Trends on Montel X-ray Optics for Inelastic Scattering and Pinholes for Synchrotron Beamlines

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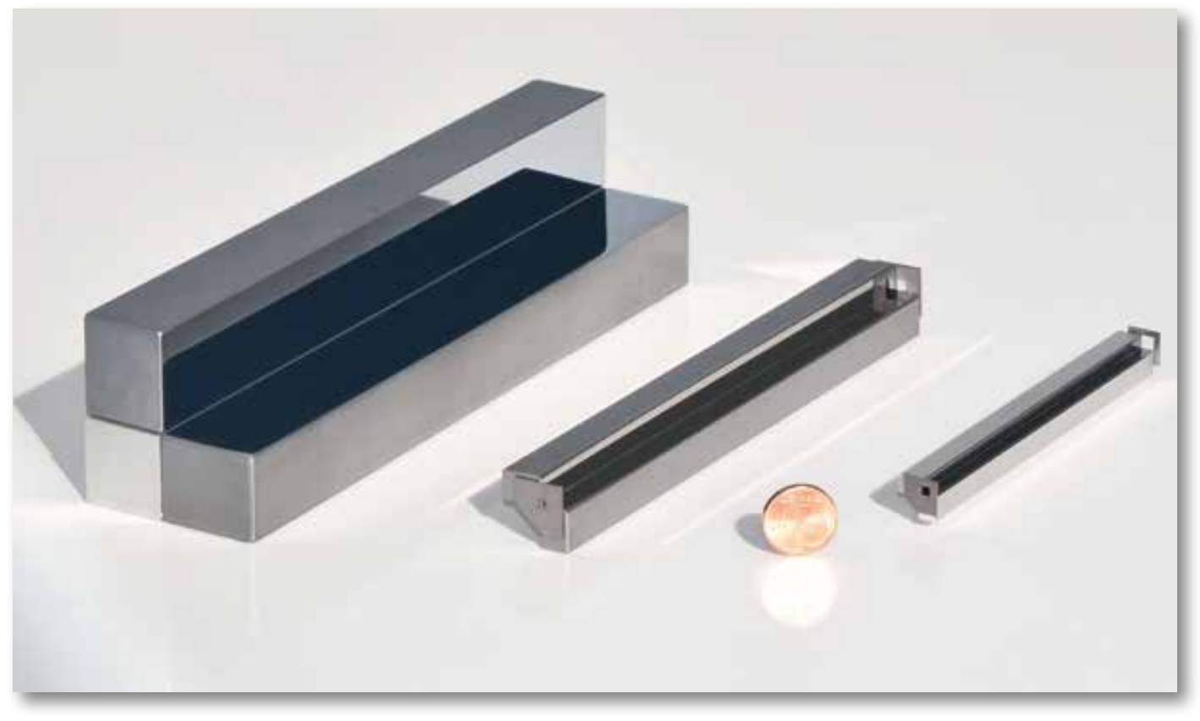
Montel Optics for Synchrotron Applications in Different Sizes

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.



