On the performance of multilayers used as monochromators for coherent X-ray imaging with hard synchrotron radiation

online version

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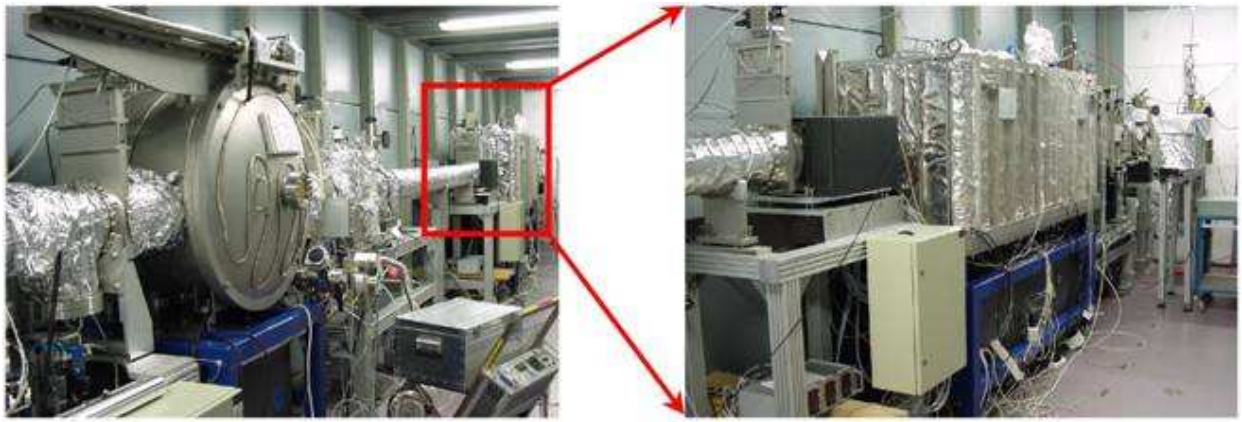
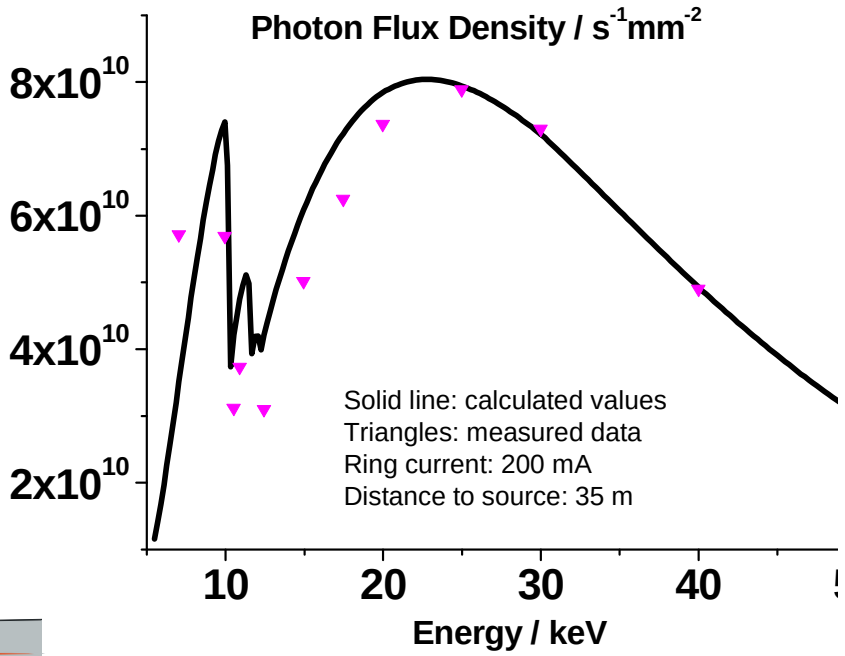
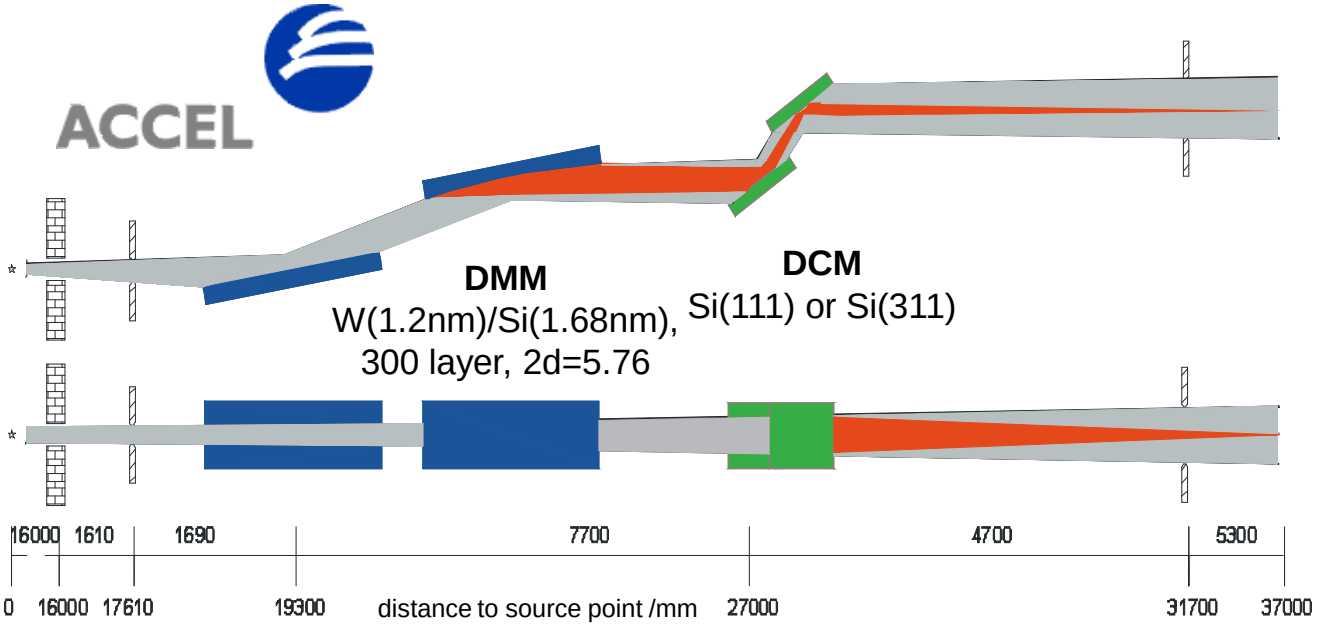
European Synchrotron Radiation Facility

Synchrotron micro-imaging using hard X-rays

BAM*line* @ BESSY (Berlin, Germany)

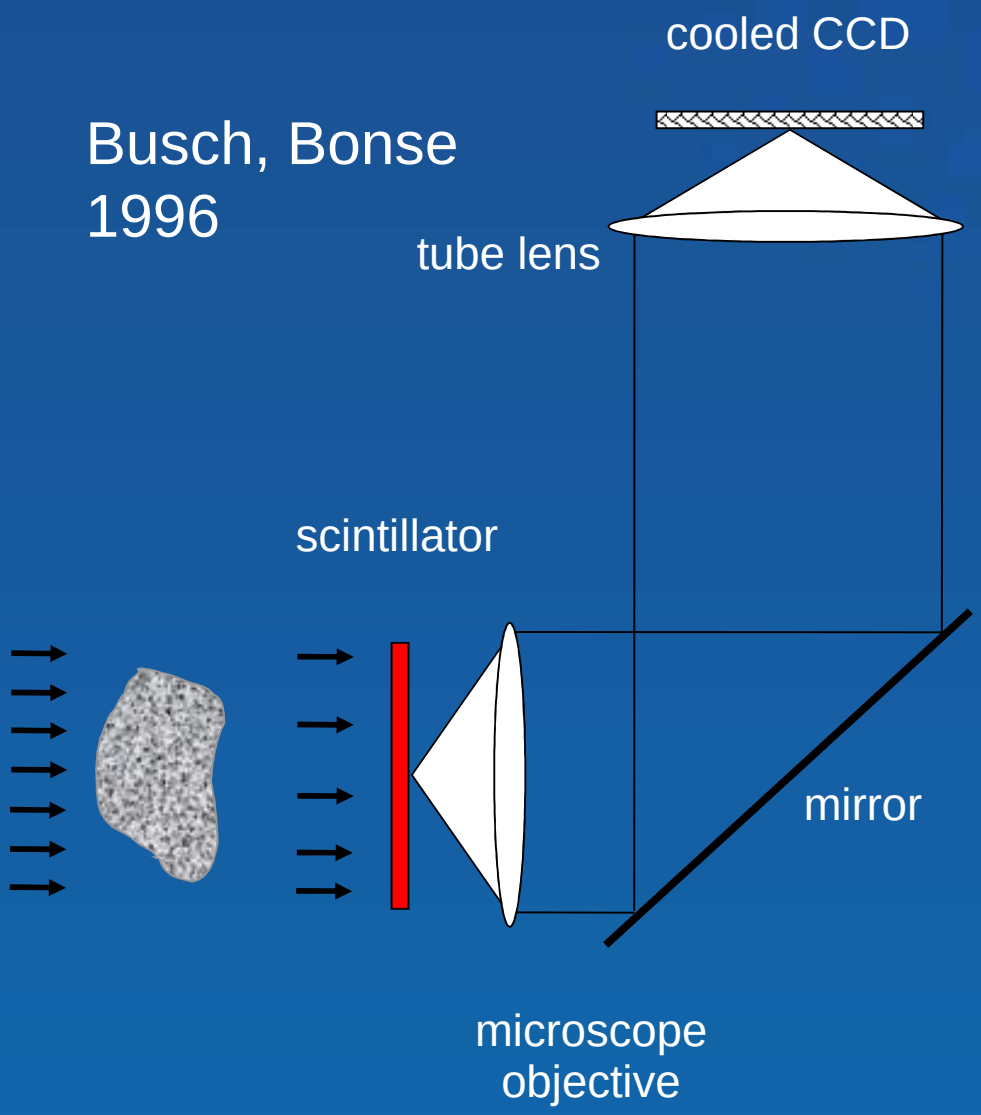






- BESSY - 1.7 GeV, 330 m, 3rd generation source
- BAM*line* - 7T WLS insertion device
- Görner et al, NIMA 2001
- Rack et al, NIMA 2008

