

Institute for Nanometre Optics and Technology

*Nanometre Optics Technologies
at Helmholtz Centre Berlin*

Alexei Erko

1st example: vitrified product concentrate:

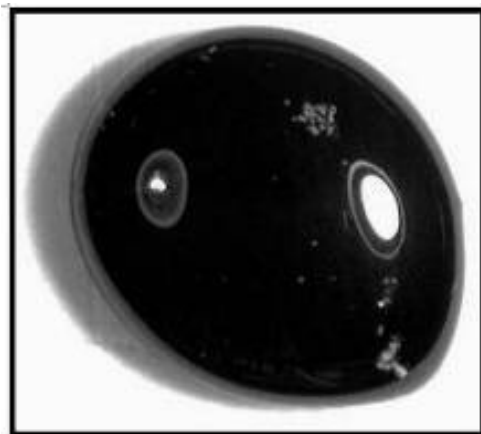
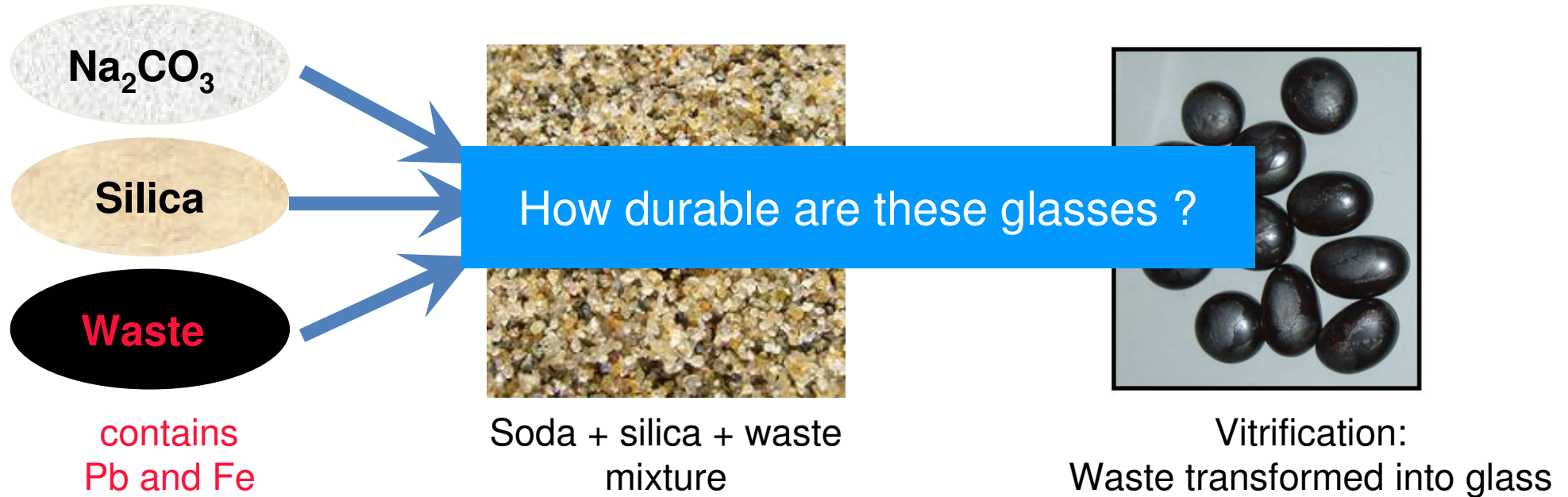
Every day millions of tons of vitrified industrial waste are on the way to storage facilities around the world.



*Pacific Heron, one of PNTL's transport ships
(Image: PNTL)*

What is vitrification?

The embedding of material in a glassy matrix.



Artificial aging of waste glasses



Annealing at 600° and 800° C

Conventional integral methods: no changes

The embedding of material in a glassy matrix.

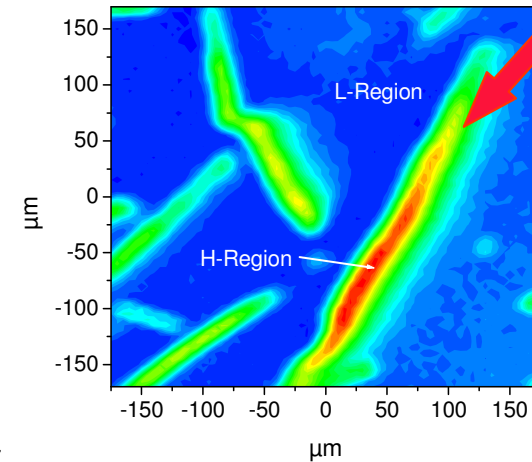
F. Pinakidou, M. Katsikini, E. C. Paloura, P. Kavouras, Ph. Komninou, Th. Karakostas, A. Erko, NIM, B246 (2006) 238

Vitrified industrial waste originating from petroleum storage tanks



Ernst-Eckhard-Koch Prize laureate Dr. Fani Pinakidou (Aristotel Uni Thessaloniki)

Toxic crystals: Fe, PbFe₁₂O₁₉ magnetoplumbite

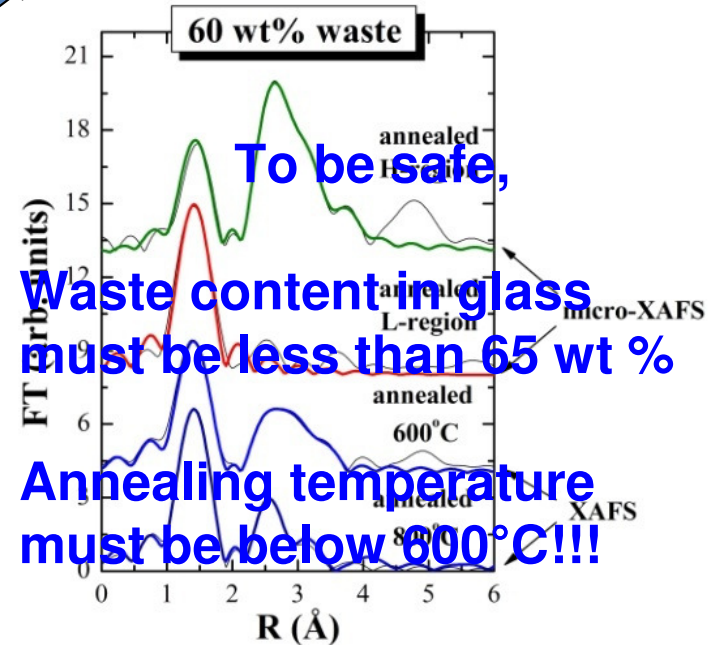
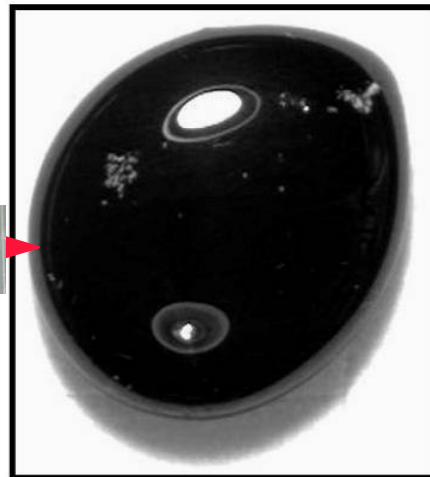


Mono-capillary X-ray optics

Synchrotron light

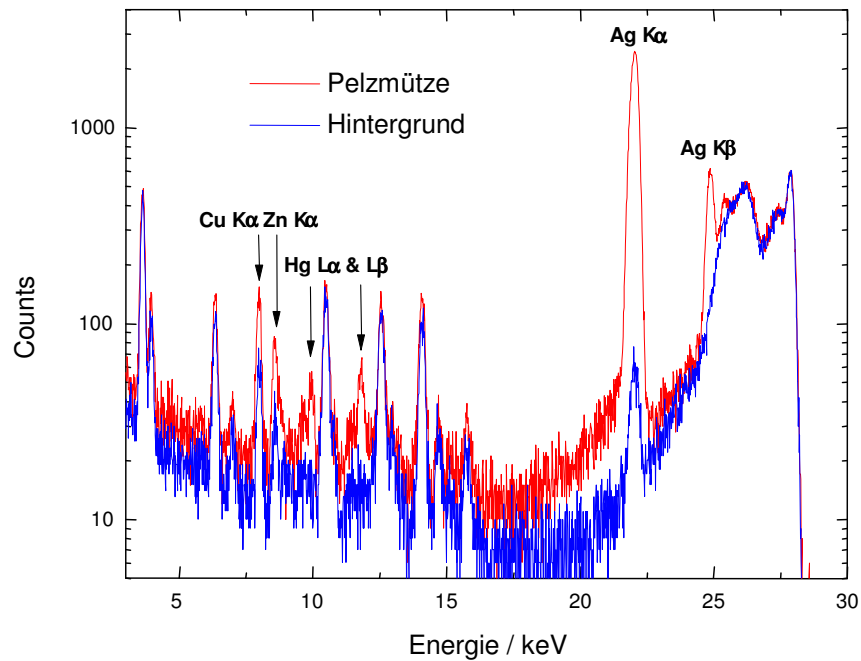


Monocapillary lens
250 nm focus



I. Reiche, J. Riederer (Staatl. Museen Berlin), M. Radtke, S. Merchel, A. Berger (BAM)

Composition of Dürers silver pencil



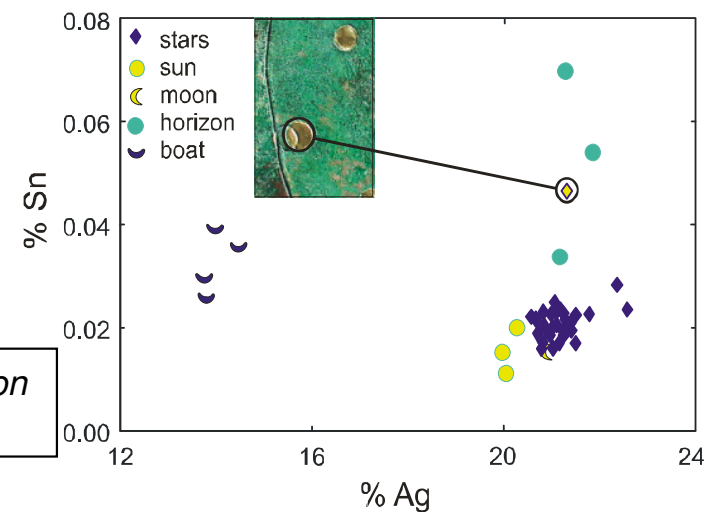
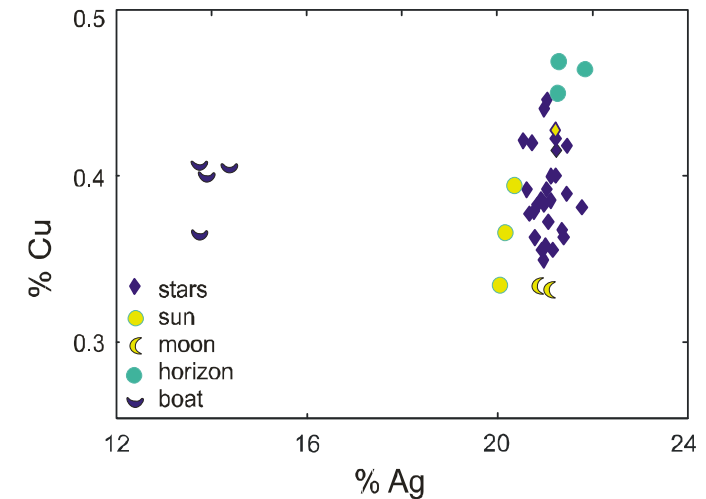
Albrecht Dürer "Thronender Bischof; Brustbild eines Mannes mit Pelzmütze" (1521)

A result: „Bischof“ and „Mann mit Pelzmütze“ have been drawn using different pencils.