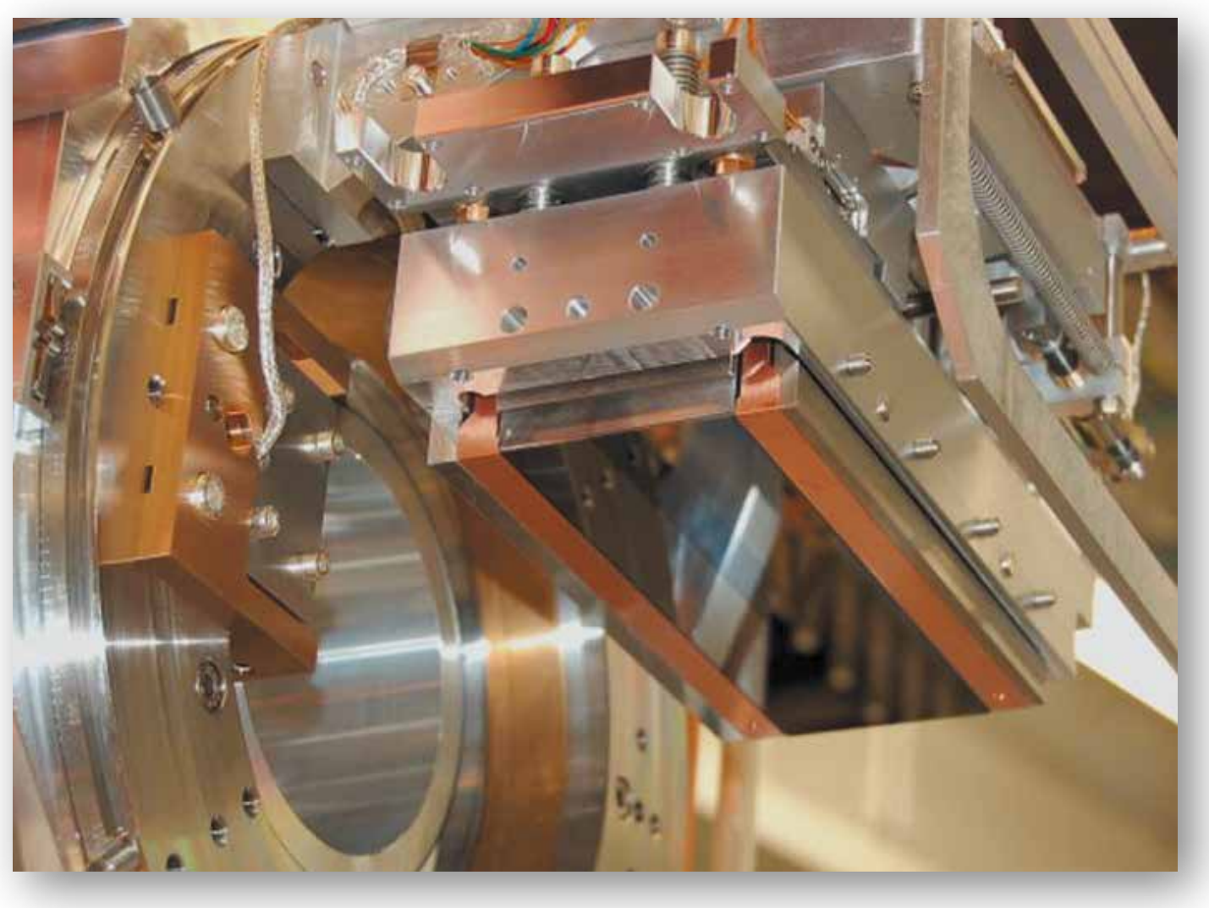
Montel Optics - 100-250 mm in length

Different cross sections from 40 x 40 mm to 10 x 10 mm. First optics, with slope errors < 2 arcsec, were sold to NSLS, DLS, APS and ESRF. They are used at inelastic scattering beamlines.

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



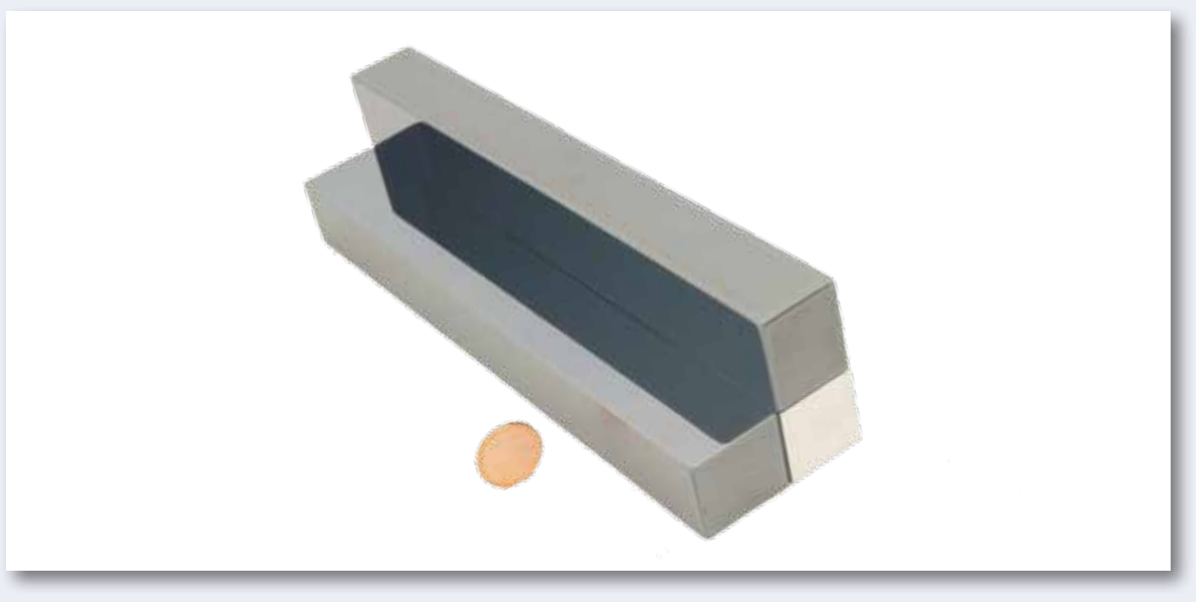
Three-striped multilayer optics for tomographic microscopy and coherent radiology, with an optimized coating for different beam energies (TOMCAT at SLS, Switzerland, Data courtesy of M. Stampanoni).

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 multilayer mirror for tests and characterization and for the analyzer system of the ultra-high-resolution IXS spectrometer

2D parallel beam multilayer optic for 9100 eV
Montelpart: 120 x 20 x 20 mm ± 0.1 mm (L x W x H)
Acceptance angle: > 10 mrad x 10 mrad
Meridional slope error: ≤ 2 arcsec (10 µrad) rms
Microroughness: ≤ 0.2 nm (rms) HSFR
Coating: W/C Multilayer

