS

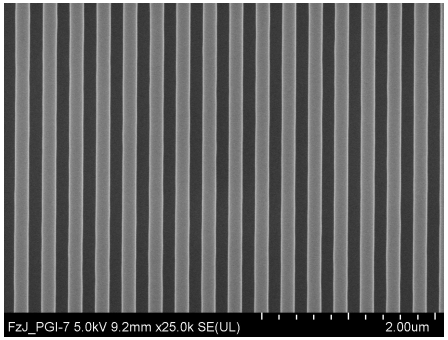


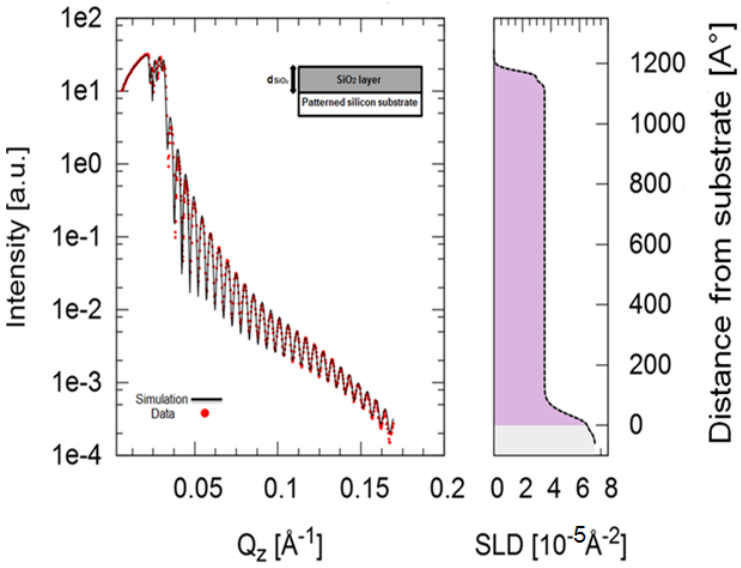
S. Disch, E. Wetterskog et al. Nano Letters **11**, 1651 (2011)

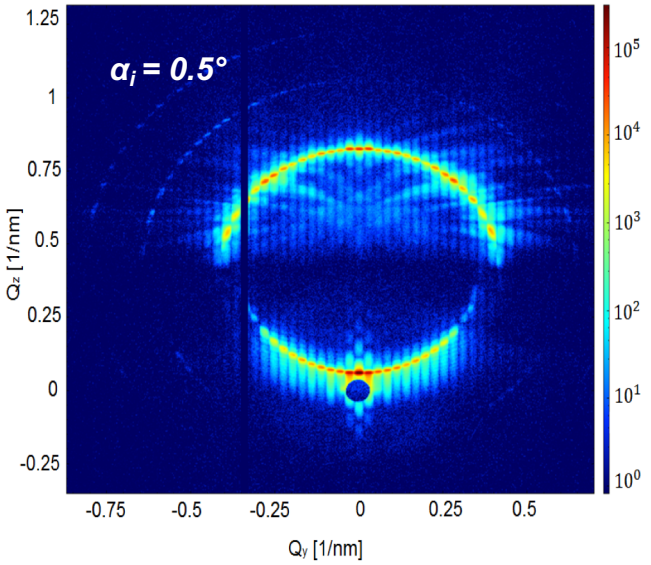
MODES OF OPERATION

Reflectometry and GISAXS: Structural characterisation of patterned Si substrates

- Patterned Si substrates for assisted self-assembly of magnetic nanoparticles
- 3D structure investigated by reflectometry and GISAXS