Principles – Detector System



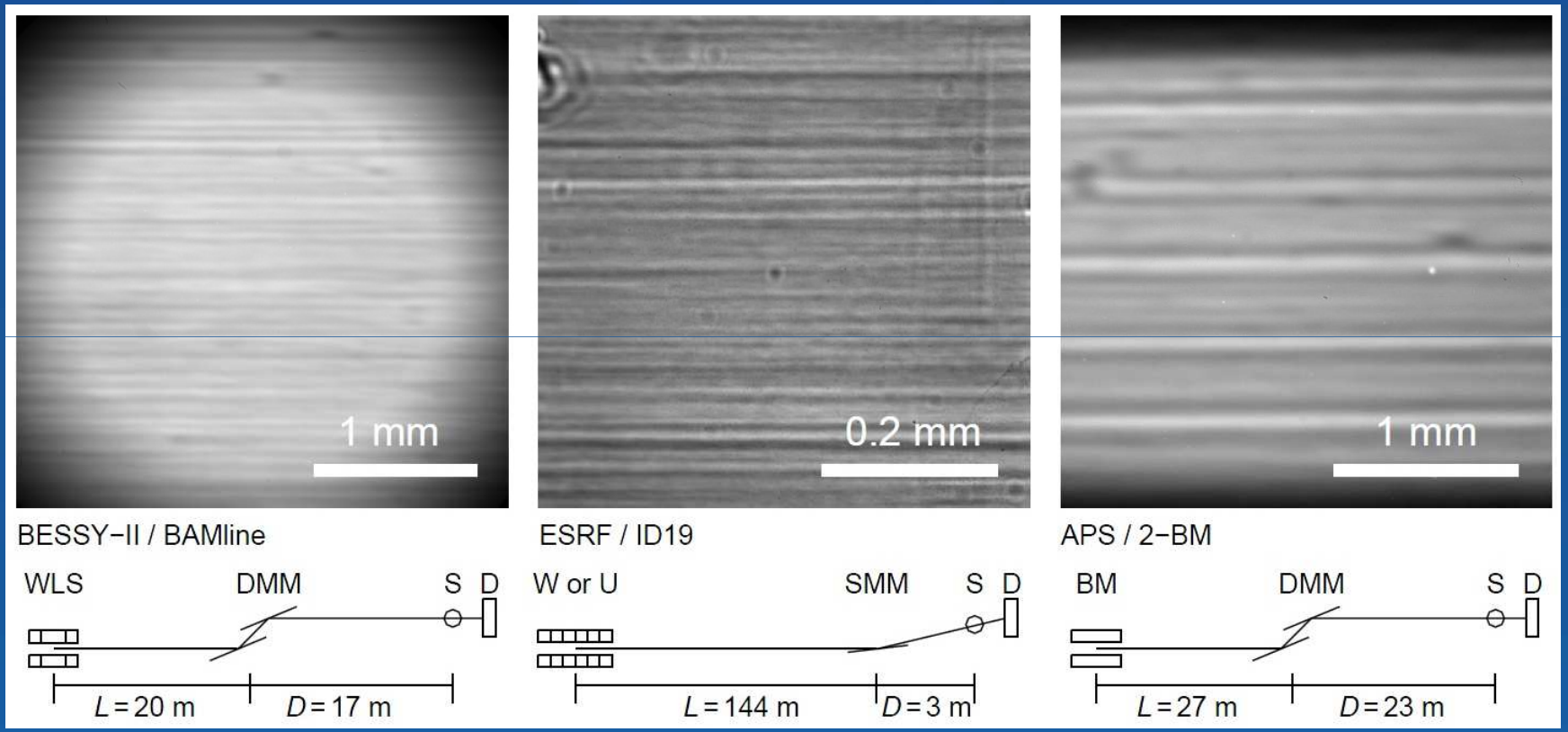
FReLoN CCD (ESRF) mounted on Optique Peter microscope (ANKA - TopoTomo-BL)

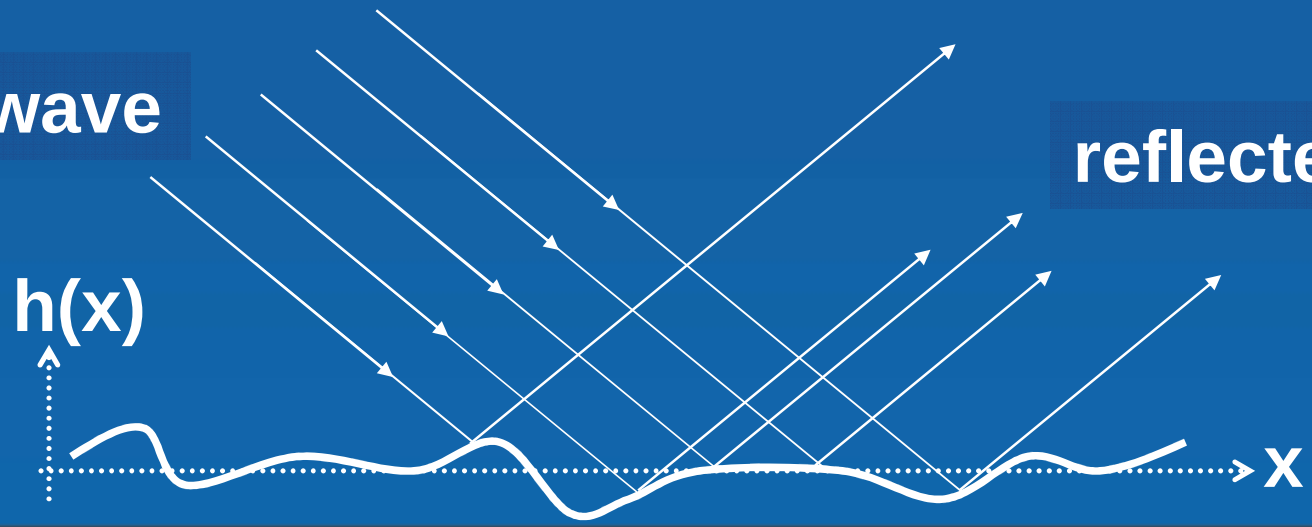
Coherence – Inline X-ray Phase Contrast

- mouthpart kinematics during feeding
- 125 FPS
- 15 µm spatial detector resolution
- Rack et al., J X-ray Sci Techn `10
- Westneat, Betz et al., Science `03

