Characterisation of diffraction gratings by EUV scatterometry and GISAXS

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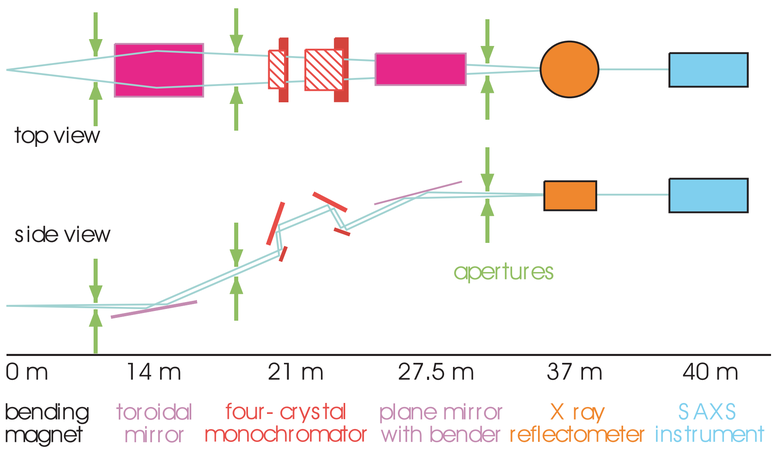
Abstract

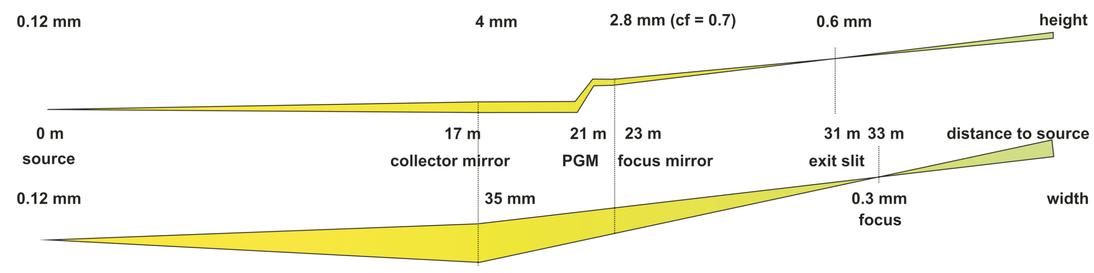
For more than 30 years, the Physikalisch-Technische Bundesanstalt has been strongly engaged in the field of metrology using synchrotron radiation. At present, at the electron storage rings BESSY II and MLS (Metrology Light Source), the activities extend over a broad range of fundamental and applied metrology in the spectral range from the far infrared to hard X-rays. EUV reflectometry and scatterometry has been developed in close cooperation with partners from industry and science for the characterization of optical elements for semiconductor lithography. In the X-ray spectral range, grazing incidence small-angle X-ray scattering (GISAXS) and X-ray reflectometry (XRR) are also used to investigate structural parameters of line gratings, especially pitch, duty cycle, groove width, and line height.