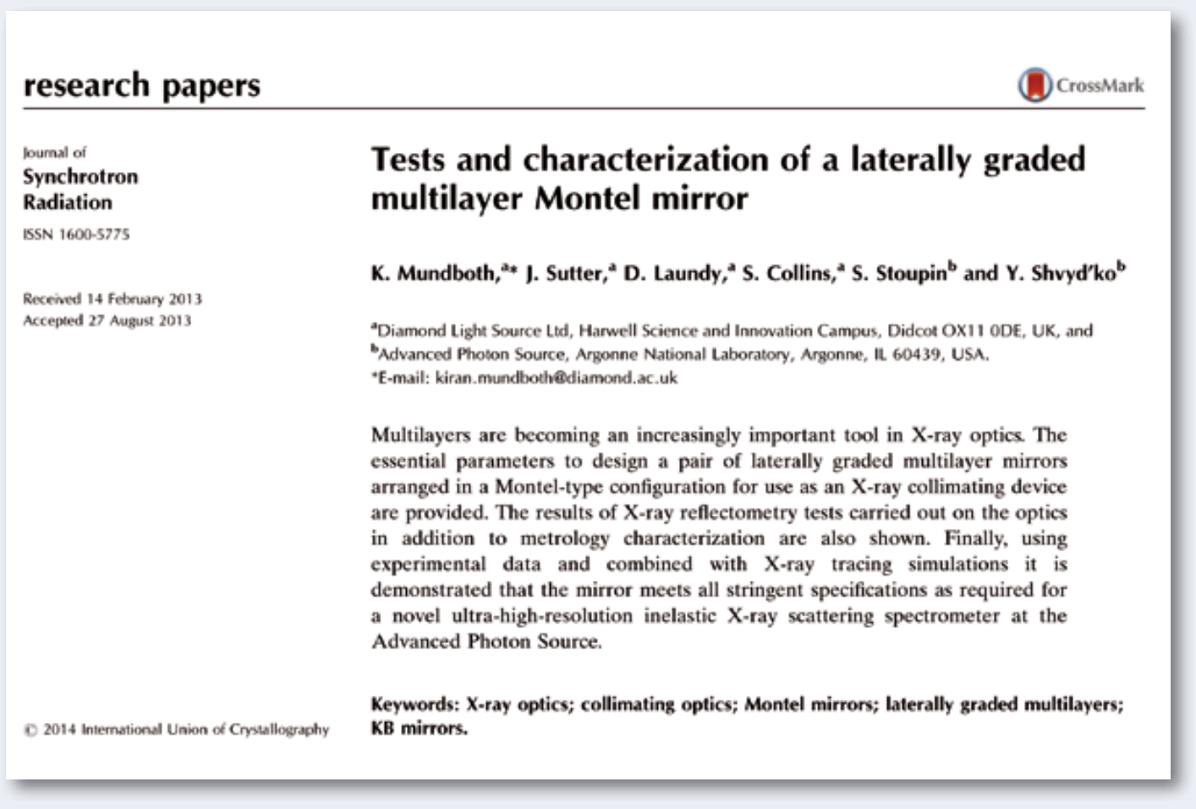


Diamond Light Source Ltd
Beamline: B16 at DLS, 34-ID at APS
Contact: John Shutter, John.Sutter@Diamond.ac.uk

Tests and characterization of a laterally graded multilayer Montel mirror
J. Synchrotron Rad. (2014). 21, 16–23

Brookhaven National Laboratory, NSLS II
Beamline: 10-ID Inelastic X-ray Scattering
Contact: Yong Cai, cai@bnl.gov

Synchrotron X-ray tests of an L-shaped laterally graded multilayer mirror for the analyzer System of the ultra-high-resolution IXS spectrometer at NSLS-II
J. Synchrotron Rad. (2011). 18, 862–870



research papers

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Tests and characterization of a laterally graded multilayer Montel mirror

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Multilayers are becoming an increasingly important tool in X-ray optics. The essential parameters to design a pair of laterally graded multilayer mirrors arranged in a Montel-type configuration for use as an X-ray collimating device are provided. The results of X-ray reflectometry tests carried out on the optics in addition to metrology characterization are also shown. Finally, using experimental data and combined with X-ray tracing simulations it is demonstrated that the mirror meets all stringent specifications as required for a novel ultra-high-resolution inelastic X-ray scattering spectrometer at the Advanced Photon Source.

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Keywords: X-ray optics; collimating optics; Montel mirrors; laterally graded multilayers; KB mirrors.

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Synchrotron X-ray tests of an L-shaped laterally graded multilayer mirror for the analyzer system of the ultra-high-resolution IXS spectrometer at NSLS-II

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Characterization and testing of an L-shaped laterally graded multilayer mirror are presented. This mirror is designed as a two-dimensional collimating optics for the analyzer system of the ultra-high-resolution inelastic X-ray scattering (IXS) spectrometer at National Synchrotron Light Source II (NSLS-II). The characterization includes point-to-point reflectivity measurements, lattice parameter determination and mirror metrology (figure, slope error and roughness). The synchrotron X-ray test of the mirror was carried out reversely as a focusing device. The results show that the L-shaped laterally graded multilayer mirror is suitable to be used, with high efficiency, for the analyzer system of the IXS spectrometer at NSLS-II.

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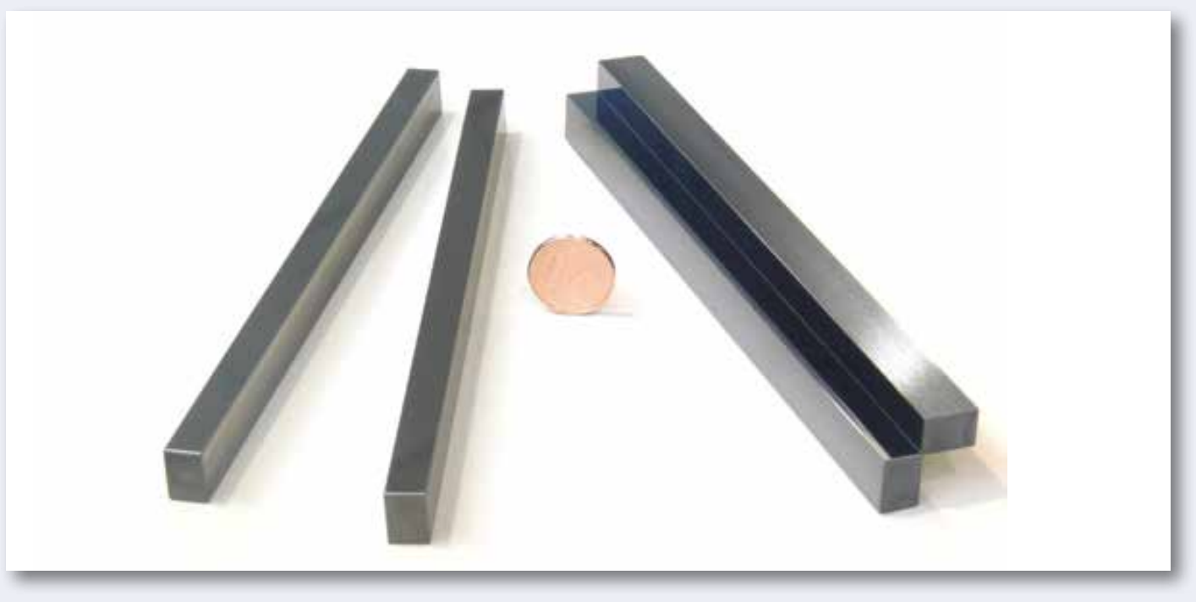
Keywords: X-ray optics; X-ray mirrors; L-shaped mirror; nested mirror; Montel optics; Kirkpatrick–Baez geometry.