Cultural Heritage. Non-destructive Testing

E. Pernicka (TU Freiberg), C.-H. Wunderlich (LfA Halle), M. Radtke, H. Riesemeyer (BAM)

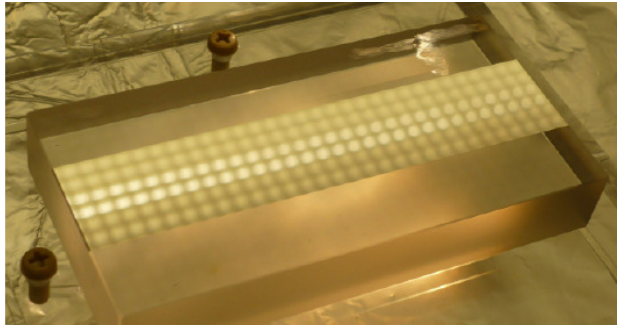
Gold composition analysis of the Nebra Skydisk (3600 v. Chr)



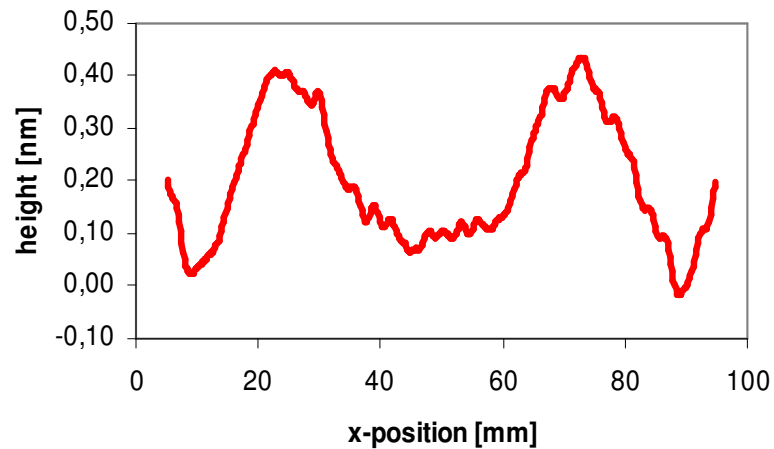
A result: The gold of the marked star showed a different composition and was possibly applied later than the other stars.

Nanometre optics: properties

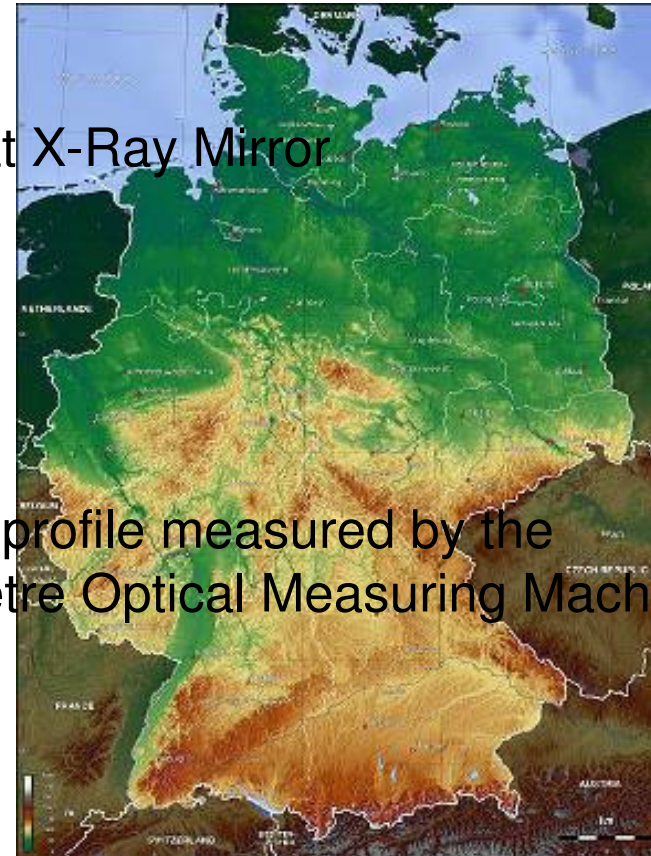
Nanometre optics are a crucial tool for research at new and existing light sources



Superflat X-Ray Mirror

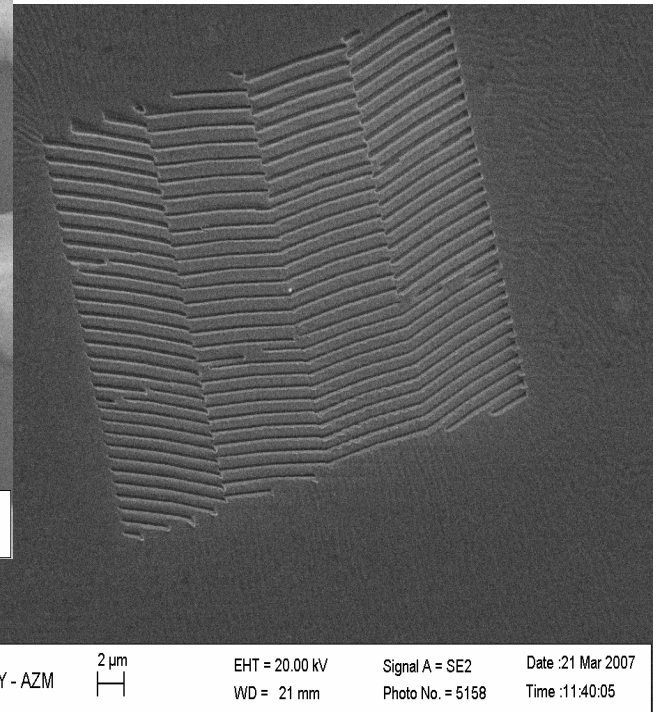
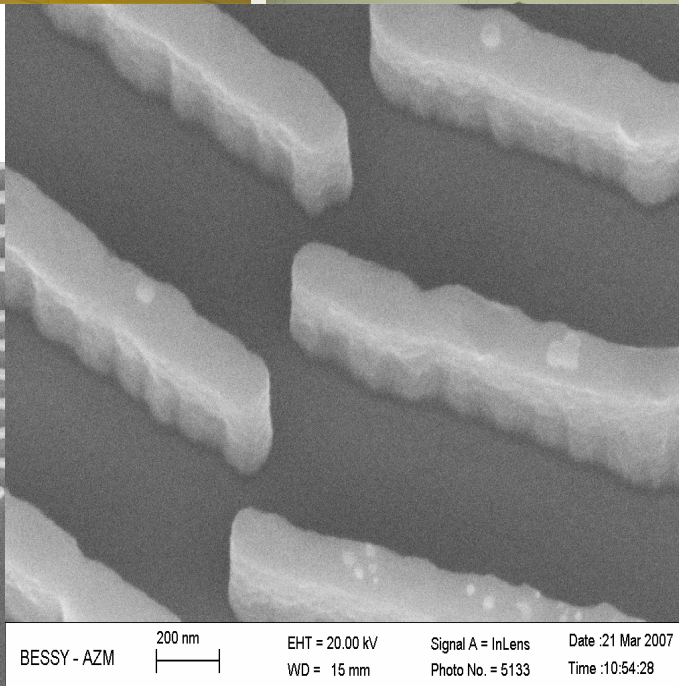
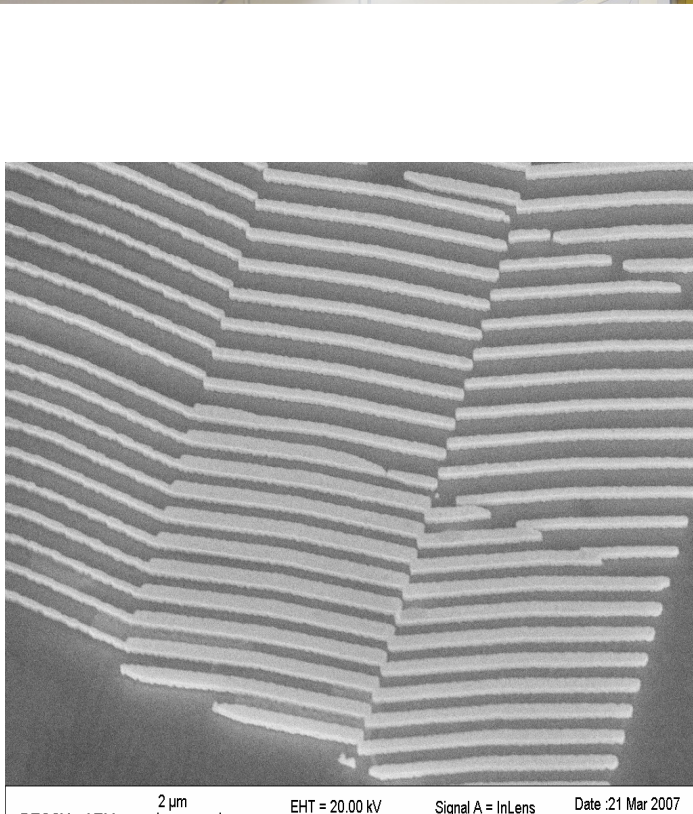


Surface profile measured by the Nanometre Optical Measuring Machine

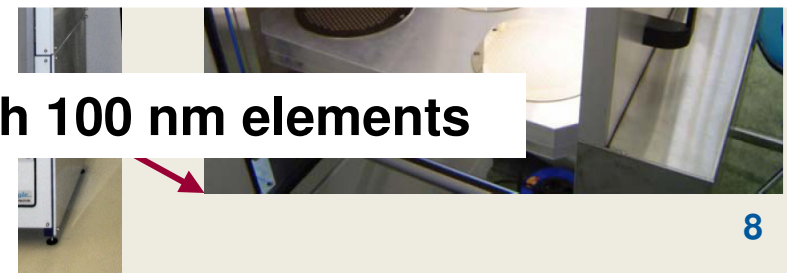


Expanding the figure accuracy of SR-Optics to the size of Germany – the Zugspitze would be a peak of 5 mm only !

What are the requirements?

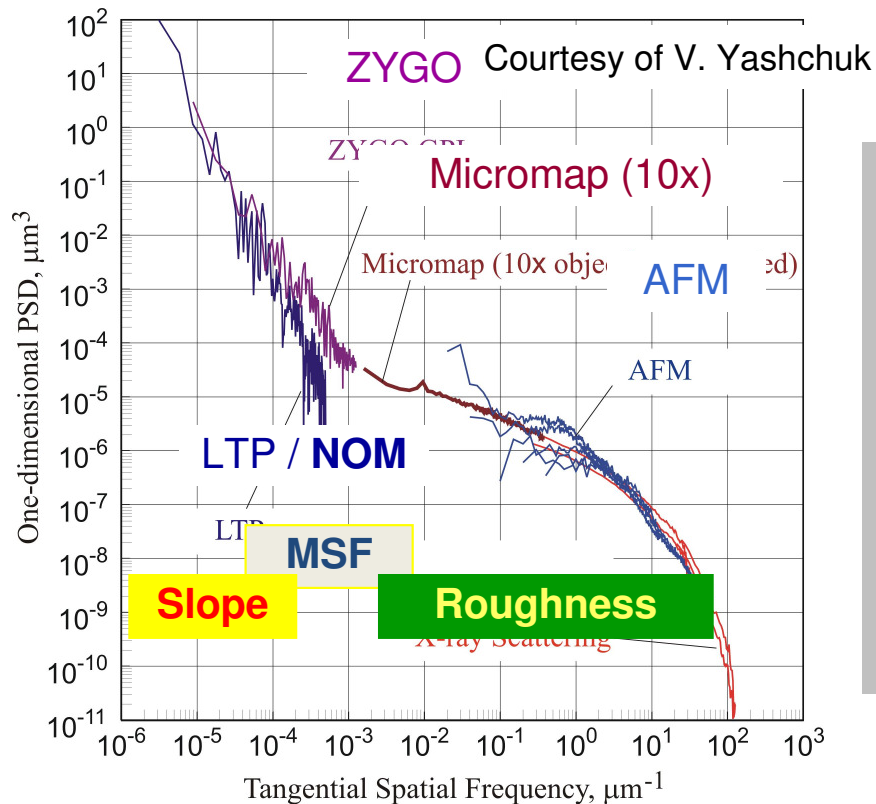


X-Ray diffraction optical lens with 100 nm elements



Ex-Situ

- **NOM** / LTP-II
- Micromap (2.5x, 5x, 10x, 20x, 50x)
- AFM
- Interferometer – ZYGO-GPI

