Trends on Thin Film X-ray Optics and Pinholes for Synchrotron Beamlines

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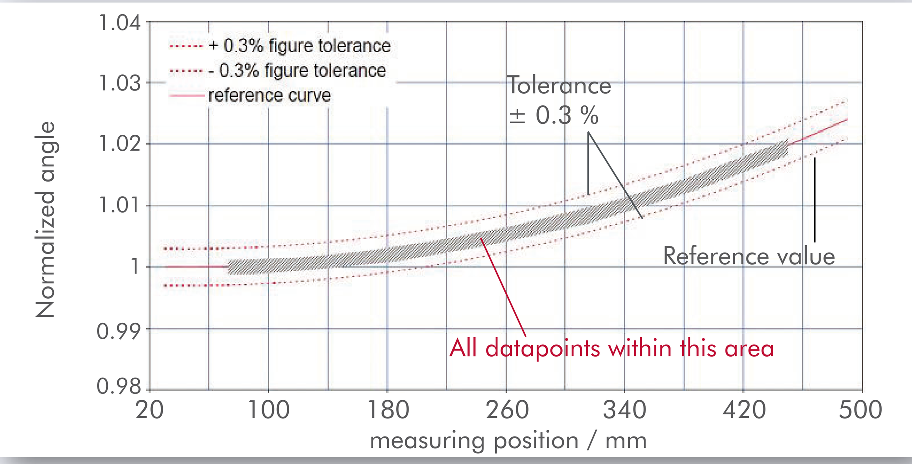
Here, we give an overview on current developments in the coating of multilayer coatings up to 500 mm, multi-stripe multilayer optics for tomography beamlines, Montel optics (nested KB) for Synchrotron applications and on our scatterless pinholes SCATEX as beam defining elements.

X-ray Optics for Synchrotron Beamlines

500 mm Multilayer Coating with 200 Pairs



The diagram shows a graded multilayer coating over 500 mm. The deviation of the desired shape in the longitudinal direction is less than ± 0.2 %. First optics were sold to the US.

Bendable 400 mm silicon mirror

Multi-stripe Multilayer Optics

At imaging beamlines multilayer optics are often used as double crystal multilayer monochromators (DCMM). For example, tomography needs a homogeneous and stable beam profile, in order to perform optimal background corrections. Because of the high coherence of the radiation, the optical components must be designed with particular care in order to avoid a deterioration of the beam quality. Multilayer coatings with up to 5 stripes were produced with films homogeneities < 0.2% as well as with lateral gradients.

Stripe A: [Ru/C]100, d=40 Å, y=0.5, R > 80 % for 10<E<22keV
Midspace: Si<111>, roughness 0.1 nm, slope error 0.04"
Stripe B: [W/Si]100, d=30 Å, y=0.5, R > 80 % for 22<E<45keV

Three-striped multilayer optics for tomographic microscopy and coherent radiology, with an optimized coating for different beam energies (TOMCAT at SLS, Switzerland, Data courtesy of M. Stampanoni).

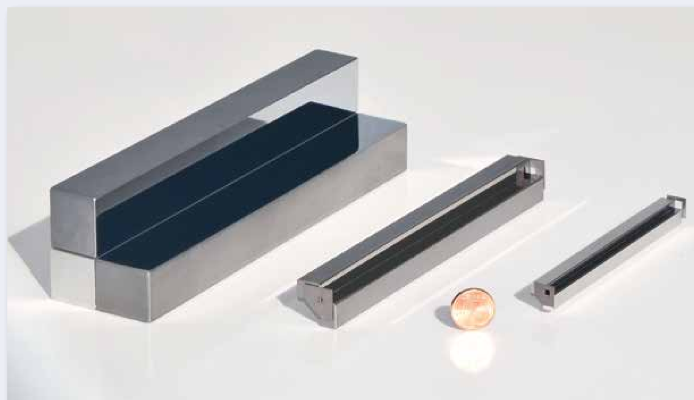
Si, orientation <0.05°
300 x 55 x 50 mm
slope error tangential: 0.25 µrad rms
slope error sagittal: 5 µrad rms
HSF Roughness < 2 Å rms

stripe 1: Ru / C
Stripe 2: W / B_4C
Period: 40 / 26 Å
Density: Ru~10.5 g/cm³ C~2.2 g/cm³ W~17.5 g/cm³ B_4C~2.2 g/cm³
Interface Roughness 3 Å rms