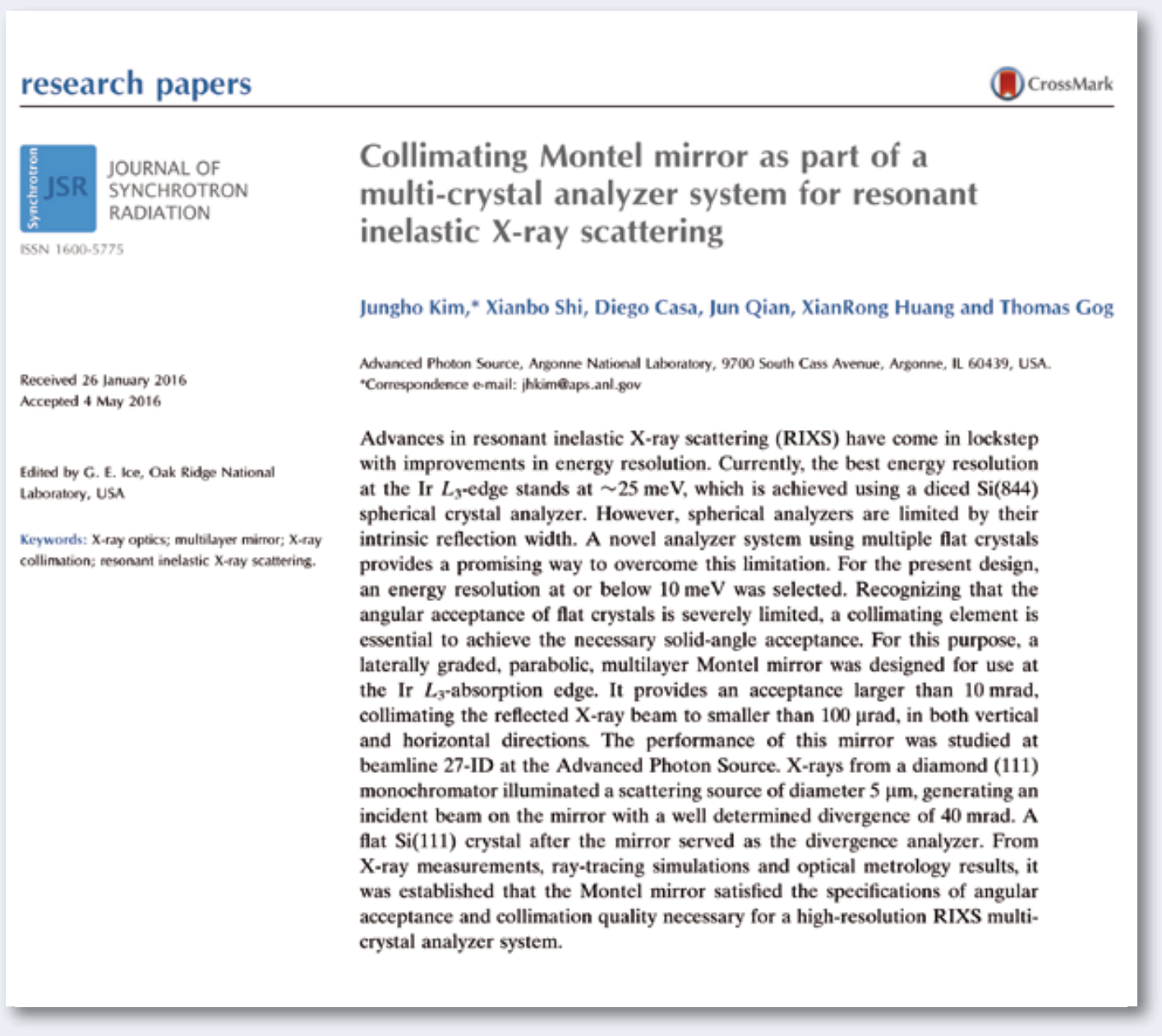
J. Synchrotron Rad. (2011). 18, 862–870

Collimating Montel mirror as part of a multi-crystal analyzer system for resonant inelastic X-ray scattering

2D parallel beam multilayer optic for 11215 eV
Montelpart: 150 x 7 x 10 mm ± 0.1 mm (L x W x H)
Acceptance angle: > 14 mrad x 14 mrad
Meridional slope error: ≤ 2 arcsec (10 µrad) rms
Microroughness: ≤ 2.0 nm (rms) HSFR
Coating: Ru/C Multilayer



Argone National Lab, Advanced Photon Source
Beamline: 27-ID
Contact: Jung Ho Kim, jhkim@aps.anl.gov



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Keywords: X-ray optics; multilayer mirror; X-ray collimation; resonant inelastic X-ray scattering.

