Trends on thin film X-ray optics and pinholes for synchrotron beamlines

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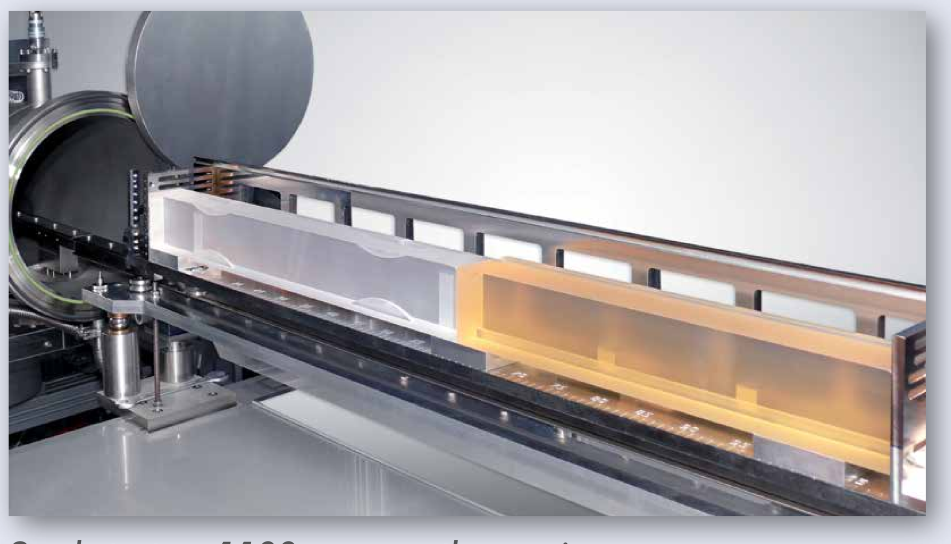
Introduction

Here, we give an overview on current developments in the coating of large total reflection X-ray optics up to 1500 mm in length, 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.

Total Reflection Optics for Synchrotron Beamlines

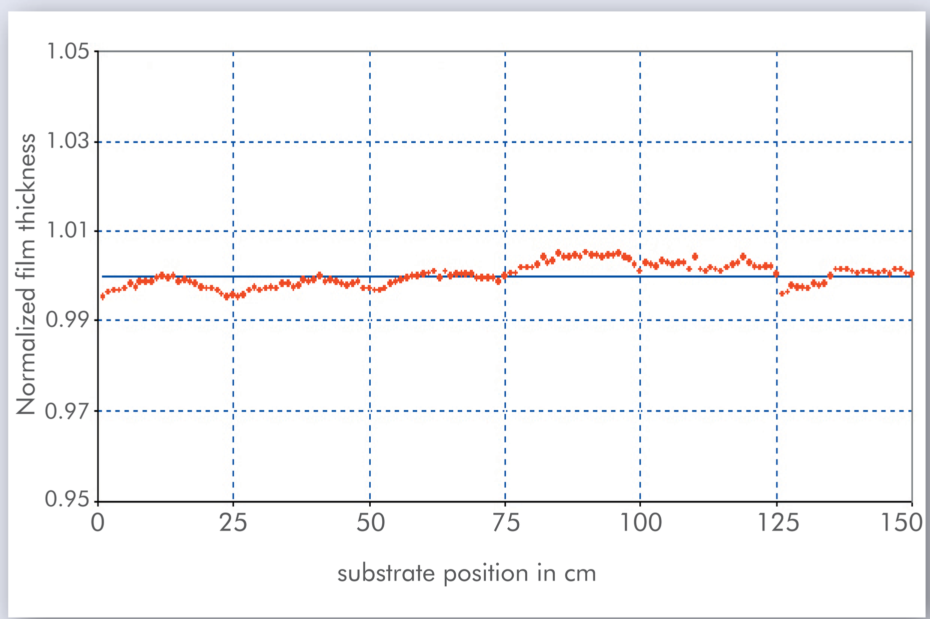
Total reflection optics for synchrotron beamlines are needed for beam guidance and beam alignment. This type of X-ray optics is used at grazing incidence angles, therefore more and more optics with lengths of 1000 mm and longer are needed.



2 substrates -1100 mm- on the carriage.

1000 mm Si mirror with special carbon coating.

