MULTILAYER LAUE LENSES FOR HARD X-RAY MICROSCOPY

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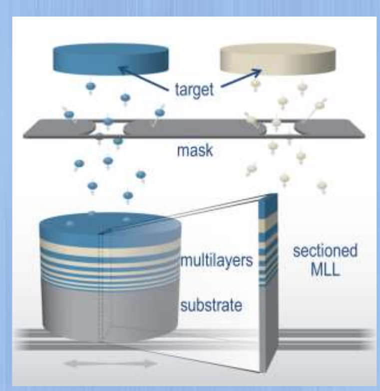
PHOTON SCIENCES

Multilayer Laue lenses

Multilayer Laue lenses (MLLs) optics offer great promise for focusing hard x-rays to nanometer level. Fabrication of MLLs rely on deposition of a depth graded multilayer thin film with layer thicknesses increasing progressively along the normal direction. Layer thicknesses typically varies between 2 and 25 nm. After the multilayer growth, multilayer is sectioned to produce an optical structure with a **very high aspect ratio** (section depth to zone width). For hard X-rays, the thinner outermost layer and the larger width achievable enable the MLL to simultaneously achieve higher **spatial resolution** and diffraction efficiency than conventional zone plates. The fabrication process for an ideal MLL reside in the **accurate placement of the layers** and **quality of the sectioning** – thickness, profile, roughness, minimal introduction of defects - for the layers to diffract in phase at the focus with **maximum efficiency**. Maintaining these requirement for high aspect ratios structures presents enormous challenges as the aperture size continues to increase.

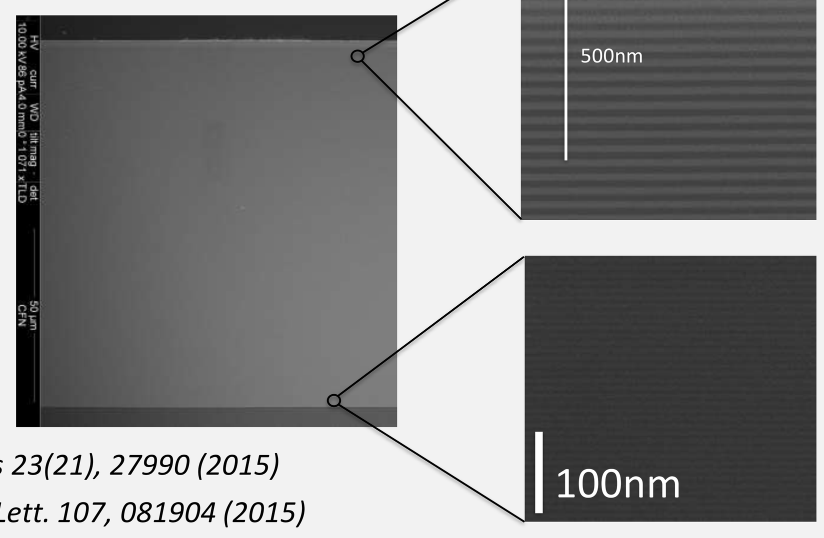
Multilayer deposition


Deposition chamber in our labs at NSLS-II

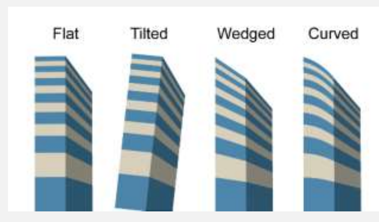


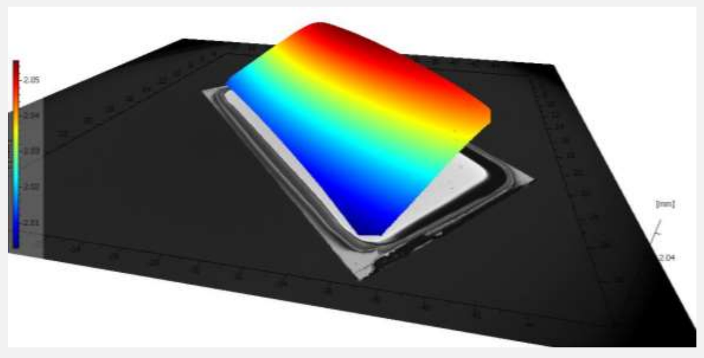
- Flat substrate
- Deposition rate calibration
- Deposition of the multilayer by sputtering
    - 2 materials deposited alternatively
    - Low interfacial roughness needed
    - Several thousands of layers
    - High thermal and temporal stability

