Soft Condensed Matter Diffraction with Microfocus Techniques

C. Riekel

European Synchrotron Radiation Facility

ID13

THE MICRO/NANO BEAMLINE

Soft Condensed Matter Group beamlines

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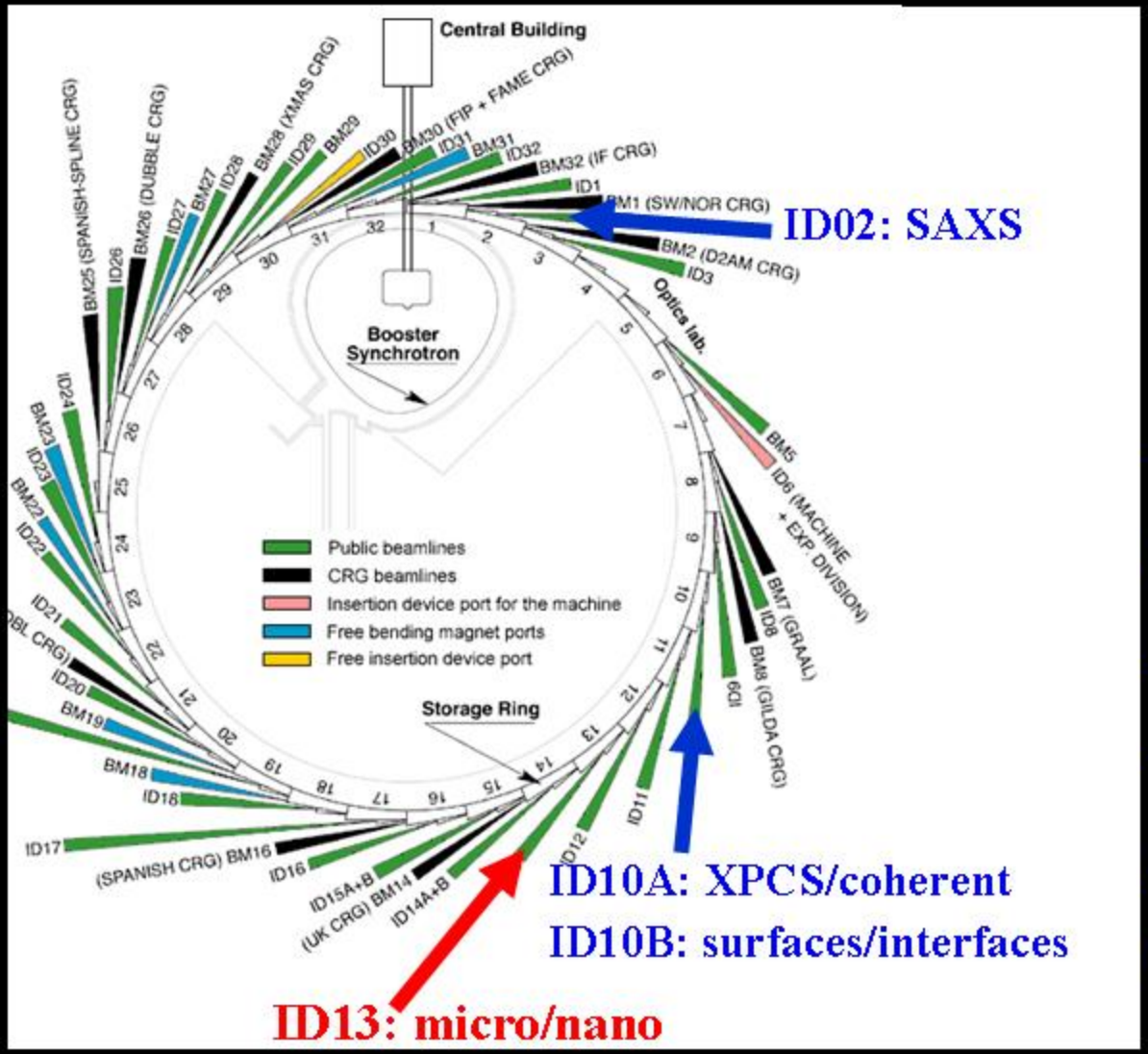

Topics

1. *ID13 beamline layout*
2. *fiber diffraction*
3. *large data sets*
4. *microRaman*
5. *optical manipulation*
6. *European SAXS fundin*

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Microfocus beamline

ID13 beamline configuration

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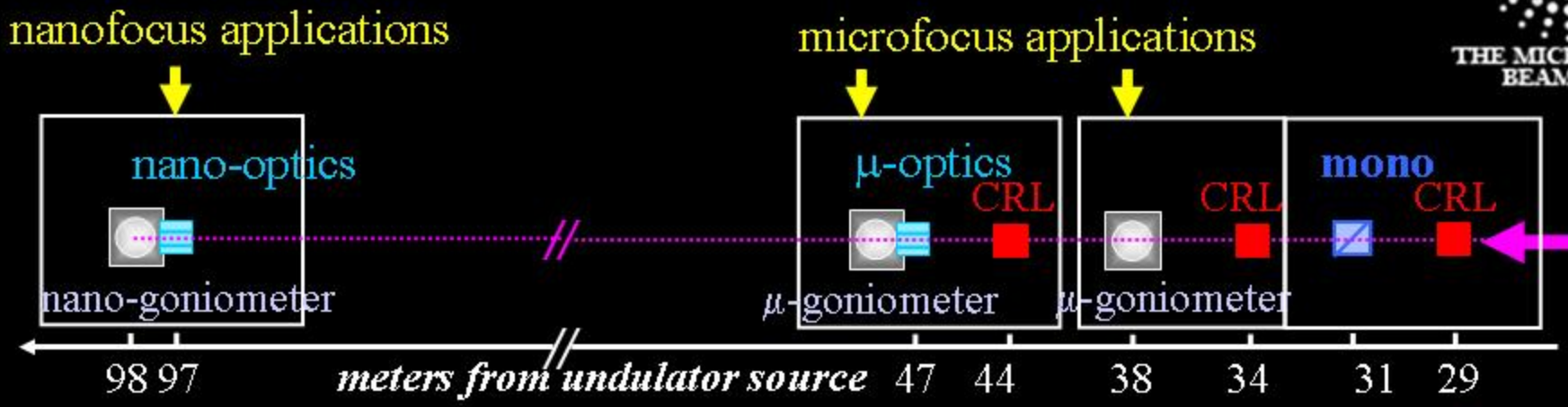


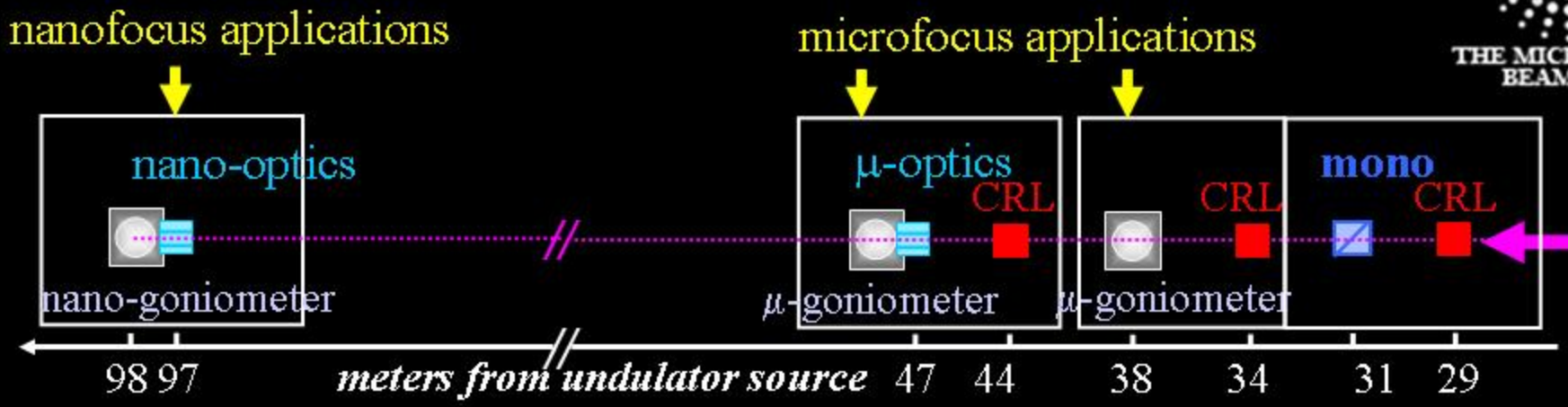
parabolic CRL+collimator **5 μm**

KB mirrors **1 μm**

linear Fresnel lenses **300 nm**

linear CRL **≈50 nm**

ID13 beamline configuration



proposed Upgrade Program Beamline 8

separate “micro” and “nano” branches by canted undulators

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Fiber diffraction

Poly (p-phenylene terephthalamide) structure

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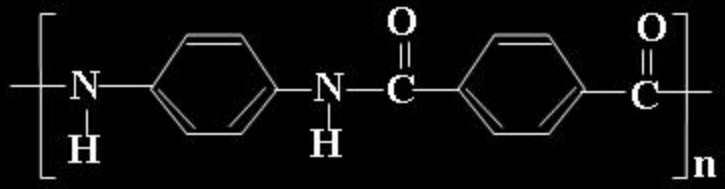
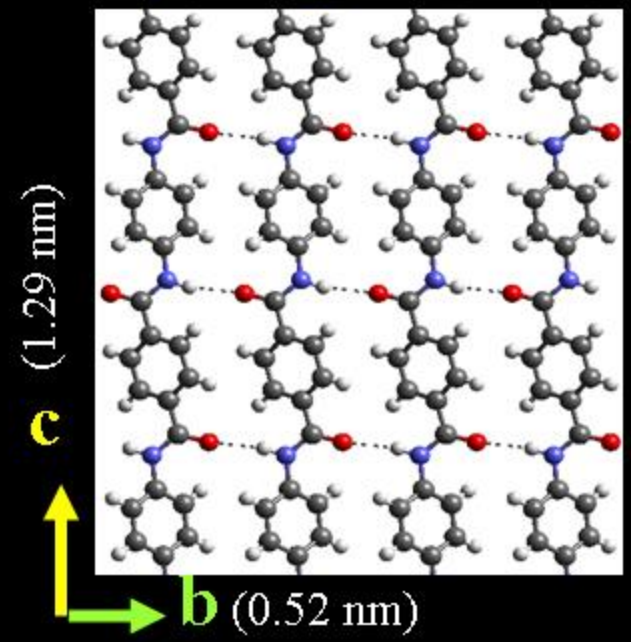