GISAXS

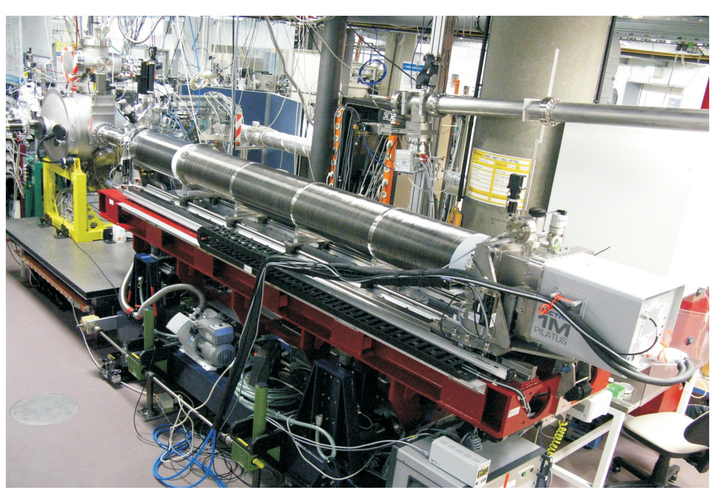


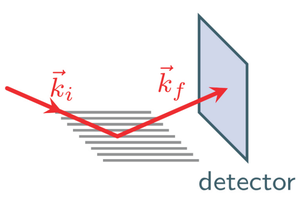
The PTB FCM beamline

EUV Scatterometry

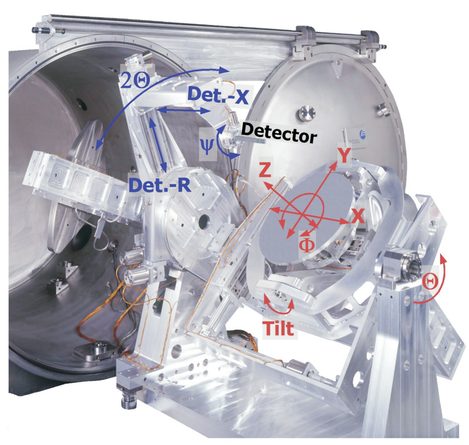


The PTB Soft X-ray Radiometry beamline





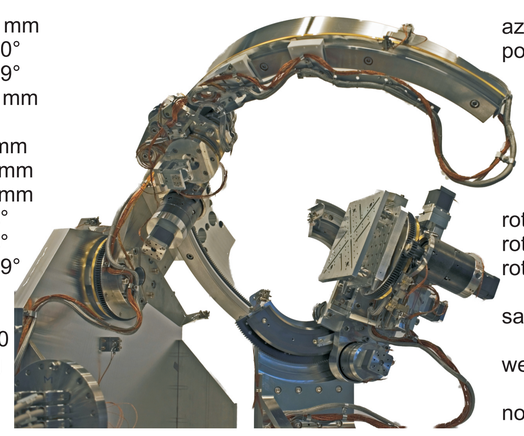
SAXS setup of HZB-BESSY. The in-vacuum Pilatus 1M detector allows for measurements at photon energies down to 1.75 keV.



Detector	
X	-3 to 127 mm
polar	-20° to 190°
flip	-179° to 179°
R	150 to 550 mm
Sample	
X	-19 to 90 mm
Y	-10 to 300 mm
Z	-15 to 140 mm
rot.-X	-30° to 100°
rot.-Y	-30° to 100°
rot.-Z	-179° to 179°