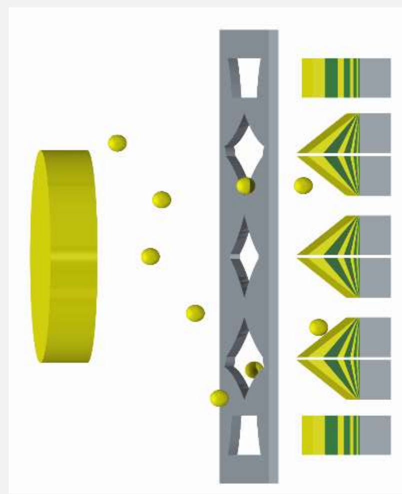
Successful deposition of a **102µm thick multilayer for MLL**, nearly twice thicker than previously reported

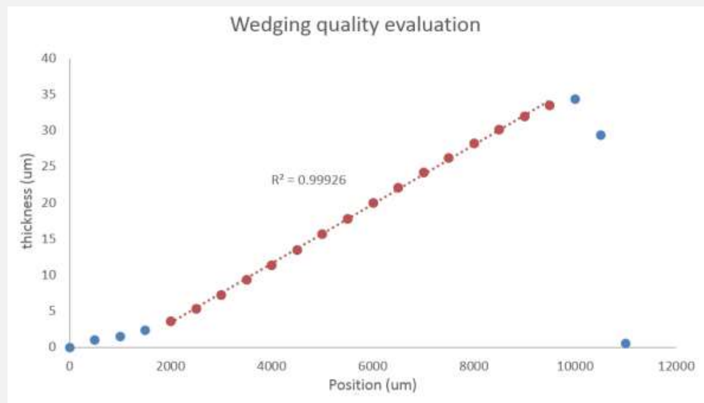


Opt. Express 23(21), 27990 (2015)
Appl. Phys. Lett. 107, 081904 (2015)





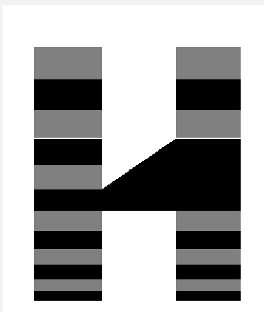


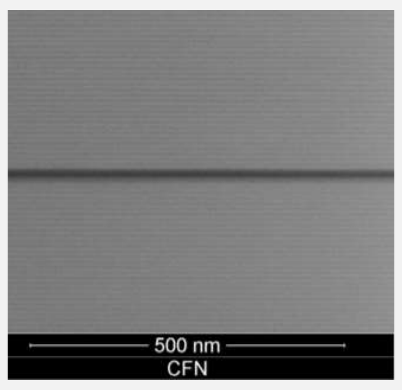


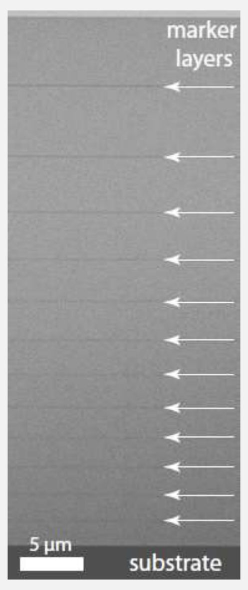
Optics Express 23 (10), 12496 (2015)