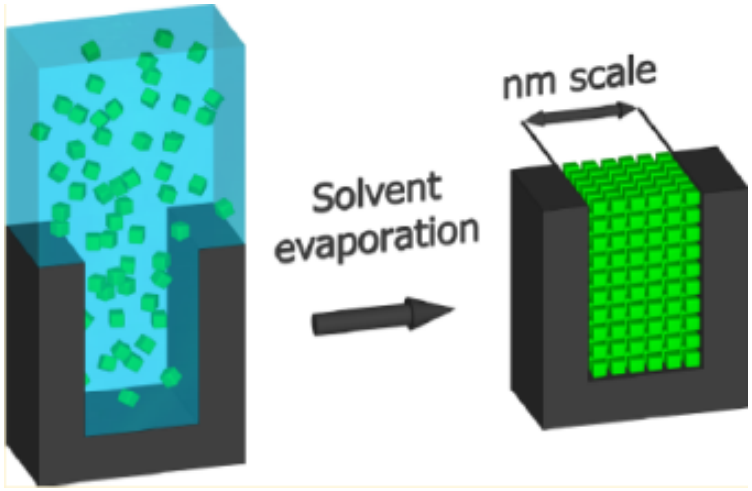




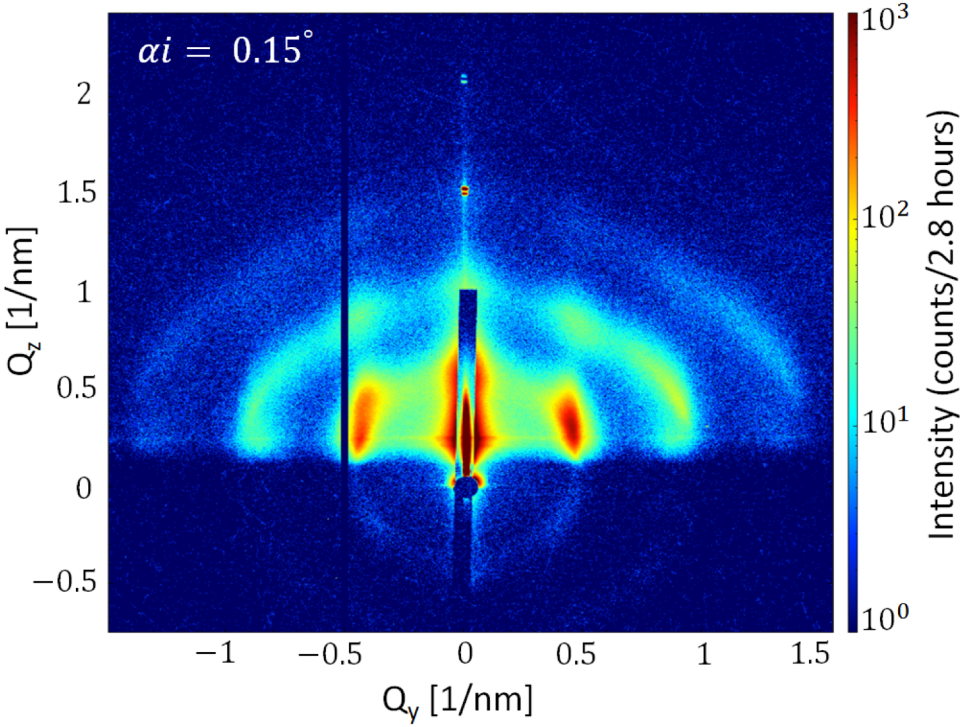
MODES OF OPERATION

Reflectometry and GISAXS:

Assisted self-assembly:



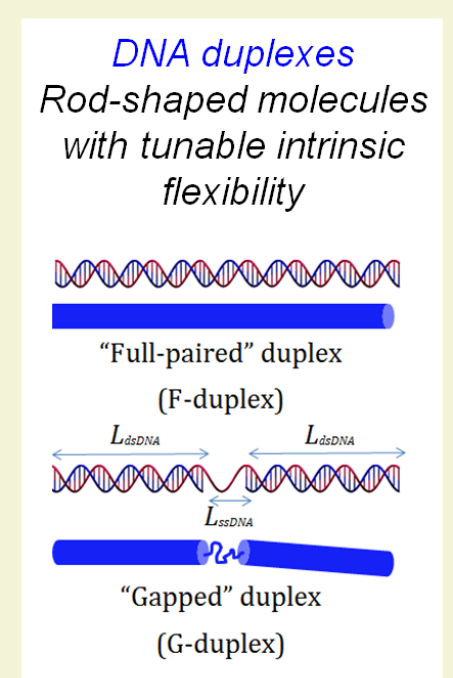
M. Agthe et al.,
Langmuir **31**, 12537 (2015)



Ultimate aim: Investigation of magnetic correlations in highly ordered 3D arrangements of magnetic nanoparticles by GISANS

