Characterisation of optical elements for soft X-ray microprobing and microscopy

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Talk outline

Experimental outline

- Microfocus X-ray source description

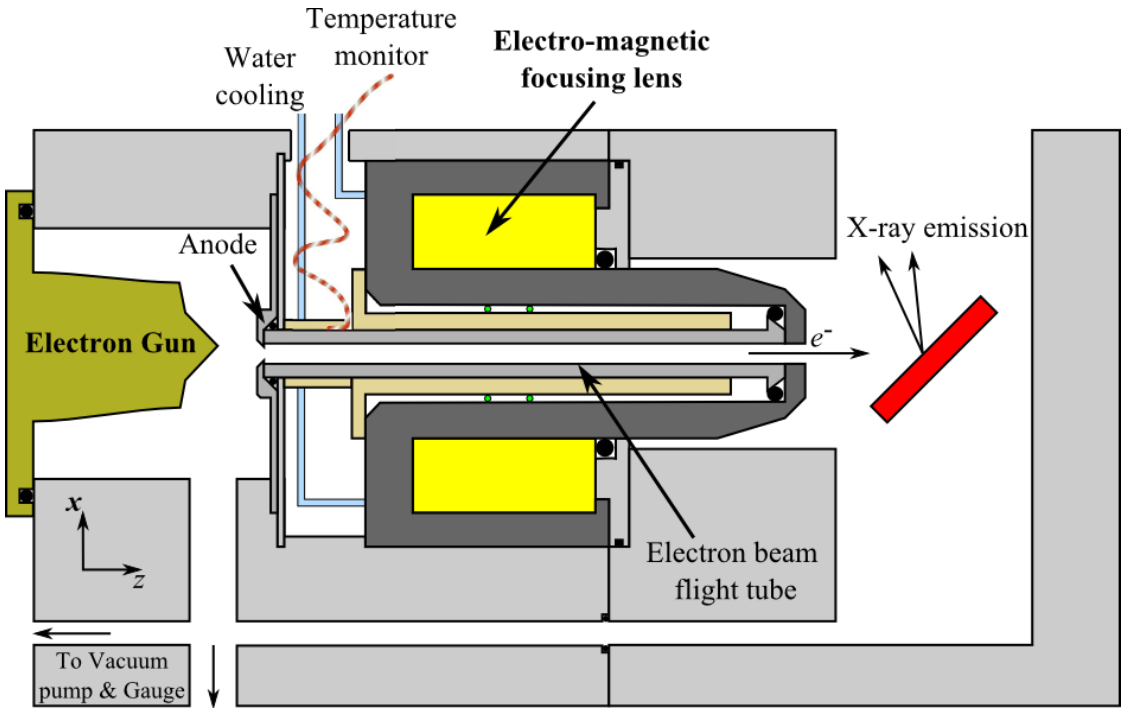
Microprobing

- Microstructured Optical Arrays (MOAs)
- Optical Characterisation

Microscopy

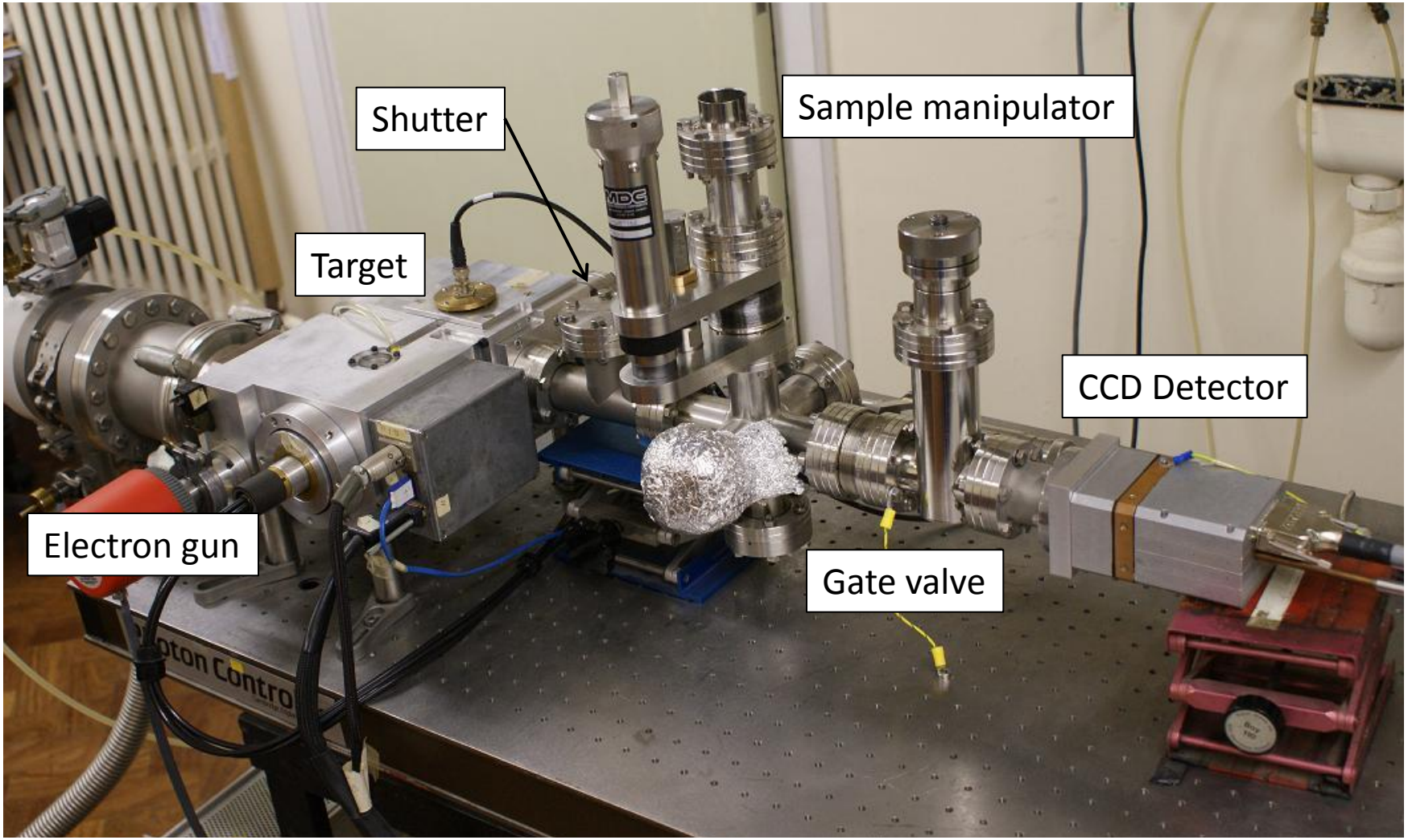
- **Mic**roscope **X**-ray **I**n-vitro (McXI)
- Zone plates
- Characterisation results