Kevlar® 29,49,149

ATOMIC STRUCTURE

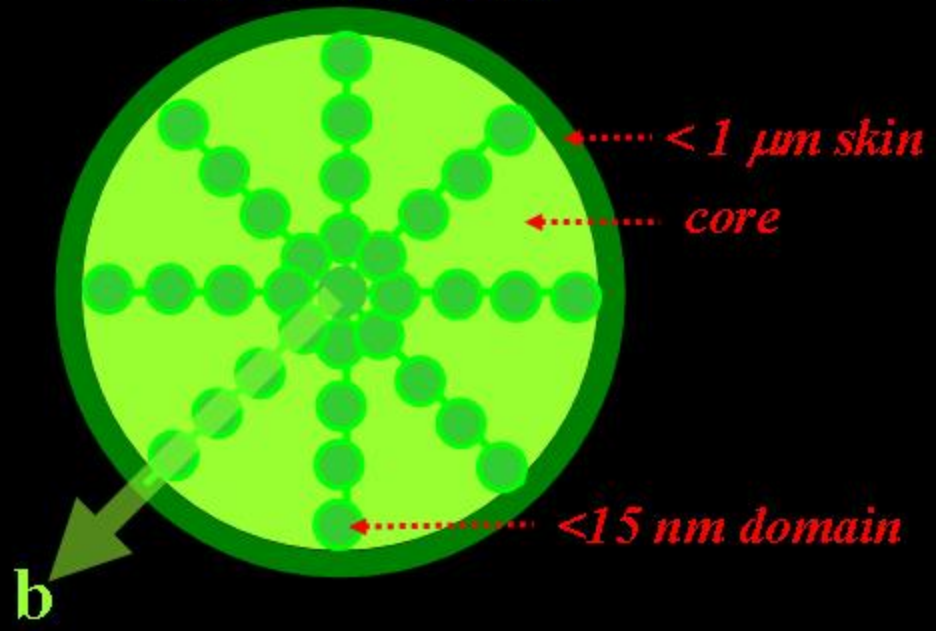
fiber diffraction



Northolt, *Eur. Polym. J.* (1974) **10**,799

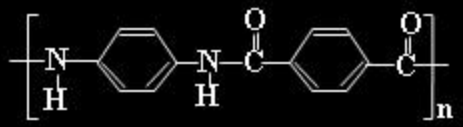
MORPHOLOGY

TEM on thin slices



Dobb et al., *J. Polym. Sc.*(1977) **58**, 237

Kevlar: micro-WAXS



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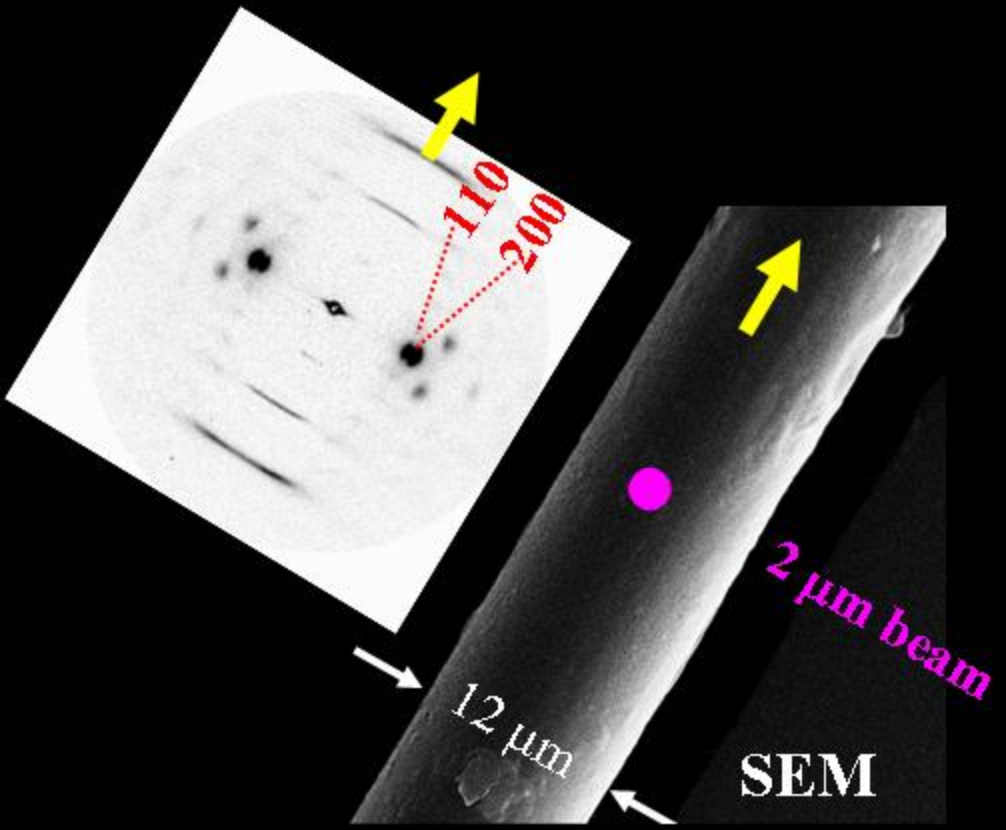
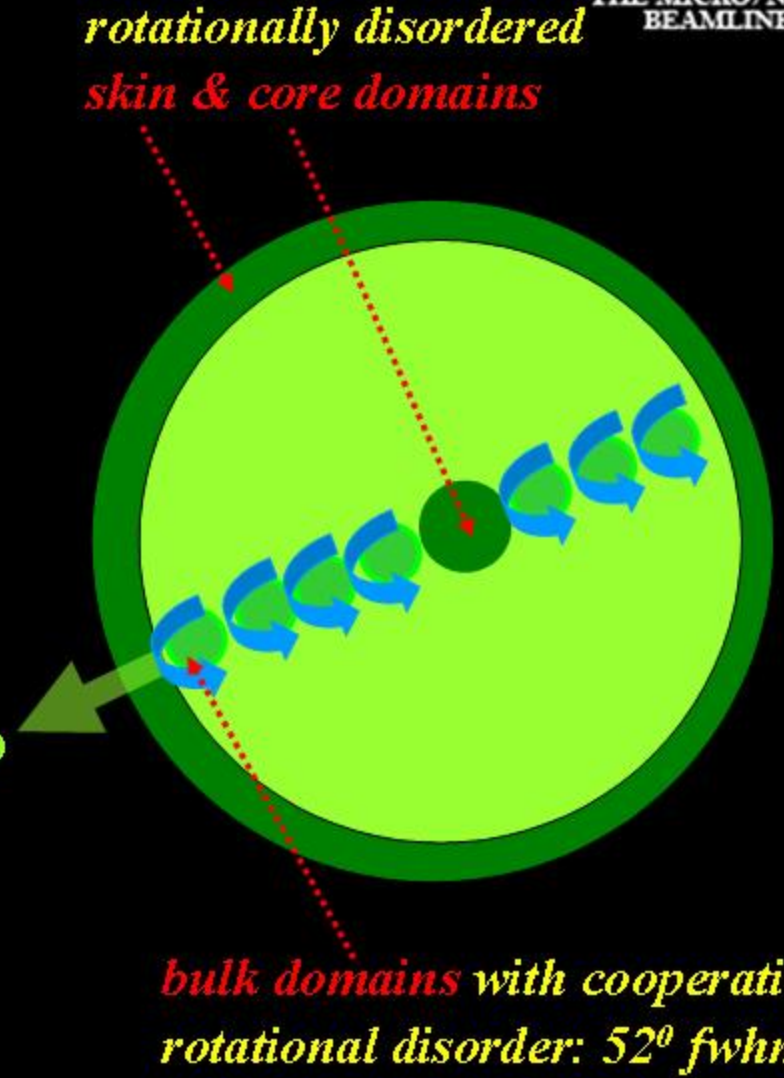
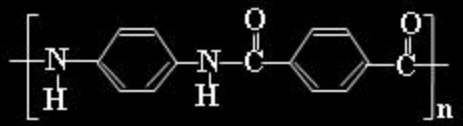