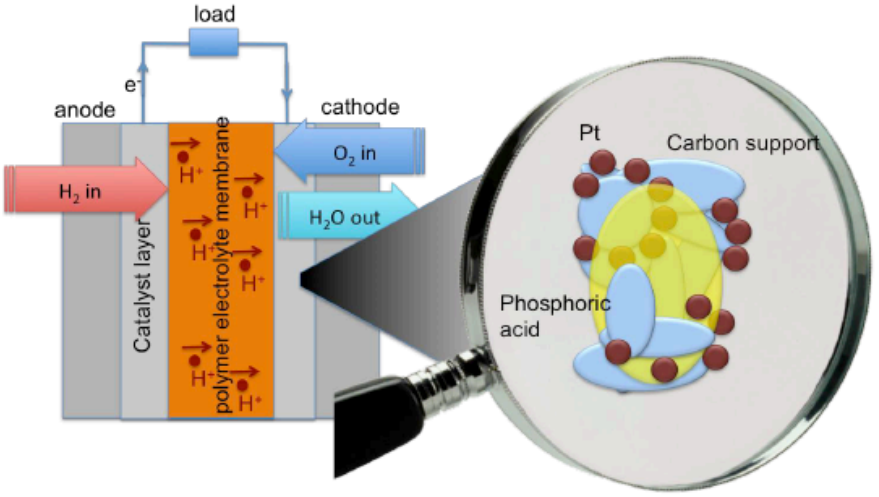
SOME OTHER APPLICATIONS

SOFT MATTER:
Ordering between DNAs



M. Salamonczyk et al.,
Nat. Comm. **7** 13358 (2016)

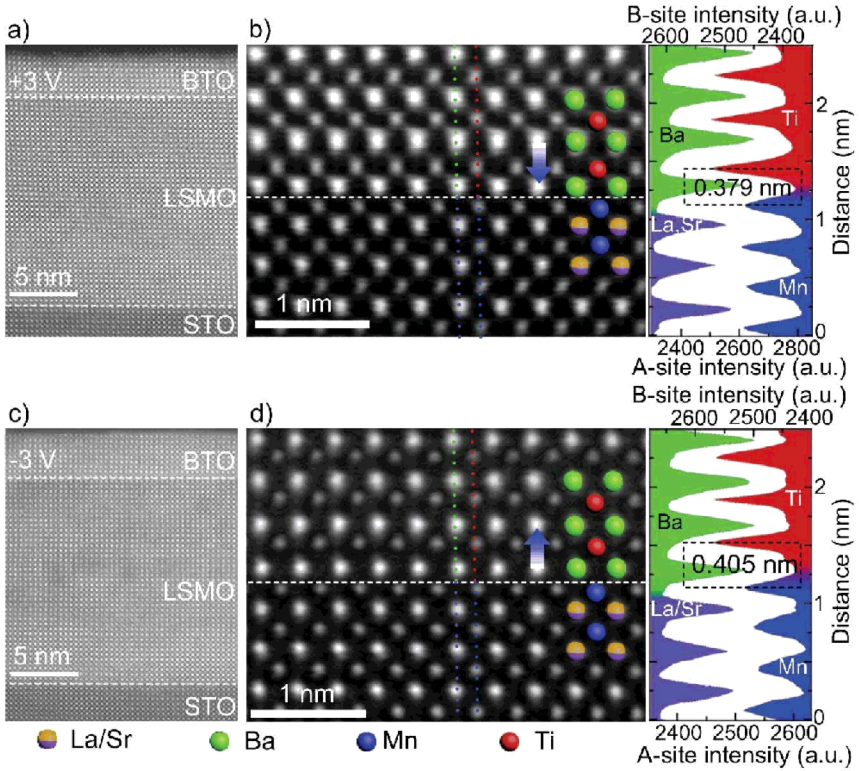
ENERGY:
Structure of catalytic layer of fuel cells



M. Khaneft et al.,
Fuel Cells **16**, 406 (2016).
O. Holderer et al.,
ECS Transactions **80**, 19 (2017)

TOWARDS INTERATOMIC LENGTH SCALES: ONE MOTIVATION (AMONG OTHERS)

Electric field control of magnetism at interfaces in oxide heterostructures



Advantages:

- Electric field more local than magnetic field
- Smaller energy consumption

B. Cui et al.,
Adv. Funct. Mater.,
26 753 (2016)

Precise determination of atomic positions and site occupancies is a prerequesite for interpreting magnetic data

TOWARDS INTERATOMIC LENGTH SCALES:

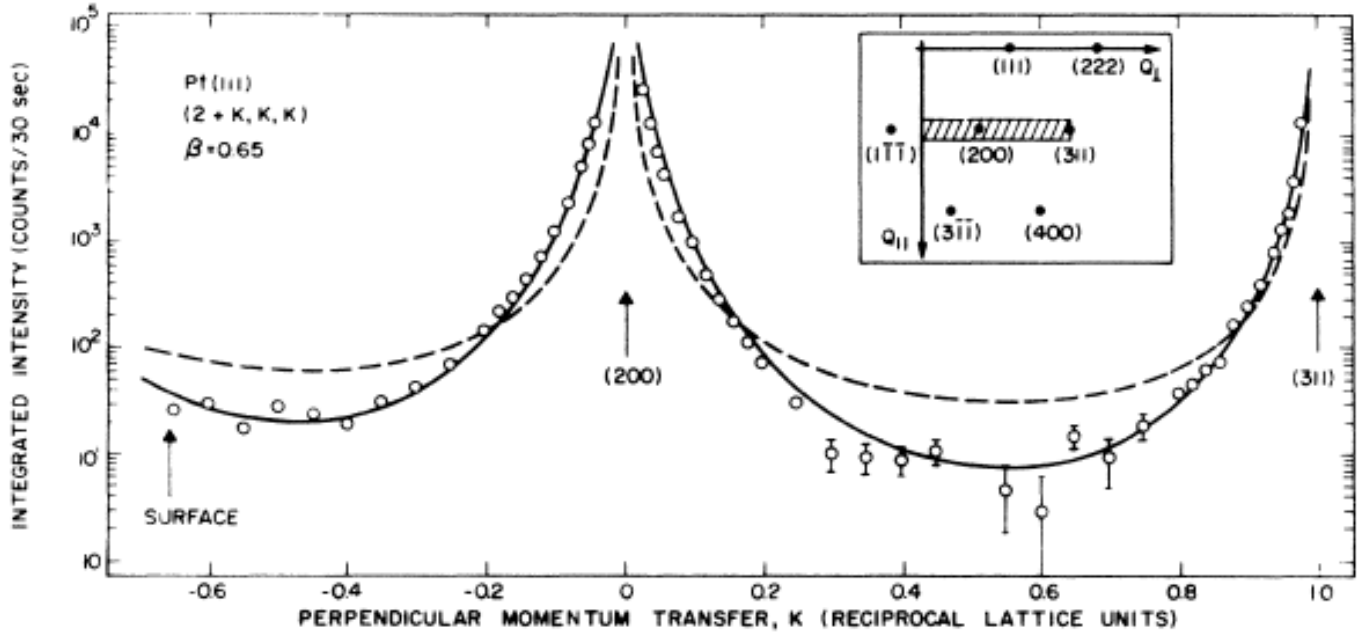
GIWAXS and Surface X-ray Diffraction

PHYSICAL REVIEW B VOLUME 33, NUMBER 6 15 MARCH 1986

Crystal truncation rods and surface roughness

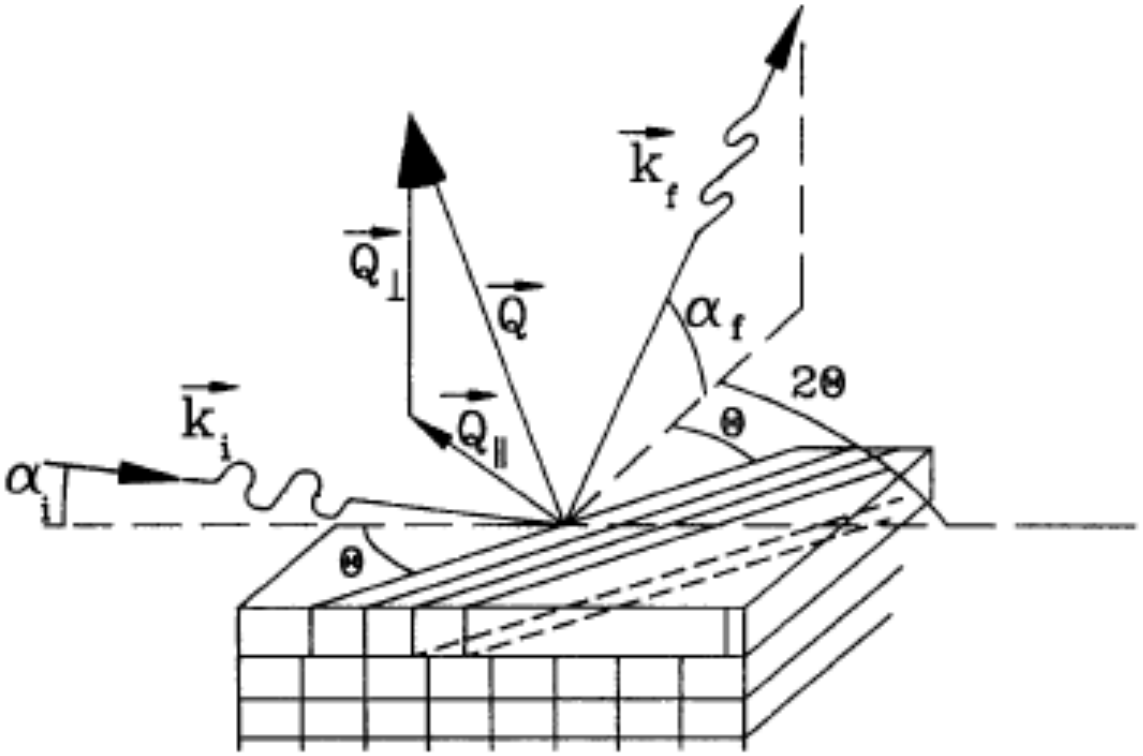
I. K. Robinson
AT&T Bell Laboratories, Murray Hill, New Jersey 07974

$$\frac{I(\text{Bragg point})}{I(\text{truncation rod})} = N_3 m \sim 10^5$$



TOWARDS INTERATOMIC LENGTH SCALES:

GIWAXS and Surface X-ray Diffraction: Experimental geometry



G. Renaud, Surface Science Reports **32**, 1 (1998)

TOWARDS INTERATOMIC LENGTH SCALES:

Characterisation of wavelength resolution at GALAXI

$$\delta Q = \sqrt{\left(\frac{4\pi}{\lambda}\frac{\delta\lambda}{\lambda}\sin\theta\right)^2 + \left(\frac{4\pi}{\lambda}\cos\theta\ \delta\theta\right)^2}$$