CMOS camera, macroscope, white bending magnet beam

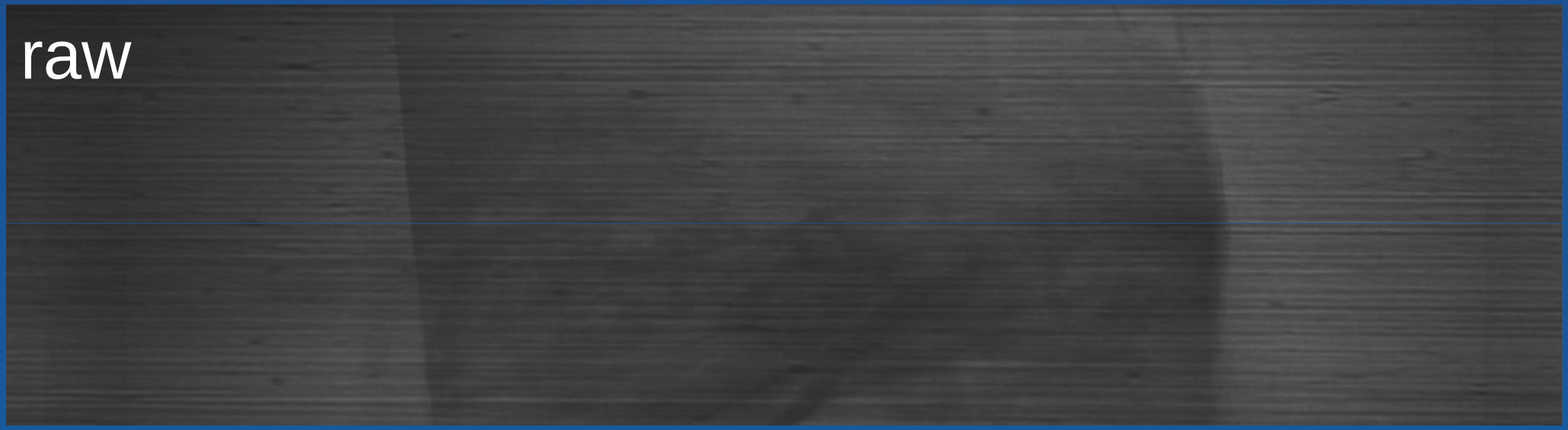
Beam Profile – „The Stripes“



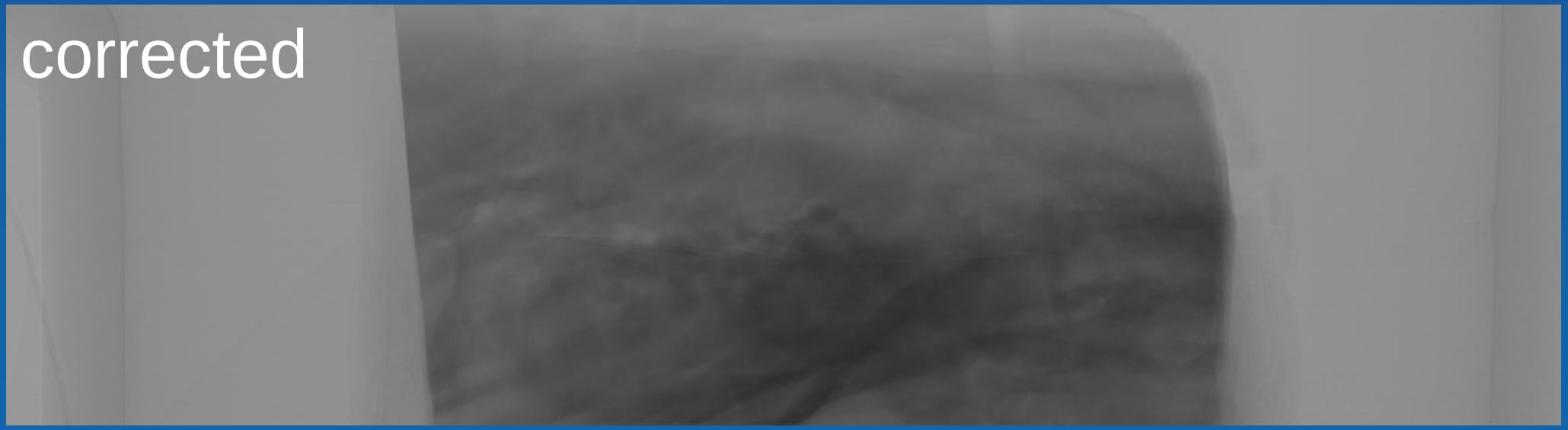


Flatfield Correction

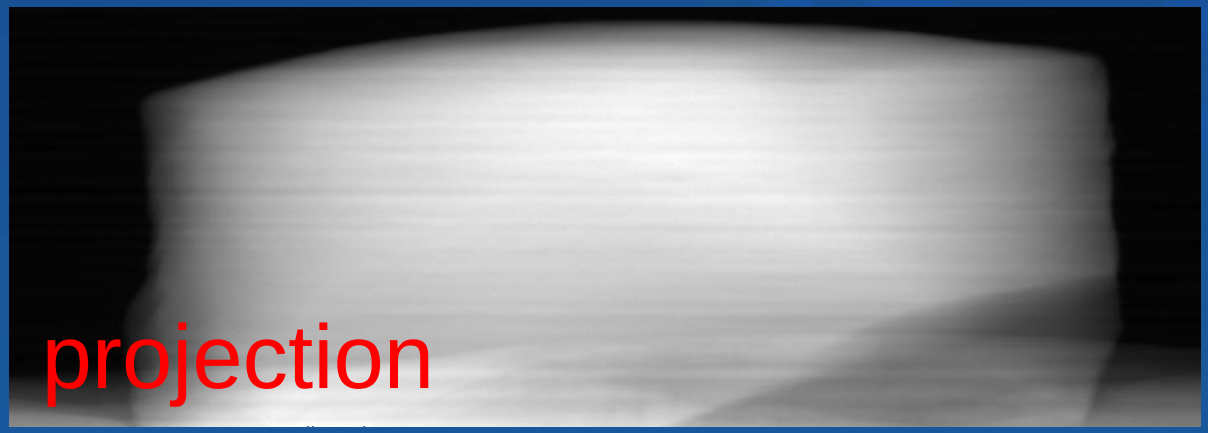
raw

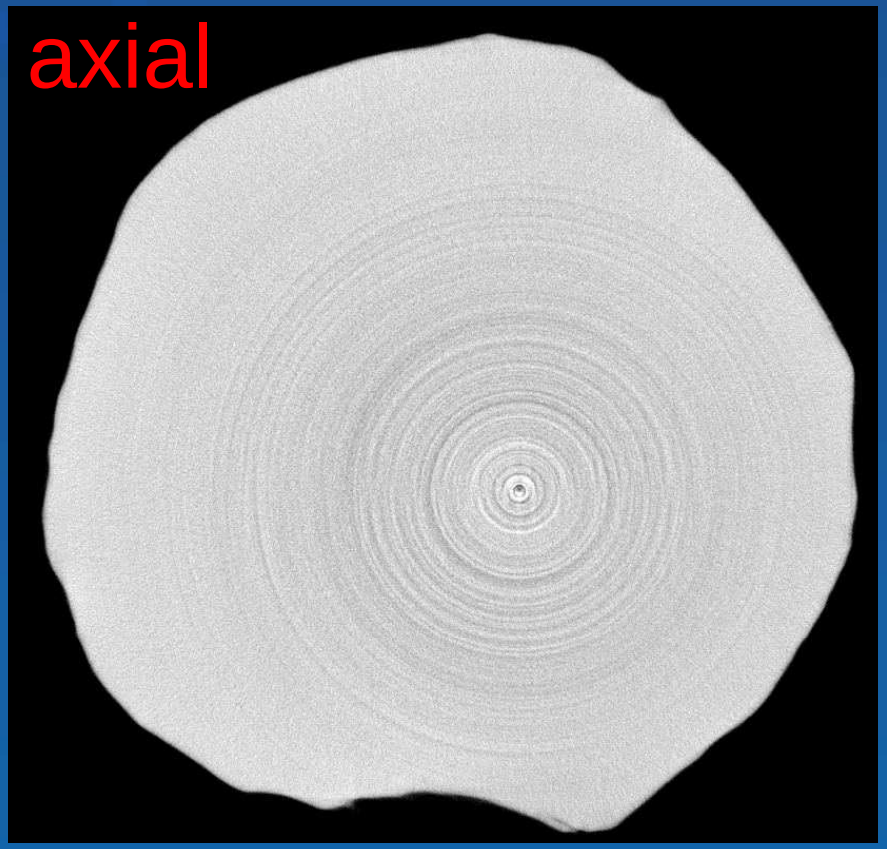


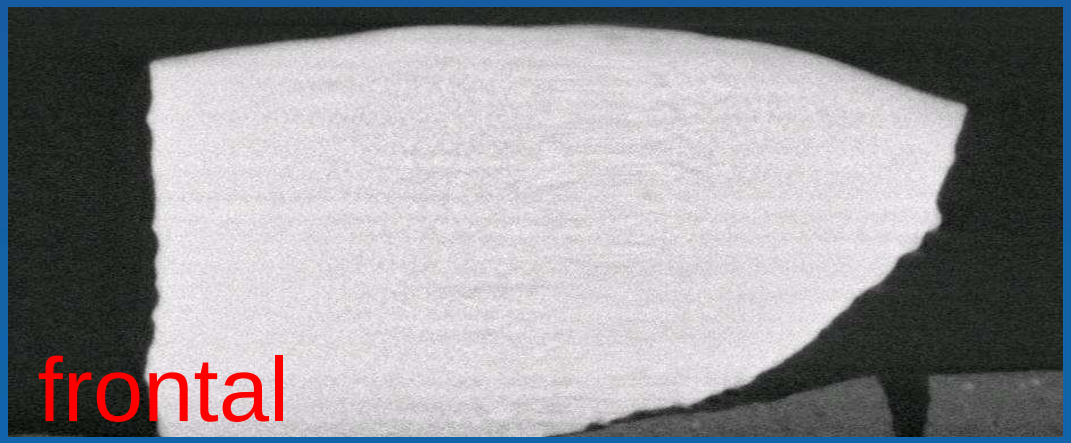
corrected



Stripe Modulations – Ring Artefacts







Multilayers & Methods

Multilayers

Si substrates (25.4 mm diameter, 6.35 mm thick), one-sided superpolished - General Optics, Gooch & Housego

Serial number	Materials	N	d (nm)	R_8^{exp}	R_8^{calc}	R_{18}^{calc}
1531	W/Si	120	2.528	–†	76%	78%
1574	Mo/Si	220	2.478	>45%†	77%	93%
1601	Mo/Si	80	3.975	70%	77%	93%
1609	Mo/Si	50	5.492	75%	76%	93%
1680	Pd/B_4C	220	2.468	>50%†	76%	93%
1681	Pd/B_4C	60	4.002	70%	76%	93%
1685	Pd/B_4C	30	3.982	61%	70%	86%