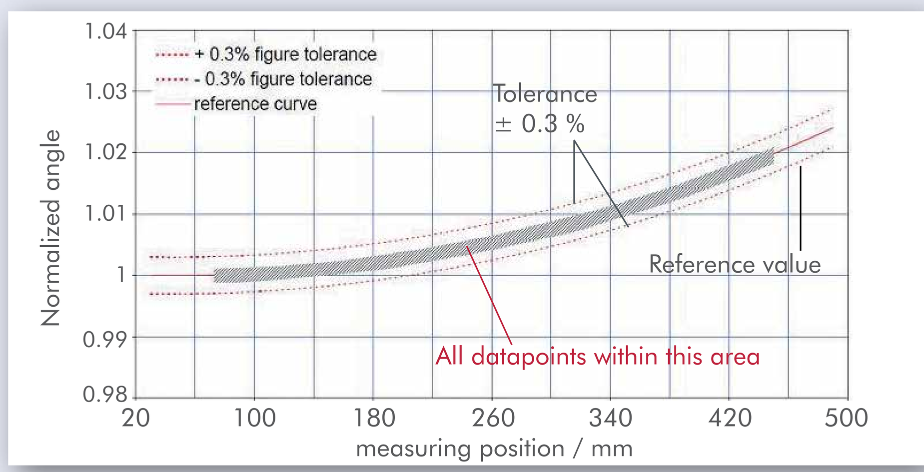
A new sputtering system for the deposition of single- and multilayers has been installed at the Helmholtz-Zentrum Geesthacht. This system enables us to produce coatings up to a length of 150 cm. The variation in film thickness over the whole length of 150 cm has been investigated by X-ray reflectometry. Good uniformity and low roughness (< 0.5nm) were observed.



Tungsten coating	
deposition length	1500 mm
Mean film thickness	35 nm
Peak-to-Valley	0.35 nm
Uniformity	**1.0 %**

Uniformity of a 35 nm tungsten coating over 1500 mm. Uniformity of thickness is better than 1%.

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

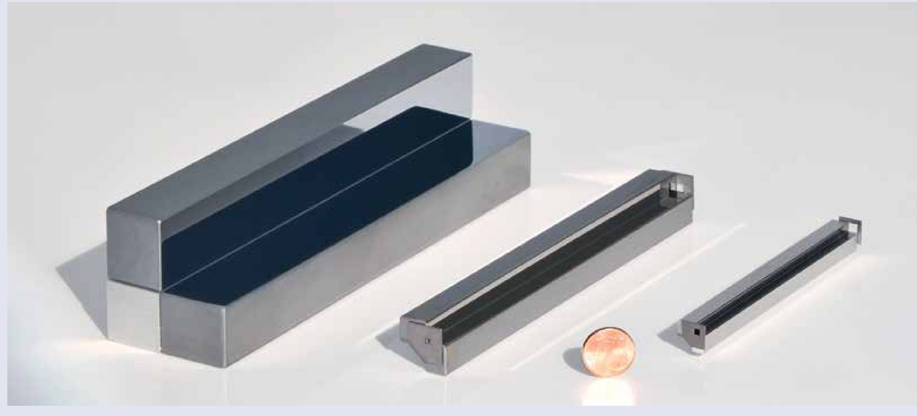
Multi-stripe Multilayer Optics

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 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).

Montel Optics for Synchrotron Applications in Different Sizes



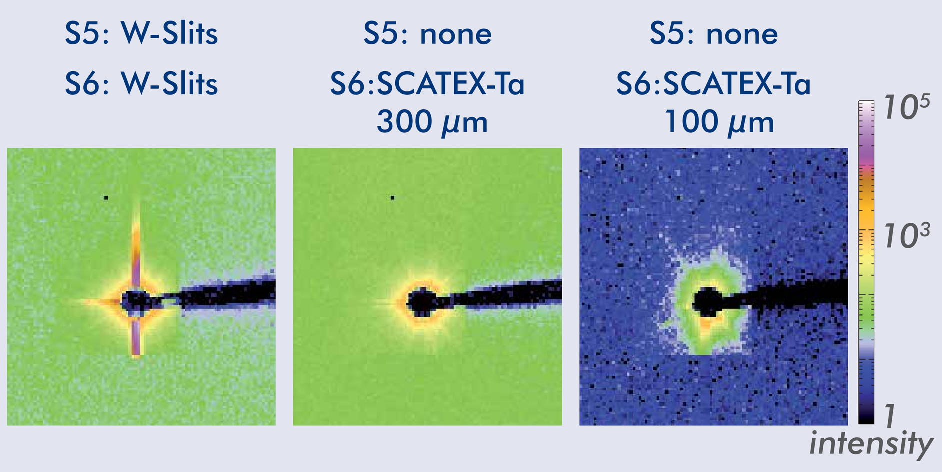
First optics, with slope errors < 2 arcsec, were sold to NSLS and Diamond for scattering experiments.