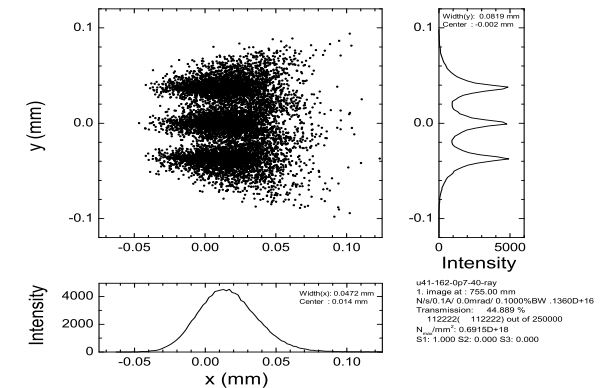
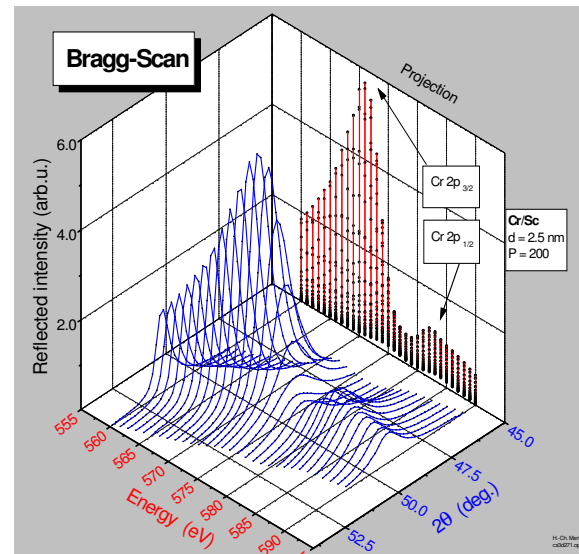


In-Situ

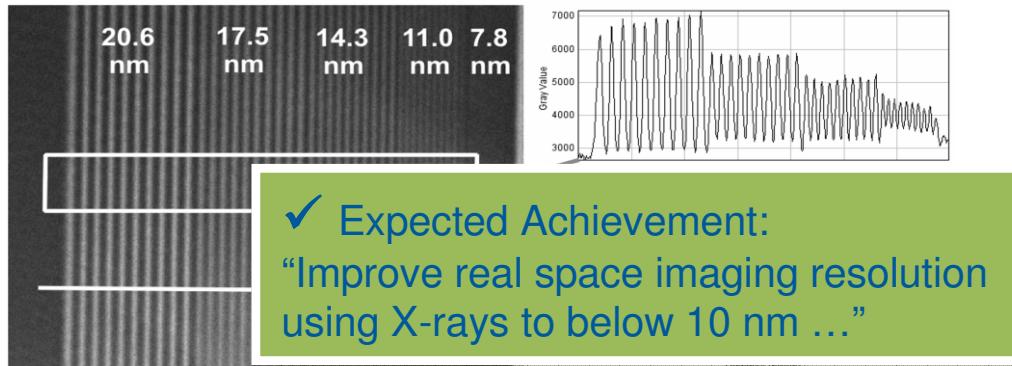
- Optics - Beamline
- Reflectometer
- Polarimeter
- Focus measuring camera

Theory

- software library for beamline optics design
- **WAVE / PHASE / ...**



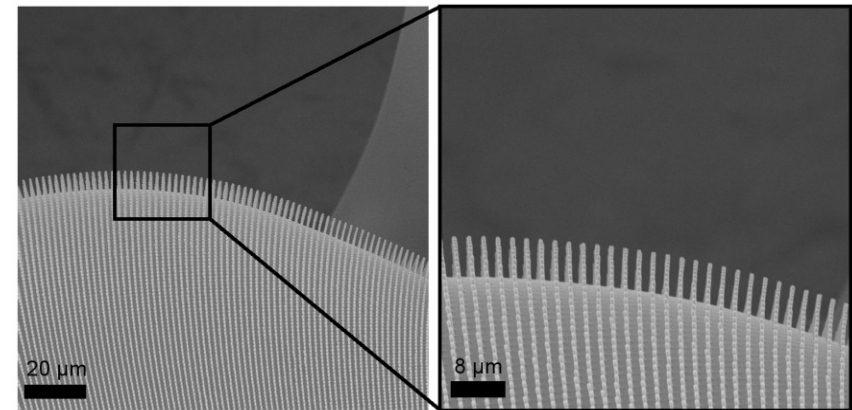
Nano zone plate technology



X-ray microscope (TXM) image of a Cr/B₄C multilayer structure with 5 different periods recorded in the third order of diffraction with a 20 nm d_m zone plate. Photon energy 700eV, $\Delta E/E = 13800$, exposure time 30 s, pixel-size 2.0 nm.

S. Werner, S. Rehbein, P. Guttman, S. Heim, G. Schneider, *Microelectron. Eng.* 87 (2010), 1557-1560

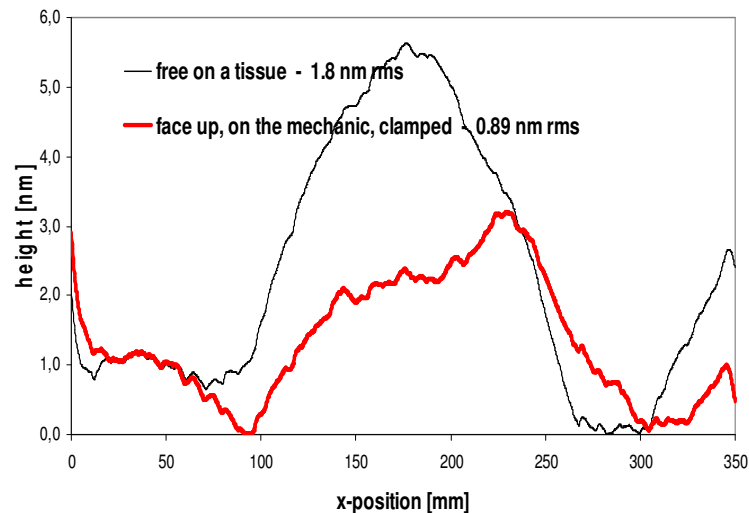
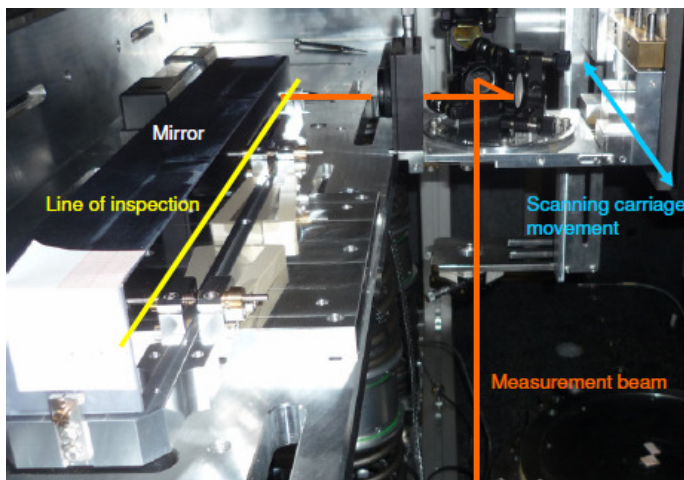
Thermoforming, Soft Lithography



Replicated polymer part fabricated by replica molding. Optical lens surface.

T. Senn, Ch. Waberski, J. Wolf, J.P. Esquivel, N. Sabaté, B. Löchel, *Microelectron. Eng.* 88 (2011), 11–16

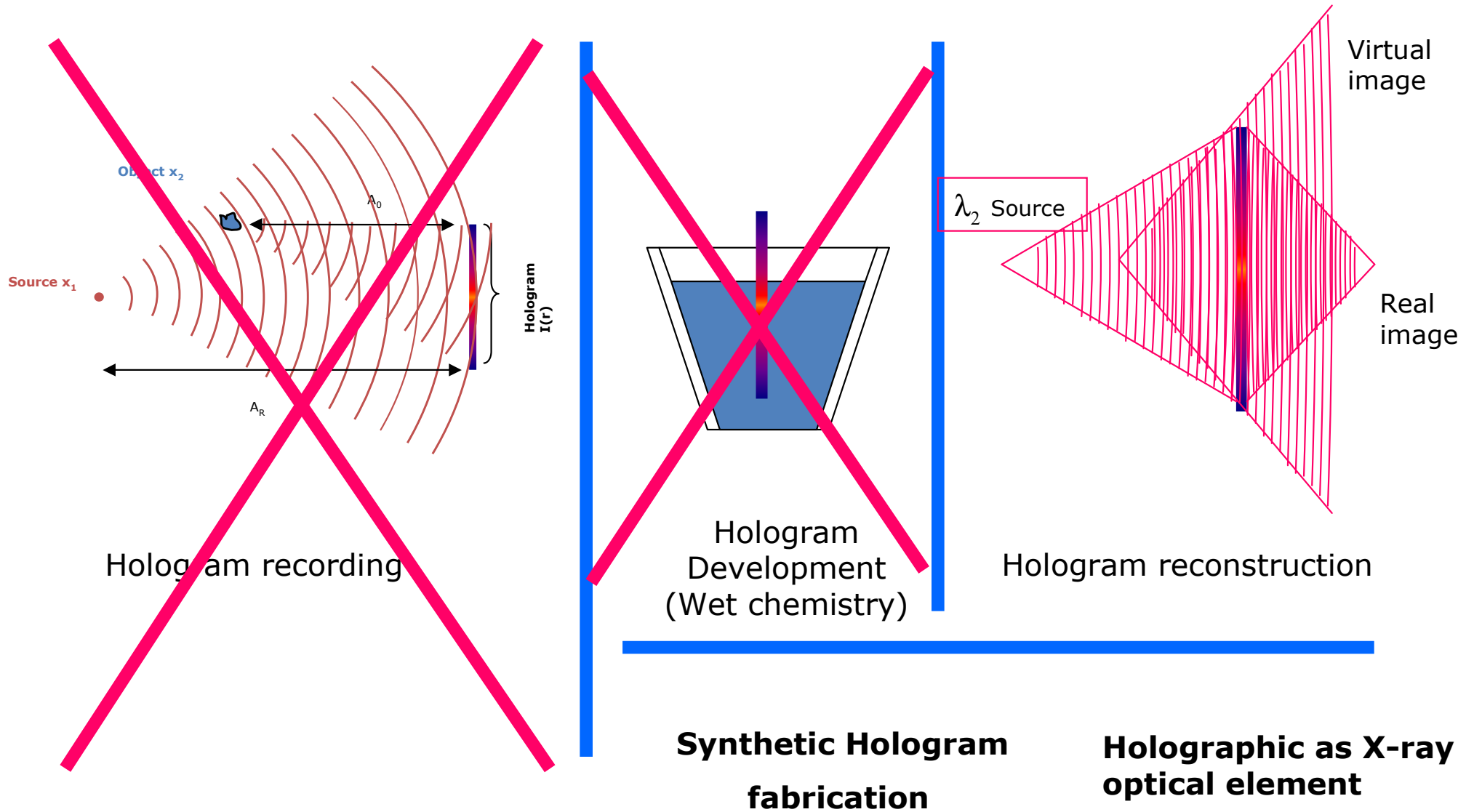
Optical nano-metrology



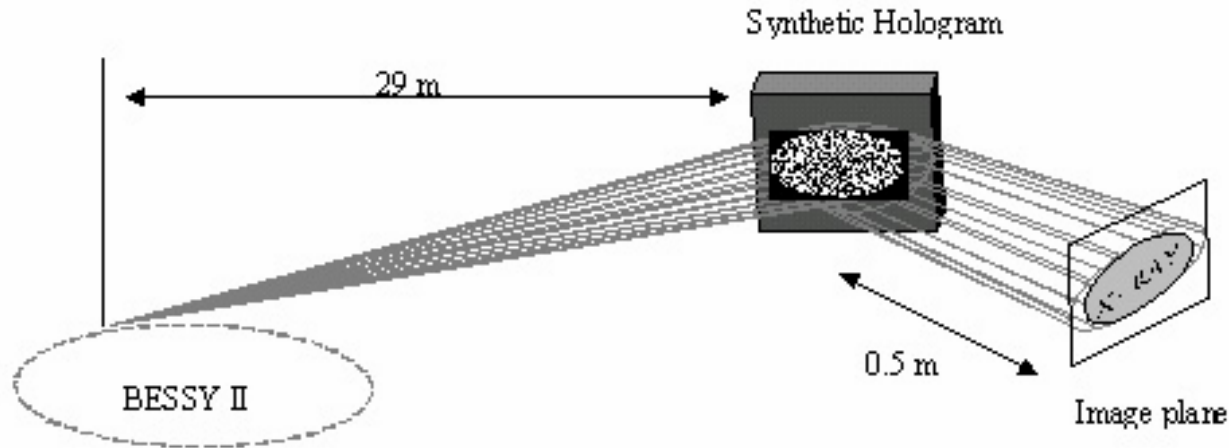
Kirckpatrick-Baez-HFM – horizontal focussing mirror for X-FEL: inspection at the HZB-NOM

F. Siewert et al.: The first diffraction limited KB-focusing mirror pair for the LCLS to be published

The main principle: Holographic process



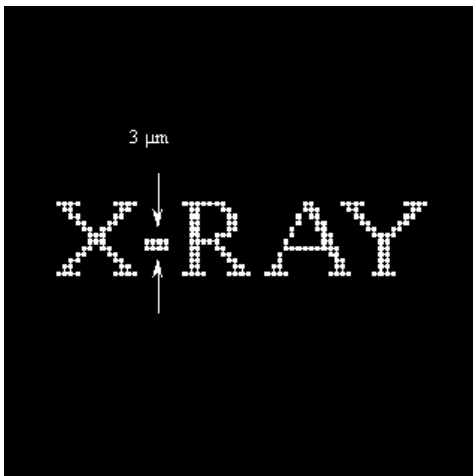
X-ray holograms



The first synthetic X-ray hologram: results

A. Firsov, A. Svintsov, S.I. Zaitsev, A. Erko, V. Aristov, Optics Communications, 2002, 202, 55–59

The scheme of the hologram reconstruction experiment at BESSY beamline.