$\Gamma = 0.5$ (nominal)

Multilayer Lab – AXO Dresden GmbH

High Precision Large Area Deposition of Nanometer Multilayers

Combination of complementary high precision deposition technologies

- Magnetron Sputtering (MSD)
- Large-Area PLD (LA-PLD)
- Dual Ion Beam Sputter Deposition (DIBD)*

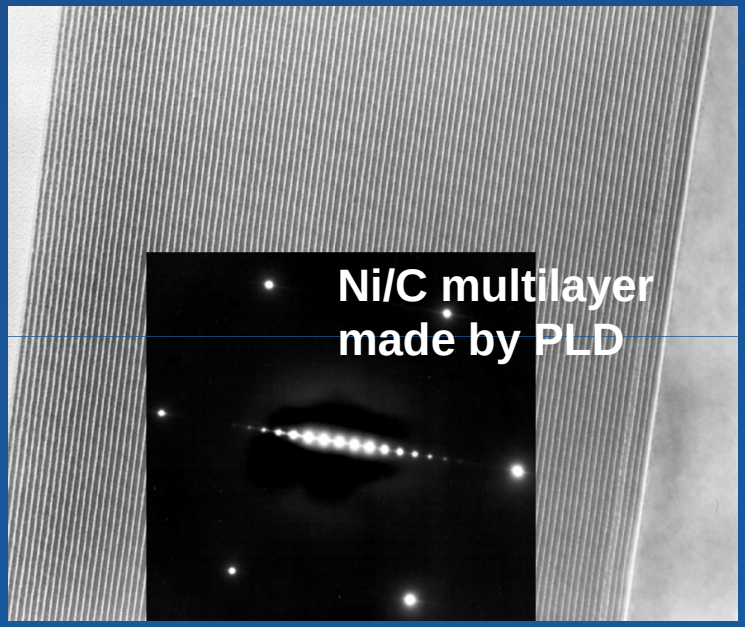
MSD and DIBD (UHV conditions):
- 8” diameter substrates
- 500 mm substrate length

LA-PLD / MSD: UHV cluster-tool system*
- 6“ diameter substrates
- automated deposition of nm-ML

* in cooperation with Fraunhofer IWS

AXO Dresden GmbH
Applied X-ray Optics
High Precision Deposition

High Precision Deposition Techniques

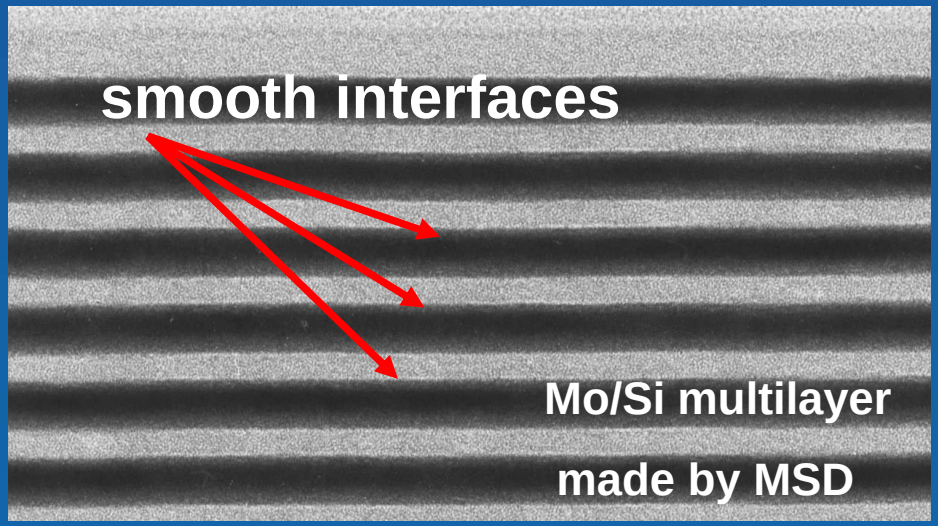


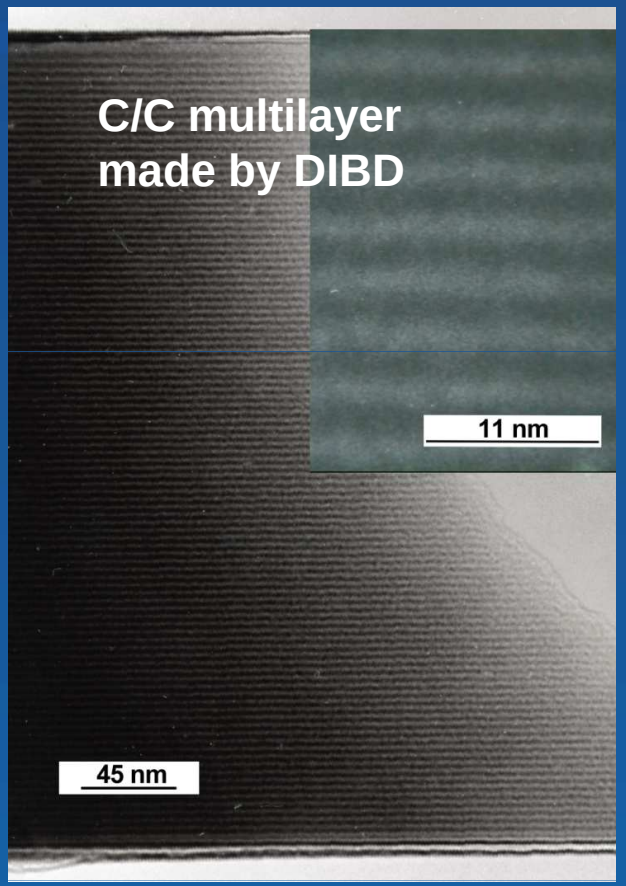
HRTEM of a PLD-Ni/C multilayer (100 layer pairs, d = 3.2 nm) and reciprocal space image of electron diffraction

MSD: W/Si,
Mo/Si ($R_{13.4nm}$= 70.1%)

DIBD: Ni/B4C,
C/C, a-C

PLD: Ni/C,
C/C, a-C





Fraunhofer IWS

AXO Dresden GmbH
Applied X-ray Optics
High Precision Deposition

Metrology Laboratory BESSY-II

HZB Helmholtz Zentrum Berlin

- BESSY-NOM
- Interference microscope
- AFM
- substrates (1”, GO) before and after coating

Siewert et al., NIMA 616 (2010)

Further Characterisation

- Specular and non-specular X-ray reflectivity (SCD beamline, ANKA and Cu-k_α laboratory source, AXO Dresden GmbH)

  → *interlayer and surface roughness*

- Full-field X-ray imaging (TopoTomo beamline, ANKA and beamline BM05, ESRF)

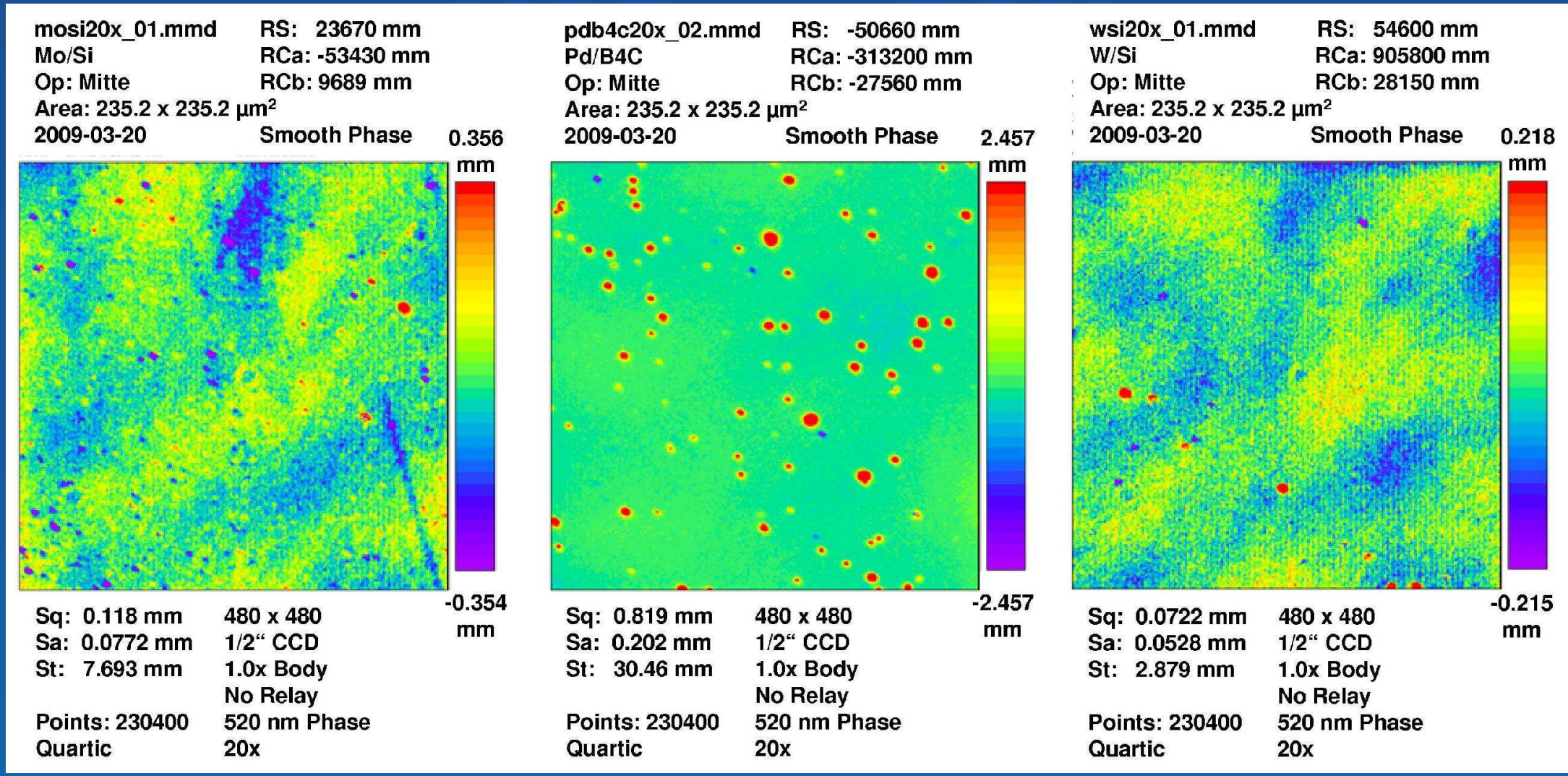
  → *stripe modulations and spatial resolution*