Collimating Montel mirror as part of a multi-crystal analyzer system for resonant inelastic X-ray scattering

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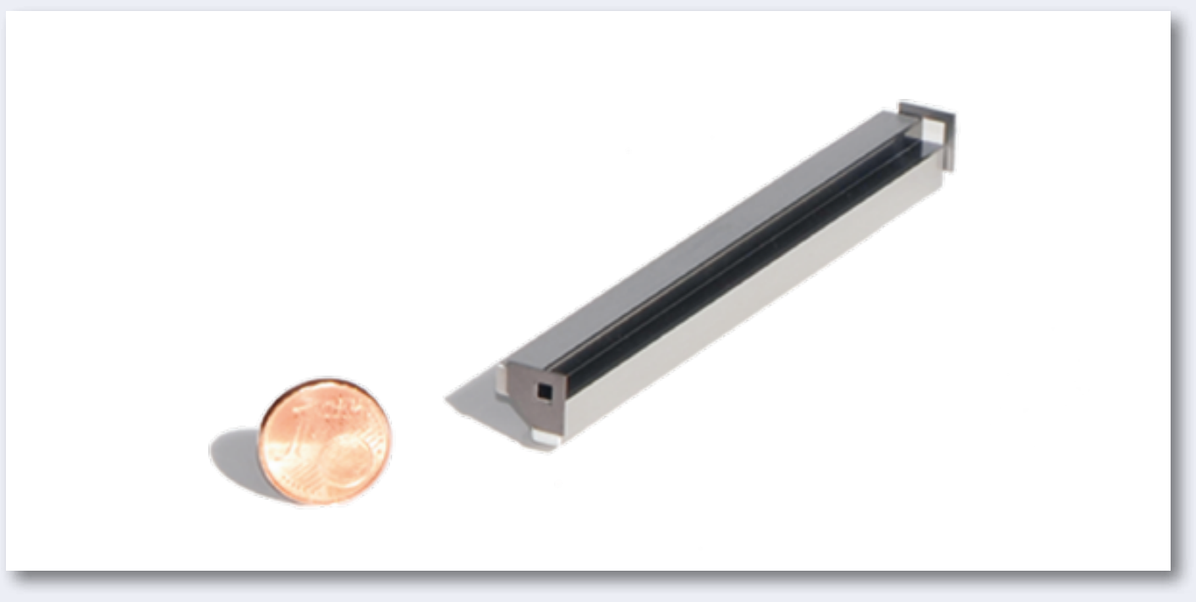
Advances in resonant inelastic X-ray scattering (RIXS) have come in lockstep with improvements in energy resolution. Currently, the best energy resolution at the Ir L_3-edge stands at ~25 meV, which is achieved using a diced Si(844) spherical crystal analyzer. However, spherical analyzers are limited by their intrinsic reflection width. A novel analyzer system using multiple flat crystals provides a promising way to overcome this limitation. For the present design, an energy resolution at or below 10 meV was selected. Recognizing that the angular acceptance of flat crystals is severely limited, a collimating element is essential to achieve the necessary solid-angle acceptance. For this purpose, a laterally graded, parabolic, multilayer Montel mirror was designed for use at the Ir L_3-absorption edge. It provides an acceptance larger than 10 mrad, collimating the reflected X-ray beam to smaller than 100 µrad, in both vertical and horizontal directions. The performance of this mirror was studied at beamline 27-ID at the Advanced Photon Source. X-rays from a diamond (111) monochromator illuminated a scattering source of diameter 5 µm, generating an incident beam on the mirror with a well determined divergence of 40 mrad. A flat Si(111) crystal after the mirror served as the divergence analyzer. From X-ray measurements, ray-tracing simulations and optical metrology results, it was established that the Montel mirror satisfied the specifications of angular acceptance and collimation quality necessary for a high-resolution RIXS multi-crystal analyzer system.