The microfocus soft X-ray source

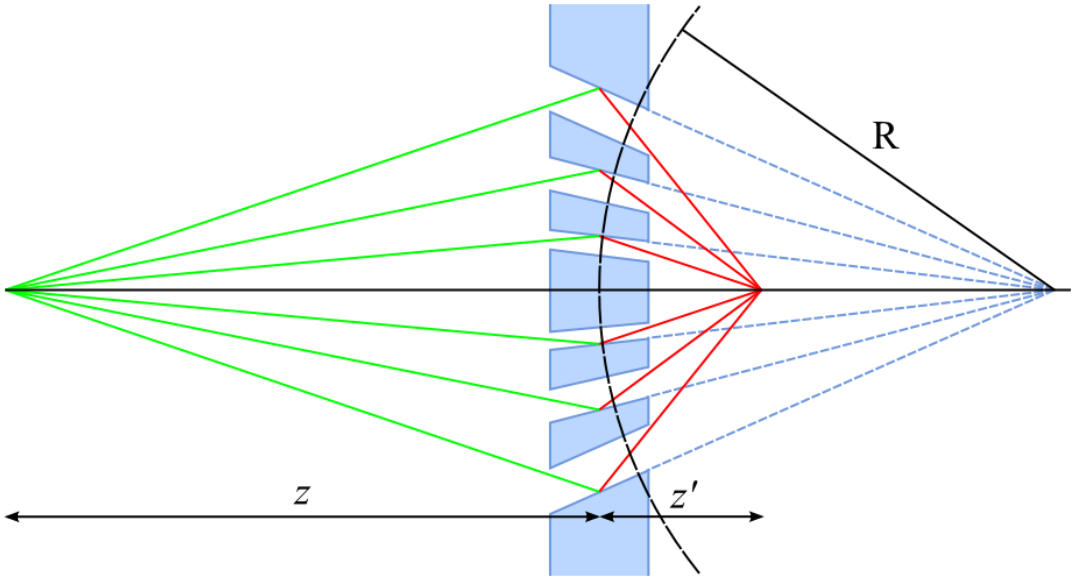


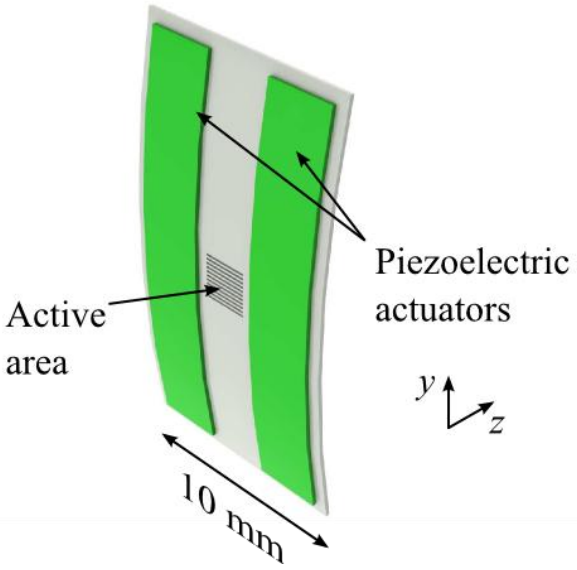
- Electron bombardment X-ray source
- Interchangeable target materials Al (K_α=1.477 keV), C (K=0.277 keV)
- ≈200 μm diameter X-ray source

Microfocus source coupled to detector



Microstructured Optical Array (MOA)





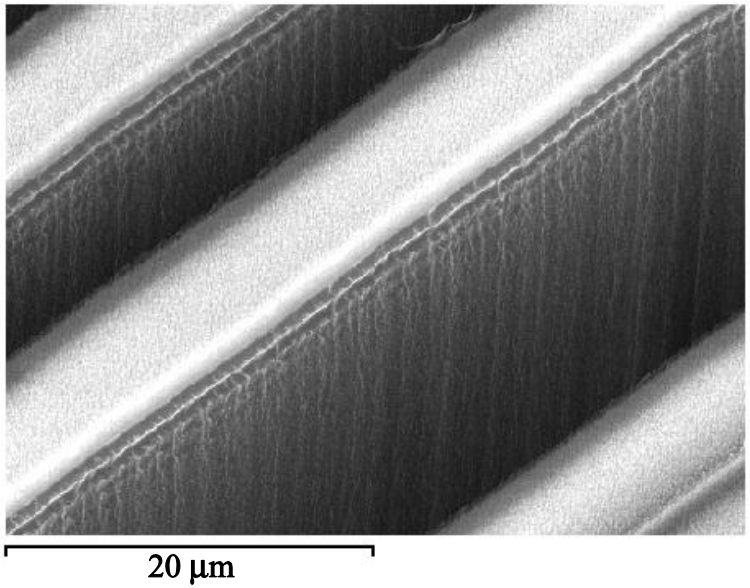
- Developed as part of the Smart X-ray Optics consortium
- Reflections from an array of channels contribute to focused spot
- Single and double reflections considered along X-ray path
- Active control of focal length
- Radiobiological microprobe experiments (2 µm diameter focused spot of Ti K_α X-rays from a 5 µm X-ray source)

R. Willingale et al. "Active Microstructured Optical Arrays of Grazing Incidence Reflectors". *X-Ray Optics and Instrumentation* (2010)