Synchrotron mirrors for PAL in Korea 300 mm in length (Operating energy range 10 – 80 KeV)

Montel Optics for Synchrotron Applications in Different Sizes

Montel optics consist of two mirros mounted side-by-side in an L-shape arrangement enabling a 2-dimensional beam shaping. A Montel optics with two elliptically shaped mirrors is point focusing, whereas two parabolic mirrors enable a collimated beam. A line focus is created with a hybrid optics, a combination of an elliptic and a parabolic mirror. High quality multilayer optics are essential for an excellent beam shaping with homogeneous beam properties. The Montel optics accumulate a lot of flux within a well-shaped, gaussian-like spot of expected size measured by 2D detectors or pin diodes. Nowadays, Montel optics are also used at synchrotrons, where they substitute the KB (Kirkpatrick-Baez) mirrors enabling a more compact design.



Montel Optics - 10-15 cm in length

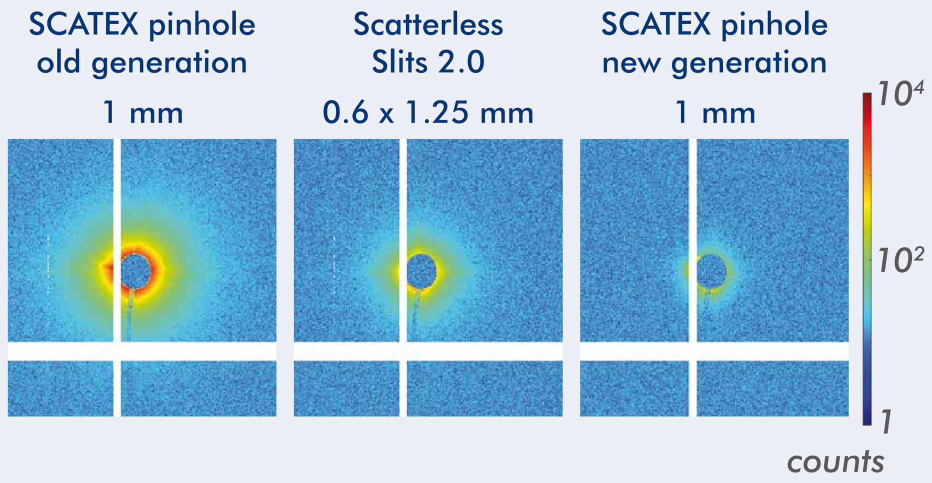
Different cross sections from 4 x 4 cm to 1 x 1 cm. First optics, with slope errors < 2 arcsec, were sold to NSLS and DLS. They are used at inelastic scattering beamlines.

Incoatec offers total reflection optics consisting of highly-stable carbon, silicon carbide, tungsten, ruthenium or other materials, multilayer coatings up to 500 mm as well as multi-stripe optics. First Montel optics with low slope errors are used at beamlines. Many research centers worldwide are using our know-how and our optics, e.g. APS · Bessy · Canadian Light Source · Diamond · Elettra · Desy - XFEL · Lyncean Tech. Inc. · NSLS · PAL · SESO · SLS-PSI · WinlightX · Zeiss.