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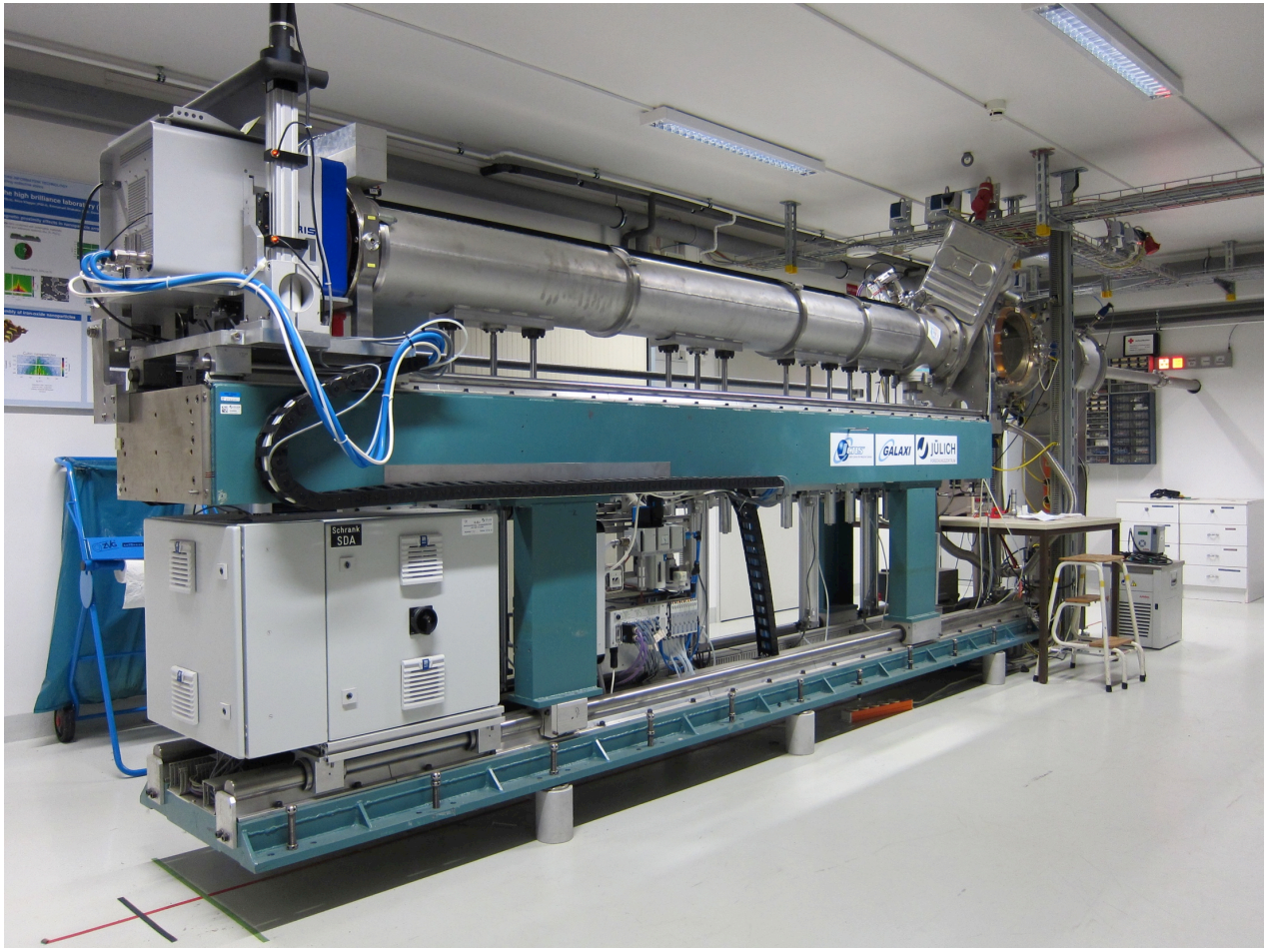