Manufacture of MOAs

DRIE

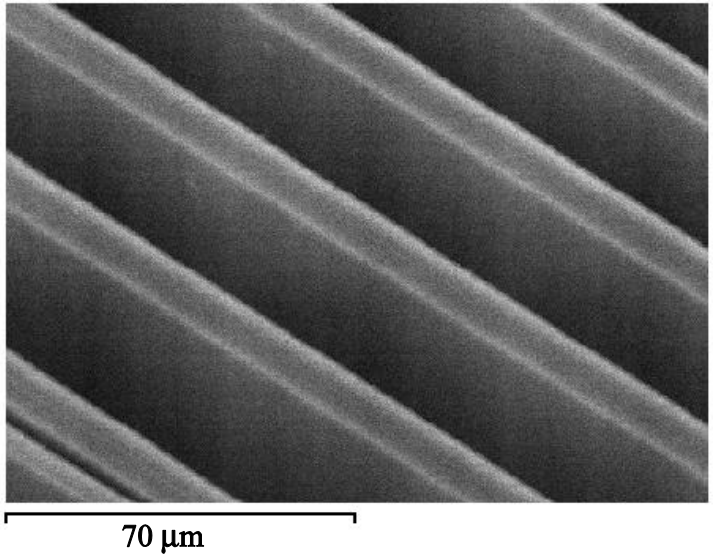
(Bosch Process)



Roughness ≈ 8 nm RMS (min.)

TMAH

(Alkaline solution)

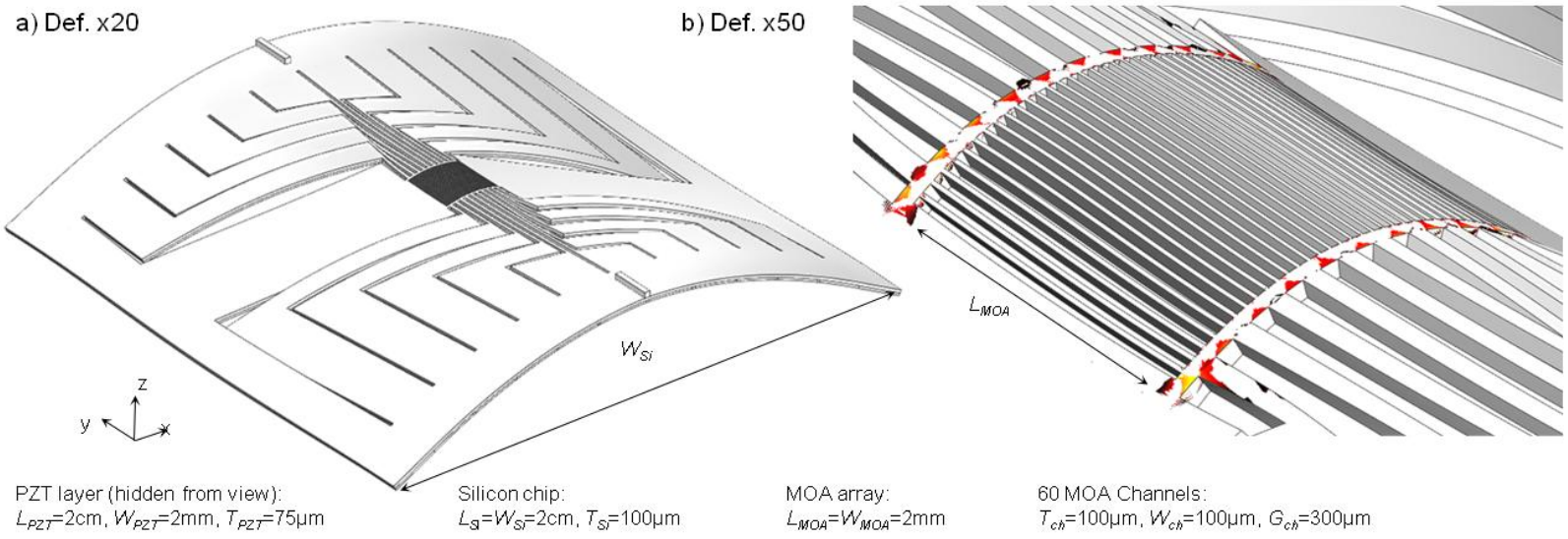


Roughness ≈ 1.5 nm RMS

C. Dunare et al. “Microstructured optical arrays for smart X-ray optics” (2009)

Spider MOAs

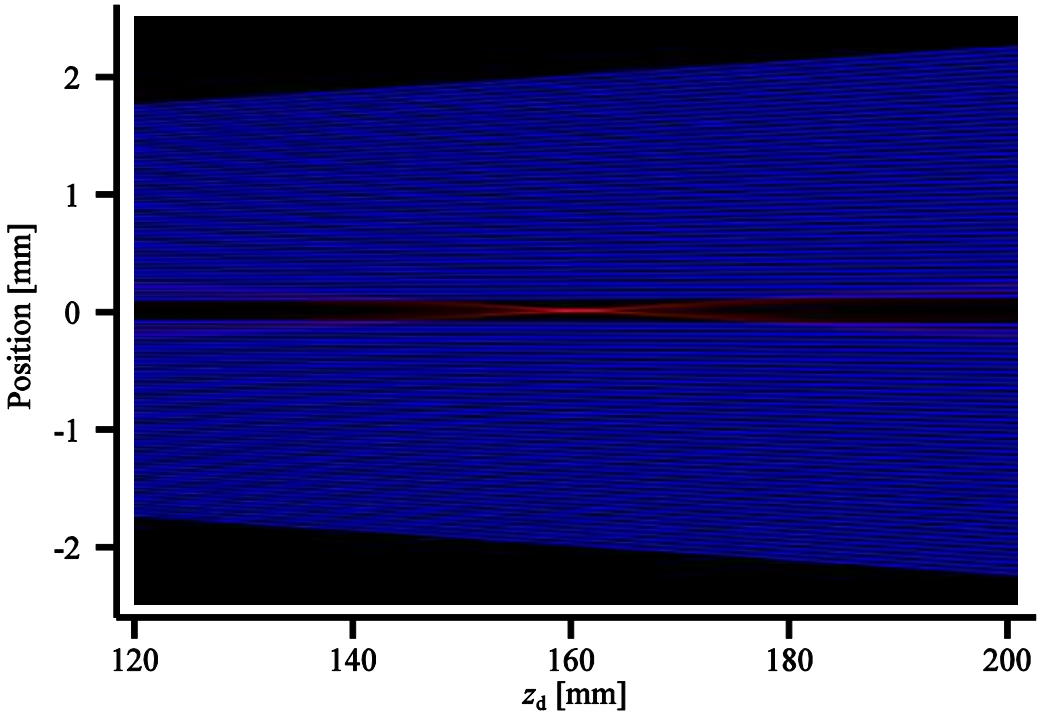
- For an appropriate focal length, R ≈ 50 mm
  - Not achievable using simple designs (R = 420 mm min.)
- Spider-like levers etched into silicon substrate enhance the curvature across the active area
- Mechanical testing of spider MOAs indicates R=30 mm