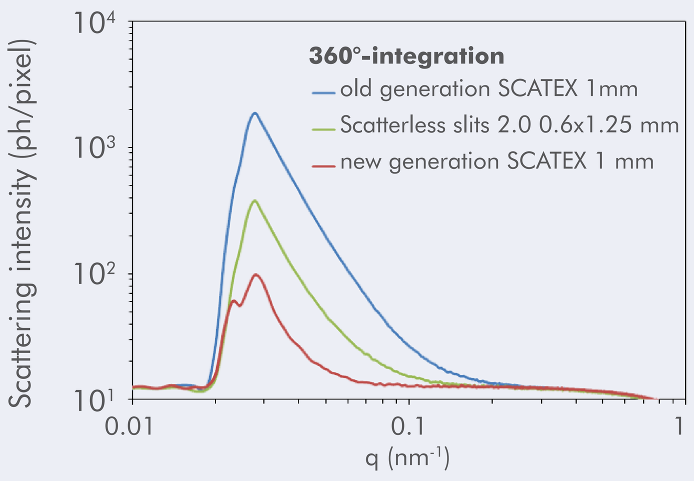
SCATEX - Incoatec´s Scatterless Pinholes for Synchrotrons

Comparison of Scatterless Slits 2.0 and SCATEX Pinholes

The measurements were performed by C. Gollwitzer at the PTB four-crystal monochromator beamline at BESSY II at 8 keV with typical photon fluxes of ~10^{10} ph/s.



Images of the parasitic aperture scattering at 8 keV with the test apertures being the beam defining element. No scatter guard inserted. The downstream photon flux was the same (variation < 1%) for all compared test apertures.



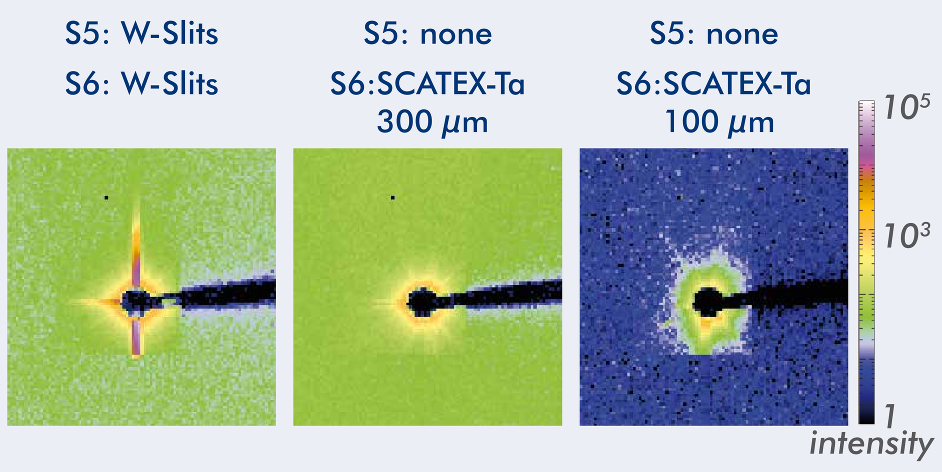
Deduced scattering intensity vs. q-plots (360°-integration) for the various tested apertures.

New generation SCATEX pinholes

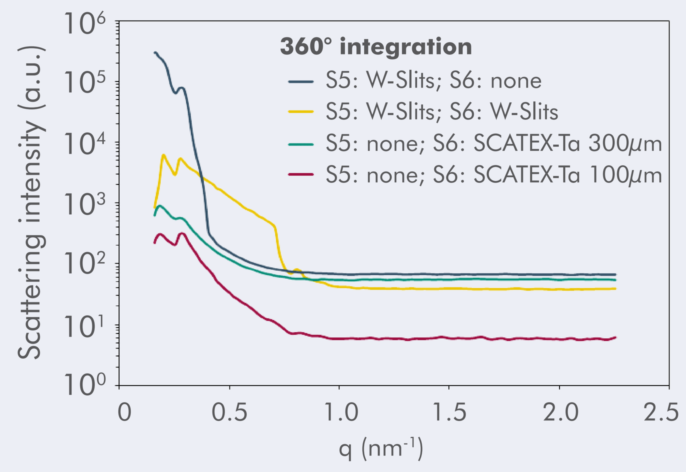
- up to 4 times less parasitic aperture scattering compared to Scatterless Slits 2.0
- up to 19 times less parasitic aperture scattering compared to old generation SCATEX Pinholes
- faster aperture scattering decay below the background at considerably smaller q-values

Comparison of Tungsten Slits and SCATEX-Ta Pinholes

The measurements were performed at 13 keV at the Nanofocus Endstation P03 beamline at PETRA III with typical photon fluxes of 10^{11}-10^{12} ph/s by C. Krywka.