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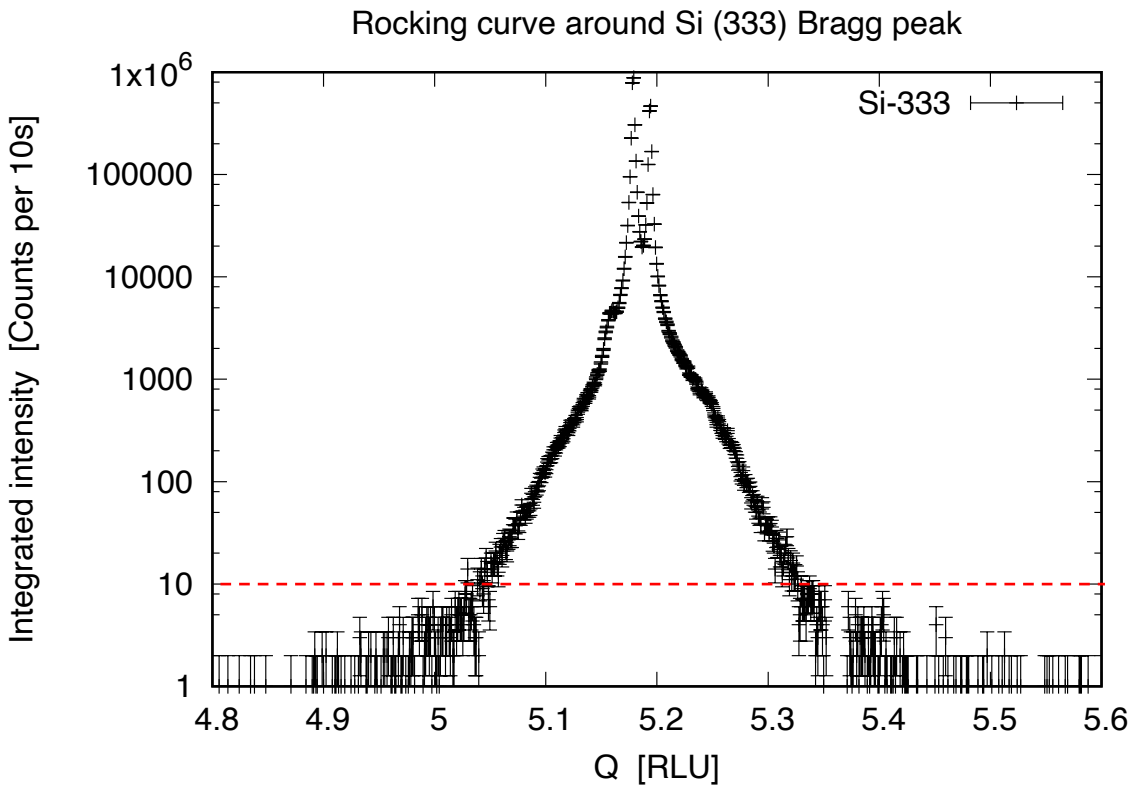