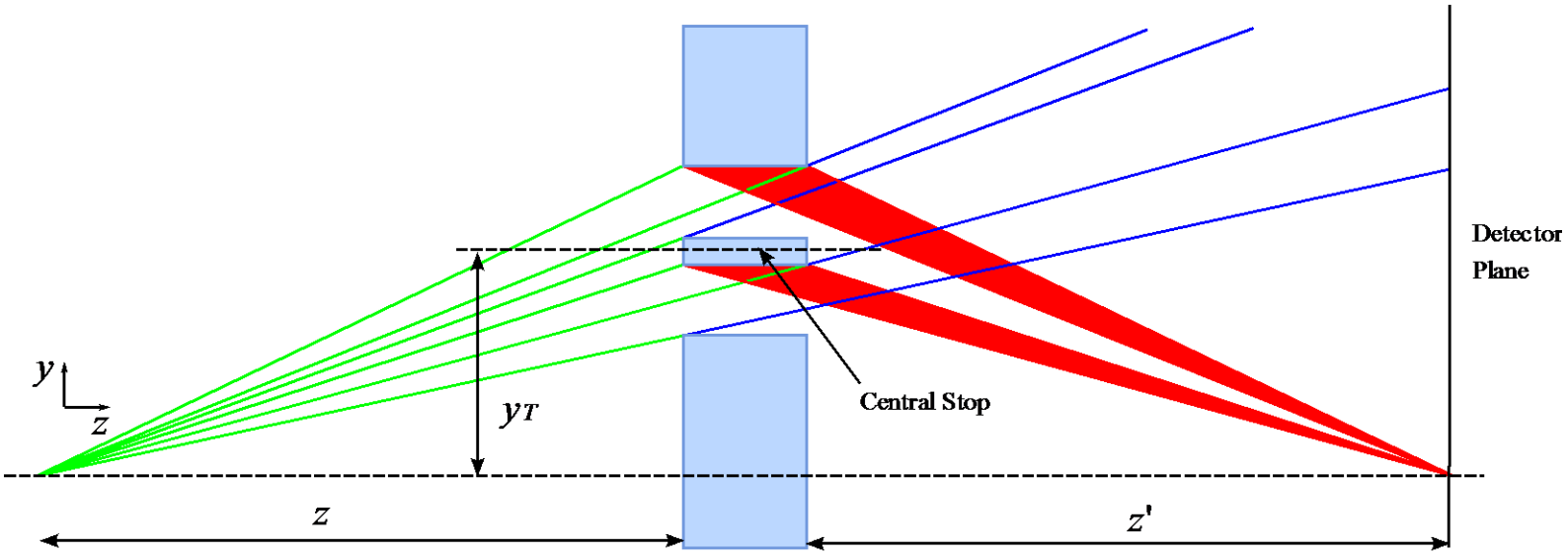
D. Rodriguez-Sanmartin, (2011) PhD Thesis, University of Birmingham

Simulation of MOA focusing properties

- Simulation of focusing effect for a MOA array
- X-rays reflected (red pixels) by each channel contribute to a common focused spot at z_d=z=160 mm
- Focused spot is isolated from unreflected (blue) X-rays by central stop

