University of Leicester

DEPARTMENT OF PHYSICS AND ASTRONOMY

A practical X-Ray Interferometer

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A Practical X-Ray Interferometer Goals

To achieve ultra high resolution in the soft x-ray band for astronomy

100 μas at 1 keV with 1 m baseline

High Resolution Astronomy

100 μas at 1 keV with 1 m baseline

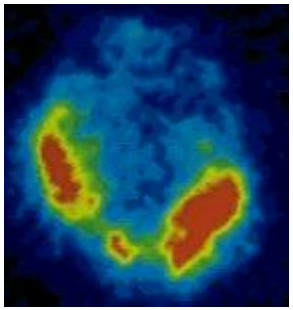
Solar diameter at 100 pc

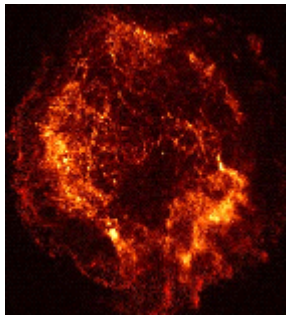
- Stellar coronae
- Accretion in nearby binary systems

1000 AU at 10 Mpc

- Origin of outflow structures or jets in AGN or other compact objects

Supernova remnant Cas A





Exosat
Resolution 18 as

Chandra
Resolution 0.5 as

XRI
Resolution 0.1 mas

Exosat : Chandra
36 : 1

Chandra : XRI
5000 : 1

XRI Requirements

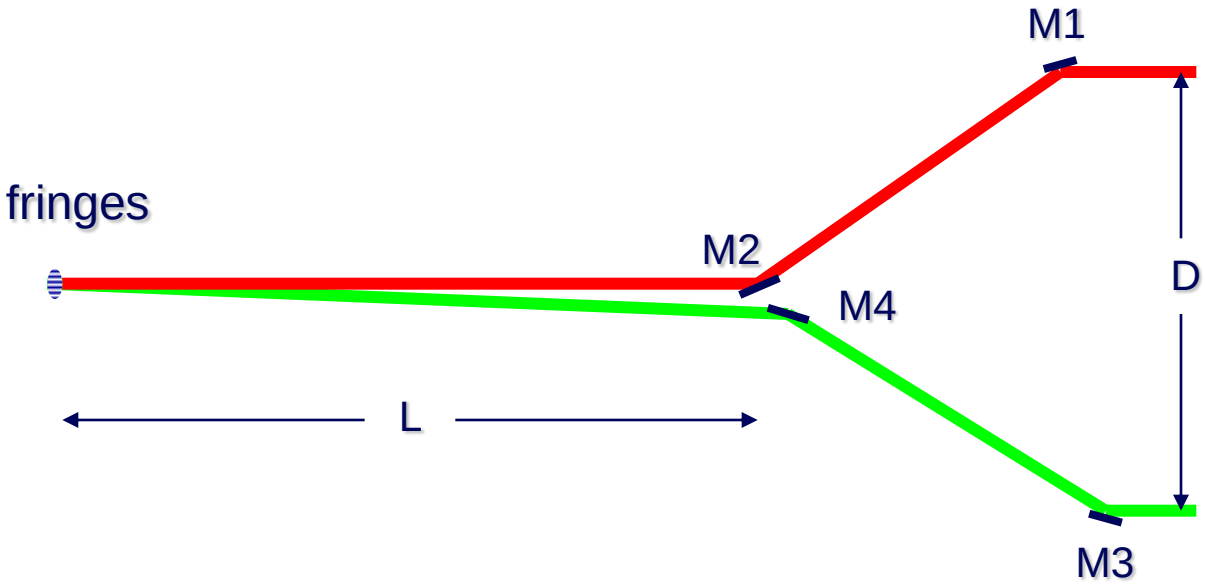
For interferometry to work,
requires fringes,
requires

