Multi-order scanning with Multilayer Zone Plate

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Motivation

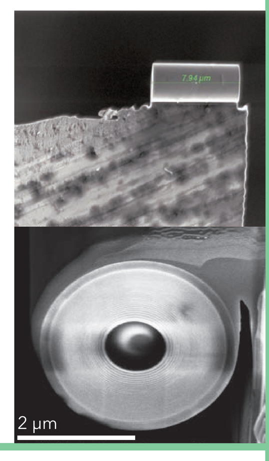
Few nanometre hard x-ray focusing enables new experiments and techniques, like
- high-resolution scanning,
- local probing, and
- local excitation of samples,

to name a few.

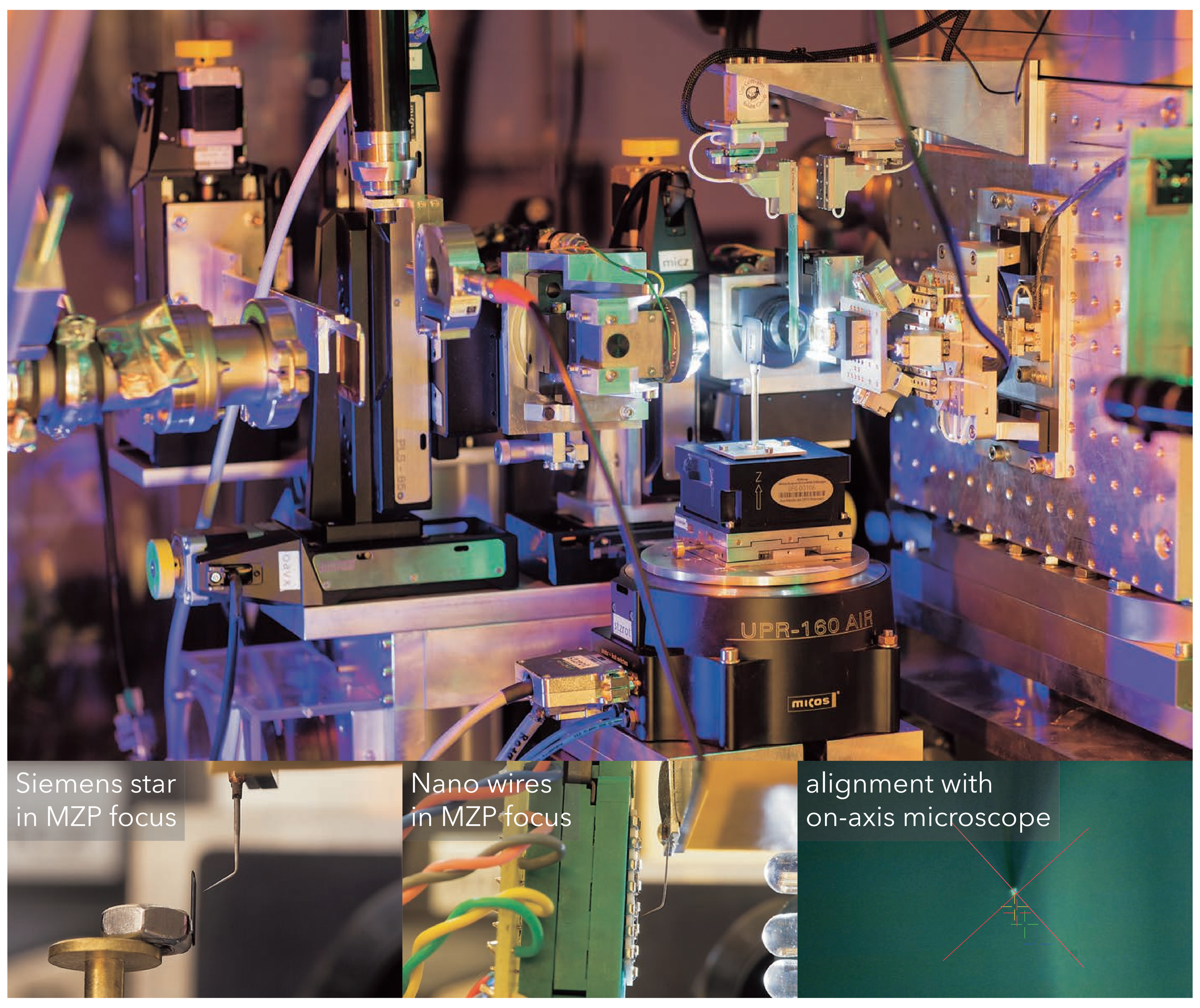
We have implemented a two-step focusing scheme using KB mirrors or CRLs to *pre-focus* a large synchrotron beam to a few-μm Multilayer Zone Plate with short focal length. In previous work, focus sizes below 5 nm have been reached [1,2,3].