sample size: 600 x 600 x 210
weight: up to 50 kg

lubricants used

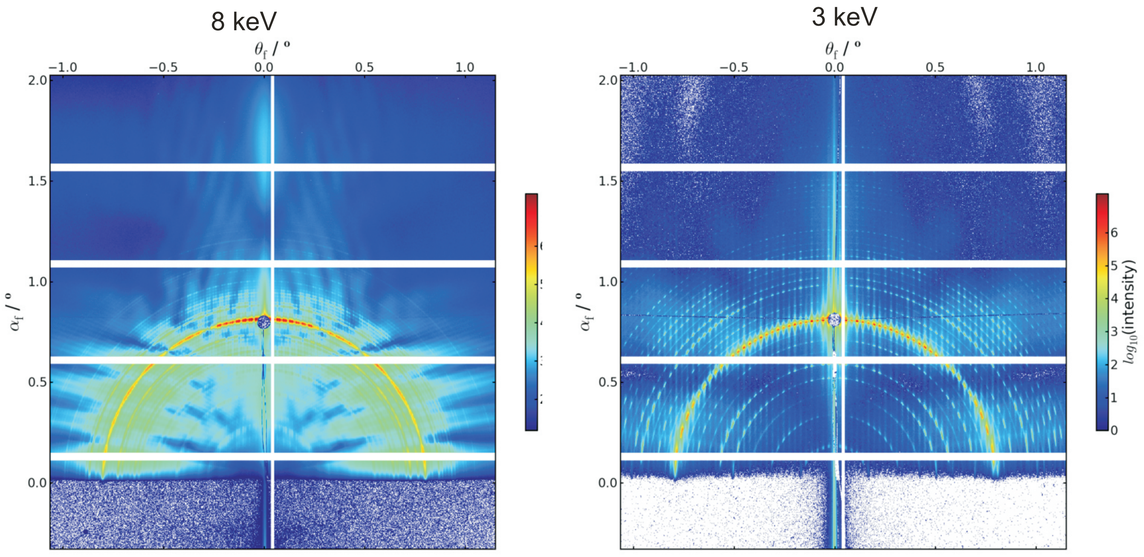


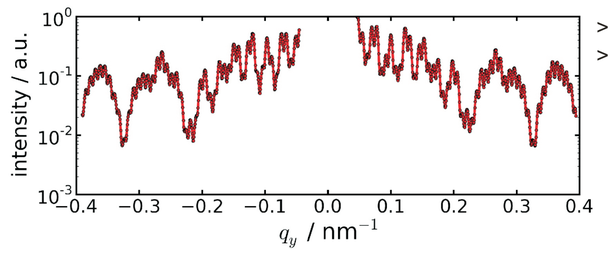
Detector	
azimut	-10° to 100°
polar	-20° to 190°
flip	-179° to 179°
Sample	
X	-10 to 90 mm
Y	-10 to 90 mm
Z	0 to 25 mm
rot.-X	-30° to 100°
rot.-Y	-30° to 100°
rot.-Z	-179° to 179°

sample size: 190 x 190 x 70
weight: up to 5 kg

no lubricants used

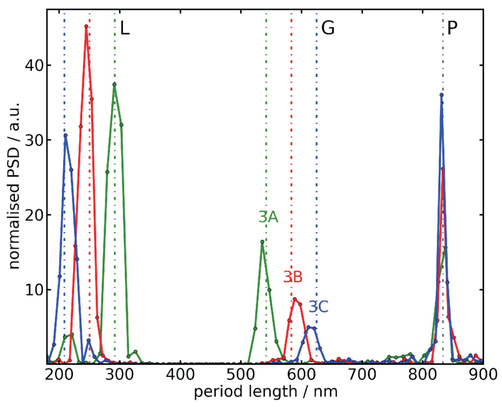
Characterization of a laminar grating [1]

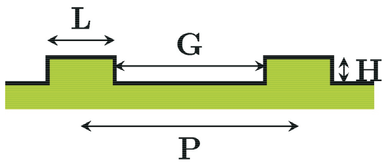




higher resolution in q at fixed geometry
important to determine dimensional grating parameters (period, line width,groove width) with low uncertainty

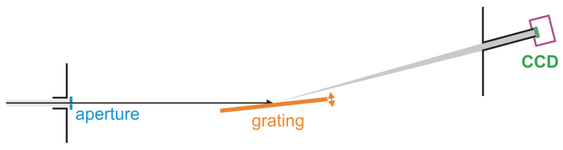
An intensity profile is extracted along the semi-circle. The relevant coordinate is q_y because the circle shows a clipping of grating truncation rods that stretch along q_z and are periodic along q_y . The power spectral density (PSD) of the Fourier amplitudes of the profile yields peaks at characteristic spacial frequencies, e.g. period, line and groove length.





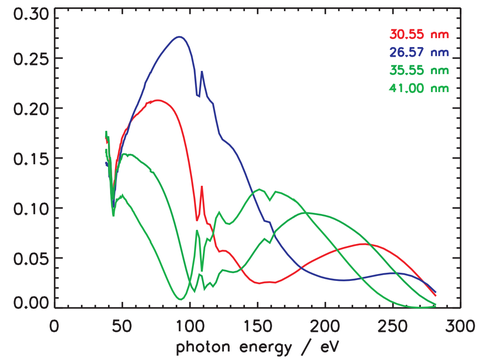
Sample:
laminar grating structures produced by e-beam writing
pitch: 833 nm (1200 lines/mm)
land width: 292 / 250 / 208 nm
etch depth: 26.57 / 30.55 / 35.55 / 41.00 nm
coating: Ru, 10 nm
produced by Fraunhofer IOF

Fraunhofer Institut Angewandte Optik und Feinmechanik



Set-up for diffuse scatter measurements
A CCD sensor is mounted at a fix deflection angle of 162° and the sample is rocked.