ΔBeam paths $\leq$ coherence length

For a *practical* XRI require

- practical Interferometer dimensions
- practical mirror Effective Area

XRI concept

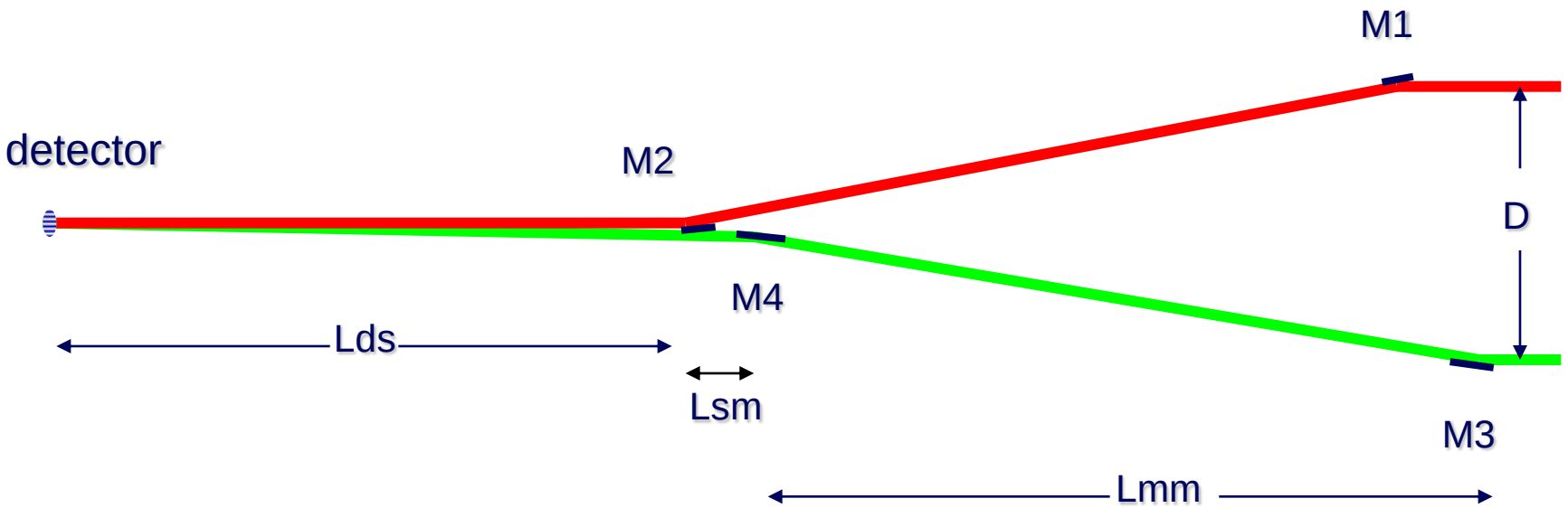


Not to scale

- 1 m baseline, D
- L = 10 m

(Telephoto system, effective focal length ~ 40 km)