Here, we present first experiments on multi-order scanning using an MZP *without* the need for an order-sorting aperture.

The MZP is grown with Pulsed Laser Deposition on a rotating wire; using a Focused Ion Beam, thick slices can be cut and glued to a lens holder [1].



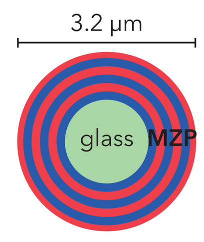
Experiment at GINIX, P10, PETRA III



Combined Focusing Optic

Compound Refractive Lenses
focus: approx. 3.6 μm × 8.4 μm
primary slits: 100 μm, coherent

MZP	Ta_2O_5 / ZrO_2 on glass fibre
radius	
glass core	0.6 μm
ML zones	1.0 μm
focal length	470 μm
energy	18.0 keV

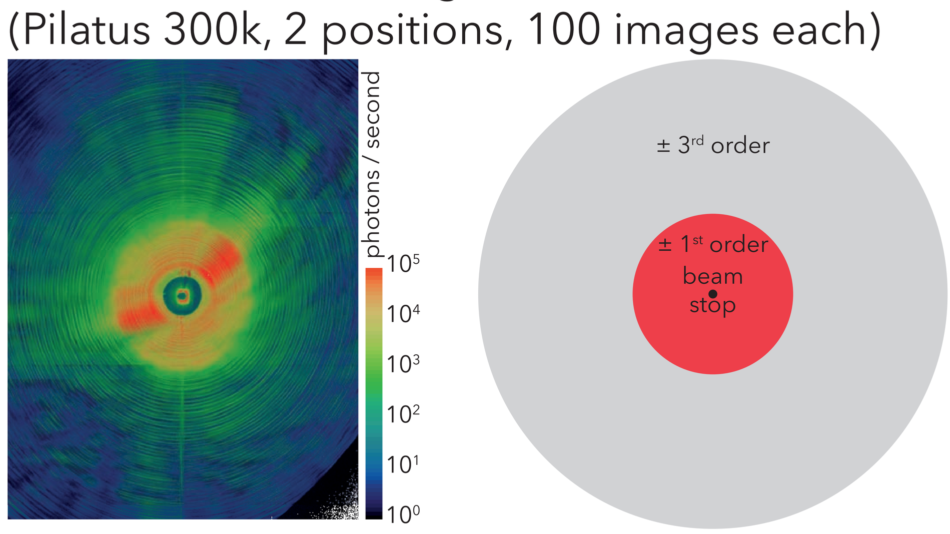


flux in 1st order
approx 3×10^8 photons/s

detector
Pilatus 300k (172 μm p.s. @ 5.5 m)

Focusing efficiency

Stitched far-field images
(Pilatus 300k, 2 positions, 100 images each)



efficiency estimated from attenuated "empty" images; using different attenuations, higher harmonics can be decomposed from

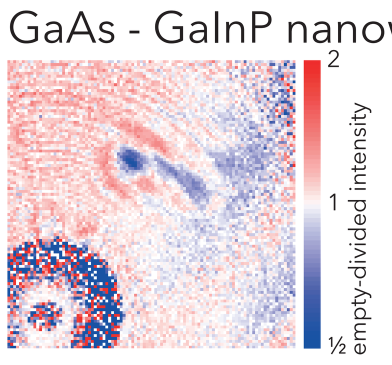
$I = att_{18\,keV}^{\#att} \times I_{18\,keV} + att_{54\,keV}^{\#att} \times I_{54\,keV}$

$I_{18\,keV}$ in 0^{th} order: ~ 5.87×10^9 ph/s
$I_{18\,keV}$ in $\pm1^{st}$ order: ~ 2.75×10^8 ph/s

corrected for geometrical acceptance (CRL-prefocus: 3.6 μm × 8.4 μm) yields an efficiency ~6.9 % in +1st order