150 nm beam: Roth et al., *Macromolecules* (2003) **36**, 1585

Kevlar: on-axis WAXS



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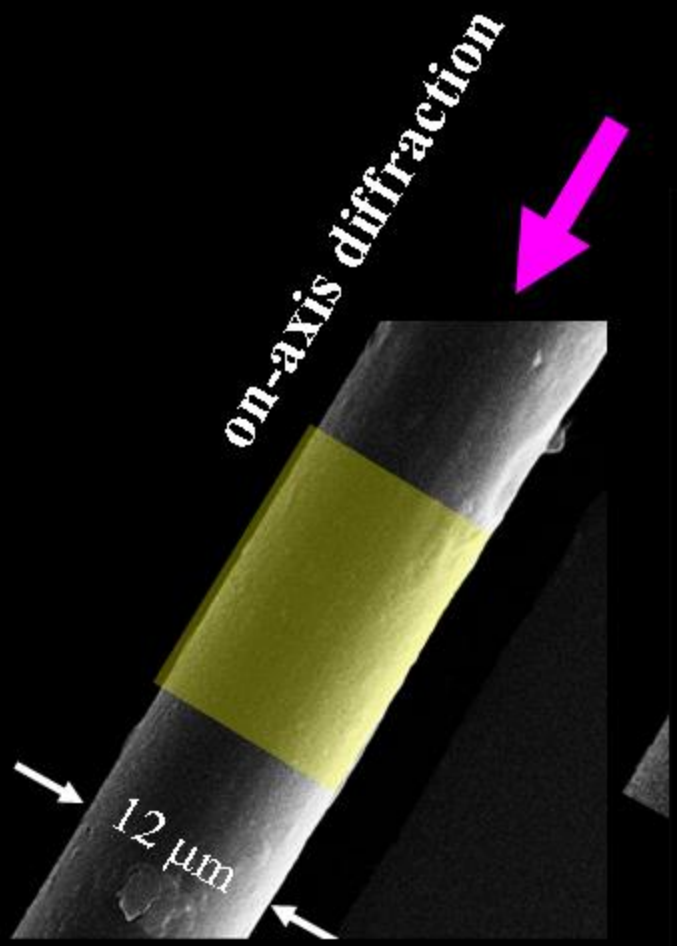
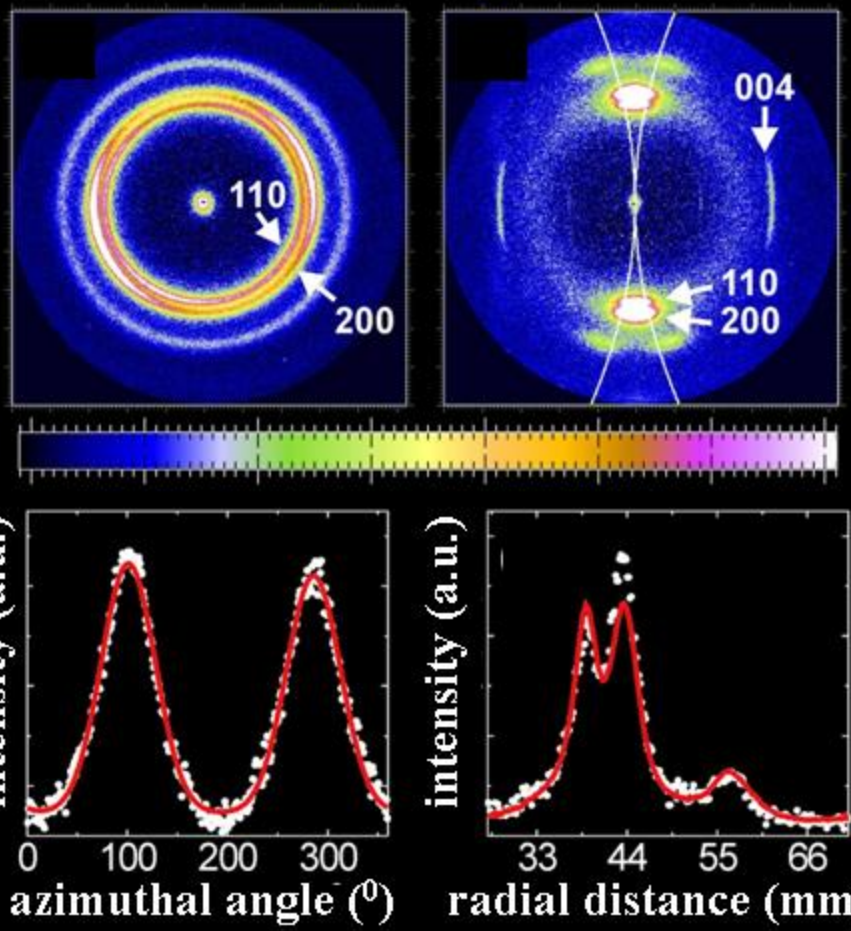
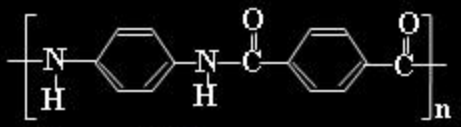


on-axis geometry "normal"



Kevlar: micro-dissection



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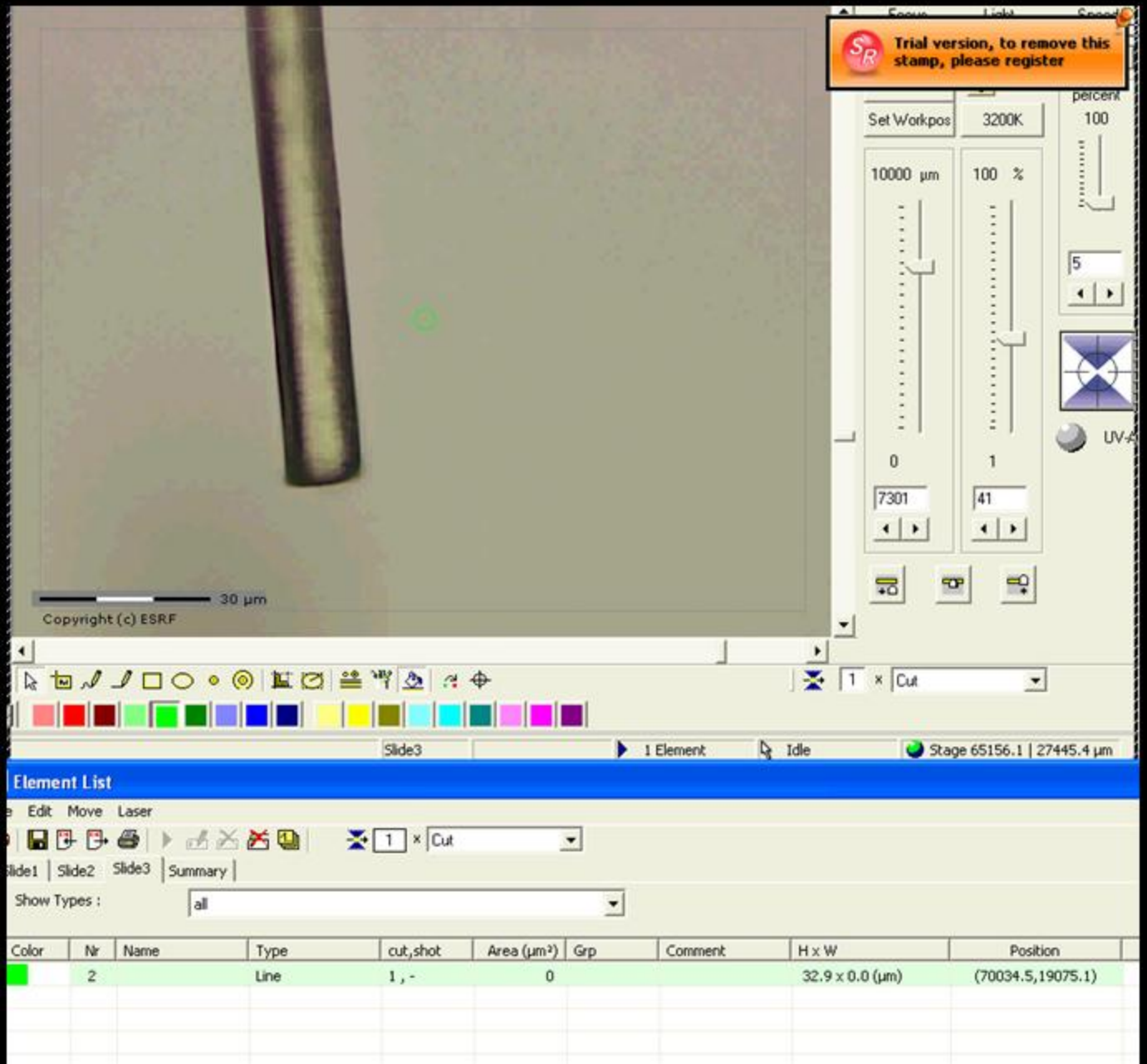
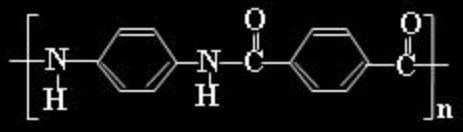


C. Koenig, ESRF-ID13

Kevlar: micro-dissection



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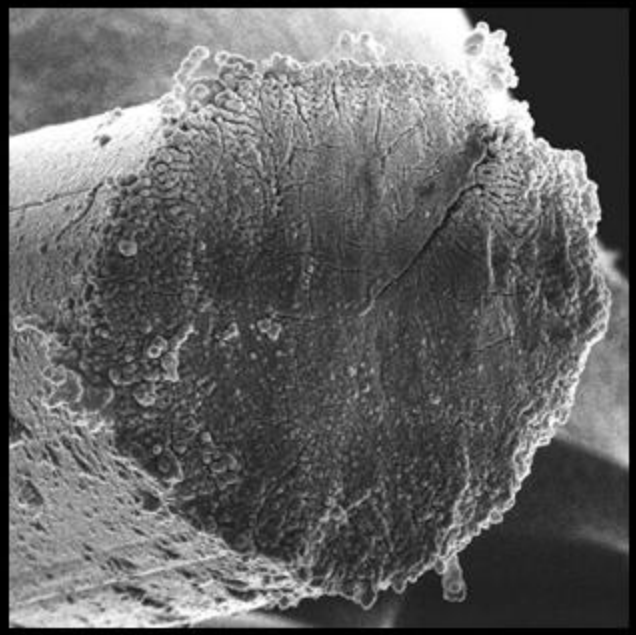
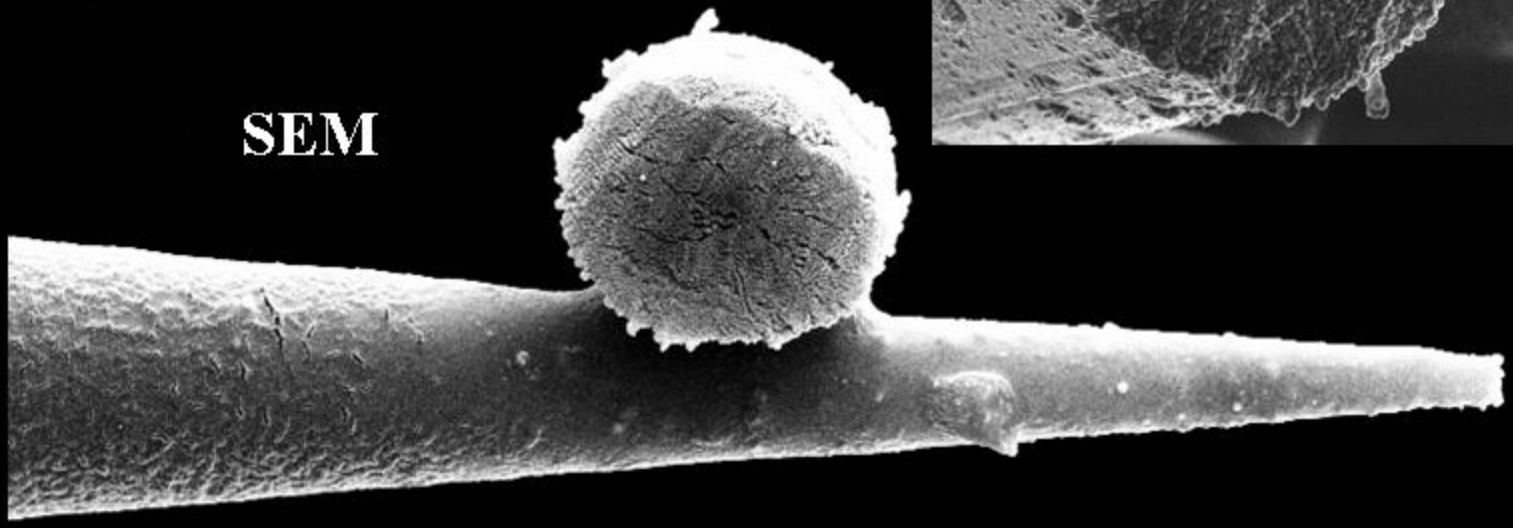
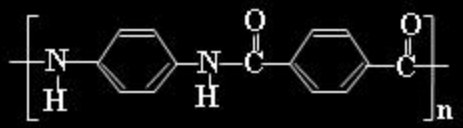