Information encoded in a hologram.

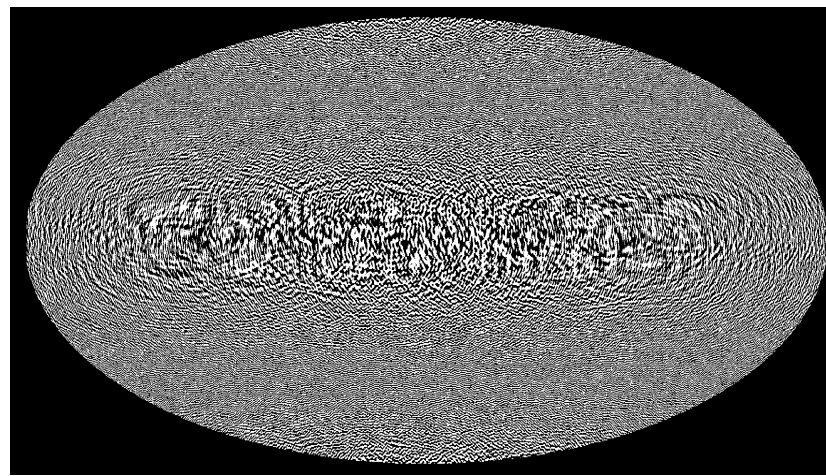
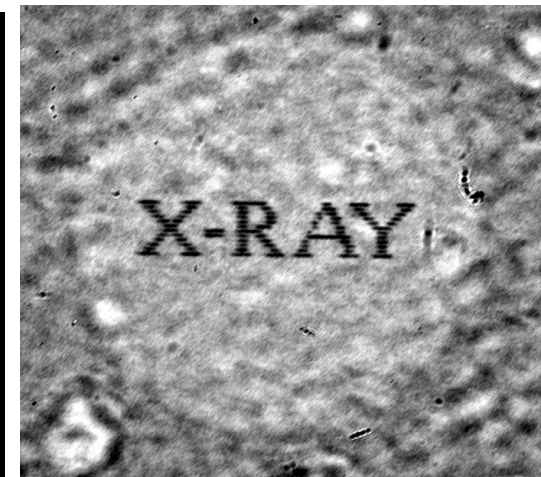
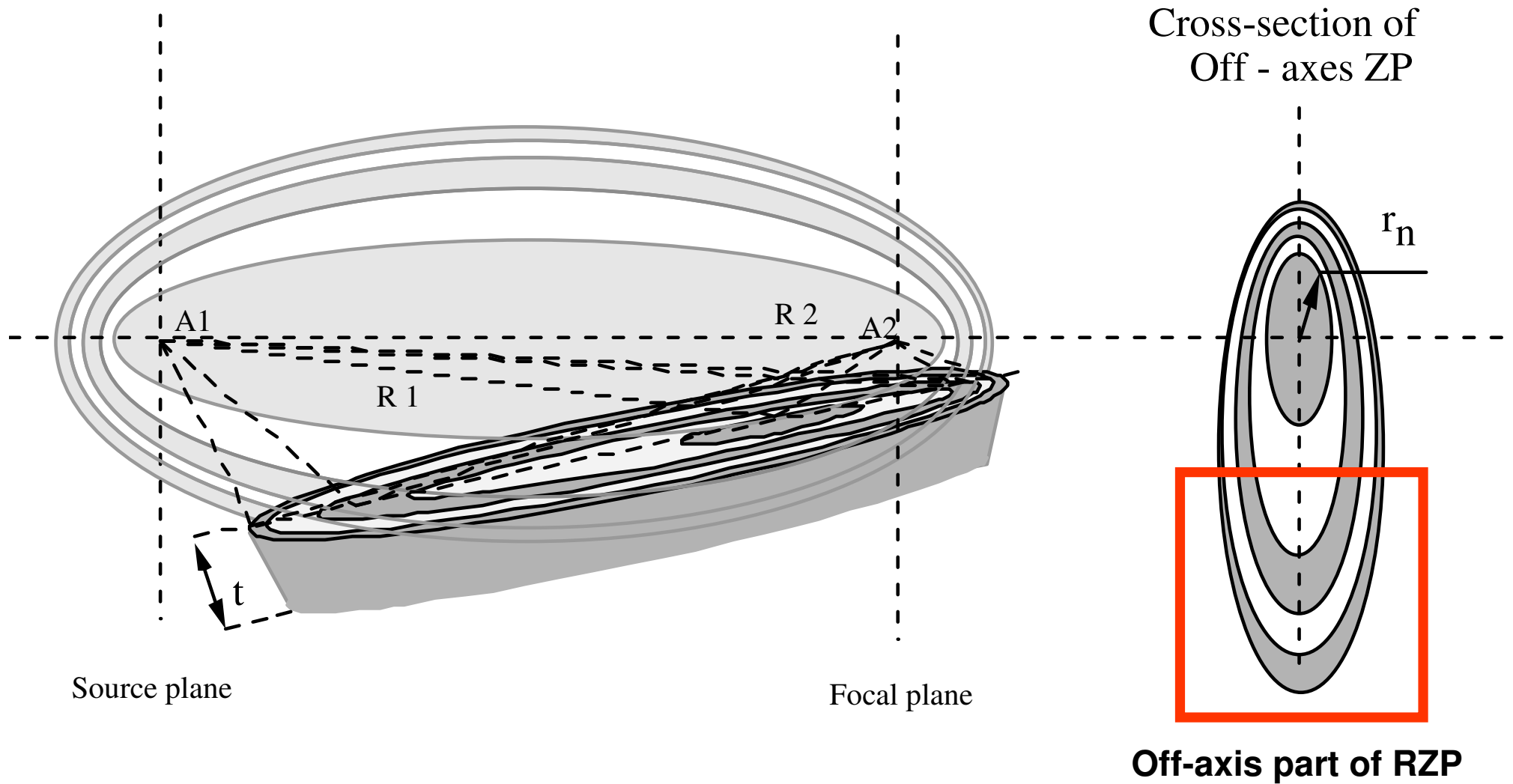


Image in SEM of a hologram structure fabricated in AZM.

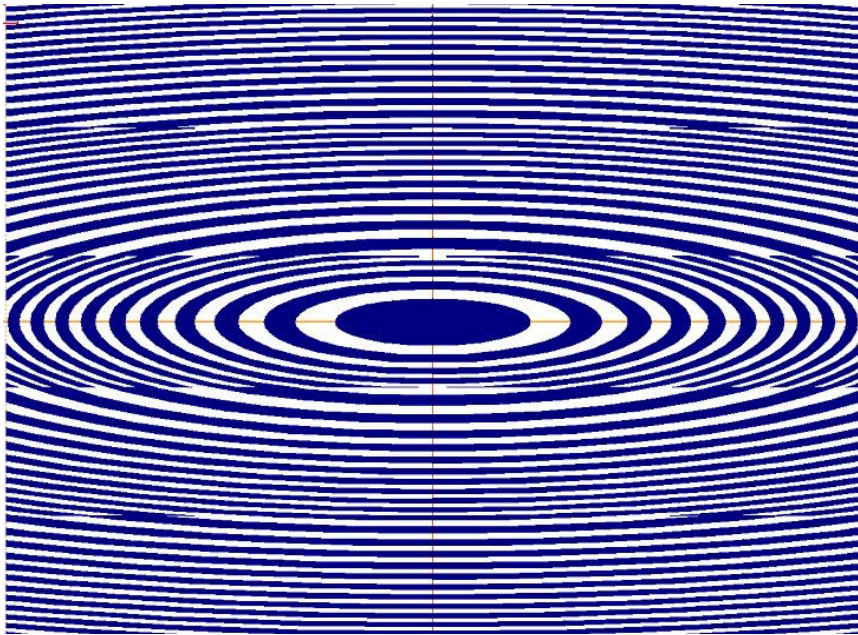


Reconstruction of the hologram at BESSY beamline.

Elliptical reflection zone plate

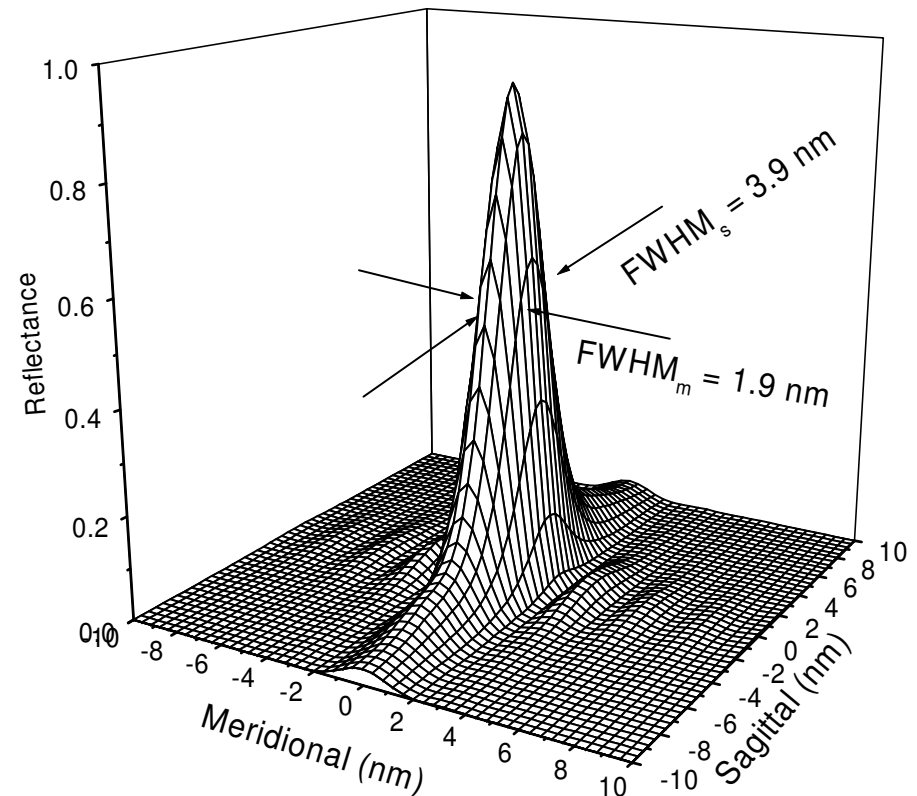


Modified reflection zone plate



Elliptical modified reflection zone plate combining the first, third and fifth diffraction orders in the sagittal direction. In the meridional (beam) direction only the first order is used. Technological resolution limit 20 nm