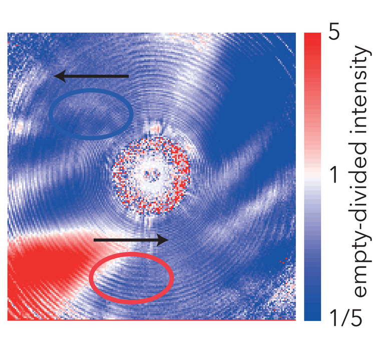
Holographic imaging in ±1st order

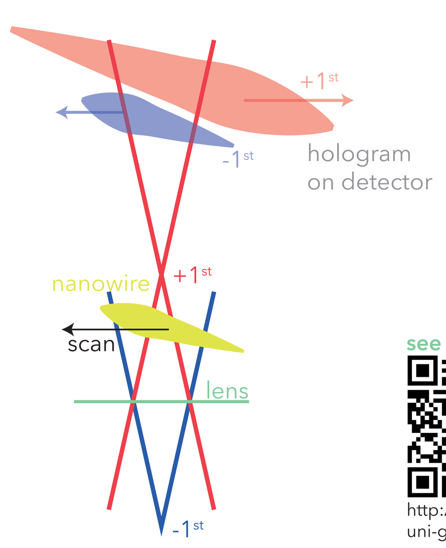
GaAs - GaInP nanowire on Si_3N_4 window, Pilatus 300k



sample ~ in +1st focal plane
distance from -1st order: ~ 0.9 mm
magnification: 5400×

2D-scan (STXM) of nanowire in +1st and -1st order

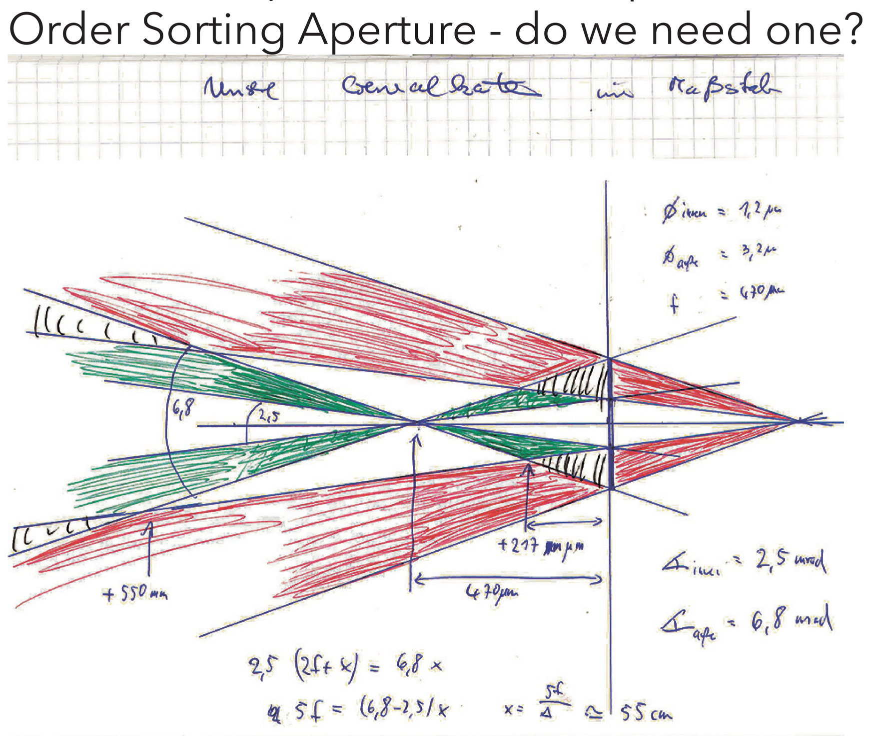




see the scan here
http://www.roentgen.physik.uni-goettingen.de/~mosterh/qr/nanostxm.mp4