- (Fractional) Talbot imaging (beamline ID19, ESRF)

  → *coherence preservation*

Results

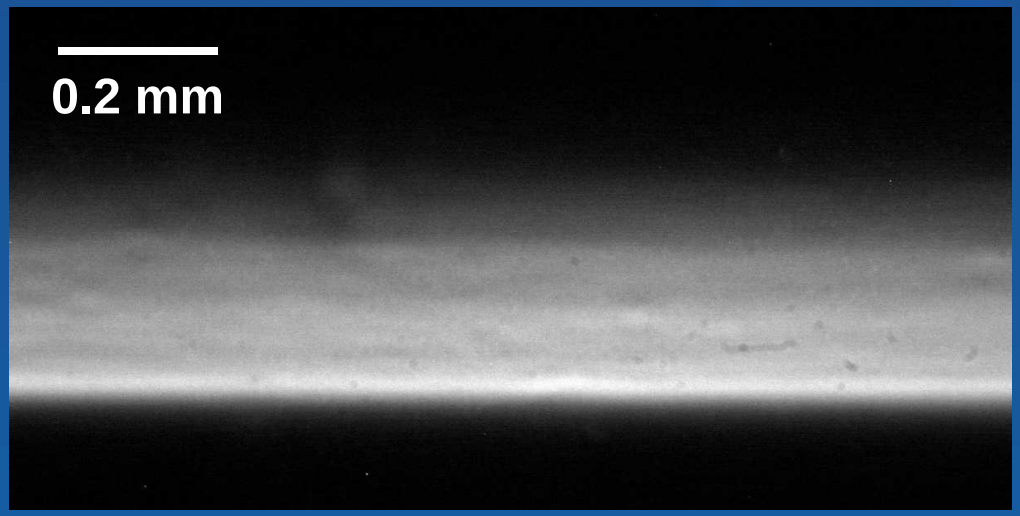
Metrology & Roughness

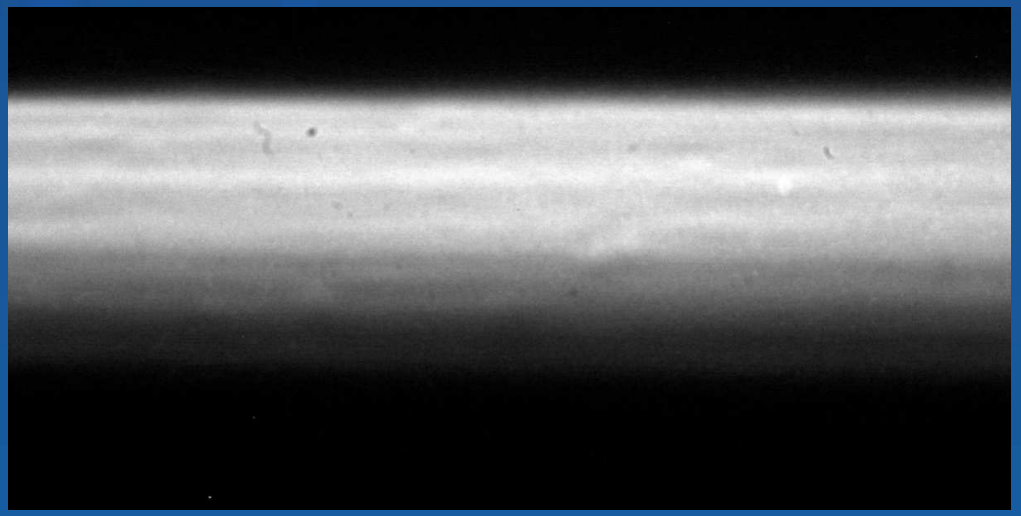


substrates: all similar high level of surface quality;
multilayers: strongly varying interlayer and surface roughness

Beam Profile vs. Number of Bilayers

Pd/B_4C





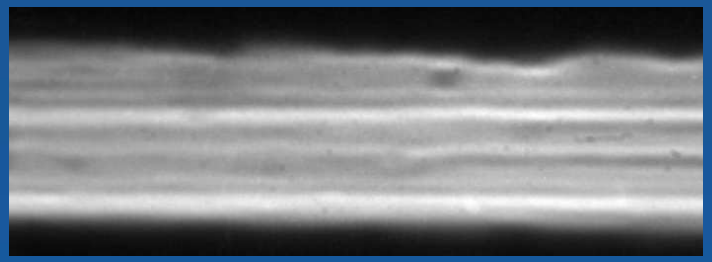
N = 30
d = 3.982 nm

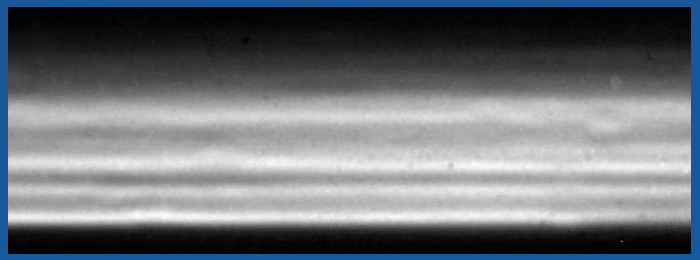
N = 60
d = 4.002 nm

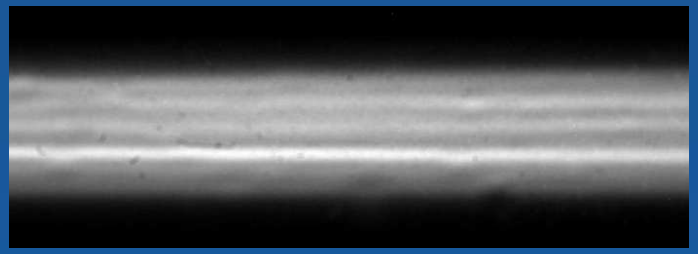
E = 18 keV

Beam Profile *vs.* d-Spacing

Mo/Si







d = 2.478 nm

d = 3.975 nm

d = 5.492 nm

(N = 220)

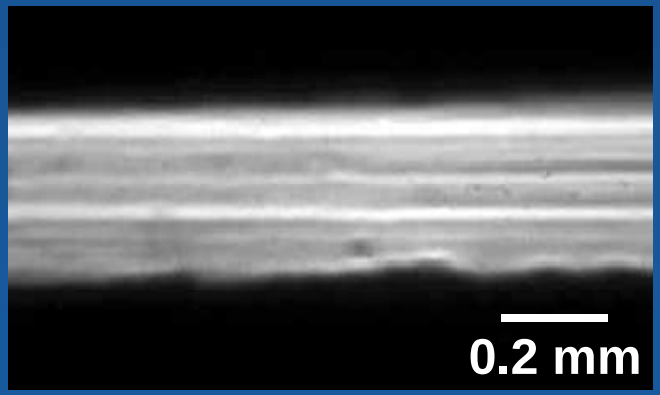
(N = 80)

(N = 50)

E = 18 keV

Beam Profile *vs.* Material Composition

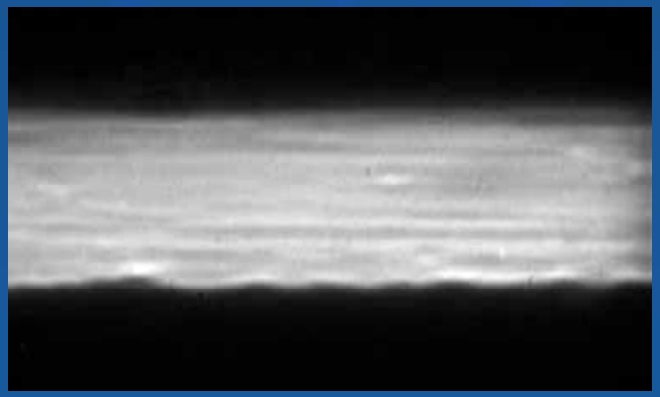
Mo/Si



d = 2.478 nm

(N = 220)