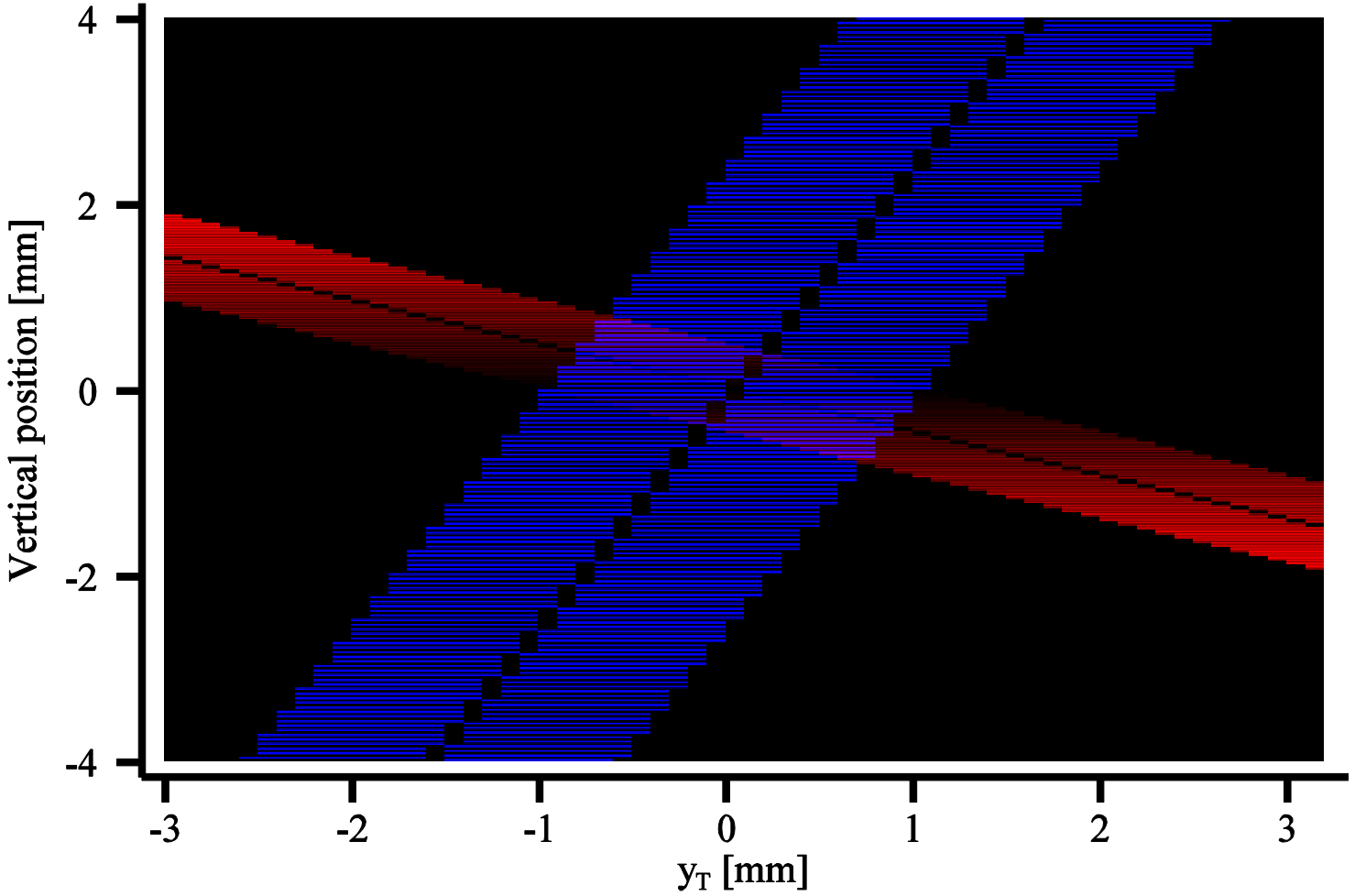


Experimental method for characterisation of MOAs

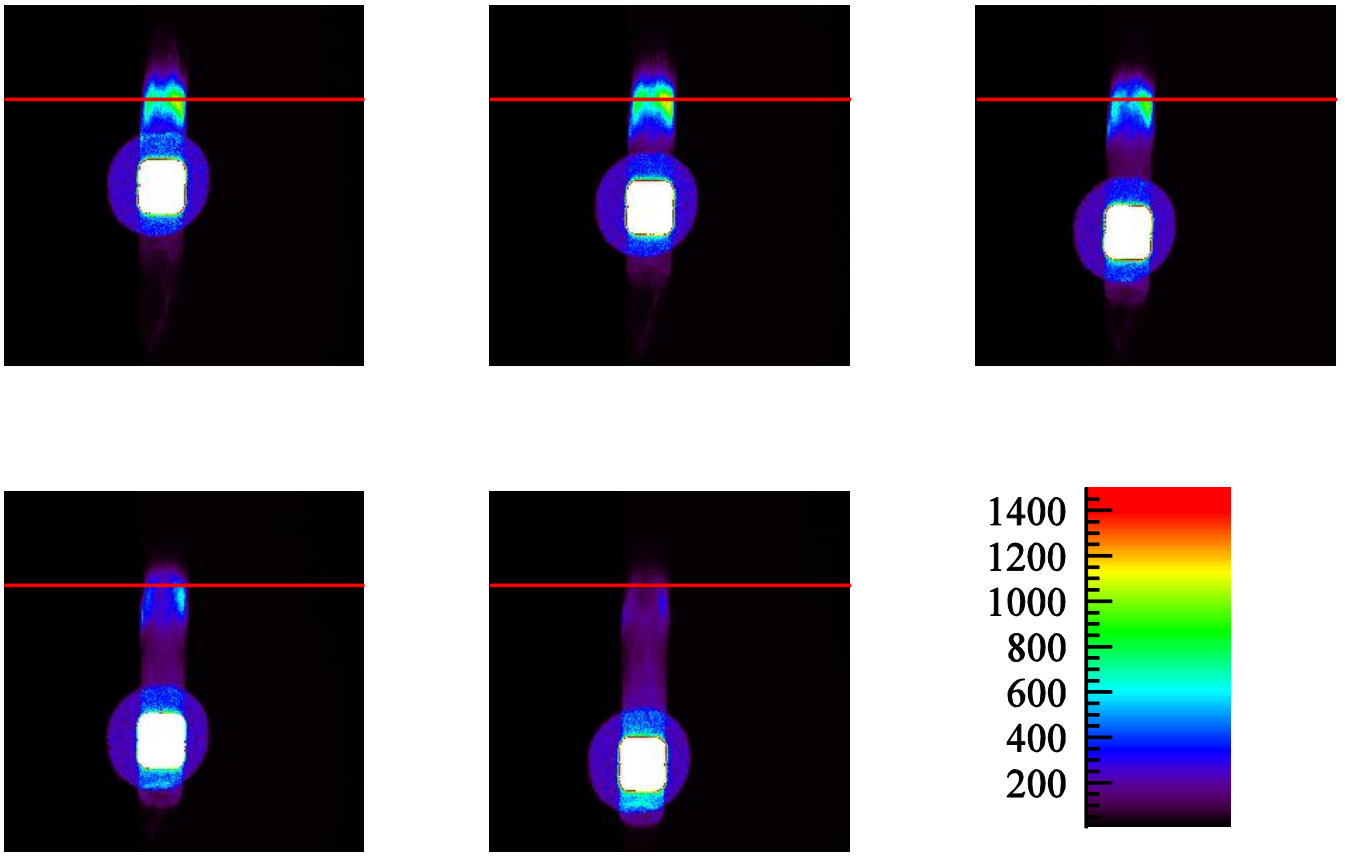


- Displacement of MOA channels from optical axis separates reflected radiation from unreflected “background”
- Ideal for use with microfocus X-ray source.

Simulation of MOA displacement (y_T)