Multi-order scanning

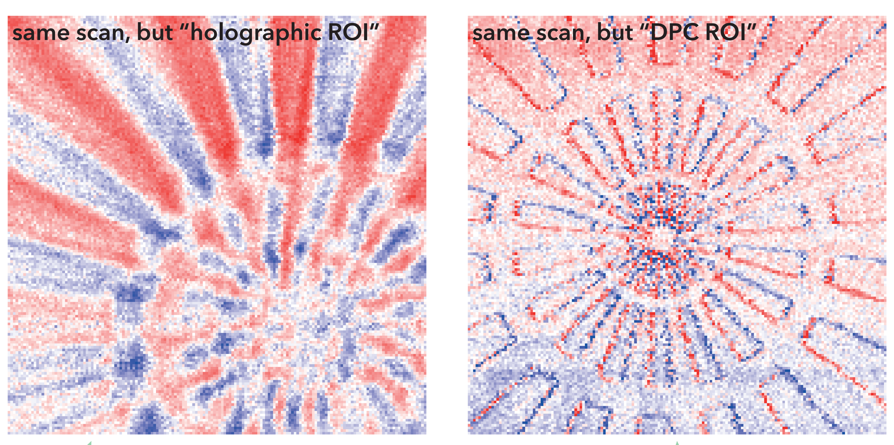
With f = 470 μm, there is little space for an Order Sorting Aperture - do we need one?

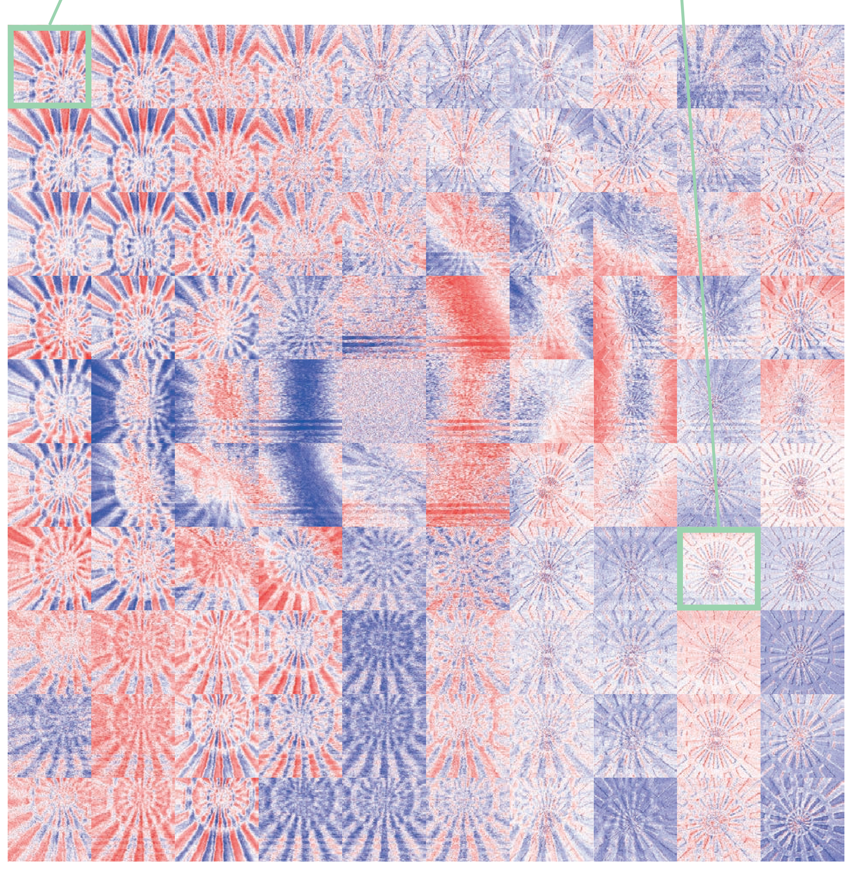


What do we see?

Without OSA, we get contrast from multiple orders simultaneously.

Can we use a software-OSA?





Different orders diverge with different angles. The active MZP layers form circular rings - and so do the orders on the detector.