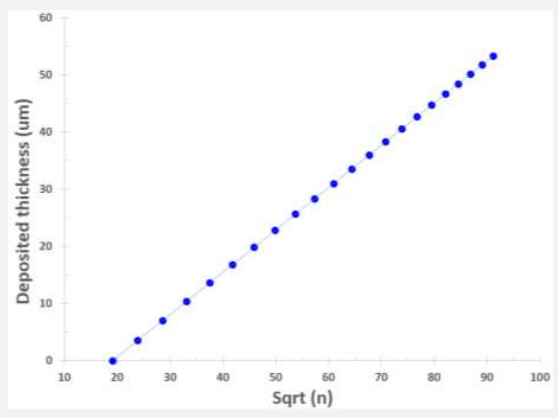
Metrology

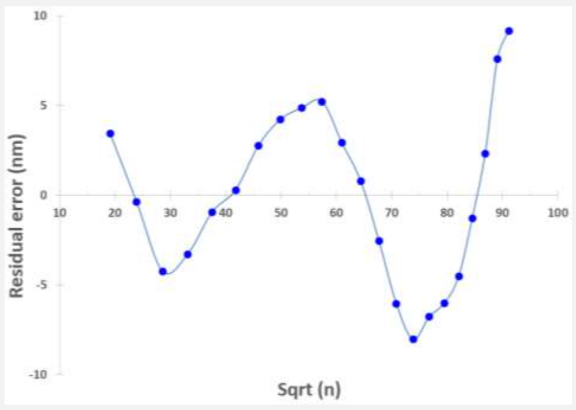
Thanks to markers built in the multilayer, post-growth ex-situ characterization via SEM can be used as a metrology tool to accurately evaluate the zone placement error







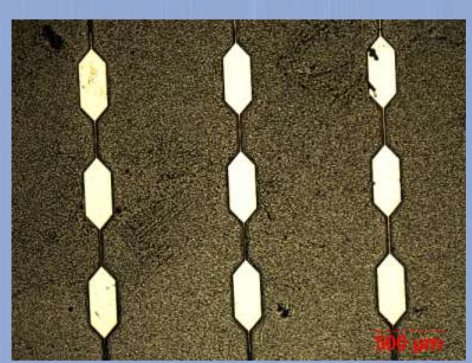




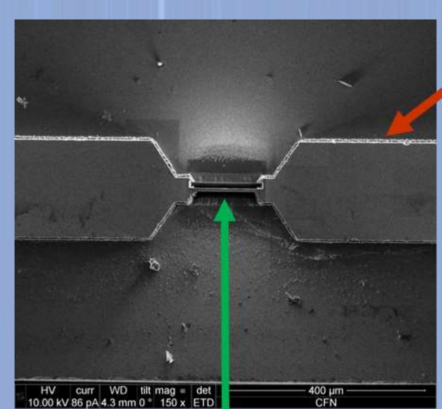
J. Phys. D: Appl. Phys. 47 (2014)

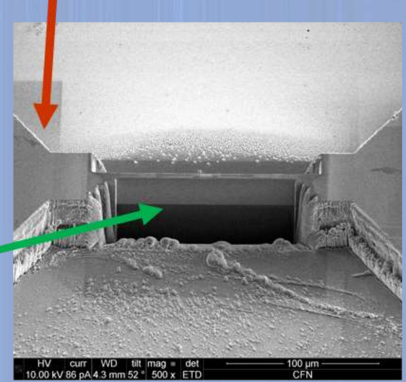
Sectioning

- High aspect ratio (1:5 to 1:20)
- Mechanical stability
- Multi-material
- Micron size sleeves
- Controlled section thickness for maximum performances
- Minimum damage