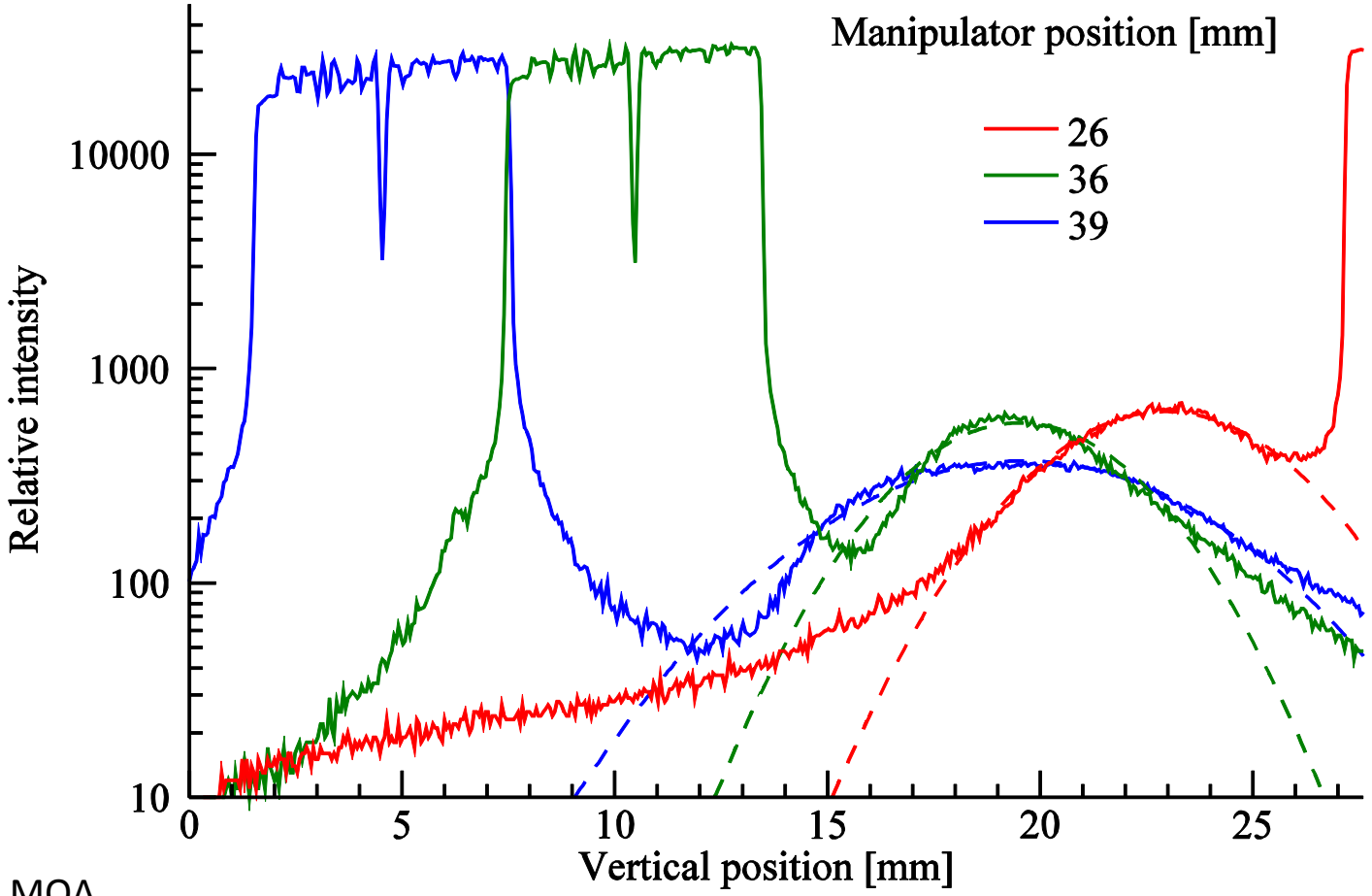


Experimental characterisation of MOAs



TMAH etched MOA
Broadband Al X-rays
z=z'=300 mm

Experimental characterisation of MOAs

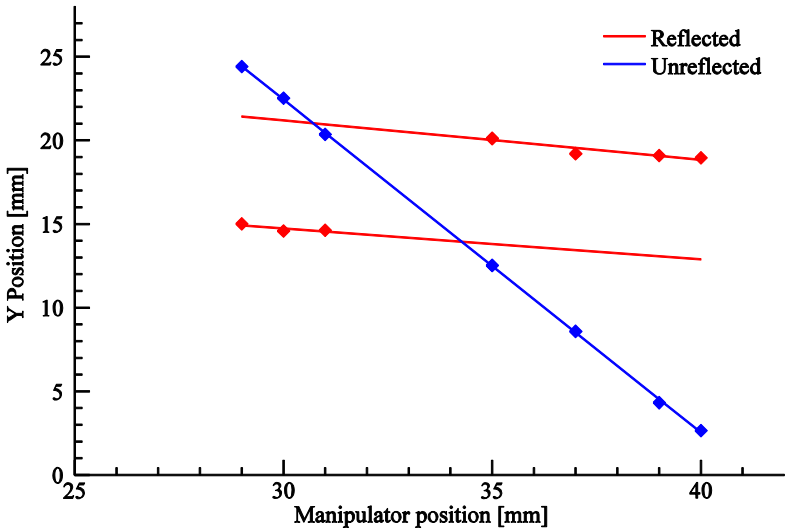


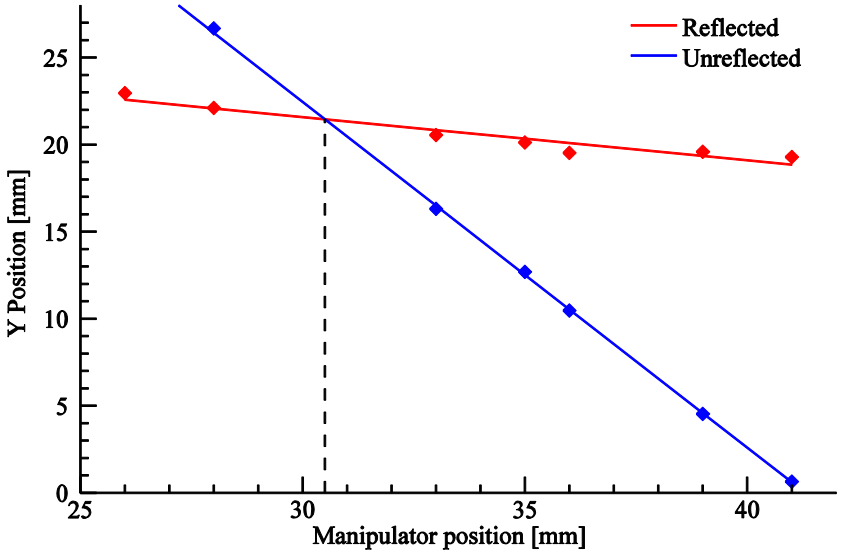
DRIE etched MOA
Broadband Al X-rays
$z=z'=300$ mm