Telescope Dimensions



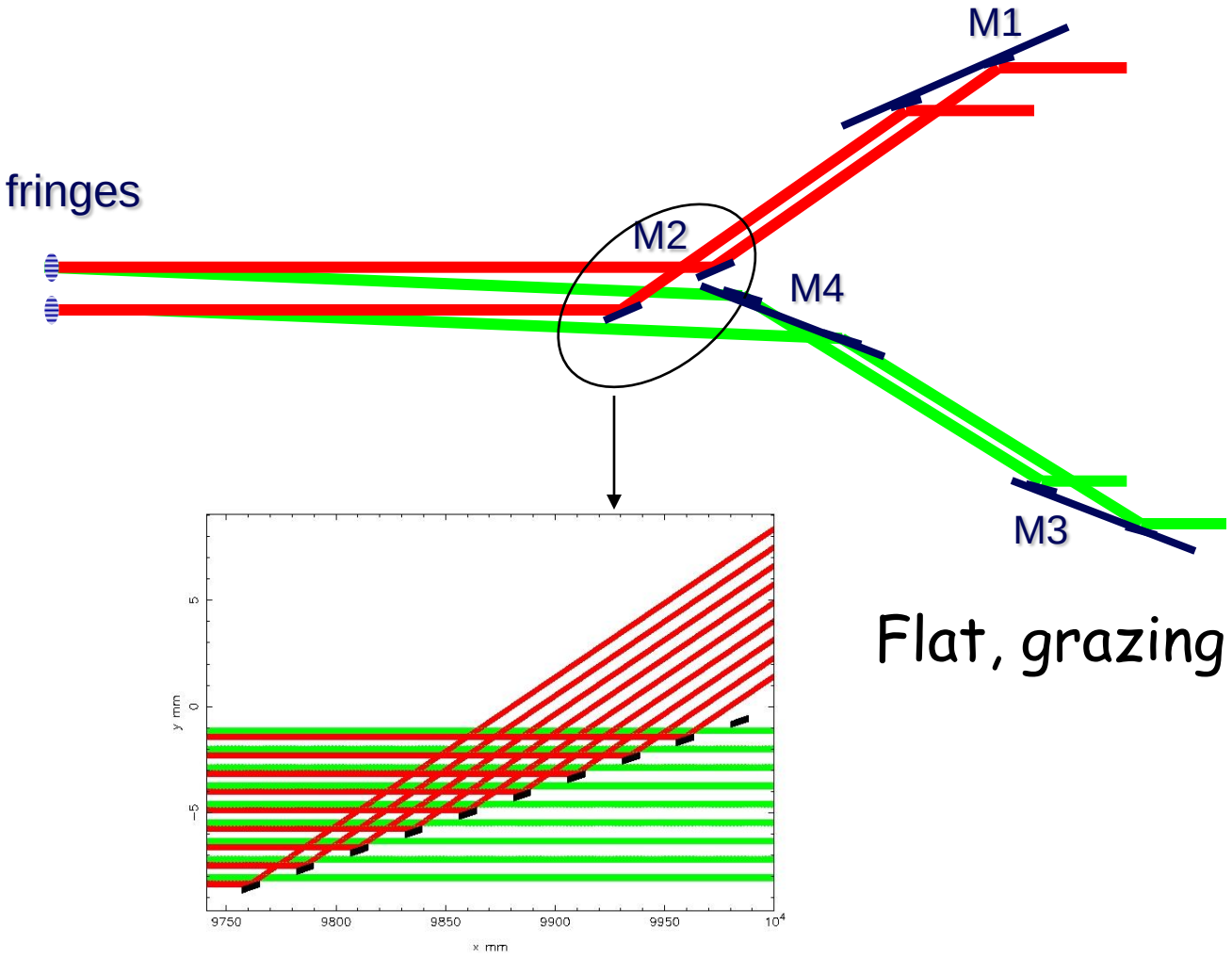
Lds = 10 m

Lsm = 0.5 m

Lmm = 7 m

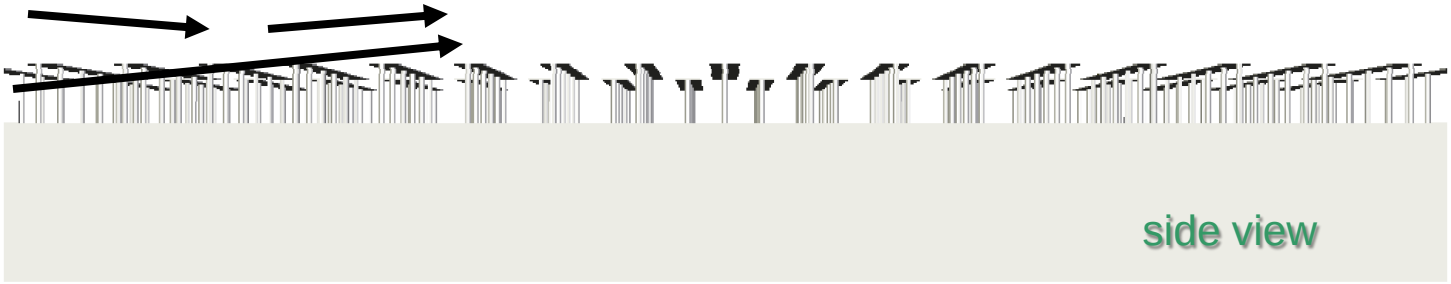
for D-spacing = 1 m

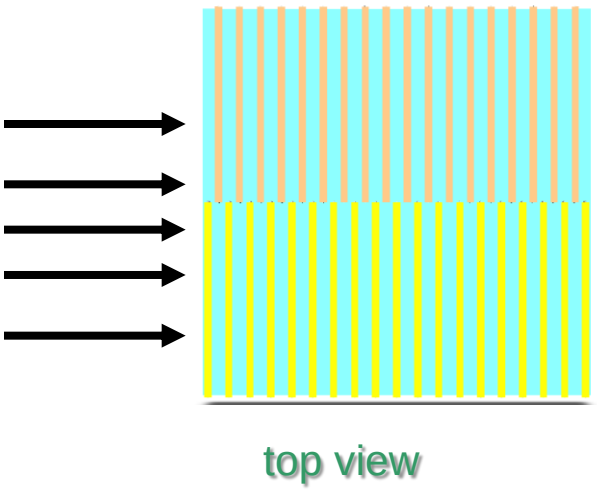