SEM



10μm

Kevlar: on-axis WAXS



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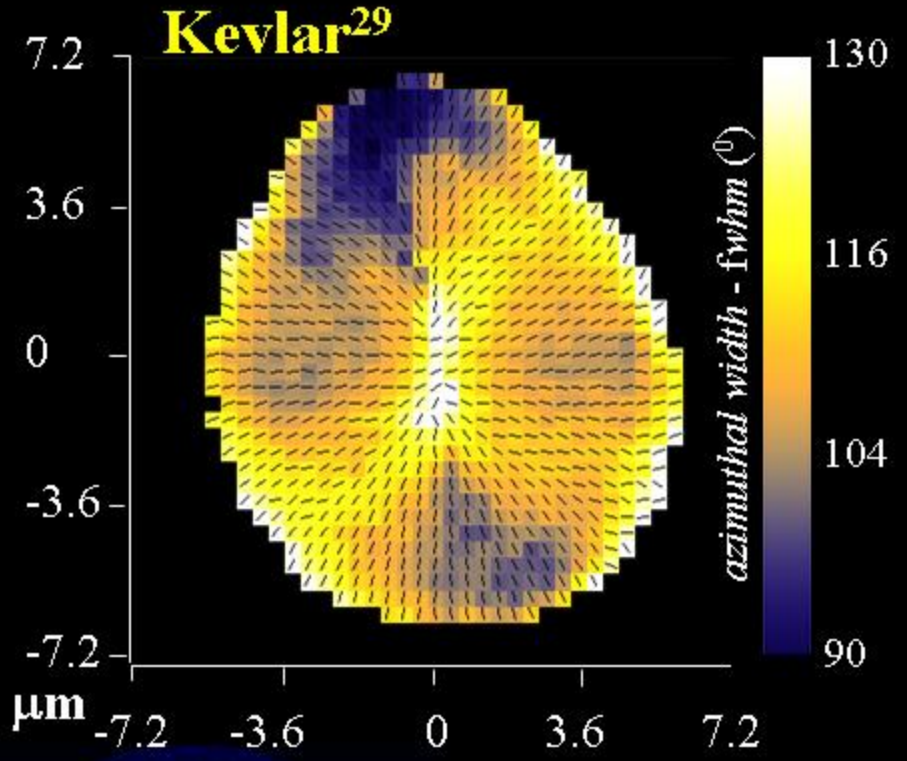
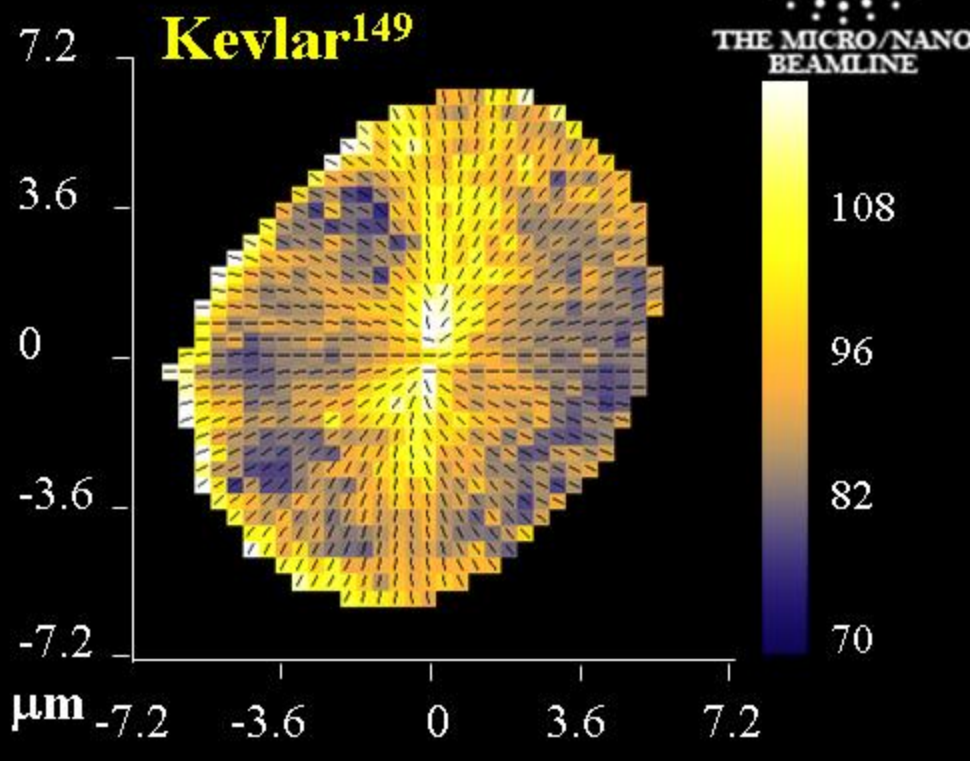
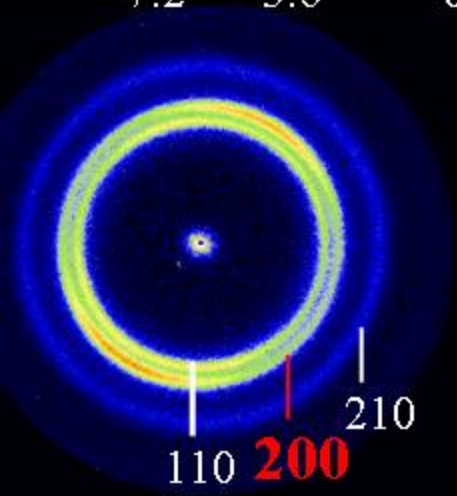