Position stability of DRIE vs TMAH

DRIE etched MOA

• Symmetrical about either side of optical axis





TMAH etched MOA

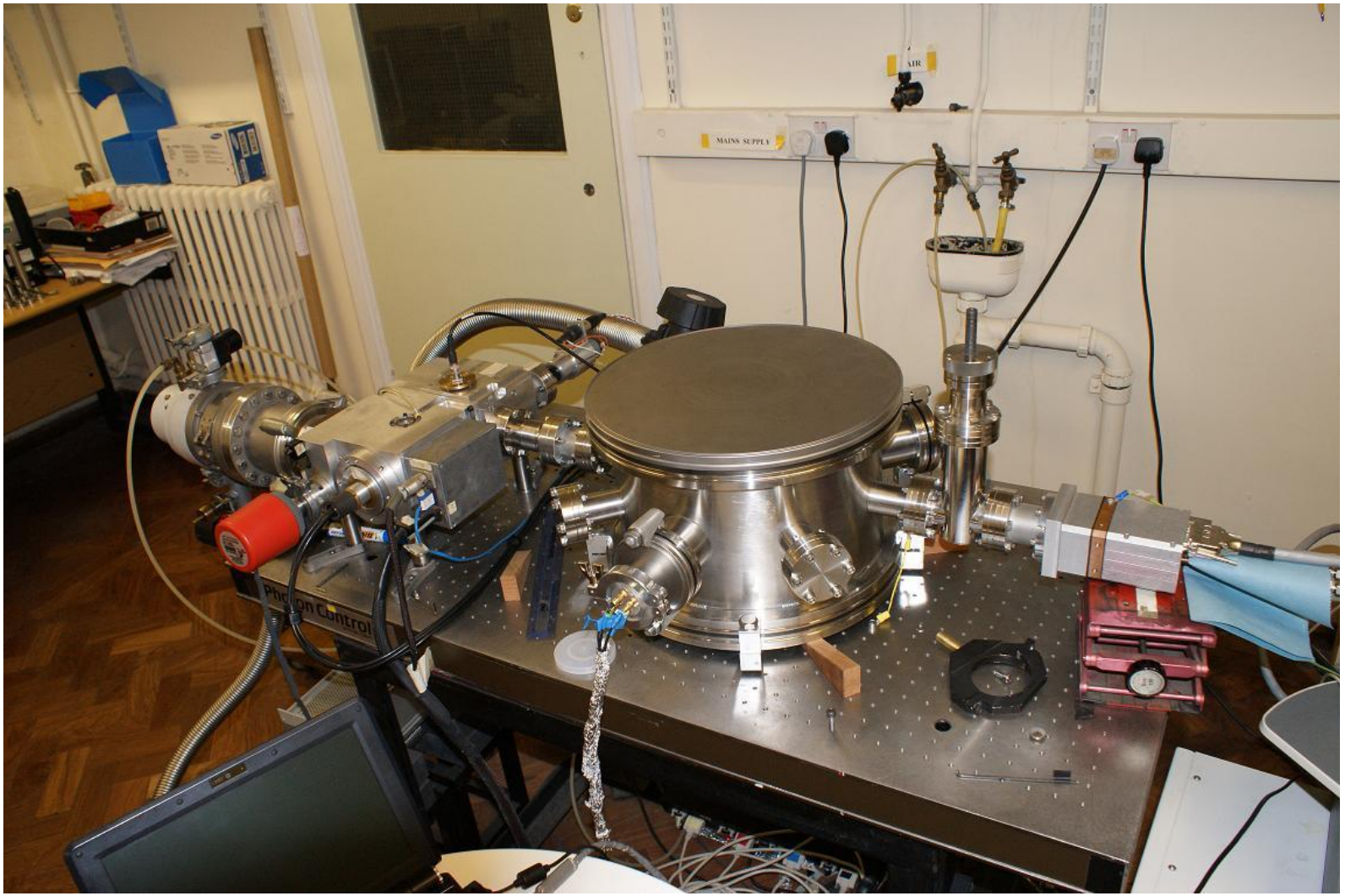
• Shift in reflected position occurs due to taper in channel structure

STSM – Characterisation of a prototype soft X-ray microscope

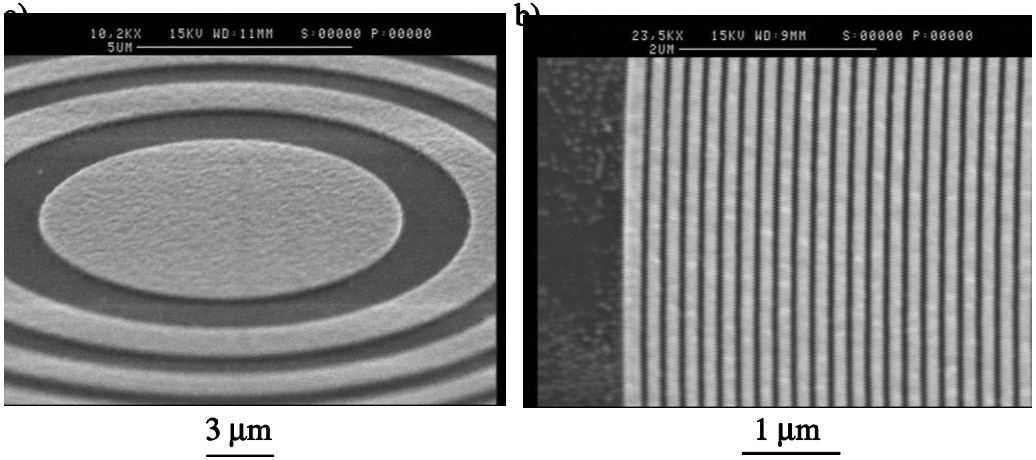
- Autumn 2009
- Aim: To characterise the performance of the McXI-I (**Mic**roscope **X**-ray **I**n-vitro) prototype soft X-ray microscope (www.mcxi.eu)
- In collaboration with NANO-UV

- Additional work has since been conducted at KCL, to characterise the microscope using the microfocus X-ray source described