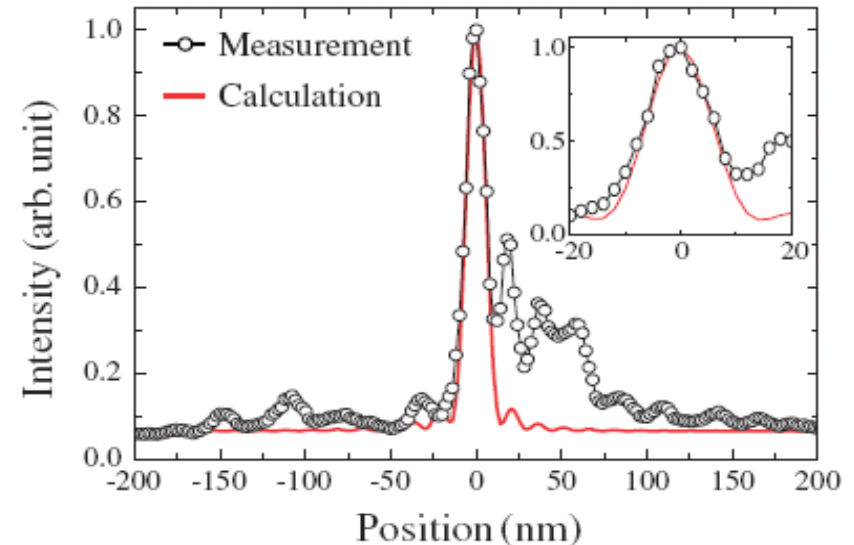
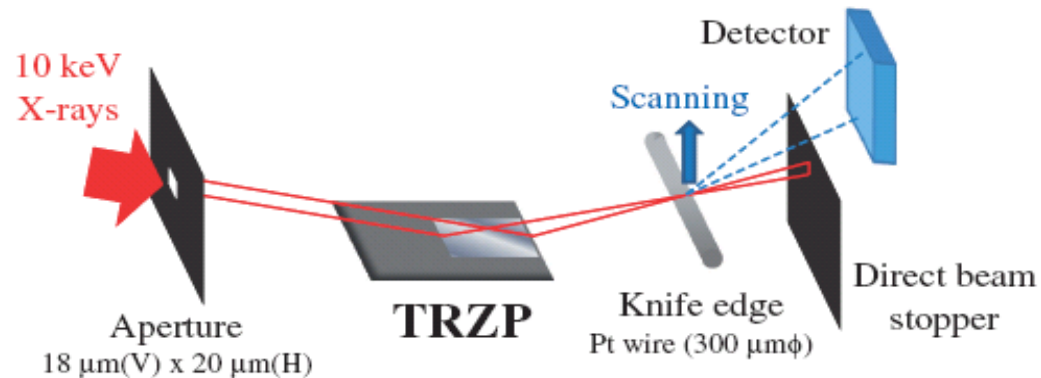
Calculated focal spot



Nanometer focusing of X-rays with modified reflection zone plates, A.G. Michette, A. Erko et al, Optics Communications, 245, (2005), 249–253.

Nanometer focusing with reflection zone plates

X-ray beam focused in one direction to a width of 14 nm at 10 keV

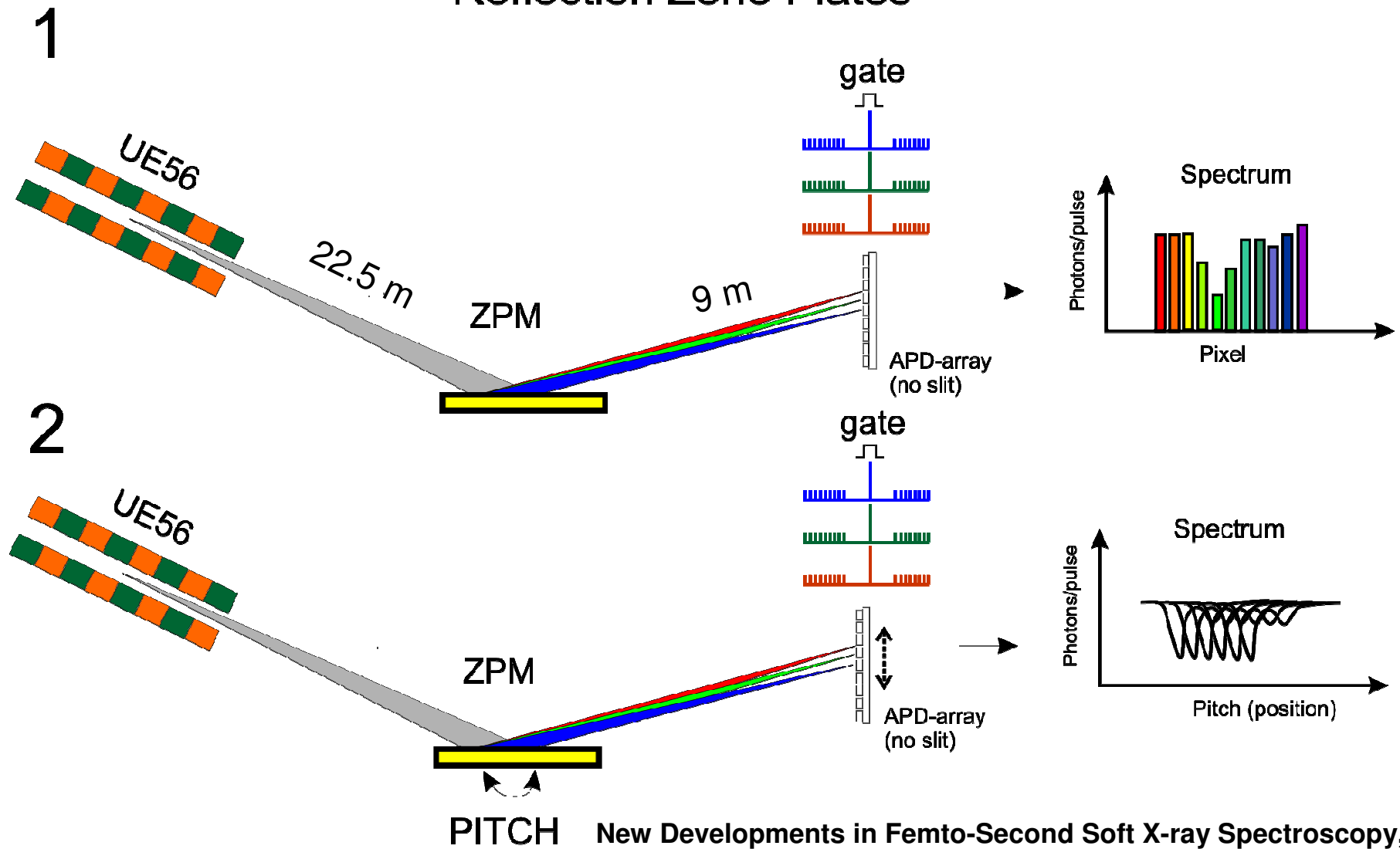


Experimental set-up for a focusing measurement of the total reflection zone plate (TRZP).

Intensity distribution of measured (plotted data) and calculated (red line) linear focusing by the TRZP. The inset shows an enlargement of the main peak.

Sub-15nm Hard X-Ray Focusing with a New Total-Reflection Zone Plate
Hidekazu Takano et al, Applied Physics Express 3 (2010) 076702

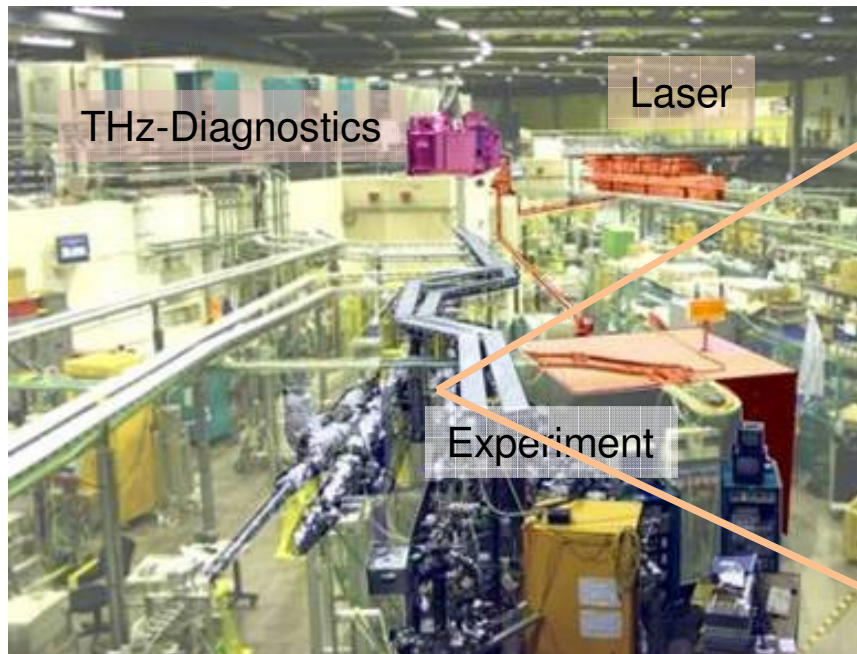
Time-Correlated Parallel detection with Reflection Zone Plates



New Developments in Femto-Second Soft X-ray Spectroscopy,
A. Erko, A. Firsov, K. Holldack, AIP Conf. Proc. 2010 1234, 177-180)

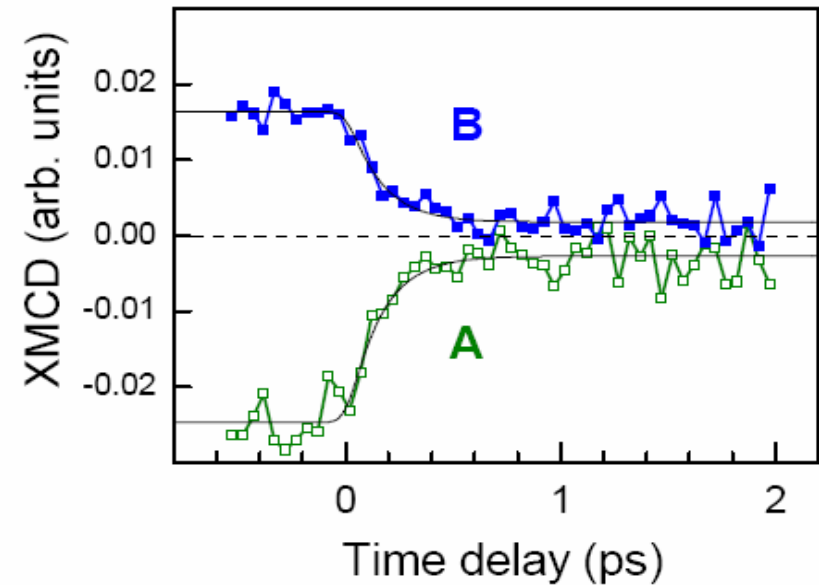
2nd example: what is the time limit of magnetic switching?

A. Erko, A. Firsov, K. Holldack, AIP Conf. Proc. (2010)
1234, 177-180



Slicing facilities in the experimental hall

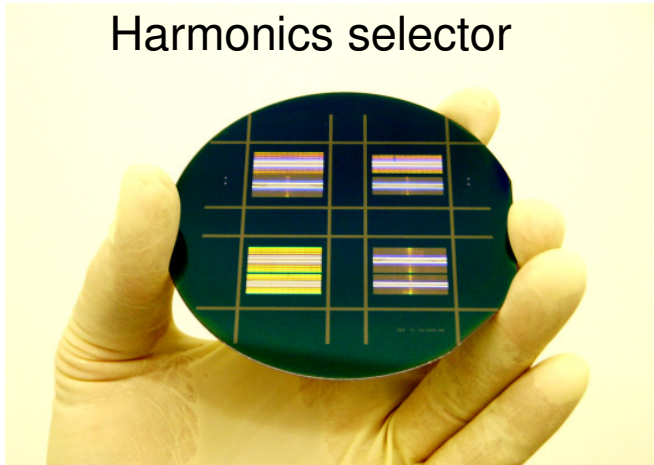
fs time-resolved dichroism (energy window ≈ 5 eV)