W/Si



d = 2.528 nm

(N = 120)

Pd/B_4C

d = 2.468 nm

(N = 220)

E = 18 keV

Interlayer & Surface Roughness

Serial number	Materials	N	d (nm)	R_8^{exp}	R_8^{calc}	R_{18}^{calc}
1531	W/Si	120	2.528	–†	76%	78%
1574	Mo/Si	220	2.478	>45%†	77%	93%
1601	Mo/Si	80	3.975	70%	77%	93%
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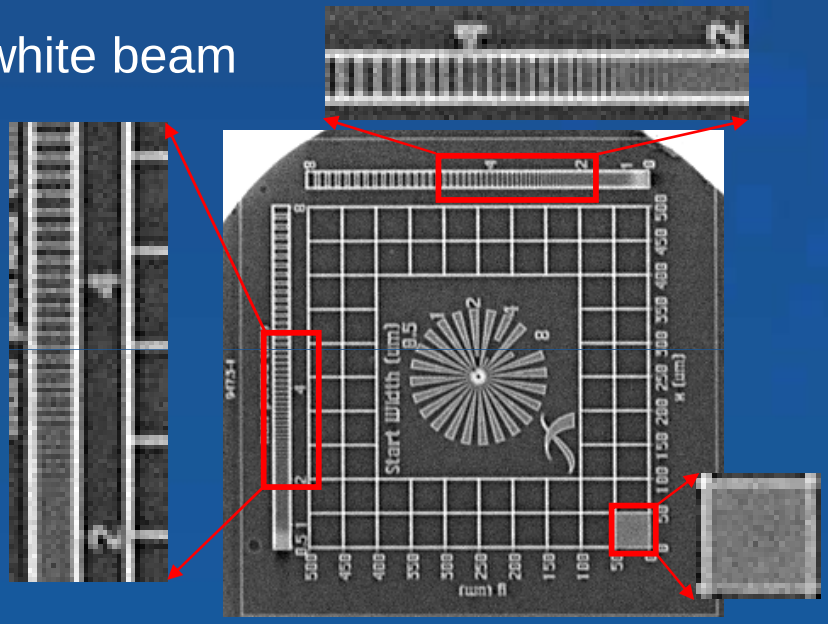
1681	Pd/B_4C	60	4.002	70%	76%	93%
1685	Pd/B_4C	30	3.982	61%	70%	86%