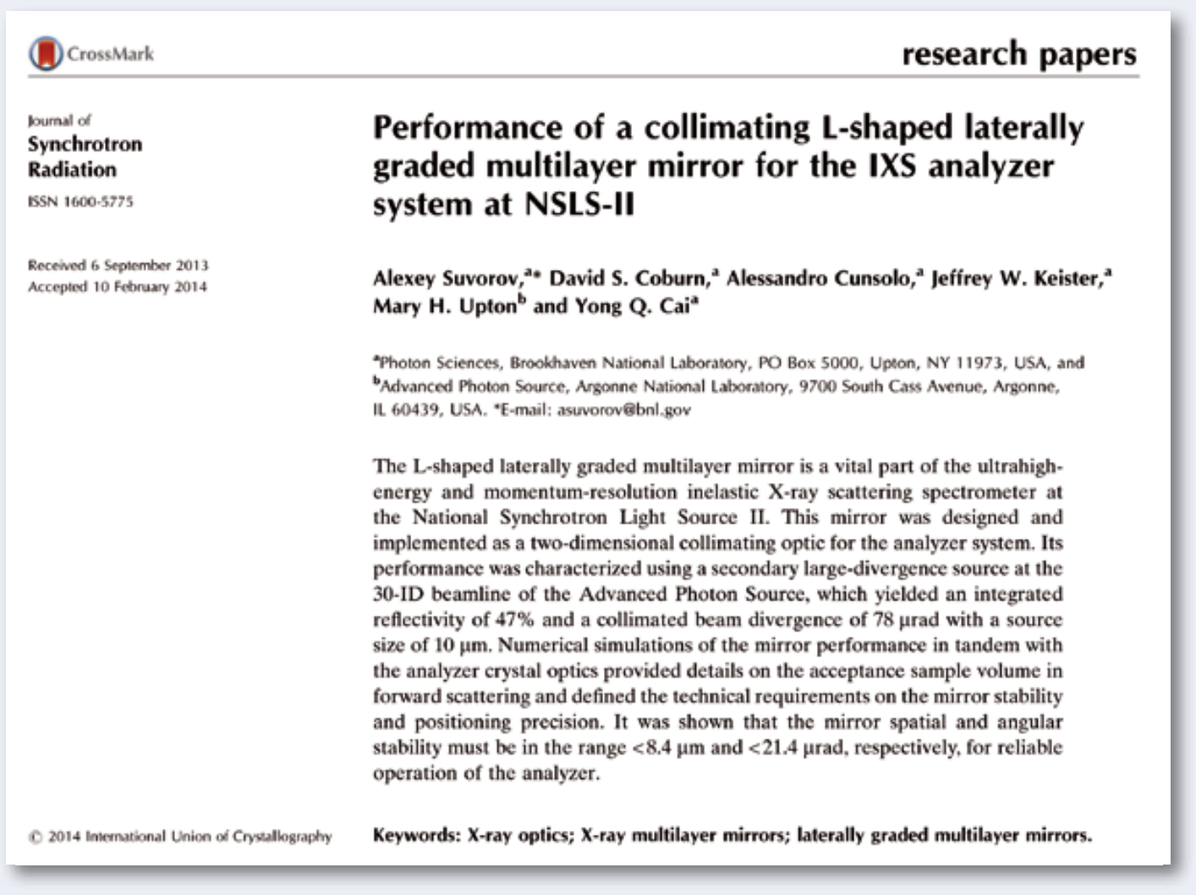
J. Synchrotron Rad. (2016). 23, 880–886

Performance of a collimating L-shaped laterally graded multilayer mirror for the IXS analyzer system at NSLS-II

2D parallel beam multilayer optic for 9130 eV
Montelpart: 100 x 4 x 6 mm ± 0.1 mm (L x W x H)
Acceptance angle: > 10 mrad x 10 mrad
Meridional slope error: ≤ 2 arcsec (10 µrad) rms
Microroughness: ≤ 0.2 nm (rms) HSFR
Coating: W/C Multilayer



Brookhaven National Laboratory, NSLS II
Beamline: 30-ID beamline at APS
Contact: Yong Cai, cai@bnl.gov



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Performance of a collimating L-shaped laterally graded multilayer mirror for the IXS analyzer system at NSLS-II

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The L-shaped laterally graded multilayer mirror is a vital part of the ultrahigh-energy and momentum-resolution inelastic X-ray scattering spectrometer at the National Synchrotron Light Source II. This mirror was designed and implemented as a two-dimensional collimating optic for the analyzer system. Its performance was characterized using a secondary large-divergence source at the 30-ID beamline of the Advanced Photon Source, which yielded an integrated reflectivity of 47% and a collimated beam divergence of 78 µrad with a source size of 10 µm. Numerical simulations of the mirror performance in tandem with the analyzer crystal optics provided details on the acceptance sample volume in forward scattering and defined the technical requirements on the mirror stability and positioning precision. It was shown that the mirror spatial and angular stability must be in the range <8.4 µm and <21.4 µrad, respectively, for reliable operation of the analyzer.

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Keywords: X-ray optics; X-ray multilayer mirrors; laterally graded multilayer mirrors.