Montel Optics - 100-150 mm in length
Different cross sections from 40 x 40 mm to 10 x 10 mm

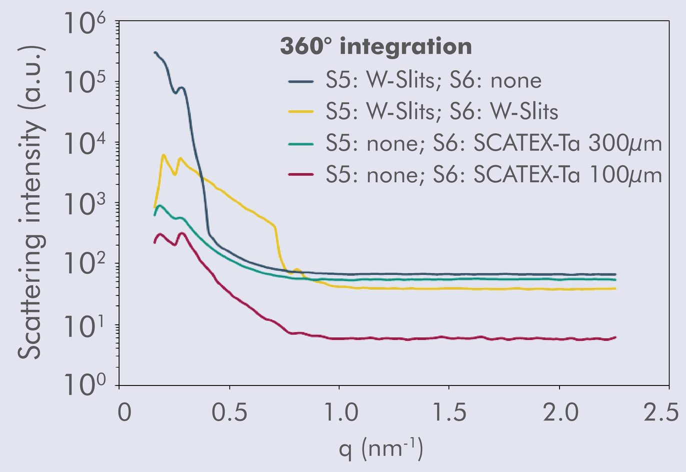
SCATEX Pinholes for Synchrotrons

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.

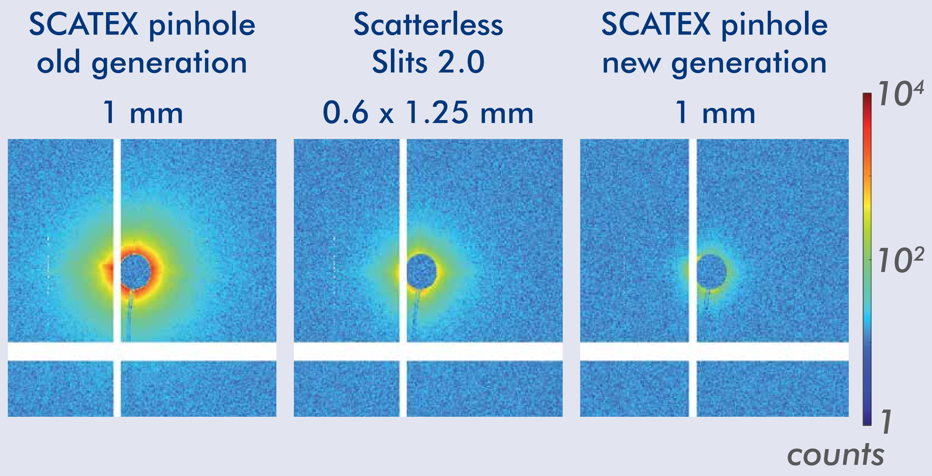


Scattering intensity vs. q-plot. The data is normalized to the number of summed up pixel. Various apertures were tested at position S5 (beam definition) and S6 (scatter guard).

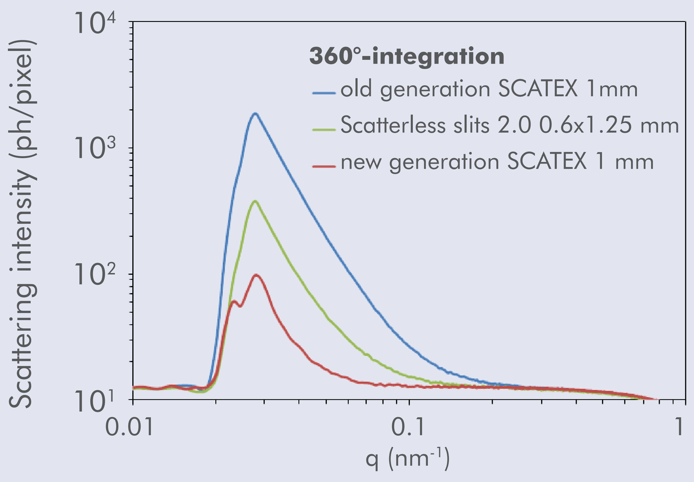
- a single SCATEX-Ta pinhole replaces both beam defining slit S5 and antiscatter slit S6
- the beam-defining SCATEX-Ta aperture can be positioned closer to the sample
- one order of magnitude less parasitic aperture scattering with SCATEX pinholes
- pinhole sizes down to 10 - 20 µm possible

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

References

In closed cooperation with HZG, Incoatec has produced total reflection optics consisting of highly-stable carbon, silicon carbide, tungsten or ruthenium and also multilayer coating 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.

Advanced Photon Source · Bessy · Canadian Light Source · Carl Zeiss · Diamond · Elettra · Hasylab at Desy · Horiba Jobin-Yvon · Jenoptik AG · Lyncean Tech. Inc. · NSLS · PAL · Seso · Swiss Light Source

Conclusion

- High precision coatings up to 150 cm in length
- Multilayer coatings up to 50 cm
- Montel optics for Synchrotron applications
- Multi-stripe multilayer optics as monochromators
- Ultra stable carbon coatings for FEL
- New generation SCATEX with less parasitic aperture scattering

The high quality and flexibility of the complete production process enable us to offer customized solutions for all kind of synchrotron applications.

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