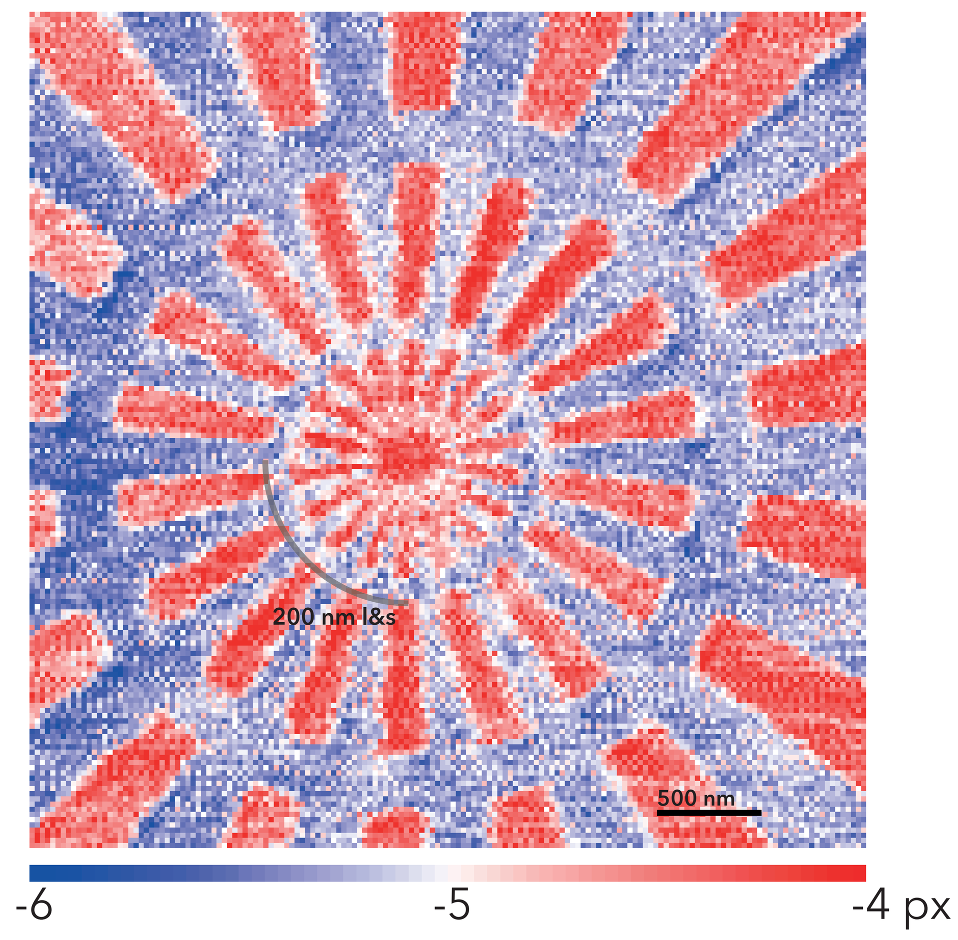
Idea: ± 3rd order can be distinguished from ± 1st order using a detector ROI in software.

Remaining problem: How to disentangle +1st from -1st ?

Actually, -1st order produces a ~5400-fold magnified holographic image - helping during alignment!

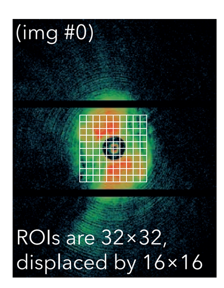
Let's just look at a STXM measurement (Siemens star, plotting horizontal centre-of-mass):

161 × 161 points, 50 nm step size, 10 ms / point



see the scan here
http://www.roentgen.physik.uni-goettingen.de/~mosterh/qr/mzpstxm.mp4

Different ROIs yield different contrast:
- left part: rather holographic images,
- lower right part: differential phase contrast,
- for larger ROIs, holographic signal vanishes,
- no visible signal from 0th order.



Multi-order scanning without OSA is possible.

Orders can be distinguished on the detector.

"Holographic orders" help during alignment.

References

[1] F. Döring et al., "Sub-5 nm hard x-ray point focusing by a combined Kirkpatrick-Baez mirror and multilayer zone plate", Optics Express 21 (2013).
[2] A. Ruhlandt et al., "A combined Kirkpatrick-Baez mirror and multilayer lens for sub-10 nm x-ray focusing", AIP Advances 2 (2012).
[3] M. Osterhof fet al., "Two-dimensional sub-5 nm hard x-ray focusing with MZP", Proc. of SPIE Vol 8848 (2013).

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Outlook

- Simulations / modelling of "holographic STXM"
- Ptychography
- x-ray induced photo current in nano wires with spatial resolution of few nm

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