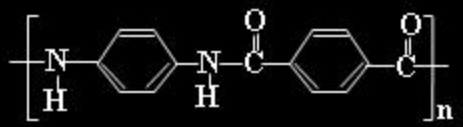


on-axis pattern - 1 µm beam

recursive fit of 200 reflection

Davies et al., *APL* (2008) **92**, 101903

Kevlar: on-axis SAXS



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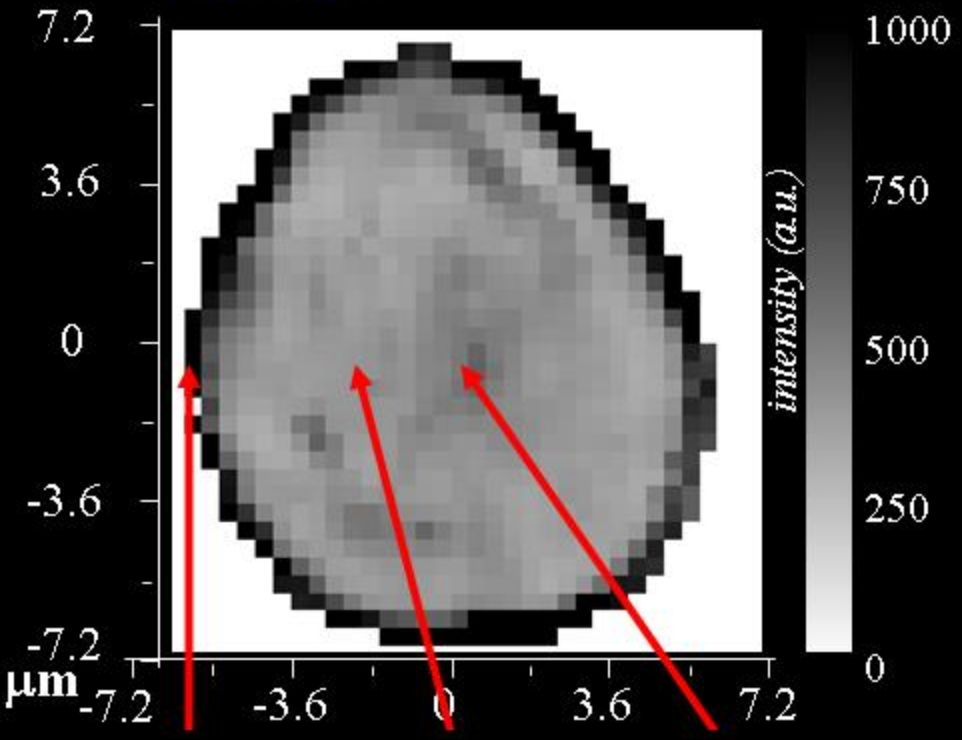
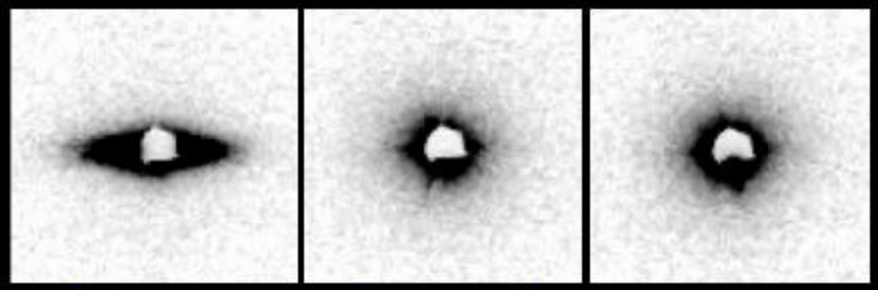
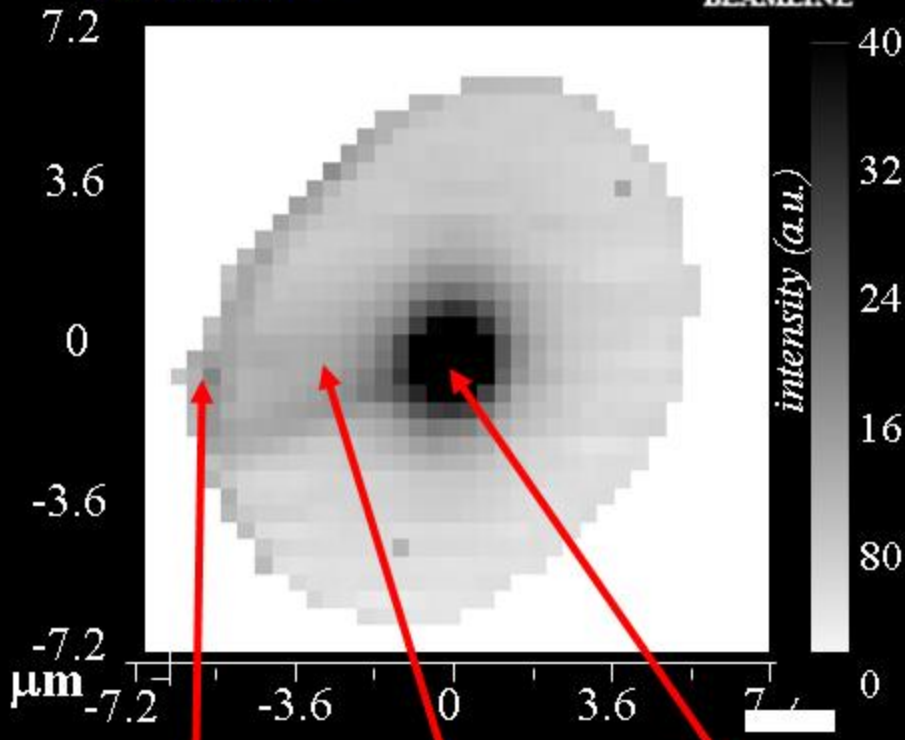
Kevlar^{29}

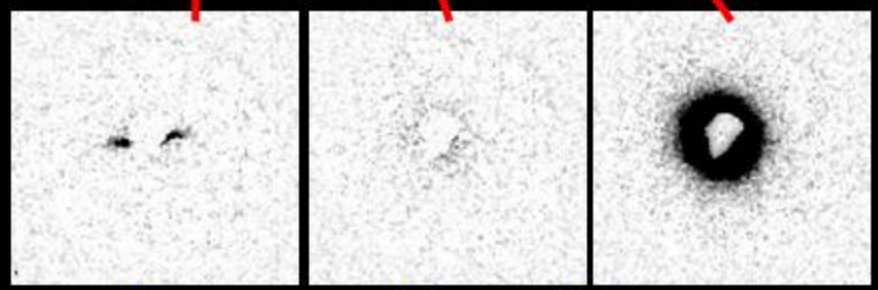




skin *intermediate* *core*

Kevlar^{149}





skin *intermediate* *core*

Davies et al., *APL* (2008) **92**, 101903

Starch granule section irradiated at 100 K

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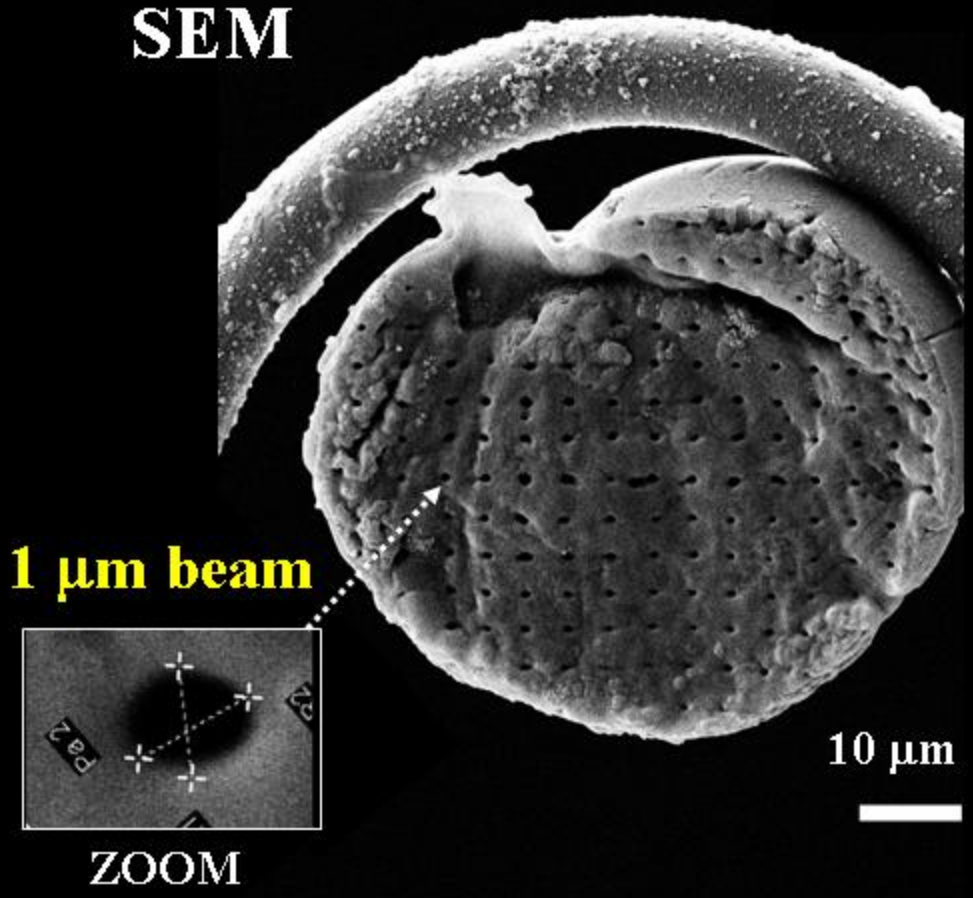

Koenig et al., *submitted*

Cricket sensor hair Seidel et al., *Micron* (2008) **39**, 198

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Large data sets

Woven composites

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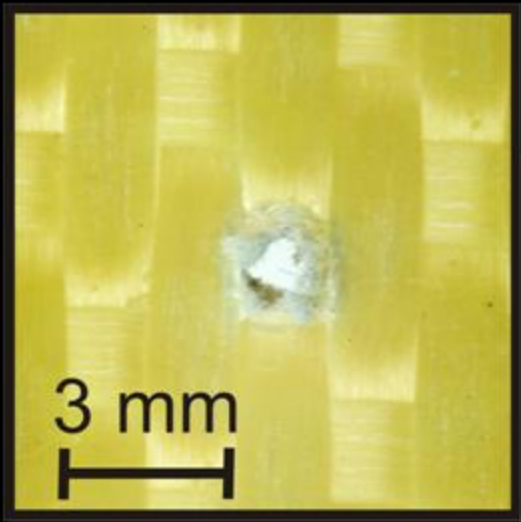
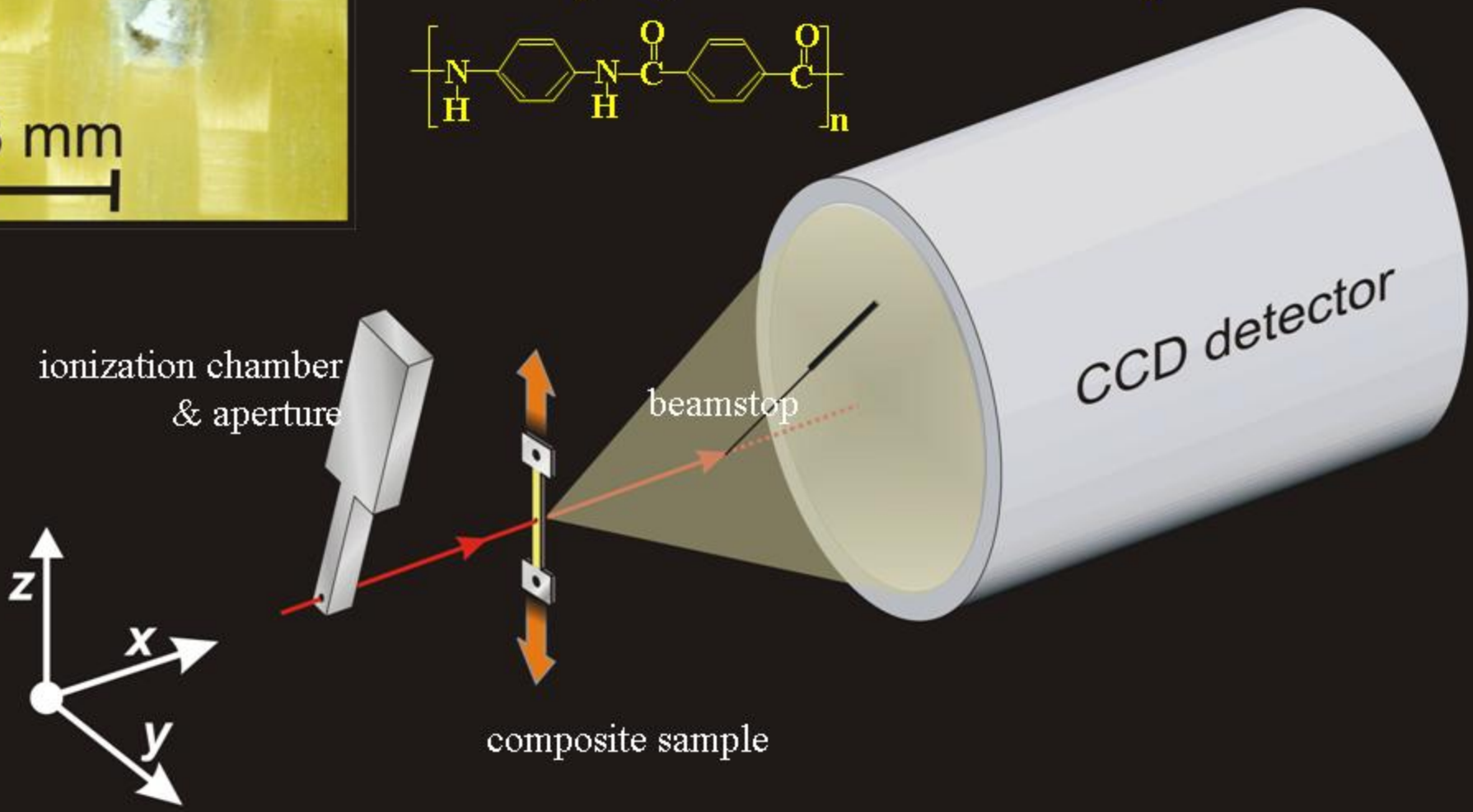