Slicing facilities in the storage ring

High Harmonics Generator Optics

Harmonics selector



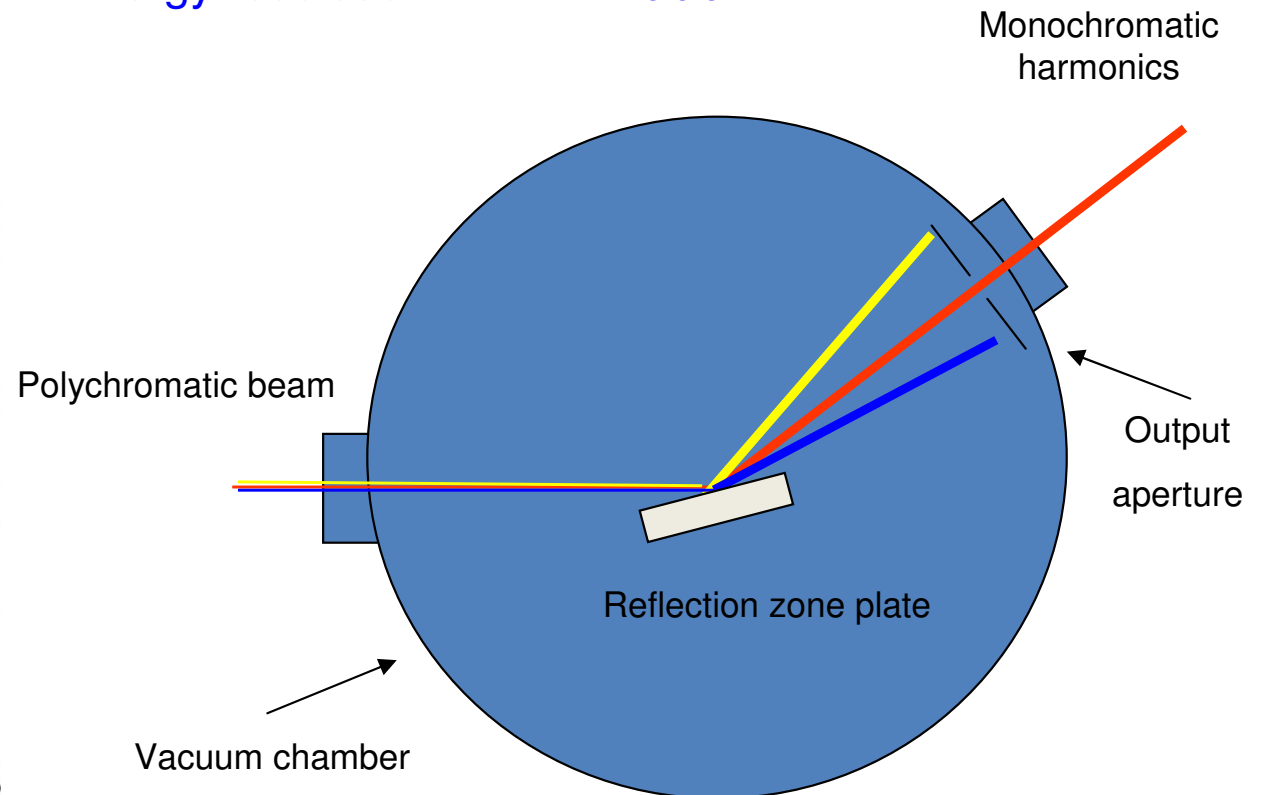
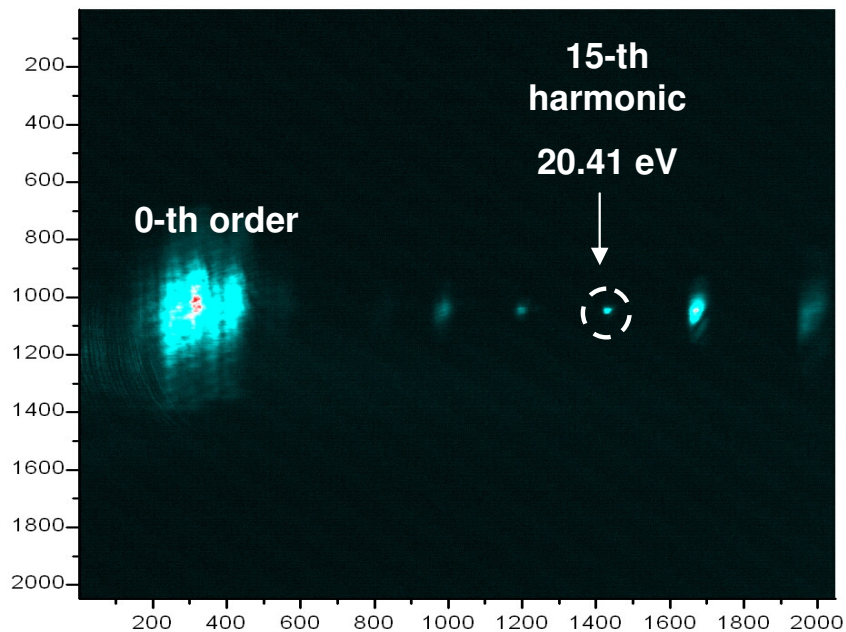
Energy range 10 eV - 60 eV

Focal length 0.5 m

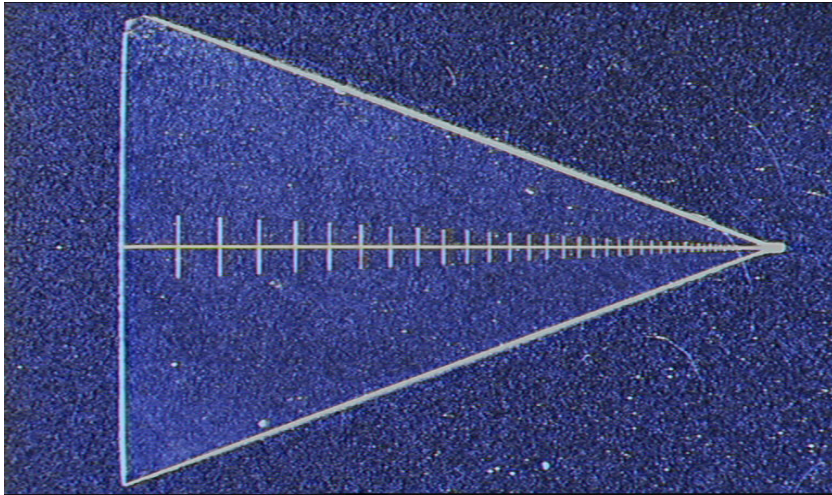
Focal size 50 μm

Time delay 10 - 50 fs

Energy resolution $\lambda/\Delta\lambda \sim 1000$

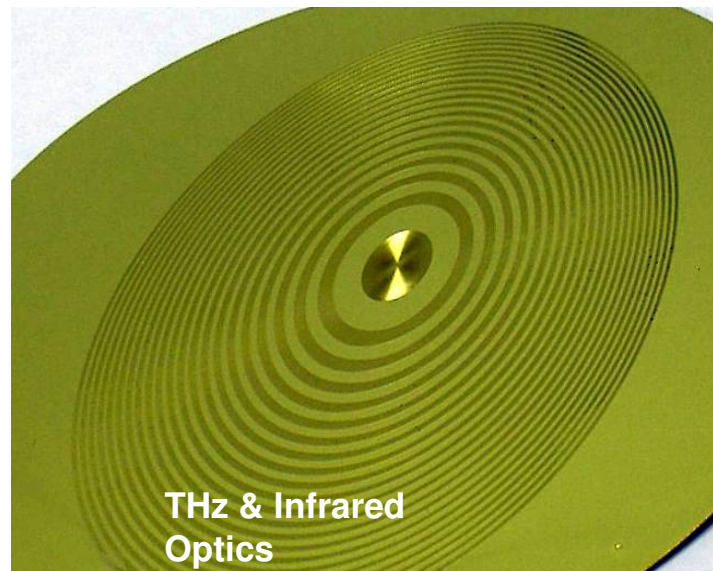


Optics for Beam Manipulations: X-ray, IR, and Neutrons & Advanced Sample Management