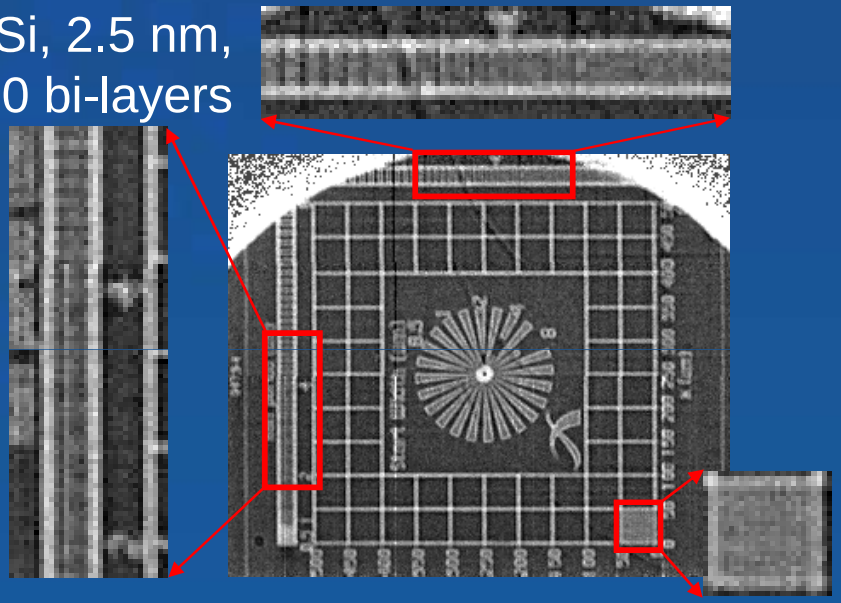
similar values

Full-field Micro-Imaging

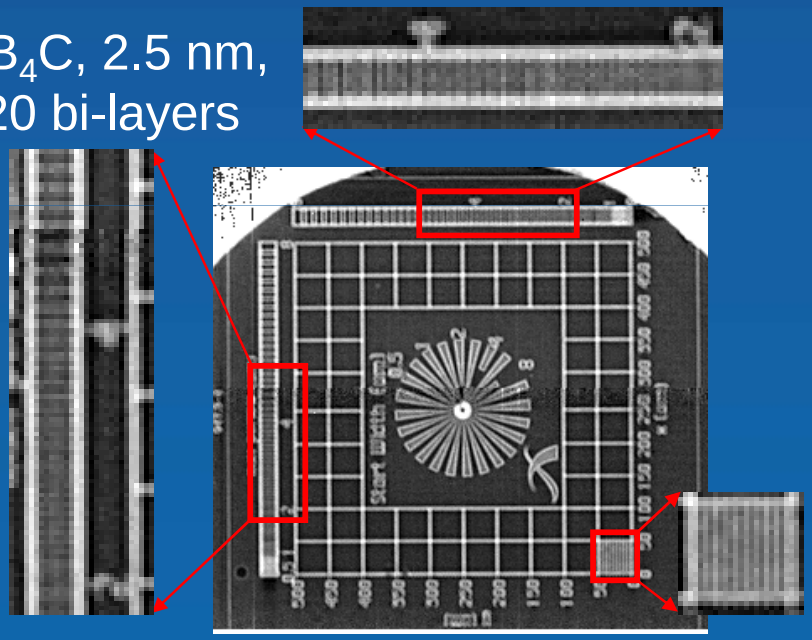
white beam



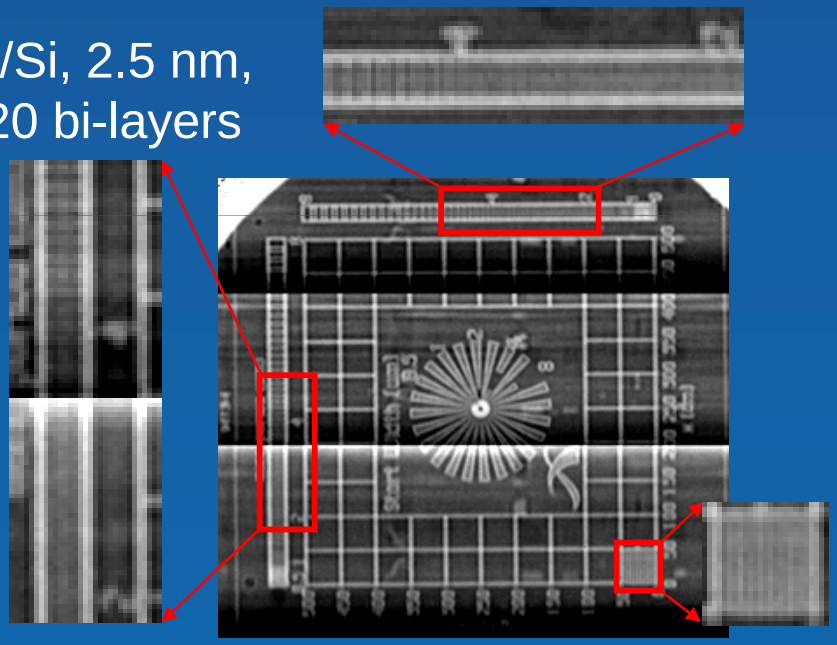
W/Si, 2.5 nm,
120 bi-layers



Pd/B_4C, 2.5 nm,
220 bi-layers

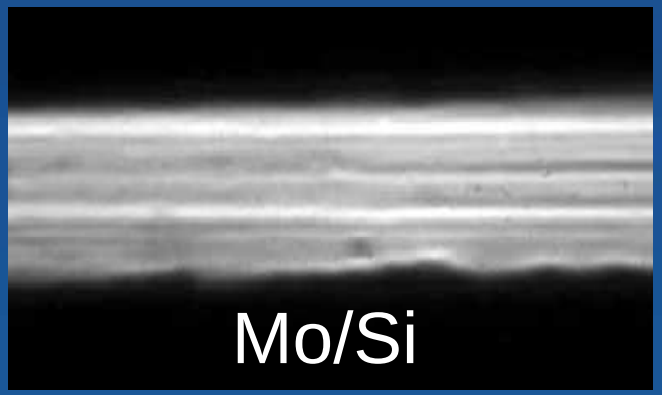


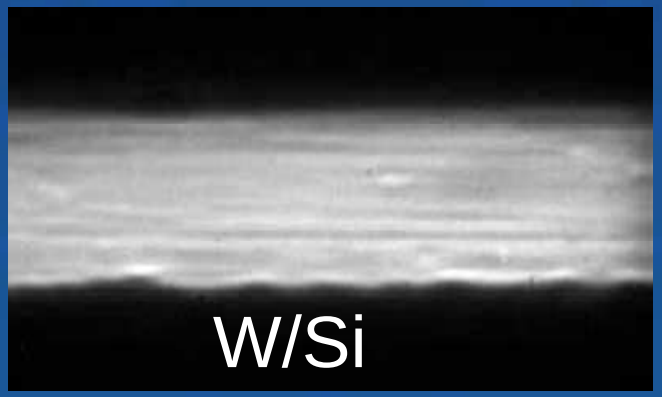
Mo/Si, 2.5 nm,
220 bi-layers

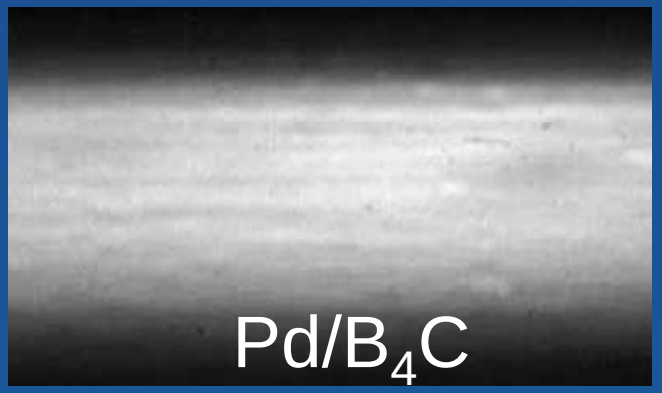


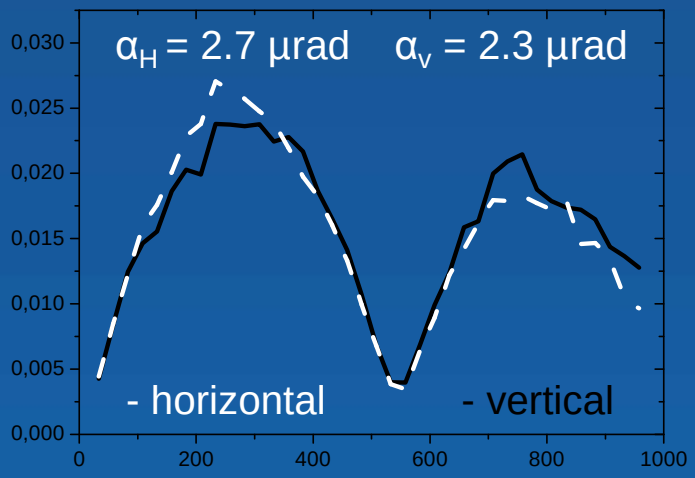
E =
18 keV

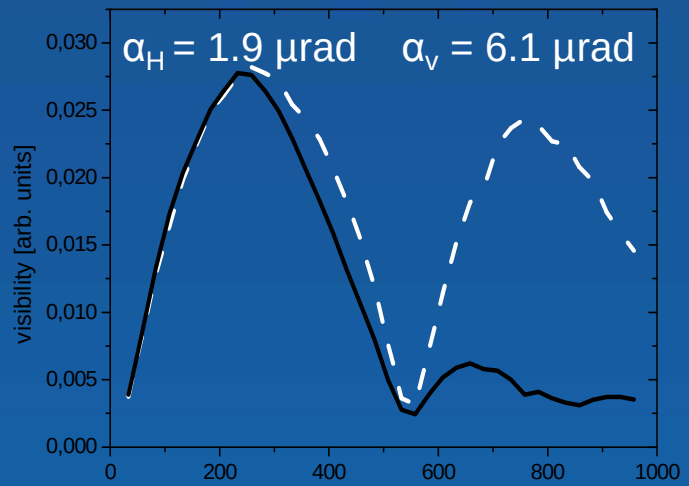
Coherence Preservation

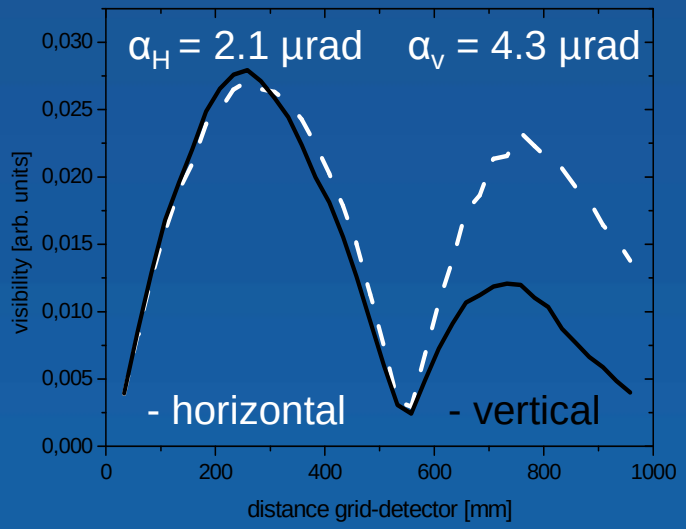


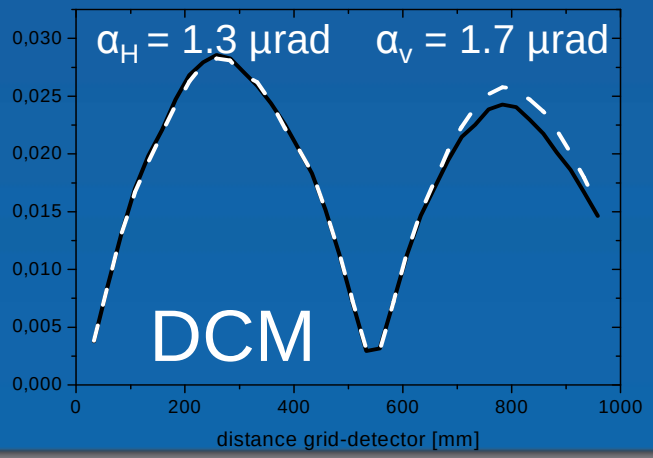










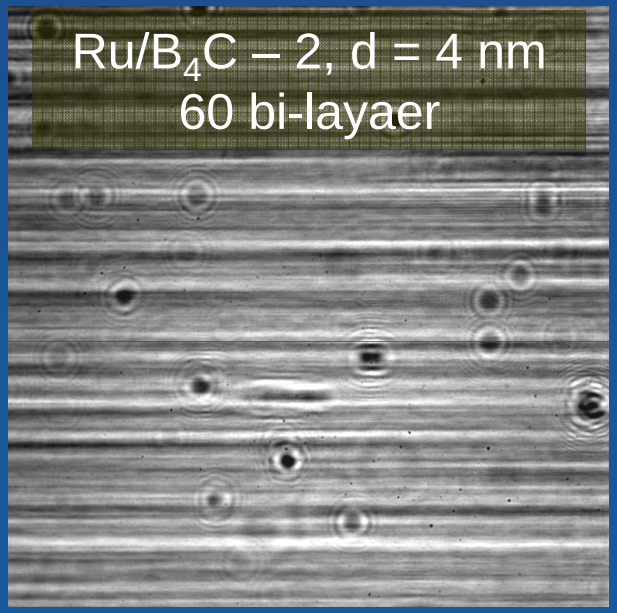


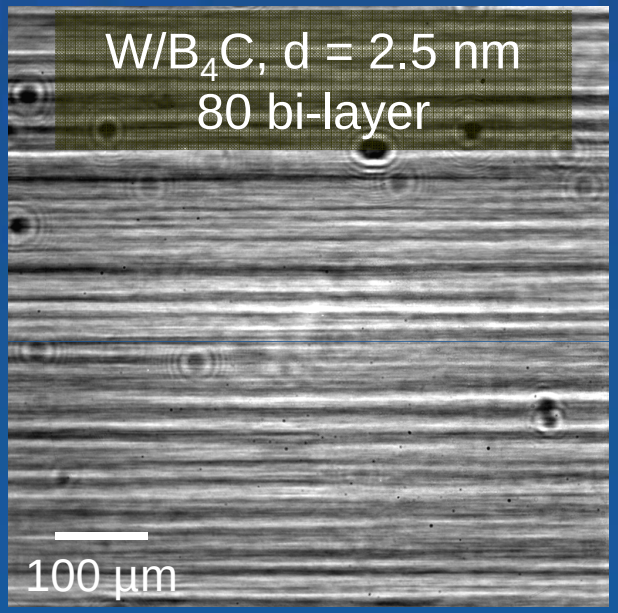
- similar substrate roughness (F. Siewert - BESSY), 1“ dia.
- similar surface layer as well as interlayer roughness (XRR)

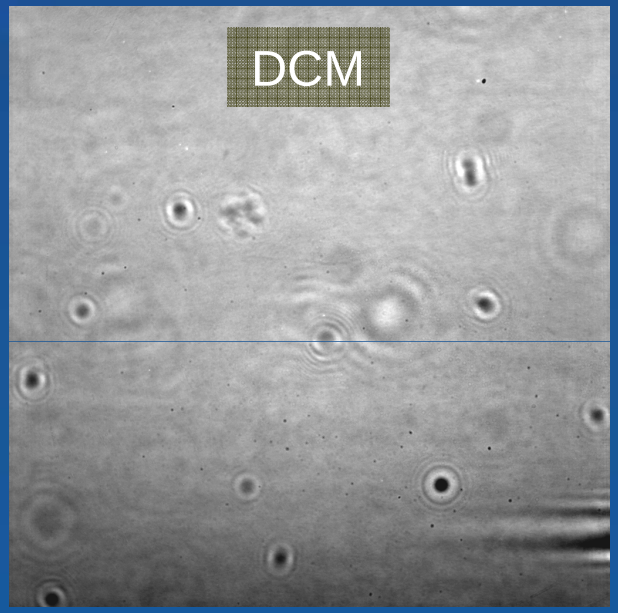
- similar spatial resolution reachable
- different coherence properties
- different stripe patterns