Kevlar/epoxy fiber reinforced composite



Composite "diffraction imaging"

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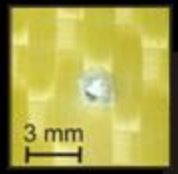
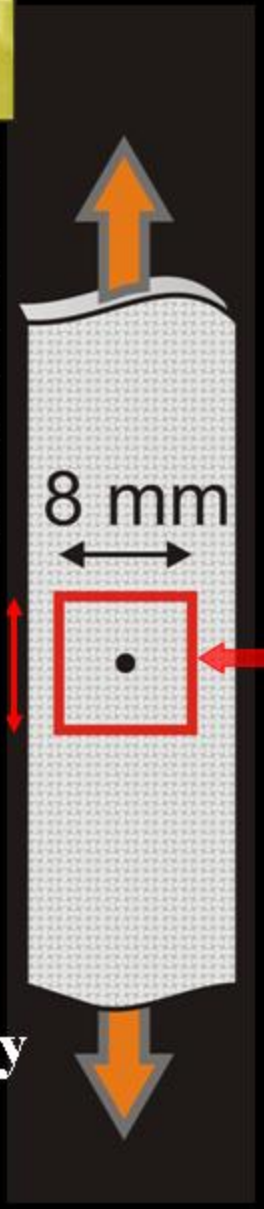
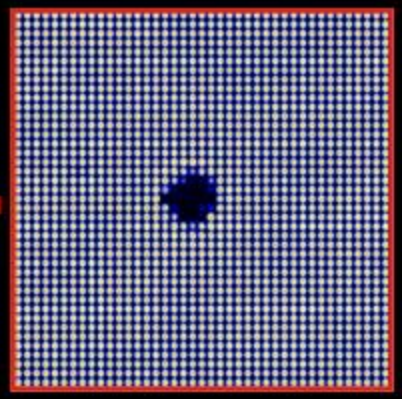




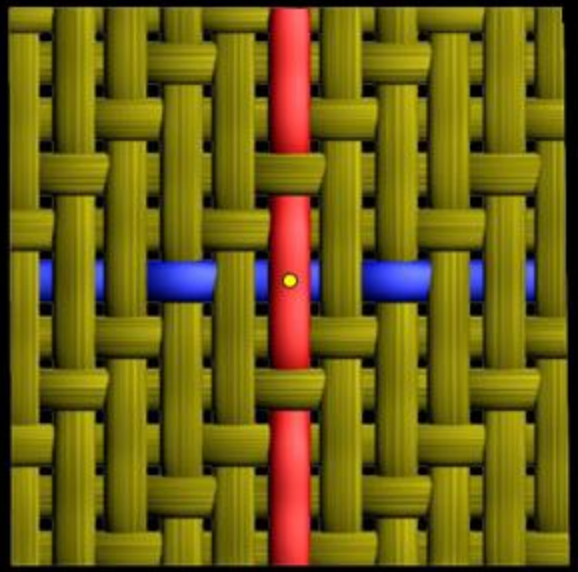
5 μm beam

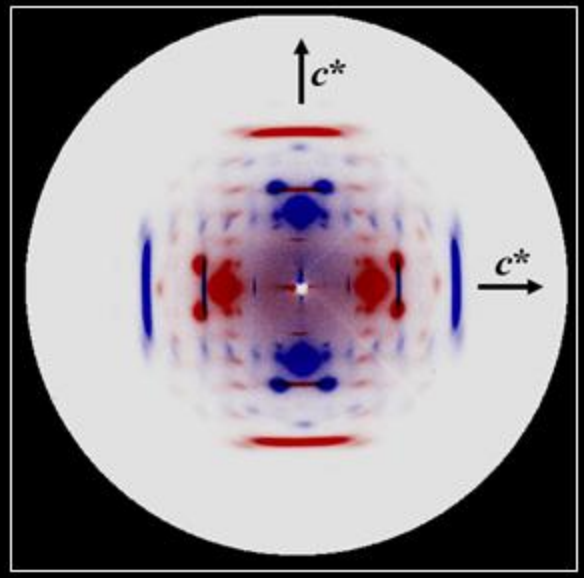


composite image

200*200 μm² mesh

1600 "pixels"





single "pixel"

Embedded yarn geometries

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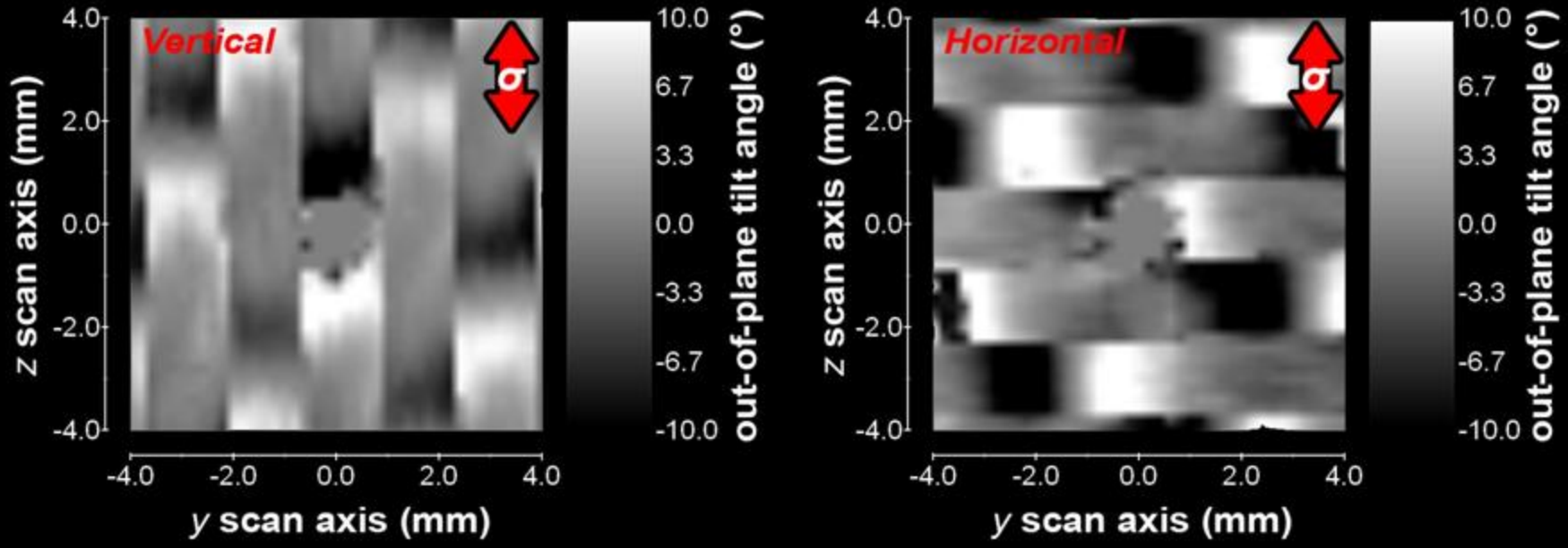