XRI slatted mirror concept



Flat, grazing incidence optics

Slatted mirror



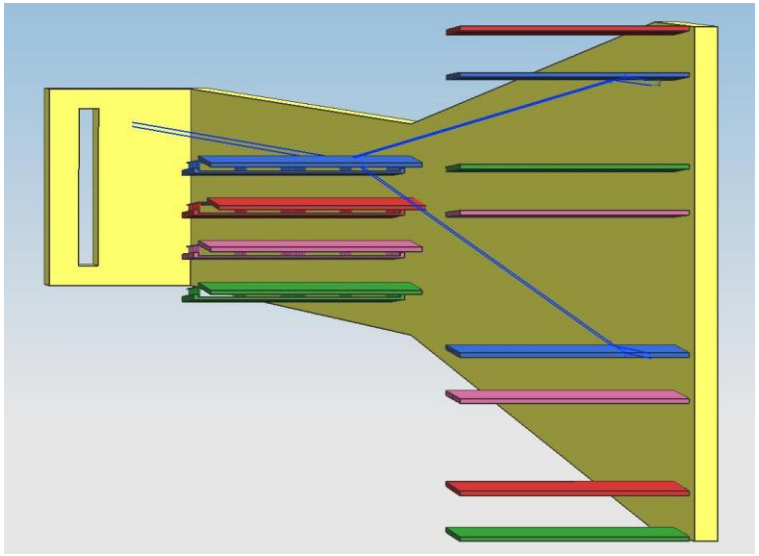


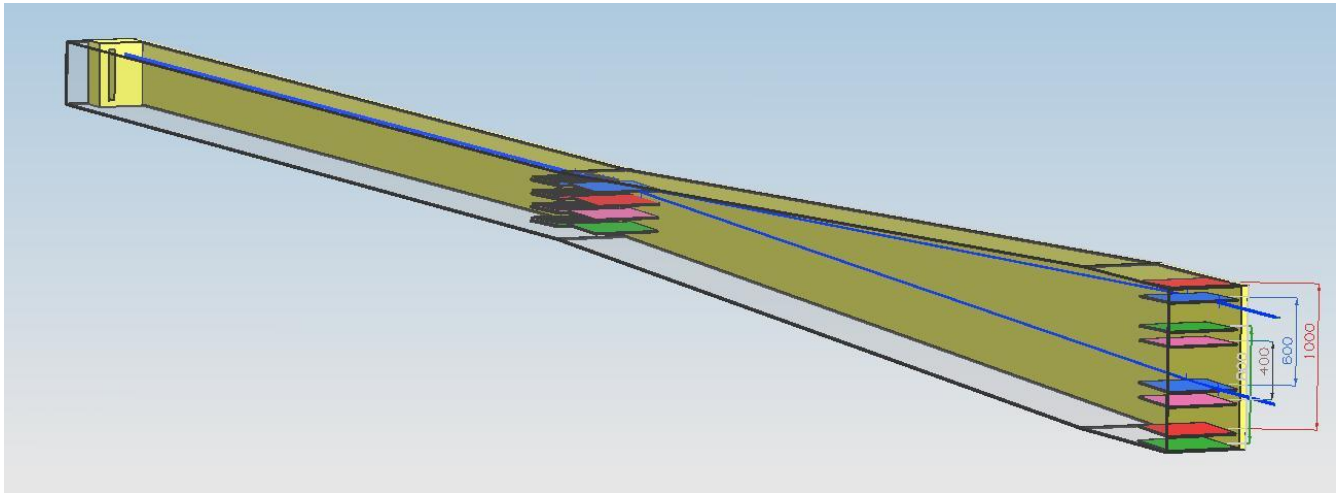
- 500 x 500 mm
- Gold coated
- 0.5 to 2 keV
- Effective area 20 cm^2