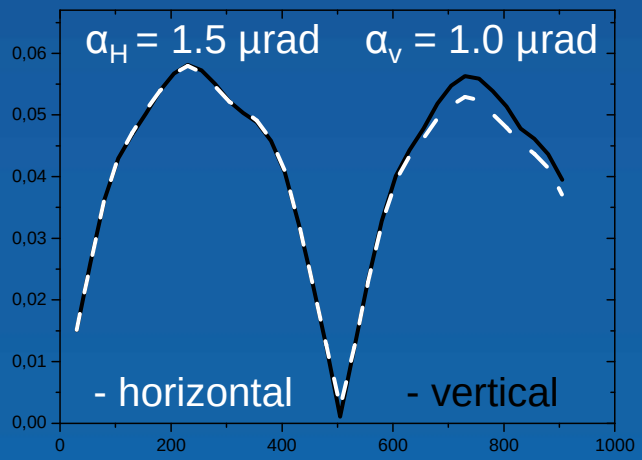
Discussion

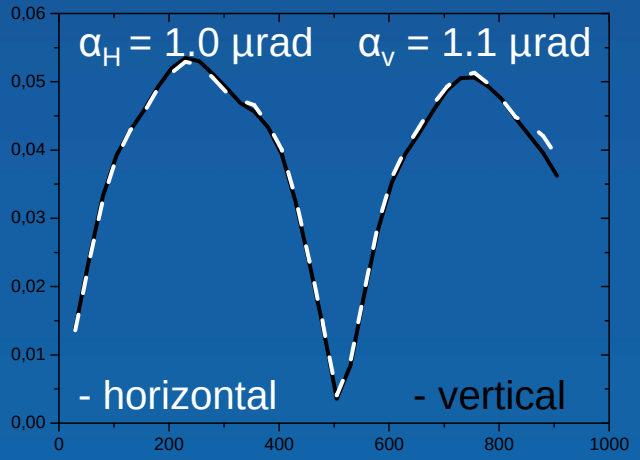
Single-Bounce Multilayer Mono - ID19

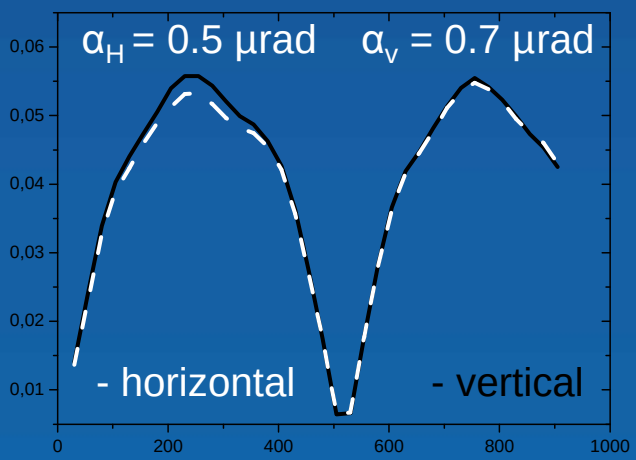




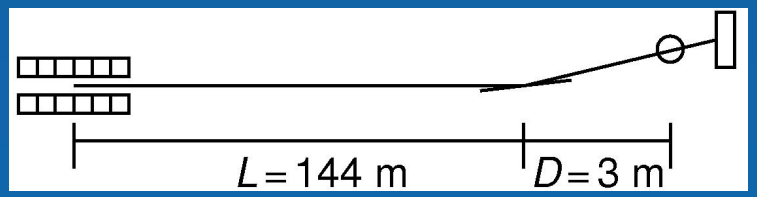






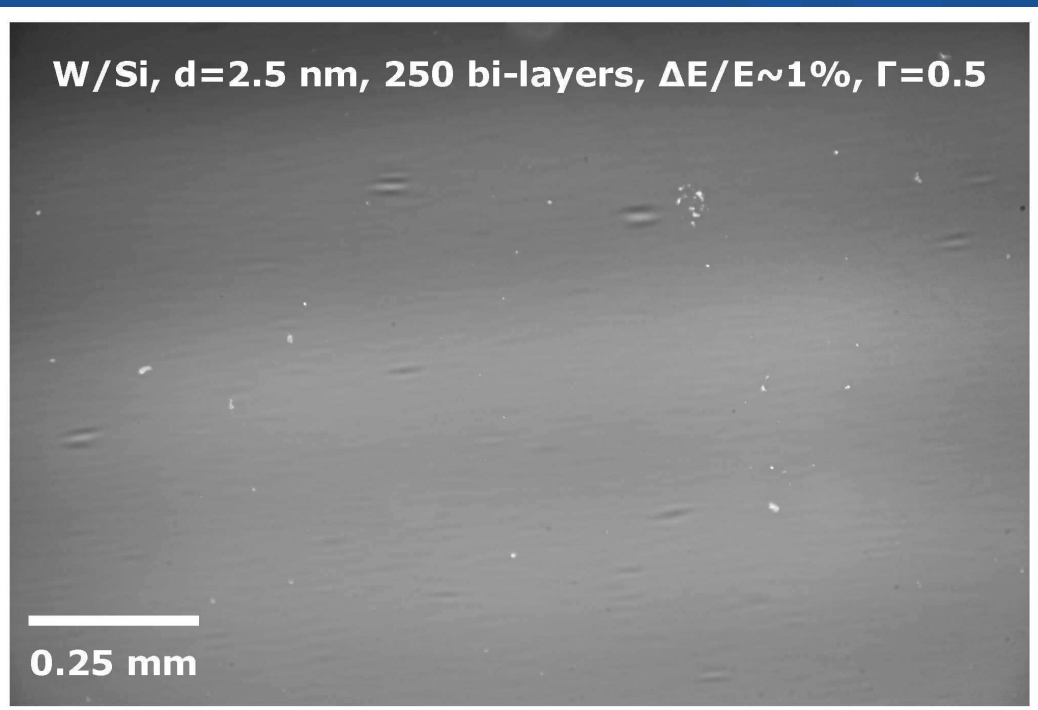


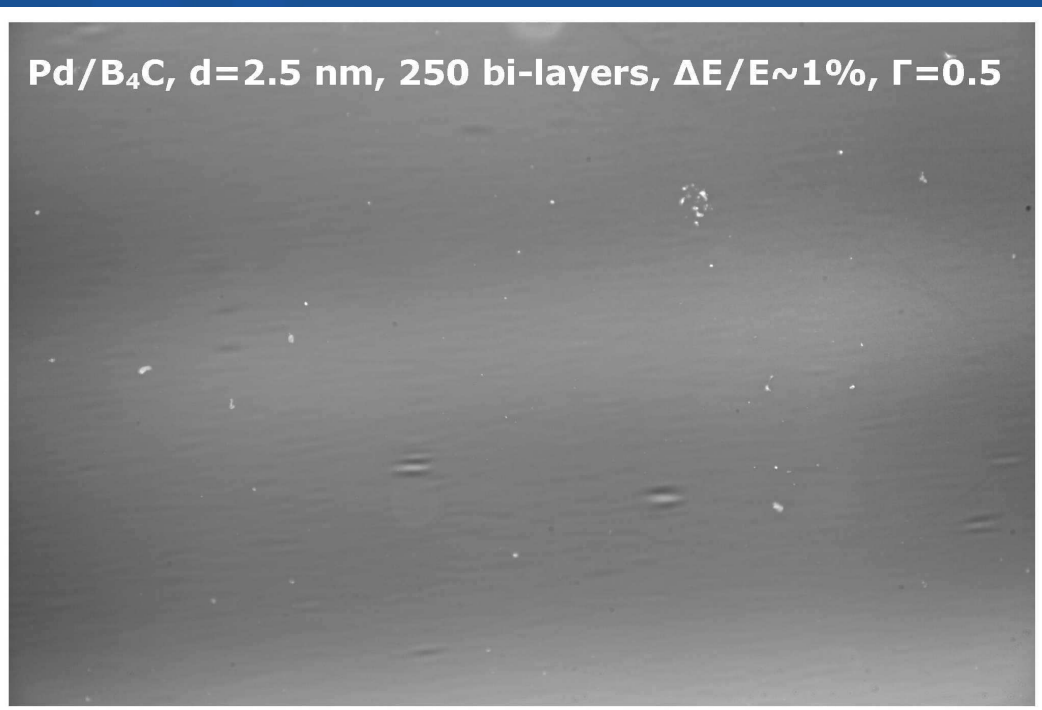
E = 18 keV



0.35 µm pixel size

DMM @ ANKA - TopoTomo Beamline





E = 18 keV, indirect high resolution detector with 0.36 µm pixel size (resolving power < 2 µm), 500 µm x 150 µm source

Thanks for your attention!

Rack, Weitkamp et al., J Synchrotron Radiation vol. 17, no. 4 (2010)
DOI 10.1107/S0909049510011623

Rack, Weitkamp et al., NIMA Special Issue SRI2010 (submitted)

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