out-of-plane yarn-tilts *from meridional reflections*

Davies et al., *APL* (2007) **91**, 044102

batch processing software: Davies, *J. Appl. Cryst.* (2006) **39**,267

current fitting record: ***about 4*10⁴ CCD-patterns for iPP spherulite***

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MicroRaman

Combined SAXS/WAXS/microRaman

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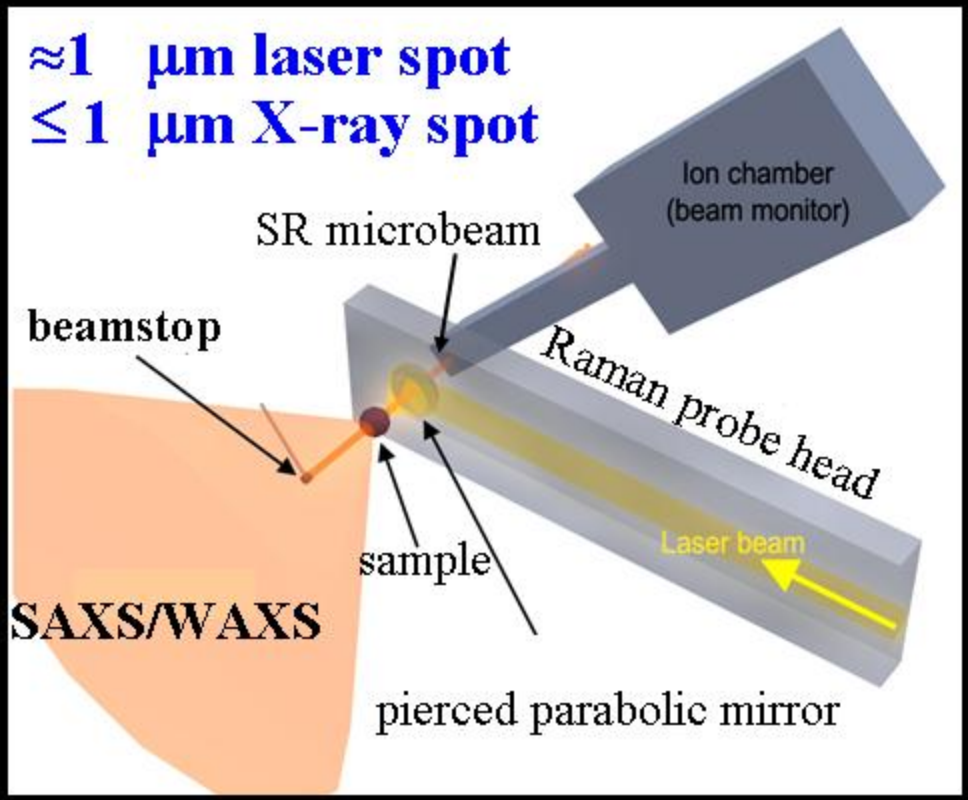
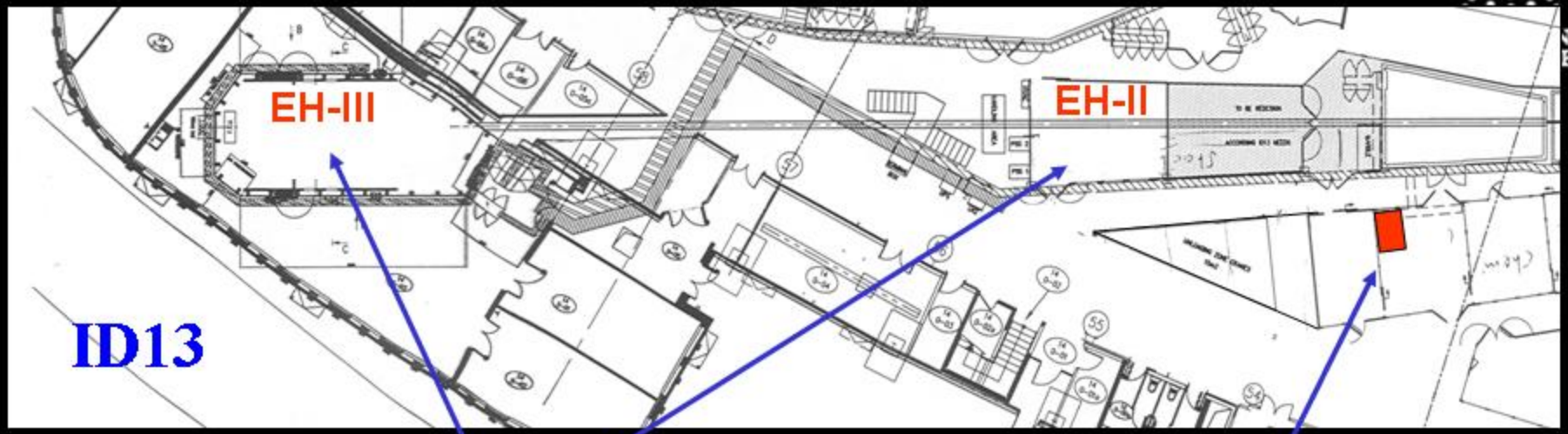
SAXS/WAXS ➡ ***long-range order***

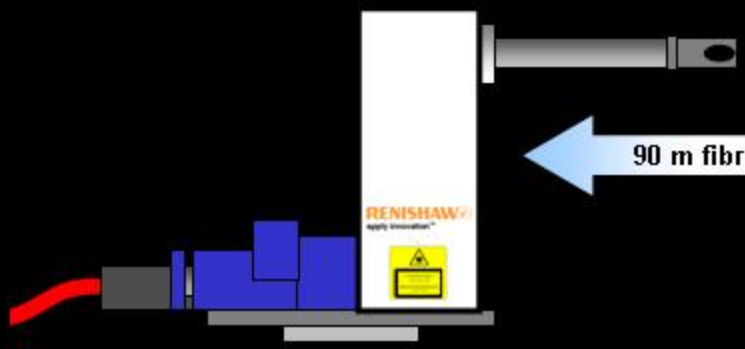
RAMAN ➡ ***molecular information***



Davies et al., *APL* (2005) **87**, 264105-1

Combined SAXS/WAXS/microRaman





remote probe with interchangeable optics and occasional relocation option

stand-alone laboratory-based microscope and spectrometer

Kevlar: complimentary molecular information

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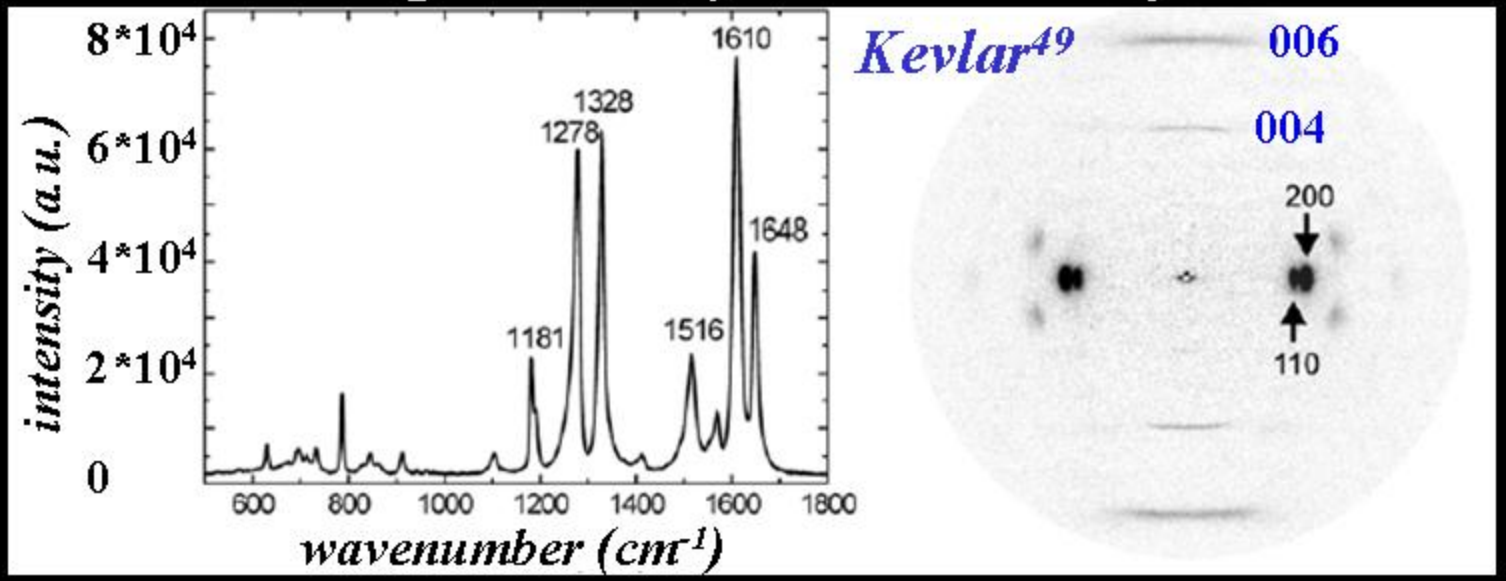
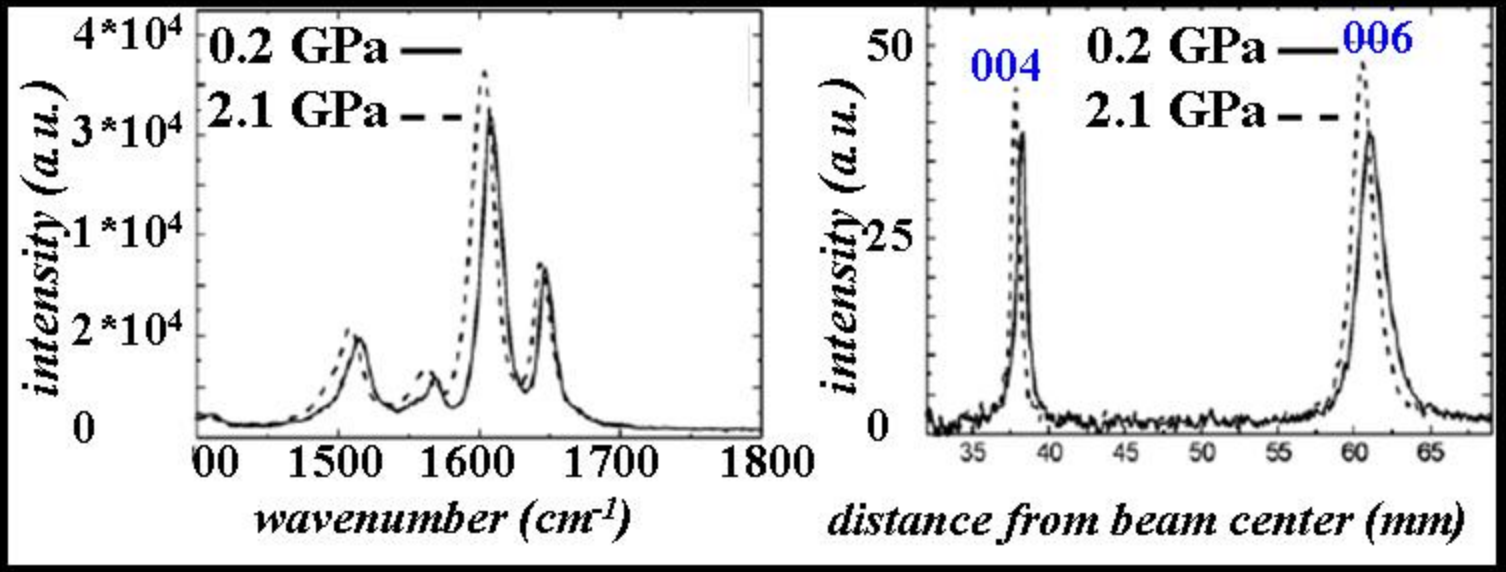