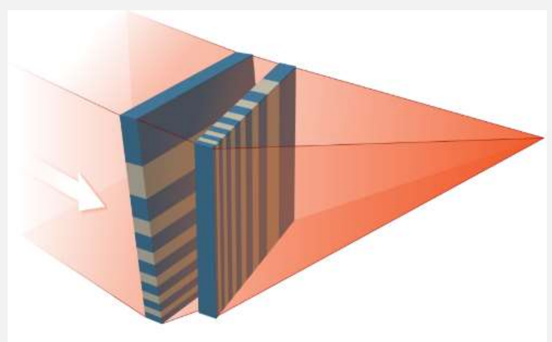


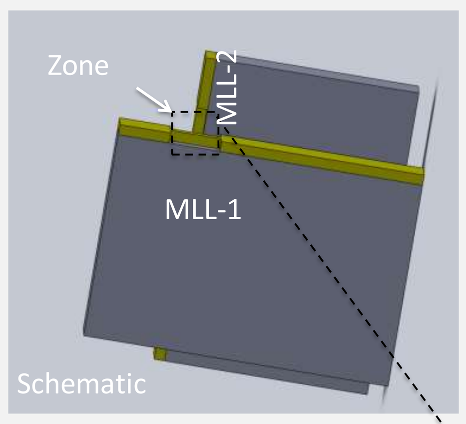
US patent #9,153,453

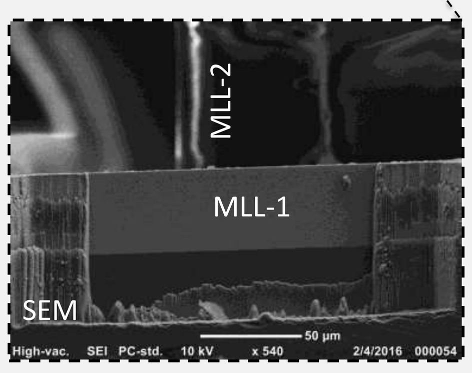




2D focusing achieved by using 2 crossed MLL







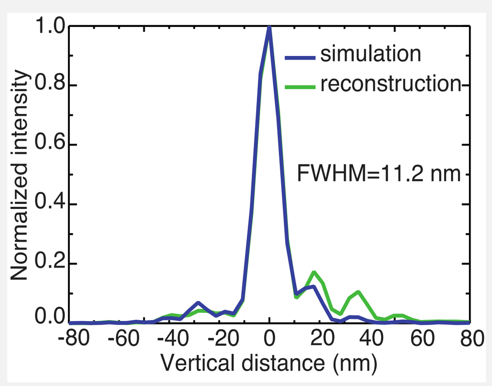
- Align independently
- Monolithic optic

Appl. Phys. Lett. 108, 261102 (2016)

Focusing performances

Flat MLLs

43 microns thick ML
WSi_2/Si
~6500 layers
Outermost zone = 4nm
Focal length =4.2mm
12keV



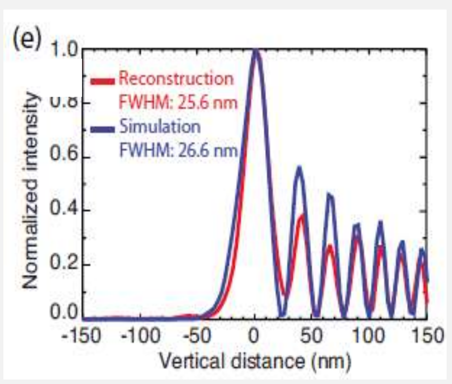
Line focus = 11.2nm

Installed at 3-ID (HXN) @NSLS-II

Scientific Report 3 (2013)

Wedged MLLs

31microns thick ML
WSi_2/Si
~7650 layers
Outermost zone = 2.8nm
Focal length=3.2mm
14.6keV



Line focus = 26nm
Efficiency ~27%

Tested at 1-BM and 34-ID-C at APS

Opt. Express 23, 12496 (2015)

MLL optics delivering a 15 x 15nm^2 focus at 12keV to users for science experiments at the 3-ID (HXN) beamline of the NSLS-II

2016 Microscopy Innovation award
2016 R&D100 award

Monolithic (Bonded MLLs) optic

43 microns thick ML and 53 microns thick ML
WSi_2/Si

Tested at 3-ID (HXN) at NSLS-II @12keV

Horizontal and vertical plane separated by 221um, consistent with metrology

Focus sizes are :
12 nm at horizontal focal plane
24 nm at vertical focal plane

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Acknowledgements

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