Telescope design

4 units

- 4 different D-spacings
- Effective area 80 cm^2





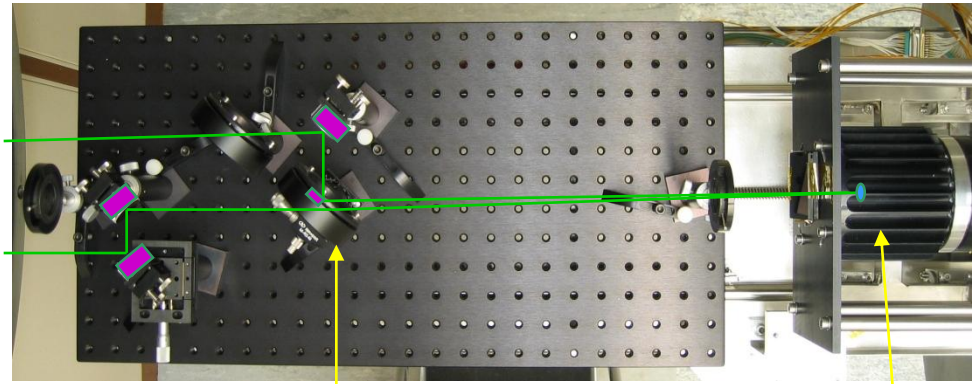
Telescope Design

- 4 units together constitute one 1-D telescope

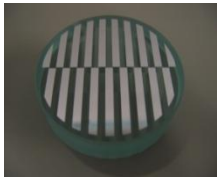
- To give a 2-D telescope
  - two adjacent telescopes at 90°
  - rotate the 1-D telescope 90°

Optical Demonstration Model

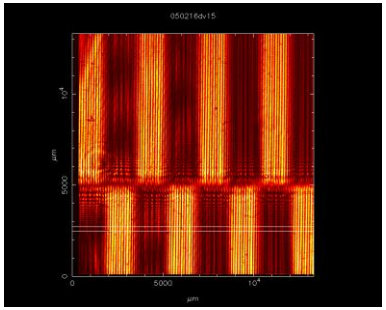
- Developed alignment and adjustment technique to produce fringes
- Obtained fringe pattern matching predictions
- Analysed data to reproduce source