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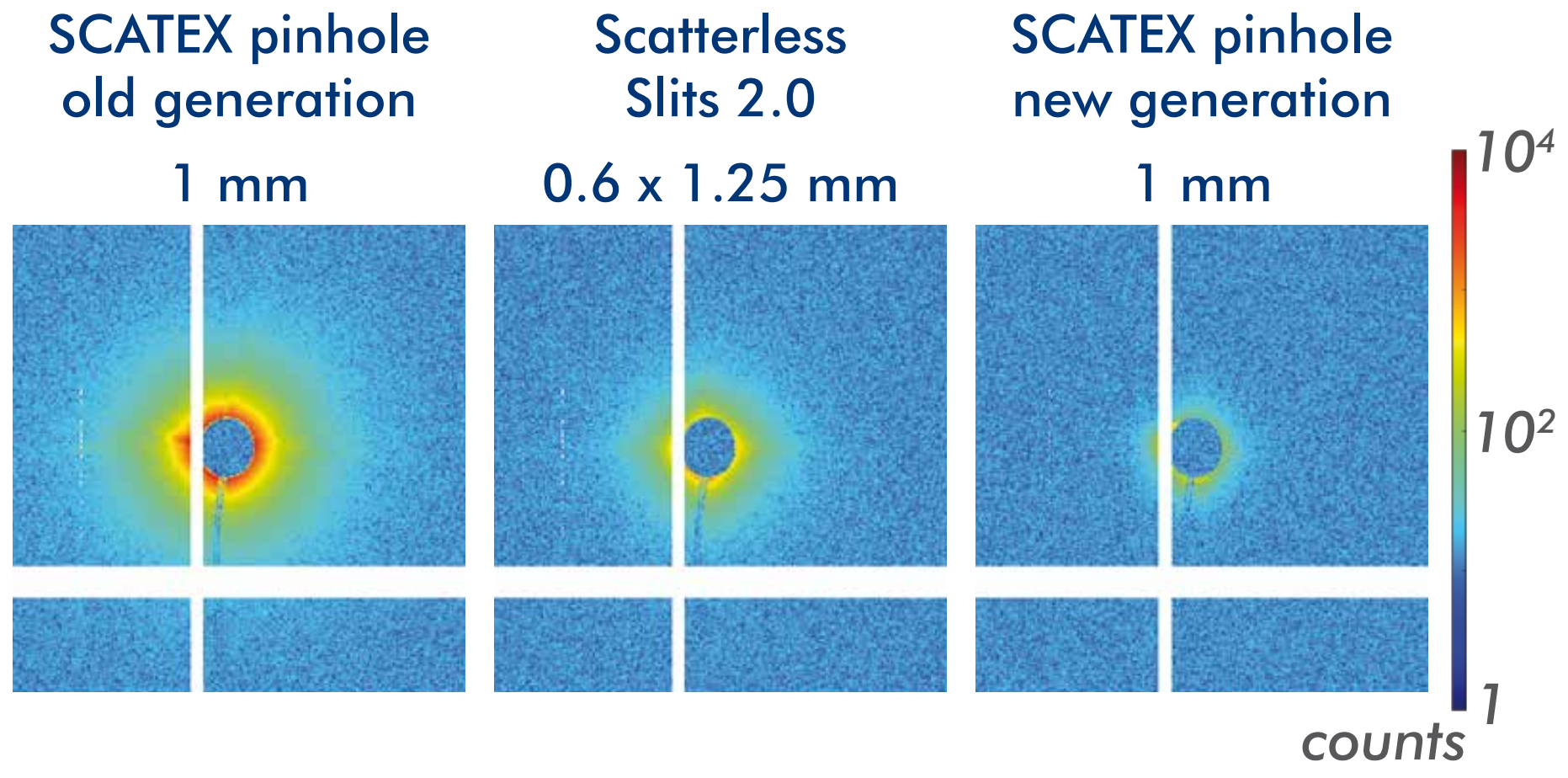
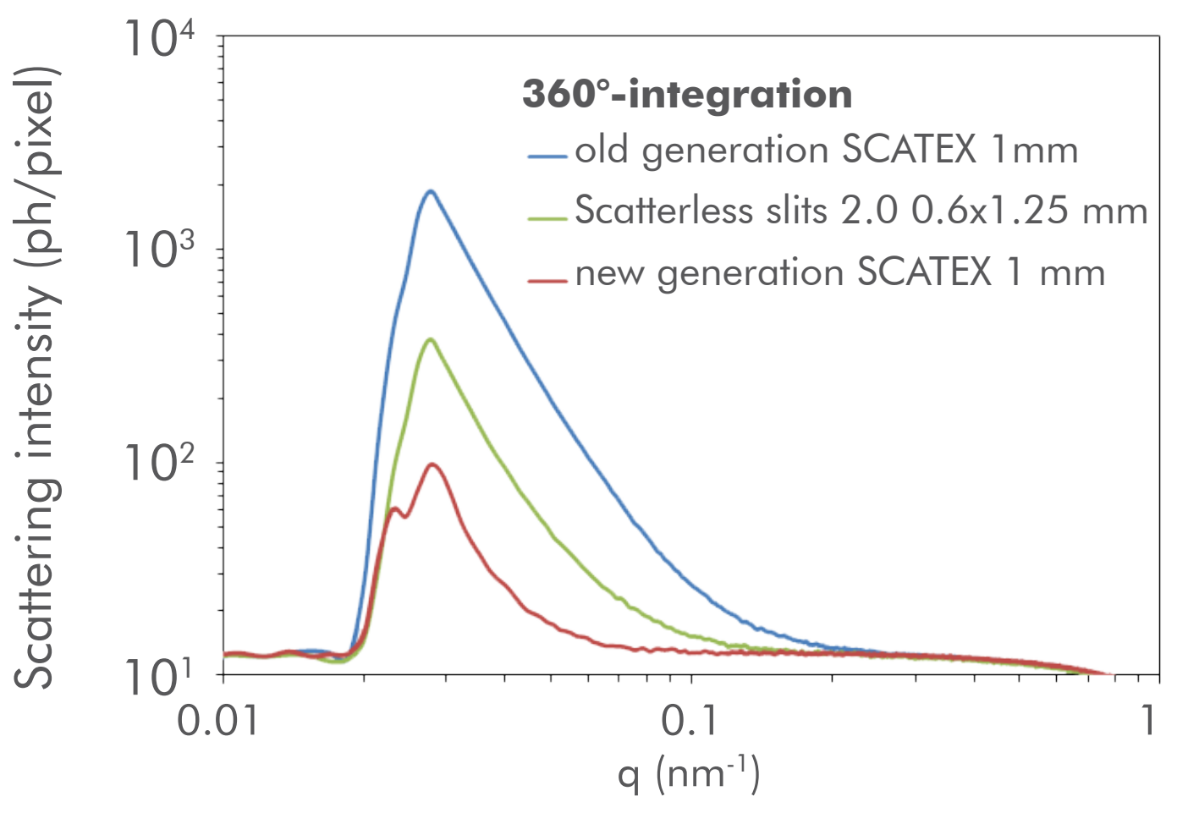
Comparison of Scatterless Pinholes SCATEX and Scatterless Slits 2.0

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.