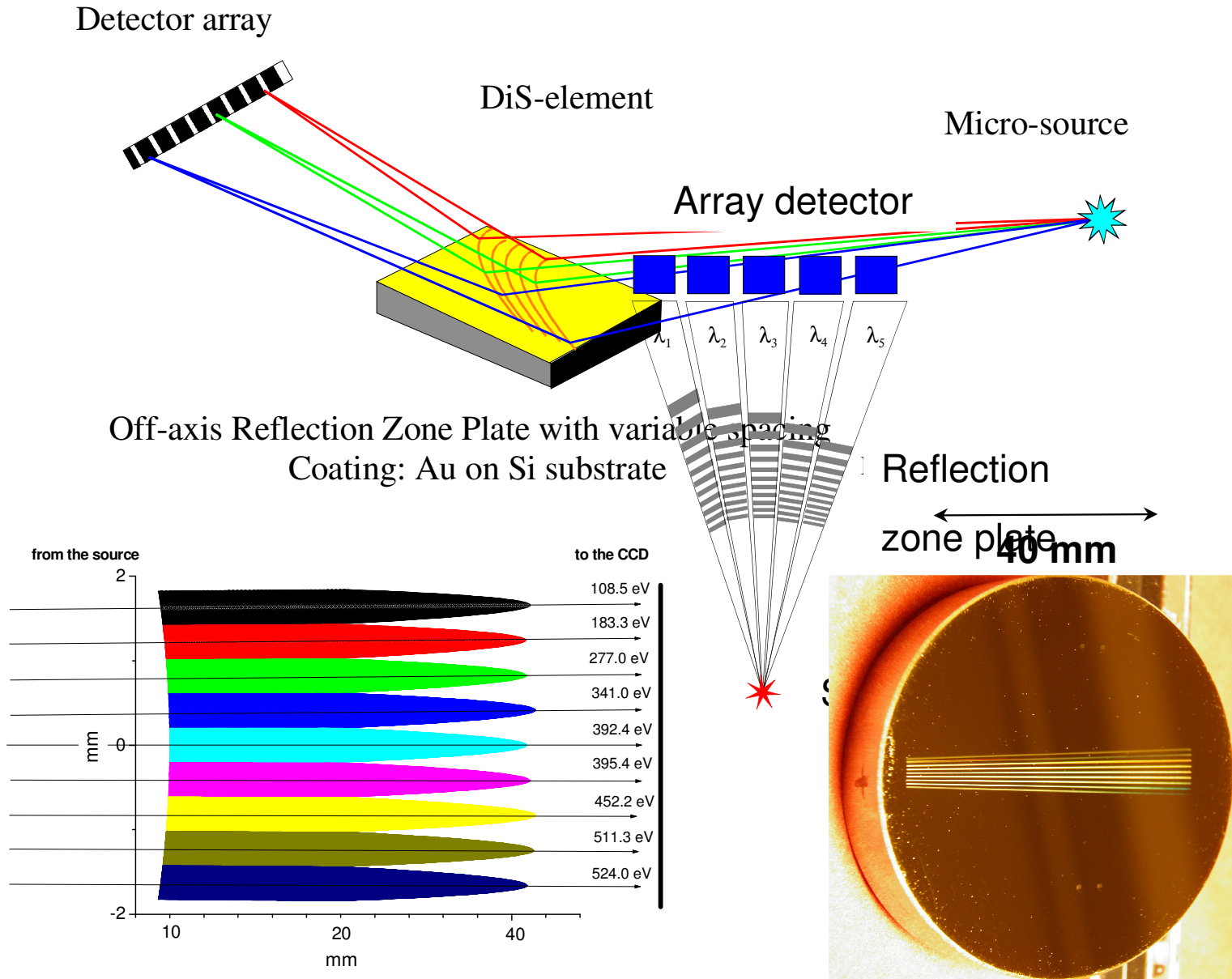


**Reflection
Fresnel lens
for THz spectro-
microscopy**

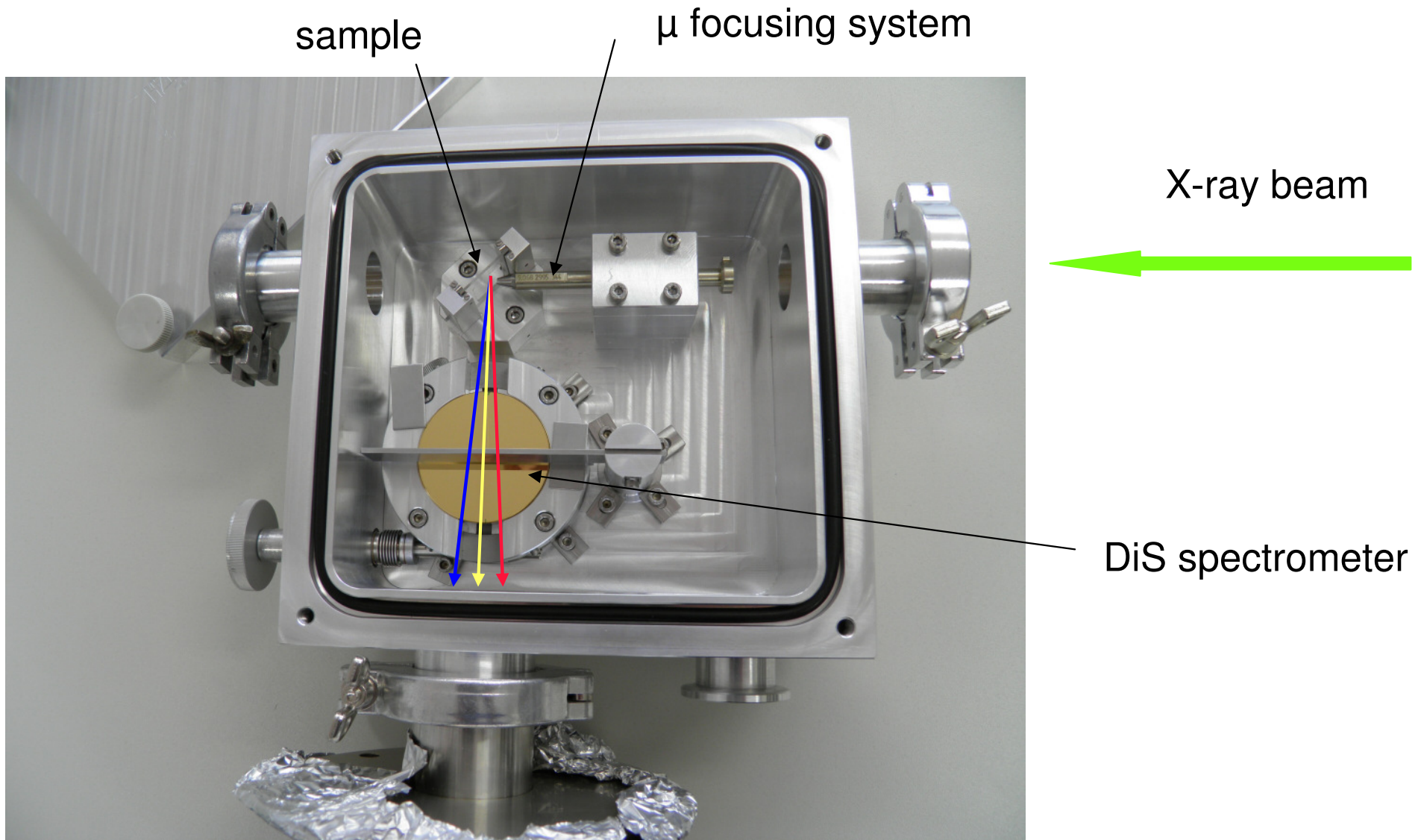
**Antenna for focusing
IR radiation**



Parallel X-ray Diffraction Fluorescence Spectrometer

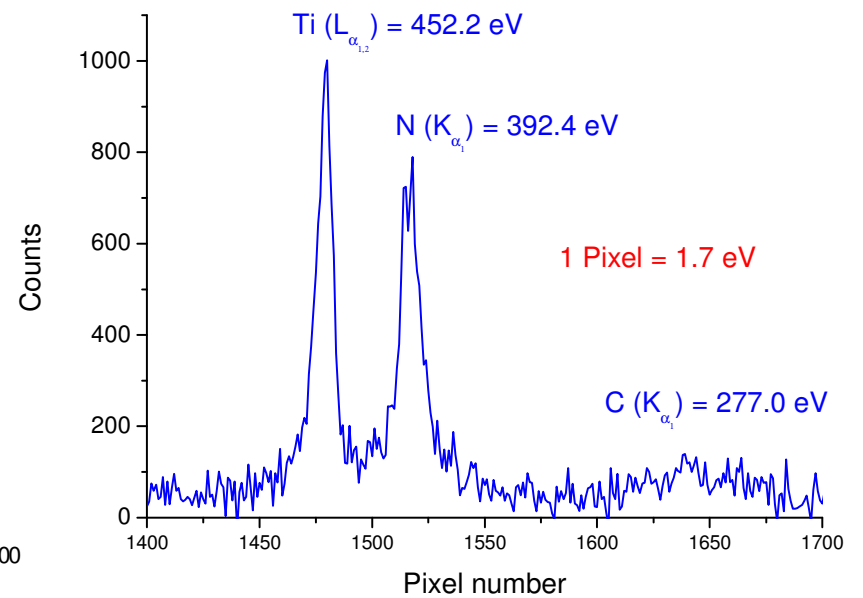
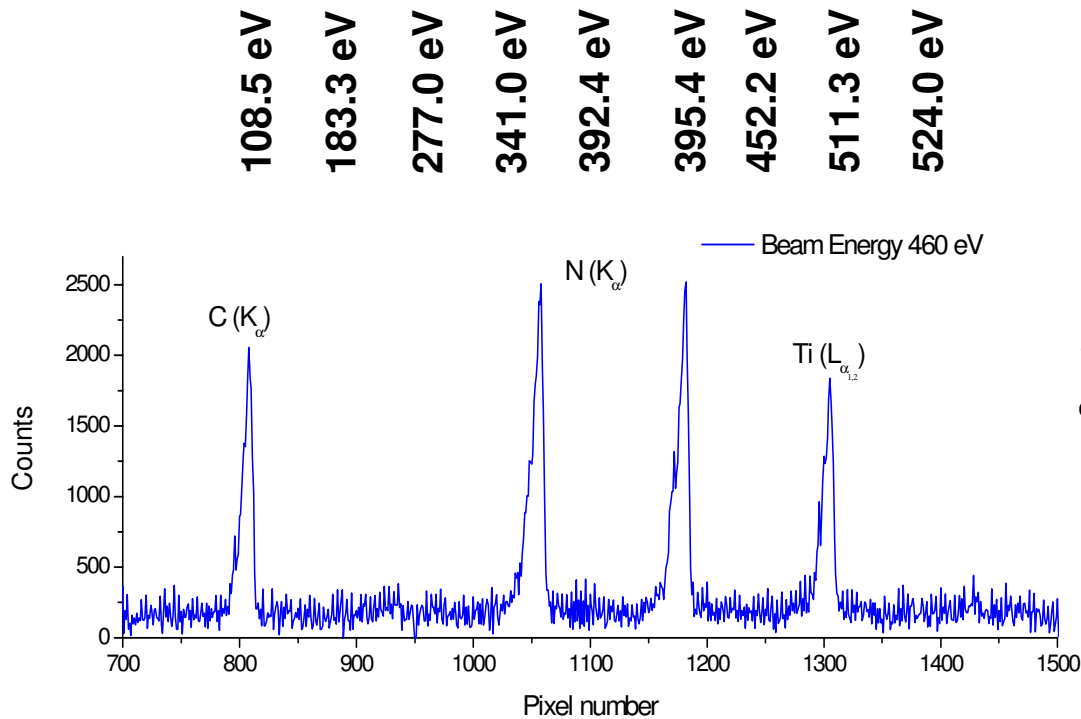
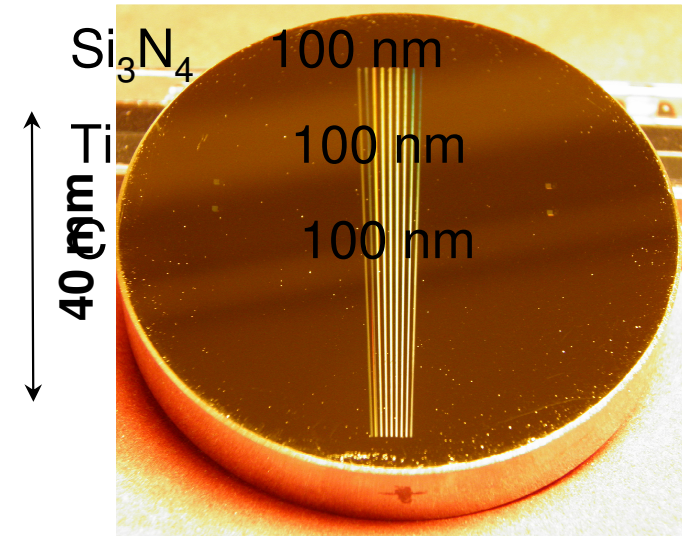
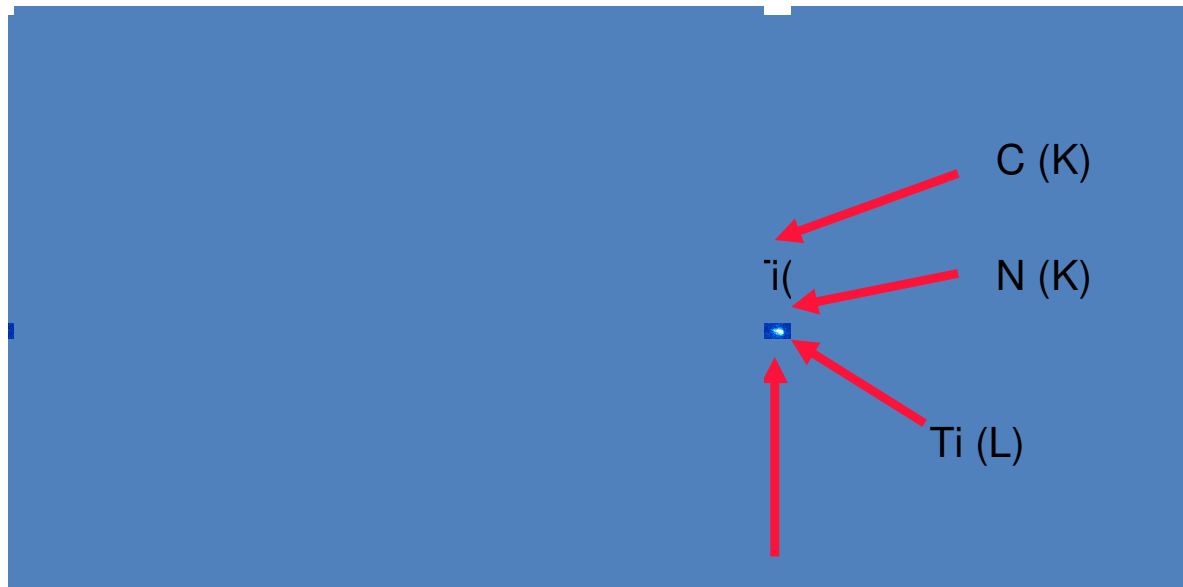


Spectrometer in vacuum vessel

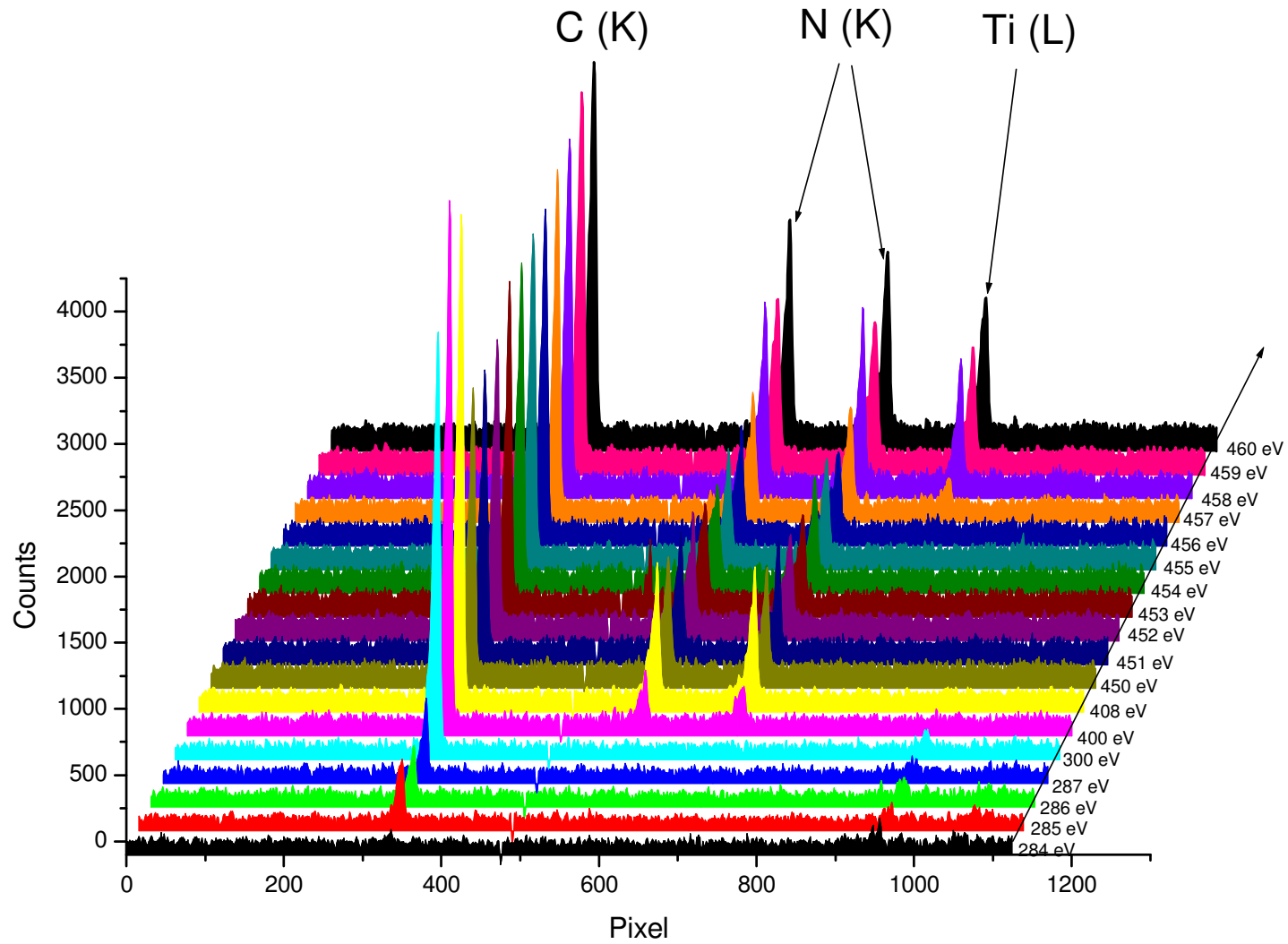


X-Ray CAMERA

DiS test at the UE52 SGM beamline BESSY II



Absorption spectra (XANES)



- Blazed gratings for X-Rays were fabricated only by Carl Zeiss
- Zeiss plans to stop fabrication of gratings soon
- A problem for HZB and all SR sources.