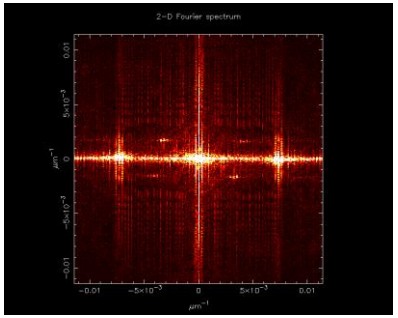


slatted mirror



camerahead

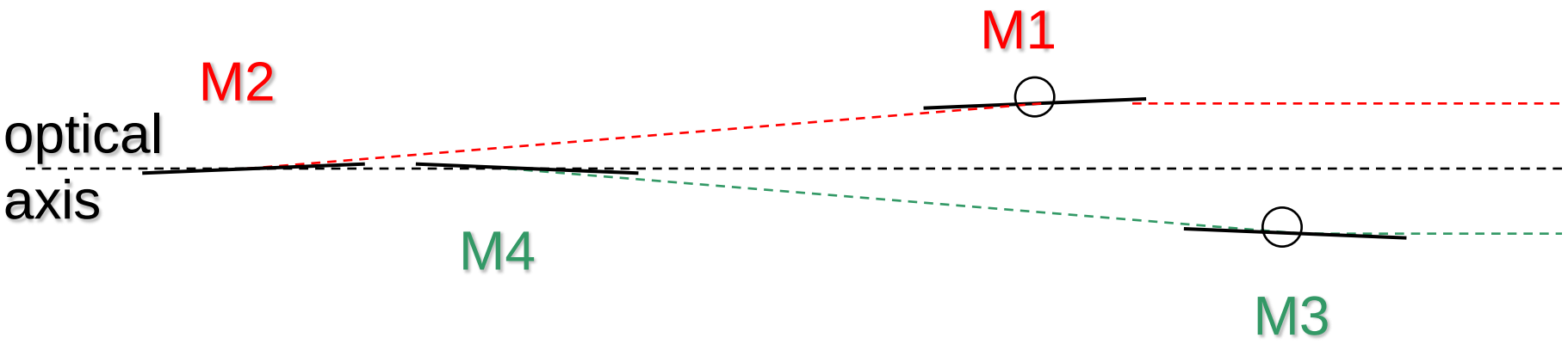




Technical issues

- Alignment, stability, tolerances
- Detector
- Slatted mirror – design and construction

alignment and adjustment

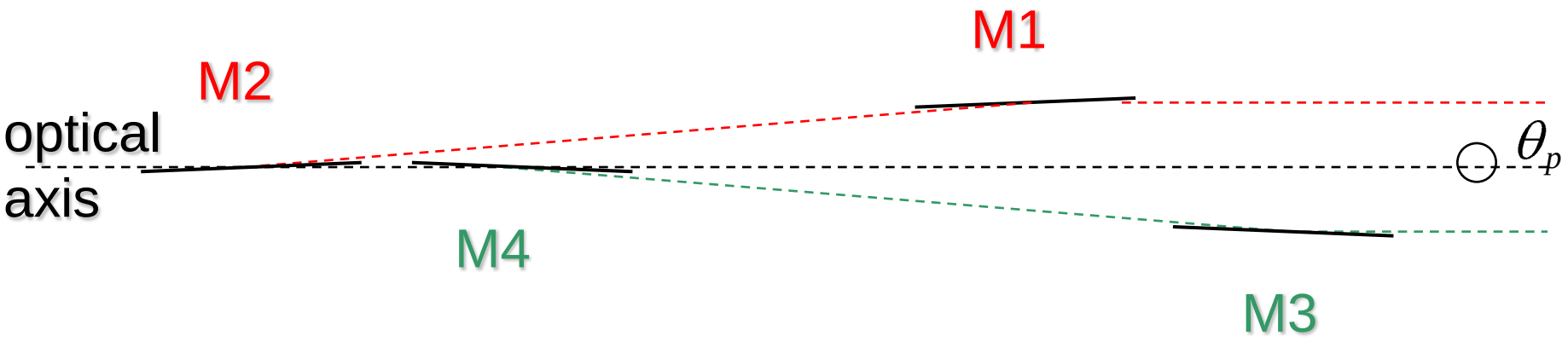


Optic axis defined by detector, M2 and M4

Set mirror positions M2 and M4 to grazing incidence θ_g

M1 or M3 rotated by ≈6 arcsec to give overlap

alignment tolerance



θ_p angular offset between point source and optical axis

Pointing angle introduces beam path difference $\Delta = D\sin\theta_p$

Pointing accuracy and FoV determined by energy resolution of detector

$$\theta_p < \frac{E}{\Delta E}\frac{\lambda}{D}$$

Tolerances

- Beam path difference < coherence length

- Effective coherence length determined by energy resolution of detector

$$L_{coh} = \frac{E}{\Delta E} \lambda_0$$

Detector

Default detector: CCD-22 (XMM EPIC-MOS)