Collimation slits:
S1: 0.5x0.5 mm^2
S2: 0.5x0.5 mm^2

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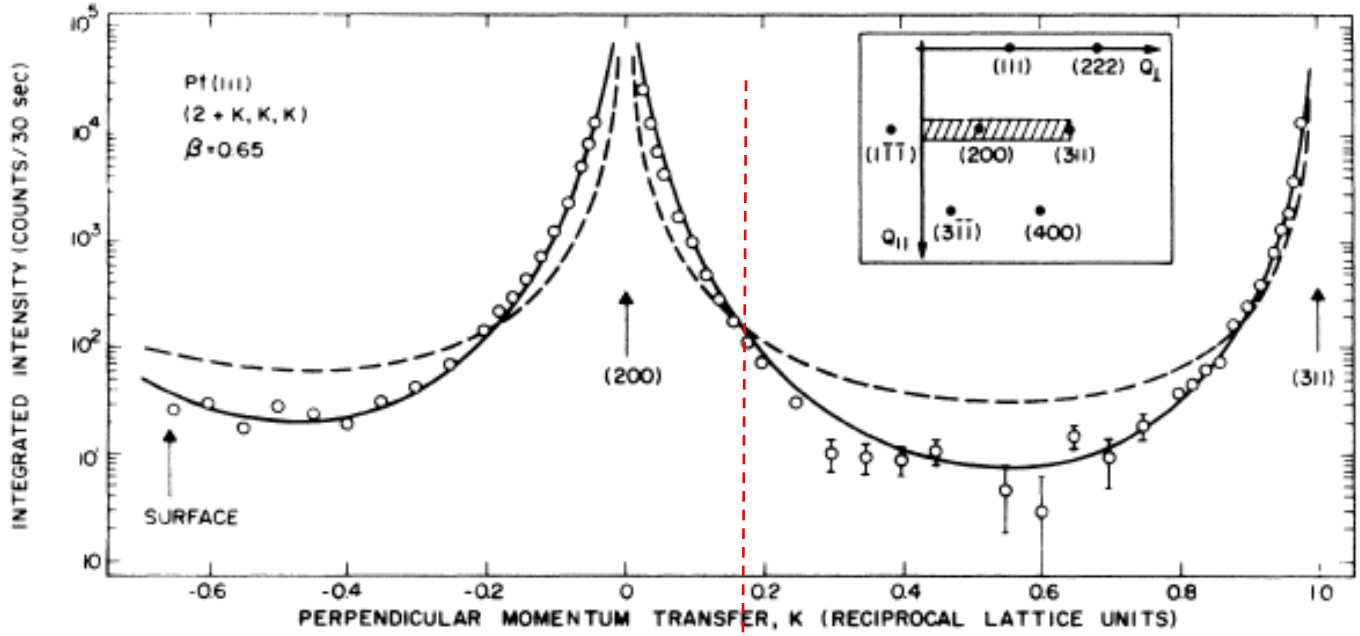

THANK YOU FOR YOUR ATTENTION