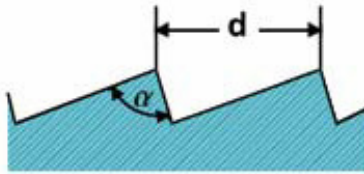
→ We want to establish a Technology Center for Highly Efficient Precision Gratings at HZB
We received 5 M€ EFRE Funding



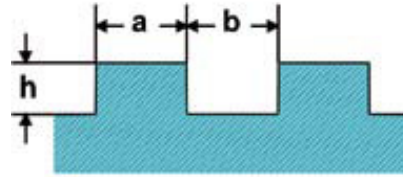
For this funding we want especially thank the Senate of Berlin

- Aim of the center:
- Development of new technologies for blazed grating fabrication:
 - Ruling technology, Interference lithography, Anisotropic crystal etching

Why blazed grating technology?



Saw-tooth profile

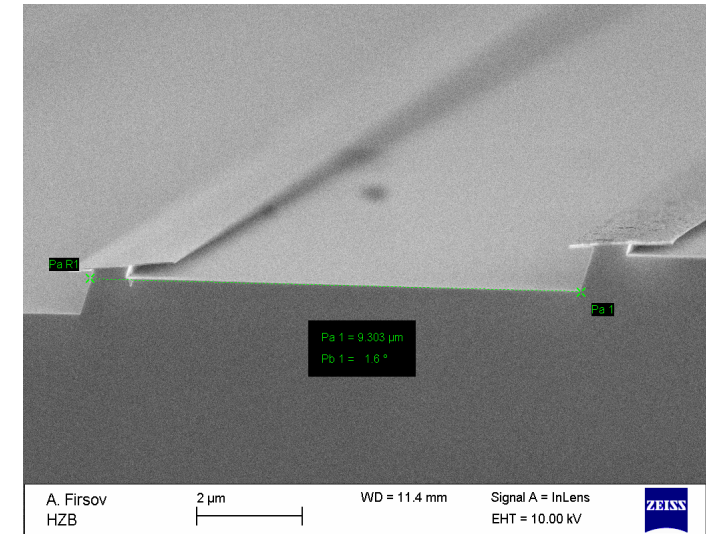
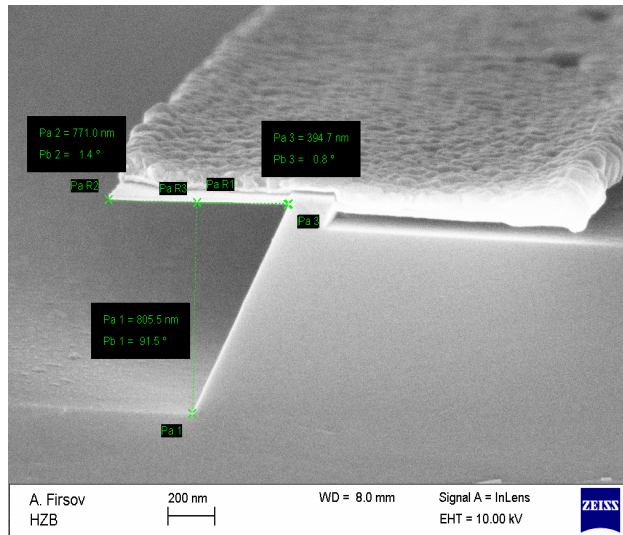
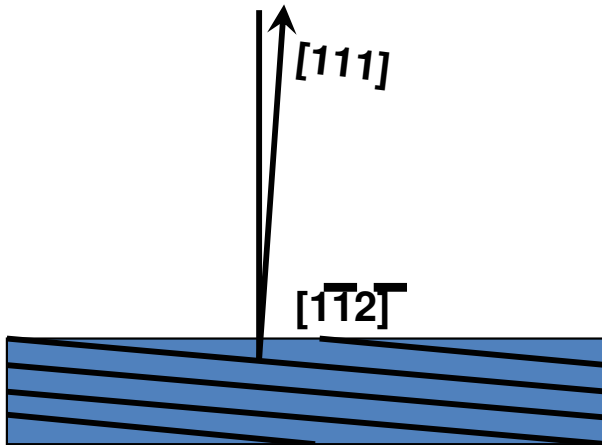


Rectangular profile

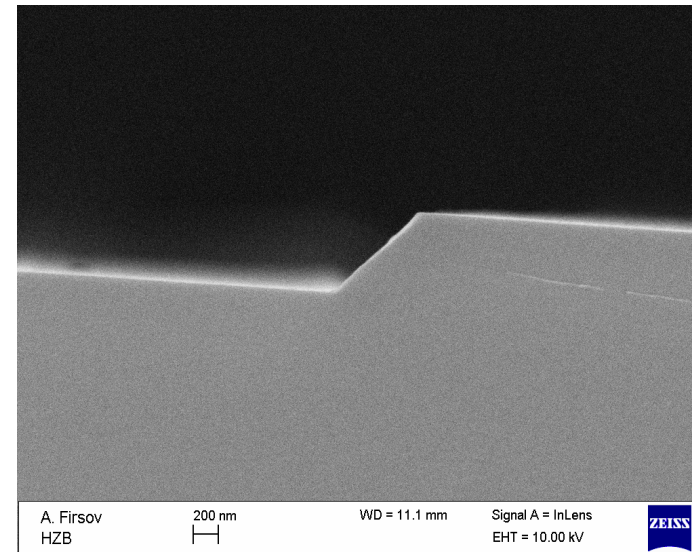
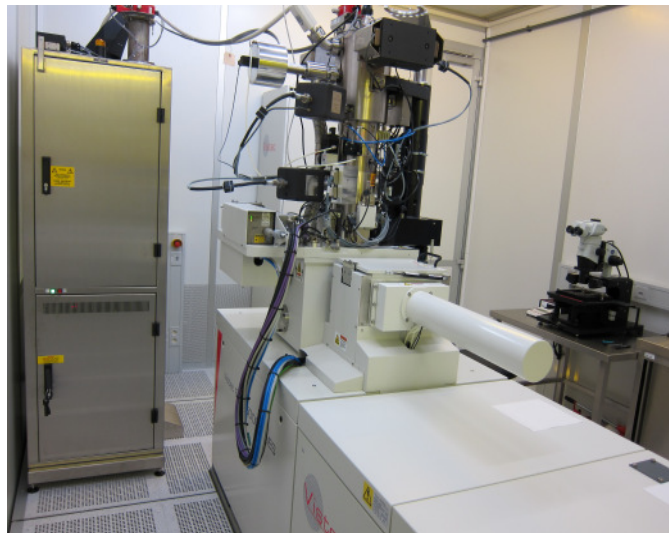
Production of mechanical ruling blazed gratings

Anisotropic etching technology

Asymmetrically cut Si crystal



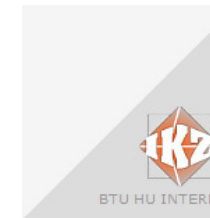
VISTEC EBPG5000plusES.
Electron beam writing system.

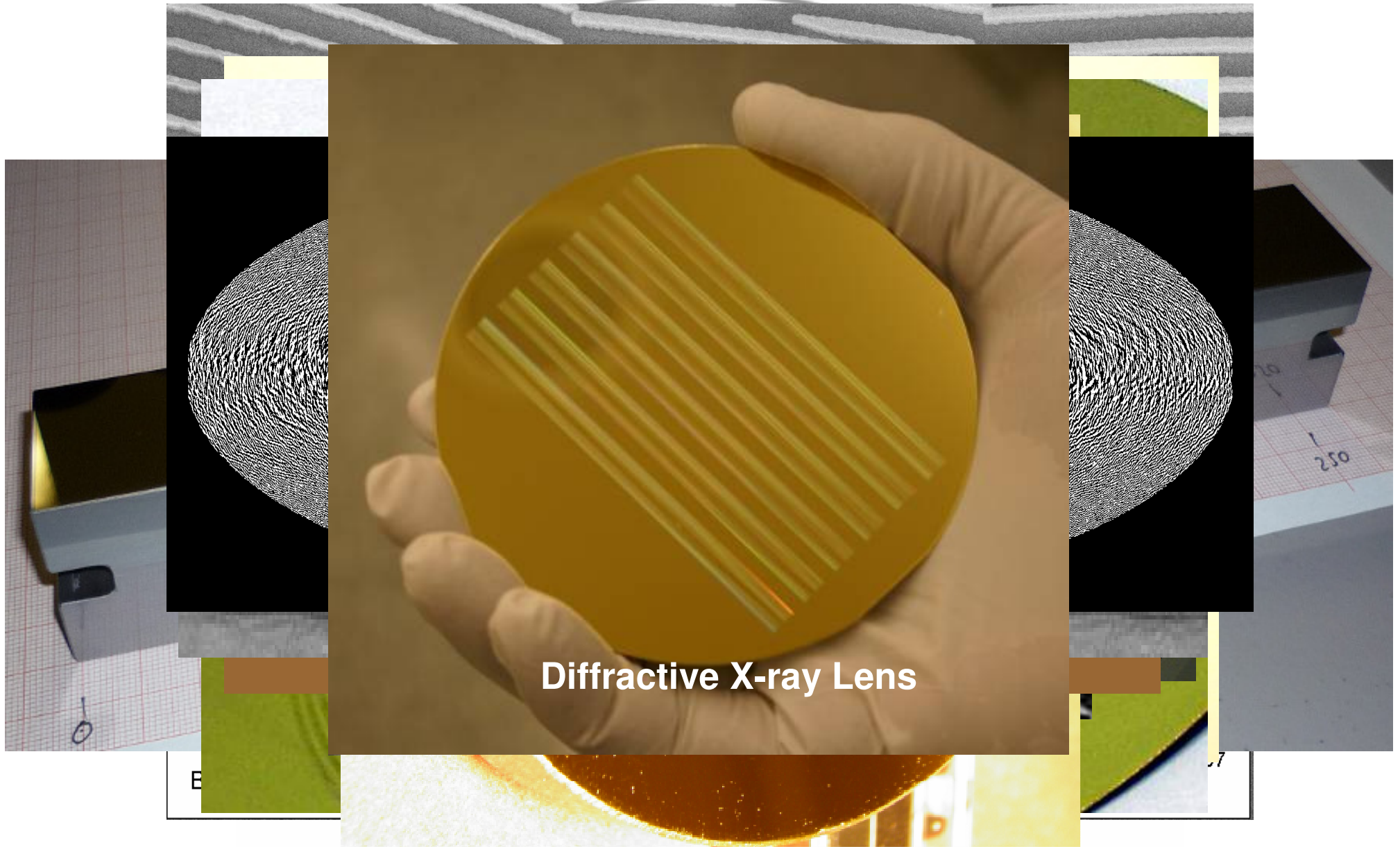


Networks:



Cooperation:





Diffractive X-ray Lens