- 600 x 602 pixels
- 40 μm x 40 μm pixel
- 0.2 – 10 keV
- At 1.5 keV, energy resolution < 100 eV
- N = E/dE ~ 20

Optimised detector to have improved energy resolution and good 1-D spatial resolution

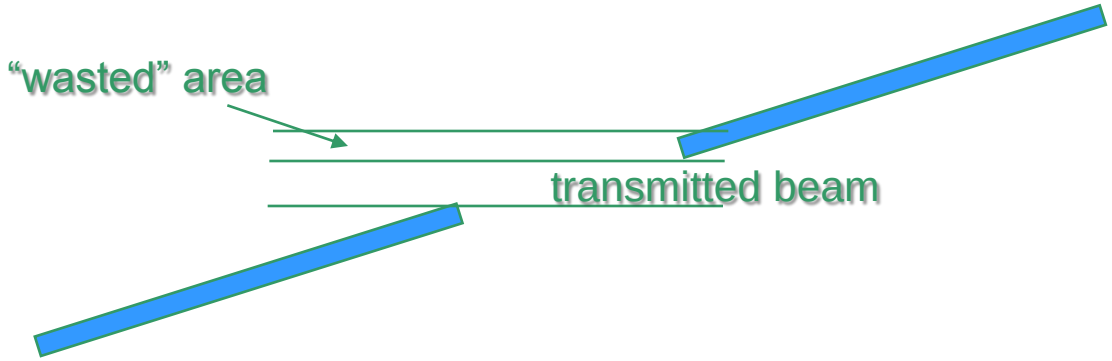
Tolerances

	CCD	STJ	Calorimeter
N	10	150	600
$L_{coh} = \frac{E}{\Delta E}\lambda_0$	10 nm	150 nm	600 nm
$\theta_p < \frac{E}{\Delta E}\frac{\lambda}{D}$	0.2 arcsec	3.1 arcsec	0.2 arcmin

X-Ray Slatted mirror

Requirements

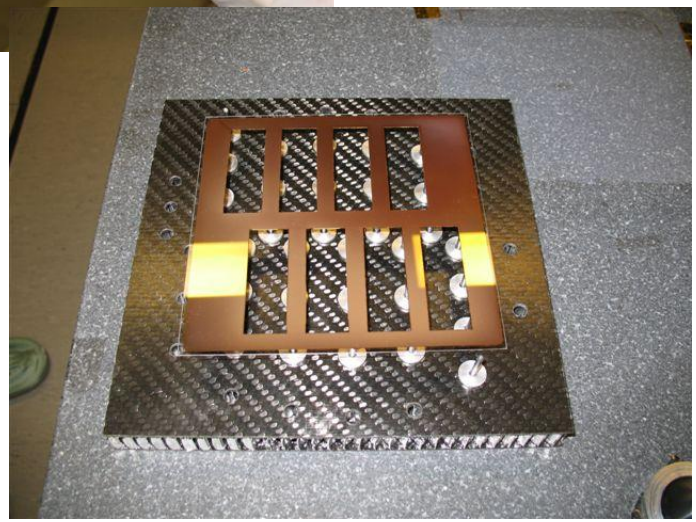
- smooth surface < 1 nm rms surface
- rigid maintain flat surface
- thin slats maximise transmitted beam throughput



Slatted mirror

0.5 mm glass
300 nm Au

carbon fibre rod support strut
carbon fibre skin honeycomb base



A Practical X-Ray Interferometer Programme

- Demonstrated principle
- Construction and testing of slatted mirror

- Full testing of XRI
- Mission feasibility study