Reflectance
1. order, c_{ff} = 2.5
for structures with land width 292 nm and different etch depth

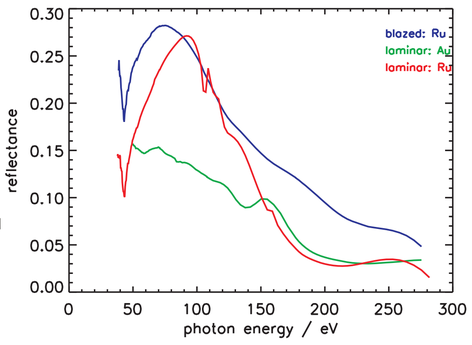


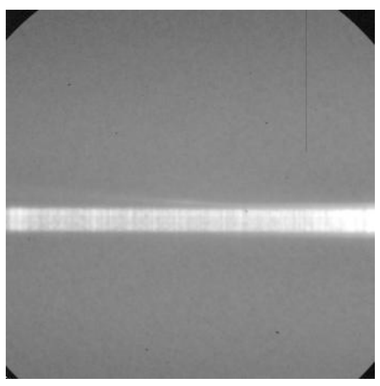
Reflectance
1. order, c_{ff} = 2.5
for 3 different gratings

e-beam laminar grating, Ru coated

holographic laminar grating, Au coated

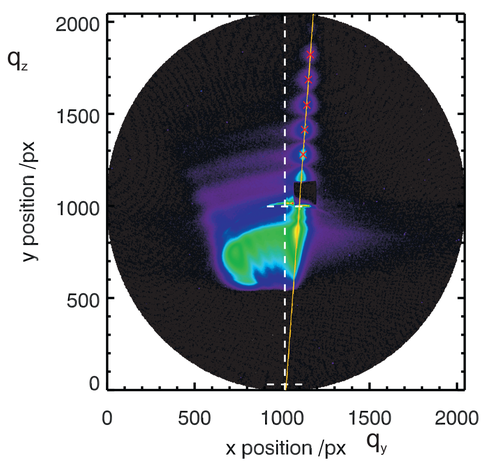
ruled, blazed grating, Ru coated

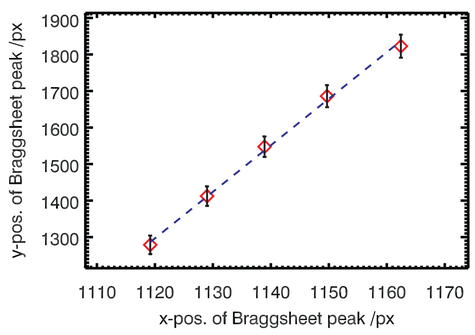




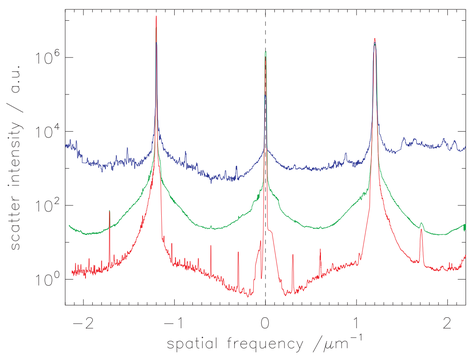
Representative diffuse scatter distributions between 0. and 1. order for the blazed, holographic and e-beam grating, from left to right. The grey scale is logarithmic and the same for all three pictures (1 to 5000).

Characterization of a blazed grating [2]





Linear fit of Bragg sheet maxima positions.
Blaze angle from linear fit: 4.5(3)°. Coating layer thickness derived from diffraction corrected Bragg sheet positions along q_z: 46.5(7) nm.



Rocking scans with the three gratings for a fix deflection angle. Data are taken with a CCD sensor and the images are stitched together.

References

1 J. Wernecke, F. Scholze, and M. Krumrey; Direct structural characterisation of line gratings with grazing incidence small-angle x-ray scattering Rev. Sci. Instrum. 83, 103906 (2012)

1 F. Scholze, A. Kato, J. Wernecke and M. Krumrey, EUV and X-ray scattering methods for CD and roughness measurement, Proc. SPIE 8166, 81661P (2011)

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