Detector images of the parasitic aperture scattering at 13 keV. In the standard beamline setup S5 denotes the position of the beam defining aperture and S6 the position of the antiscatter aperture.



Scattering intensity vs. q-plot. The data is normalized to the number of summed up pixel. Various apertures were tested at position S5 (beam definition) and S6 (scatter guard).

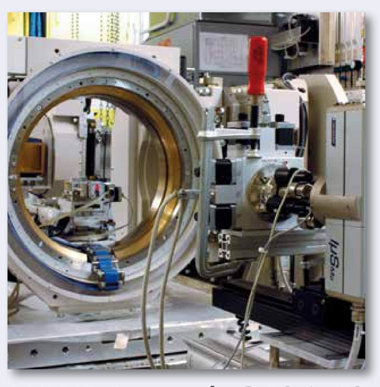
- a single SCATEX-Ta pinhole replaces both beam defining slit S5 and antiscatter slit S6
- the beam-defining SCATEX-Ta aperture can be positioned closer to the sample
- one order of magnitude less parasitic aperture scattering with SCATEX pinholes
- pinhole sizes down to 10 - 20 µm possible

Upgrades with Microfocus Source IµS and Scatterless Pinhole SCATEX

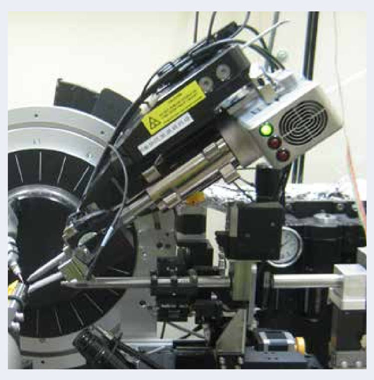
The IµS is a low power air cooled X-ray source for diffractometry applications. It can be used at synchrotrons as a screening source or a backup during downtime periods. At the small-molecule crystallography beamline 11.3.1 at ALS the IµS is used together with the synchrotron in a dual source set-up. The IµS is equipped with Montel optics. Therefore, we can form either a highly collimated beam with a low divergence (below 0.5 mrad) or a focusing beam with higher divergence (up to 10 mrad) and very small focal spots at the sample (diameters downto 100 µm). The Cu-IµS with collimating optics can be used for (GI)SAXS and X-ray diffraction studies. With the Mo- and Ag-IµS highly absorbing and radiation-damage sensitive materials can be investigated. The data quality can be further improved by combining the IµS with scatter-free SCATEX pinholes, which reduce the background by eliminating parasitic scattering that is observed with conventional metal apertures.

Incoatec offers a unique possibility to upgrade your existing diffractometer or beamline by installing the high-performance, air-cooled microfocus source IµS and/or scatterless pinholes SCATEX.

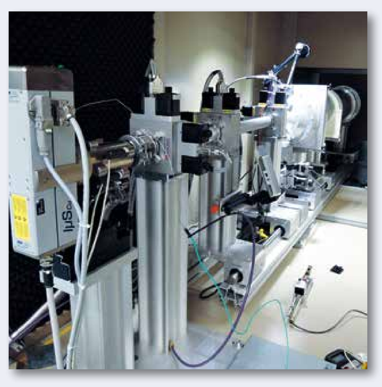
XRD/XRR setup in synchrotron optics lab at ESRF in Grenoble, France



HRXRD and GISAXS setup at synchrotron beamline (Petra III, DESY) in Hamburg



Mo-IµS as second source at small-molecule beamline 11.3.1 at ALS



IµS and SCATEX in a customized SAXS setup at University of Hamburg

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