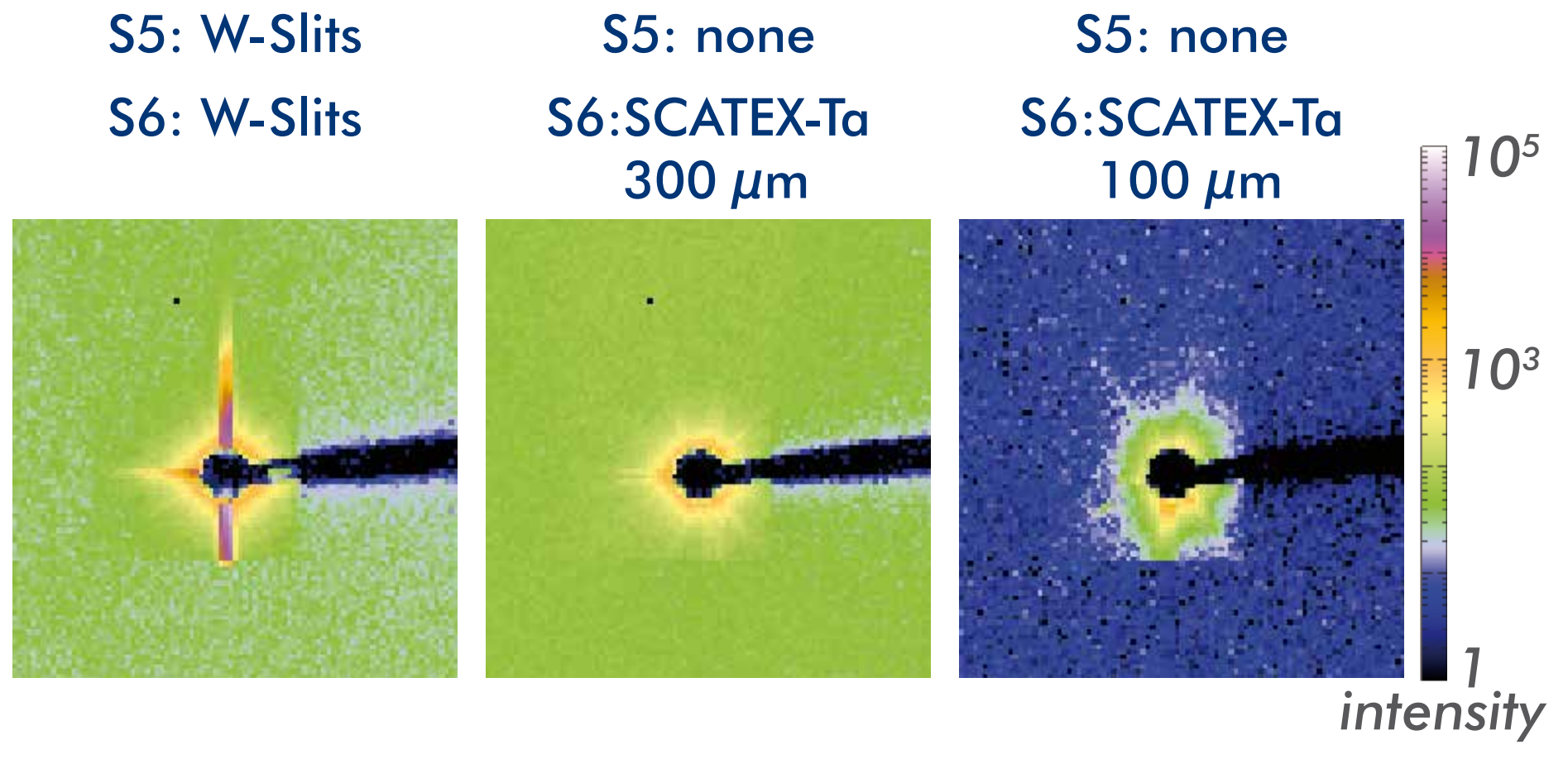


Deduced scattering intensity vs. q-plots (360°-integration) for the various tested apertures.

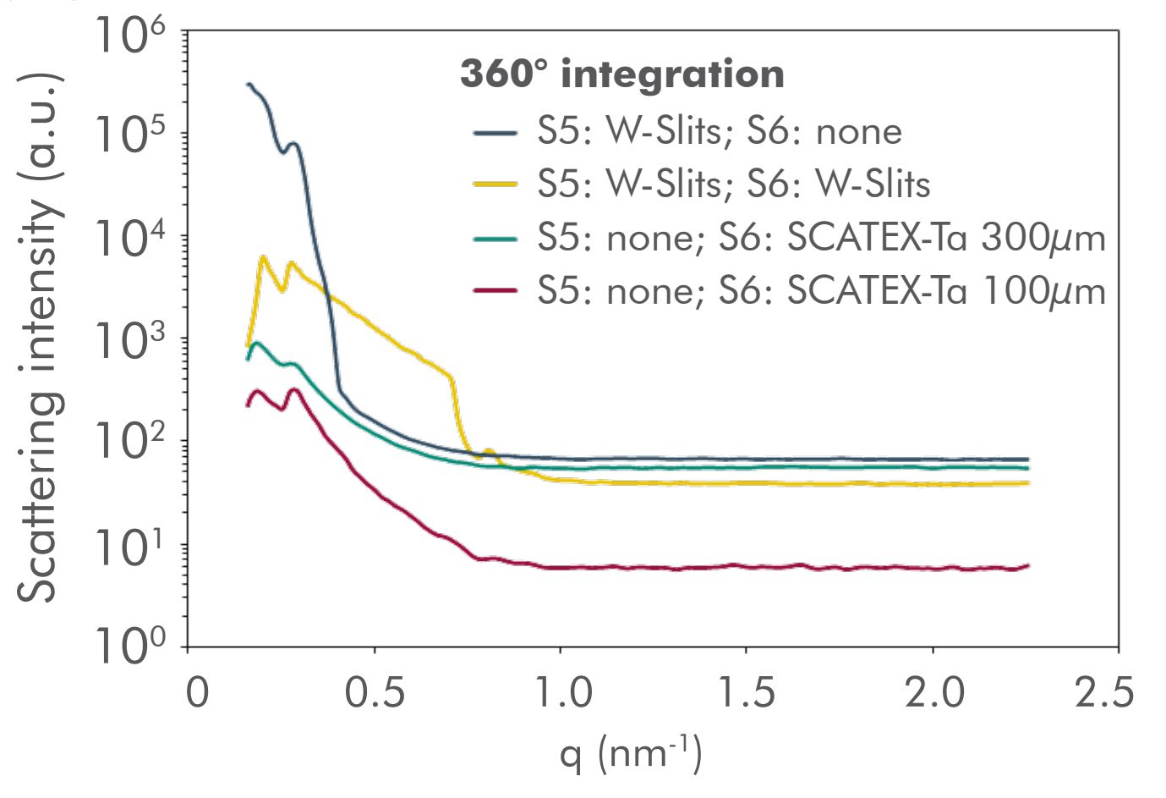
- up to 4 times less parasitic aperture scattering compared to Scatterless Slits 2.0
- faster aperture scattering decay below the background at considerably smaller q-values

Comparison of SCATEX-Ta Pinholes and Tungsten Slits

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

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