McXI-I microscope

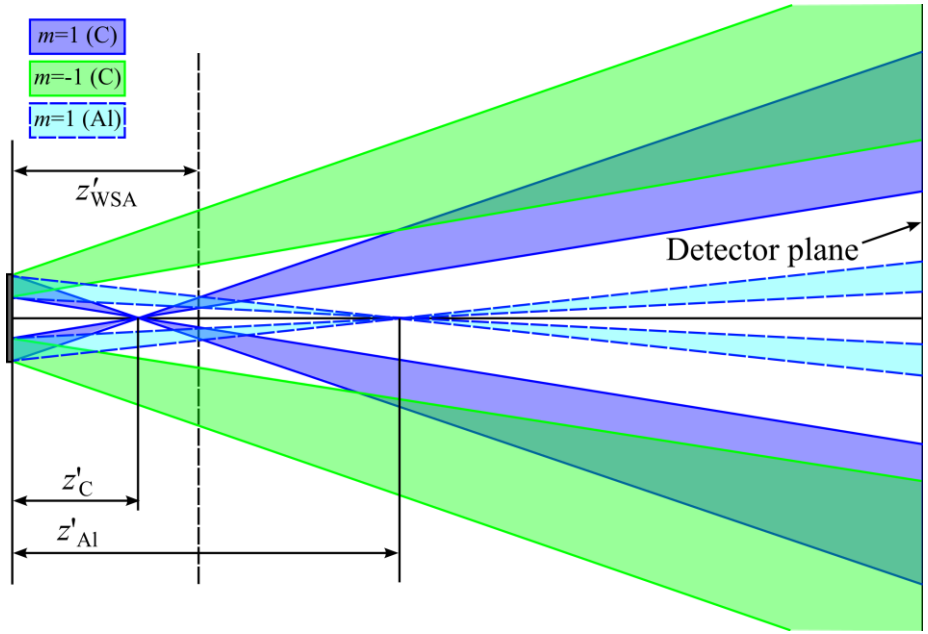


Zone Plate (ZP) characterisation

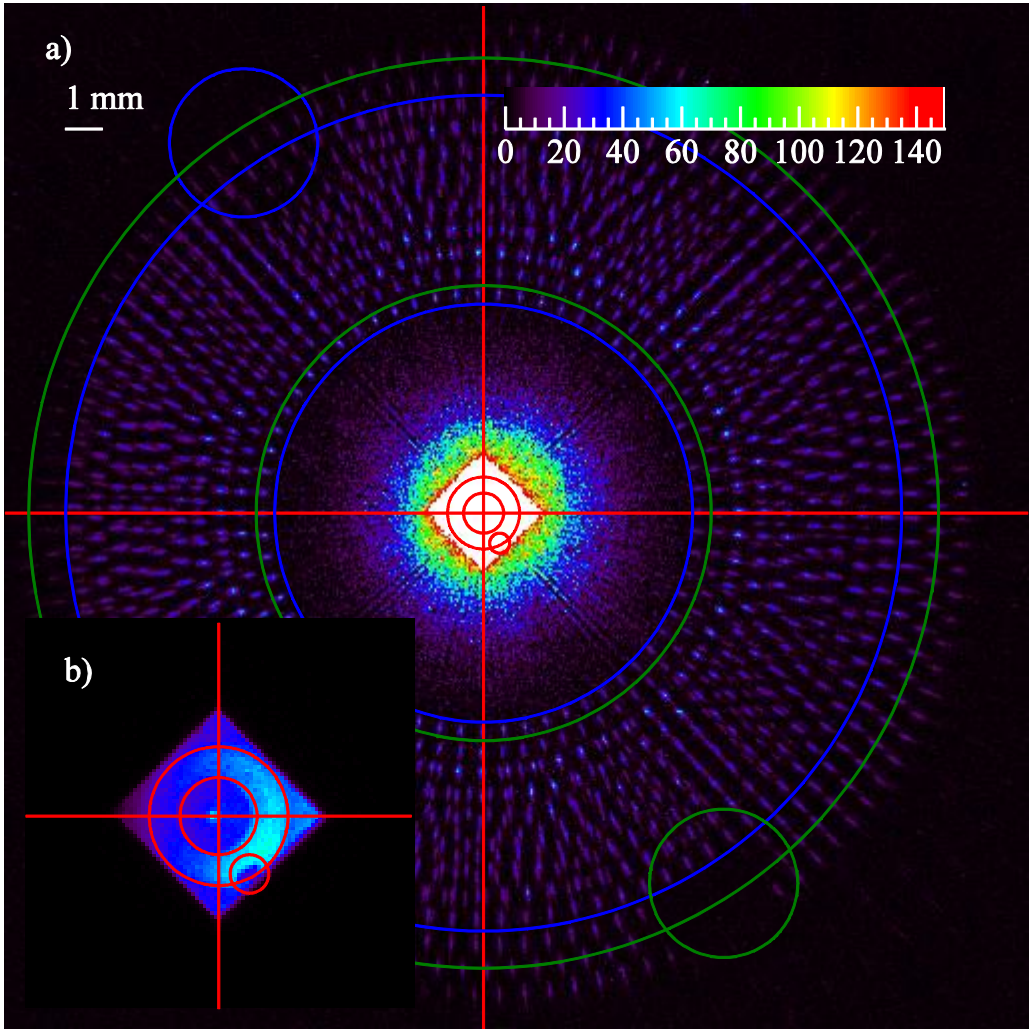


Typical Au electroplated ZP (d_n=100 nm)
Silson Ltd.

1st order diffraction pattern produced by ZP (C, Al)



Diffraction pattern of Condenser ZP



Broadband X-rays produced by C target

Conclusions

- A microfocus X-ray source has been developed at KCL for characterisation of soft X-ray optics
- This source has been used to characterise unactuated MOAs, and shows good comparison with simulation
  - The performance of actuated MOAs may now be considered in a similar manner
- Initial tests of the performance of the McXI-I microscope have also been performed using this X-ray source

Acknowledgements

King's College London (KCL)

- Graeme Morrison
- Alan Michette
- Slawka Pfauntsch

Members of SXO consortium

- University of Birmingham
- Scottish Microelectronics Centre (SMC)
- STFC Daresbury
- Mullard Space Science Laboratory (MSSL)
- University of Leicester
- University College London

The Smart X-ray Optics Consortium was funded by UK Research Councils' Basic Technology programme, grant code D04880X

NANO-UV

- Peter Choi
- Grainne Duffy
- Keith Powell

STSM funded by COST MP0601

Development of McXI-II microscope

- NANO-UV (Paris, France)
- Silson Ltd. (Northampton, UK)
- Delong Instruments (Brno, Czech republic)

Supported by supported by the Eurostars Program McXI Σ!4885