WAXS



Raman

Davies et al., *Macromolecules* (2006) **39**, 4834

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Optical manipulation

Optical tweezers

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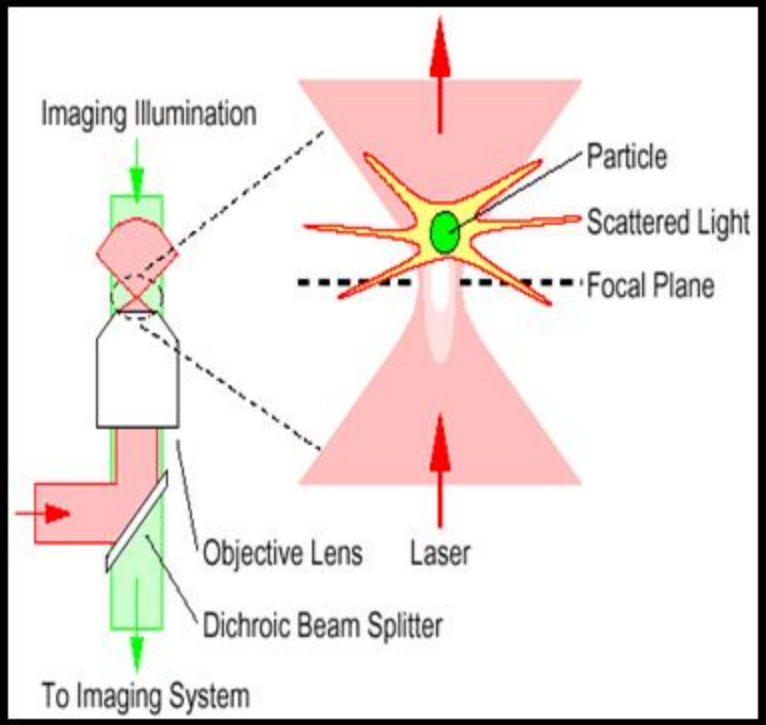

Gradient force trap ***(tens of pN)*** *obtained by tightly focusing a CW laser beam through a high NA objective*

Ashkin et al., *APL* (1971) **19**, 283

Ashkin, *et al Optics Letters* (1986) **11**, 288

$$F = Q\frac{n_m W}{c}$$

F trapping force

Q dimensionless efficiency coefficient

W **power of the laser beam**

$\mathbf{n_m}$ **refractive index of the medium**

c light speed

Schematic optical tweezers set-up

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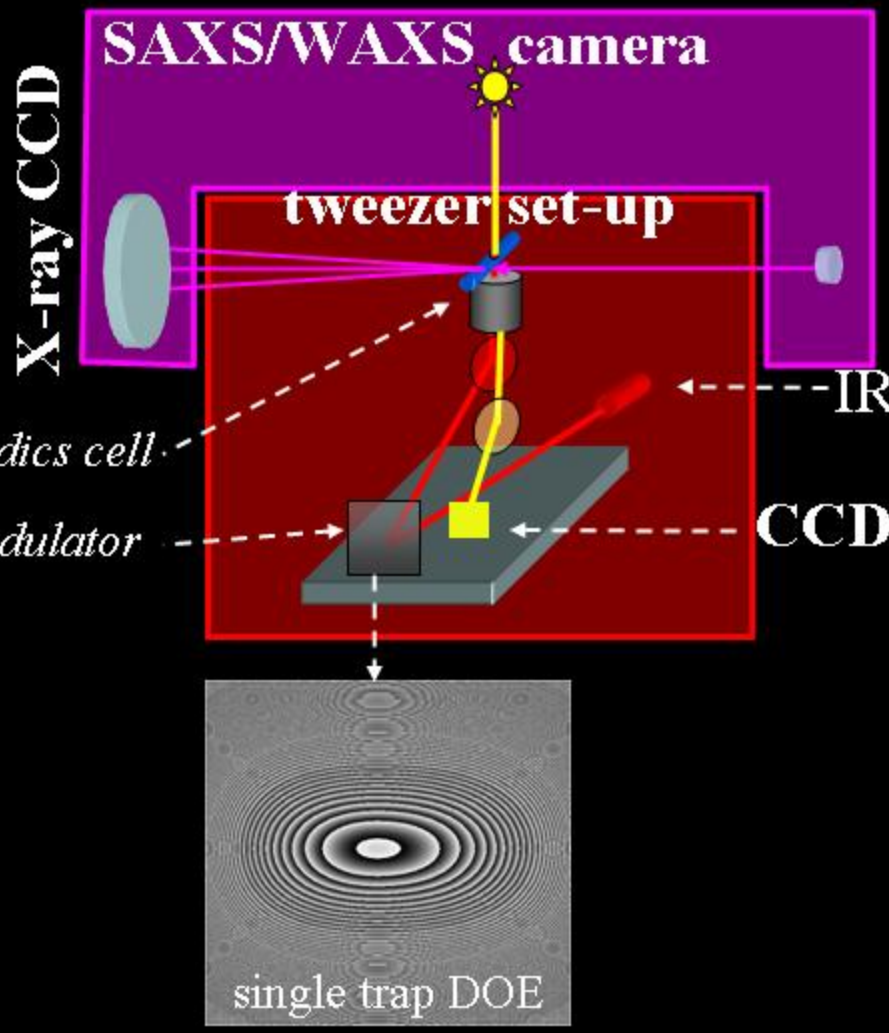

DOE: *diffractive optical element*

liposomes Cojoc et al., *APL* (2007) **91**, 234107-1

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European SAXS funding

SAXS at high brilliance European synchrotrons for bio- and nano-technology

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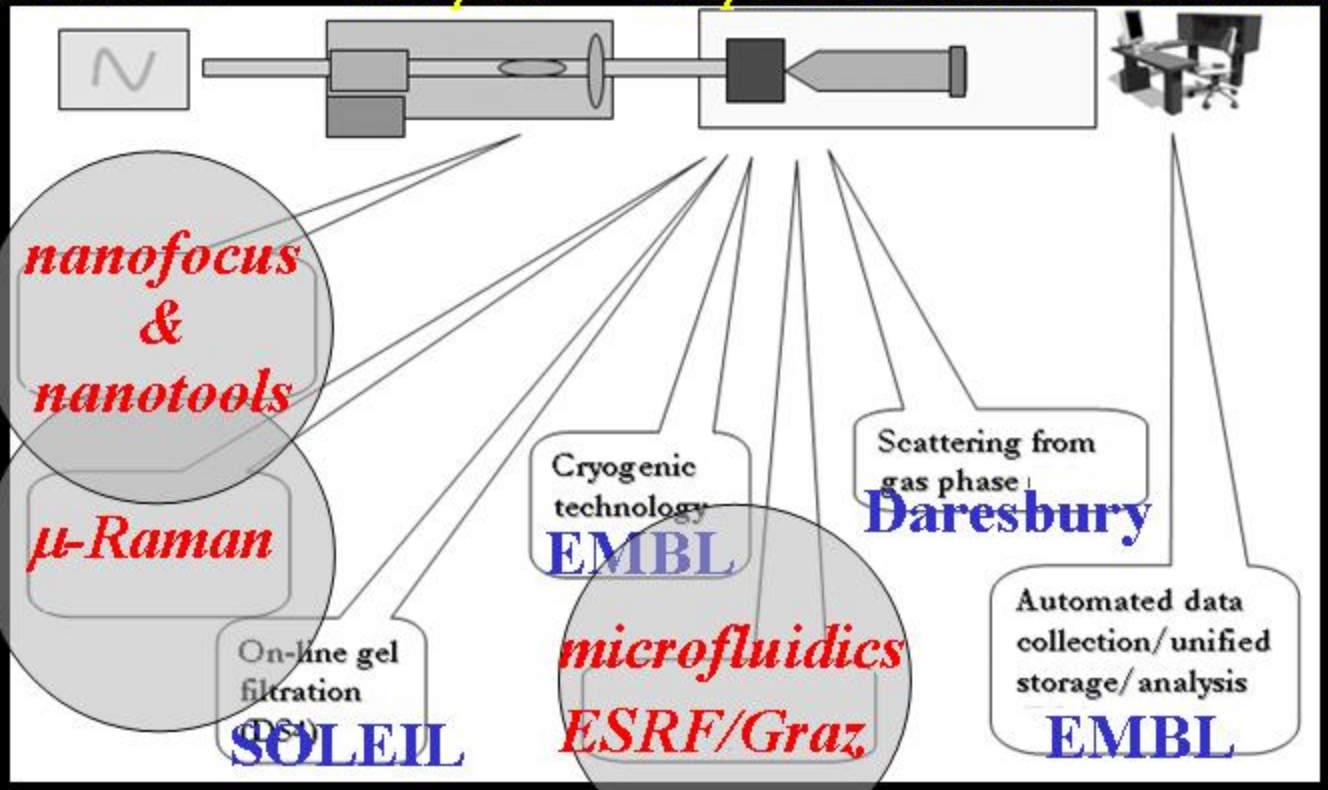
EEC FP6 grant; spokesman: D. Svergun, EMBL-Hamburg

SR source *BL optics* *sample environment* *data analysis*



Acknowledgements

ID13 beamline team

M. Burghammer	*instrumentation, nanobeams …*
R. Davies	*polymers, μRaman, data analysis software*
D. Popov	*single crystal diffraction*
R. Gebhardt	*biological GISAXS (SAXIER)*
L. Lardiere	*technician*
L. Eybert	*engineering*
M. Perez	*software*
S. Petitdemange	*software (HFSP)*

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HFSP

FP6
SaxieR