An Aperture Backscatter X-ray Beam Position Monitor at Diamond

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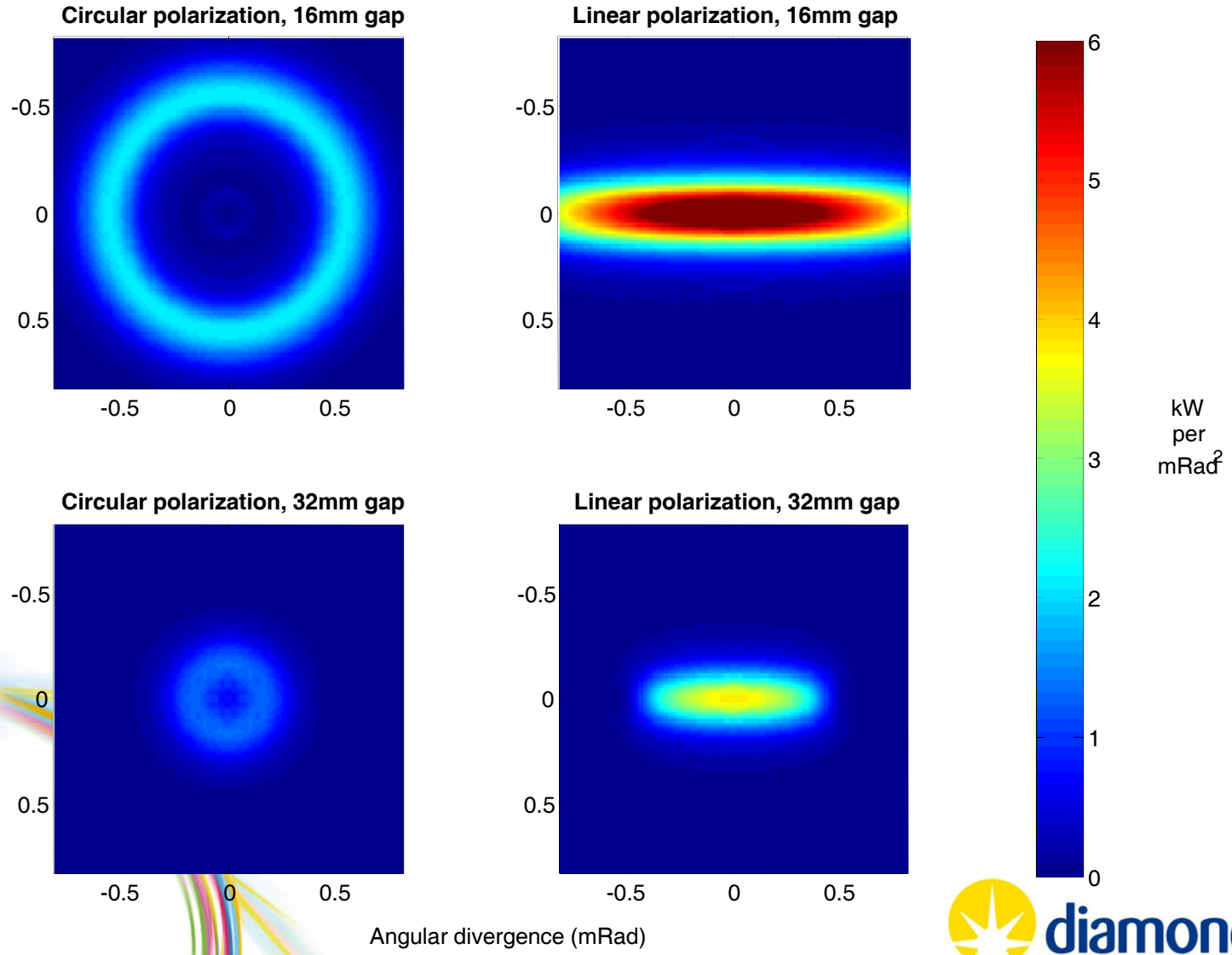
Introduction

- We have designed and commissioned a new prototype XBPM at Diamond, imaging the backscattered radiation from a copper aperture in the Front End.
- This allows us to measure the beam centre of mass, irrespective of beam shape.
- This is of particular interest for Elliptically Polarising Undulators where the profile of the beam varies strongly with change of beam polarisation.
- This solution is capable of operating with the full white beam, and has been designed to fit into the same physical space as the standard front end XBPMs in use at Diamond.

Different beam shapes from I06



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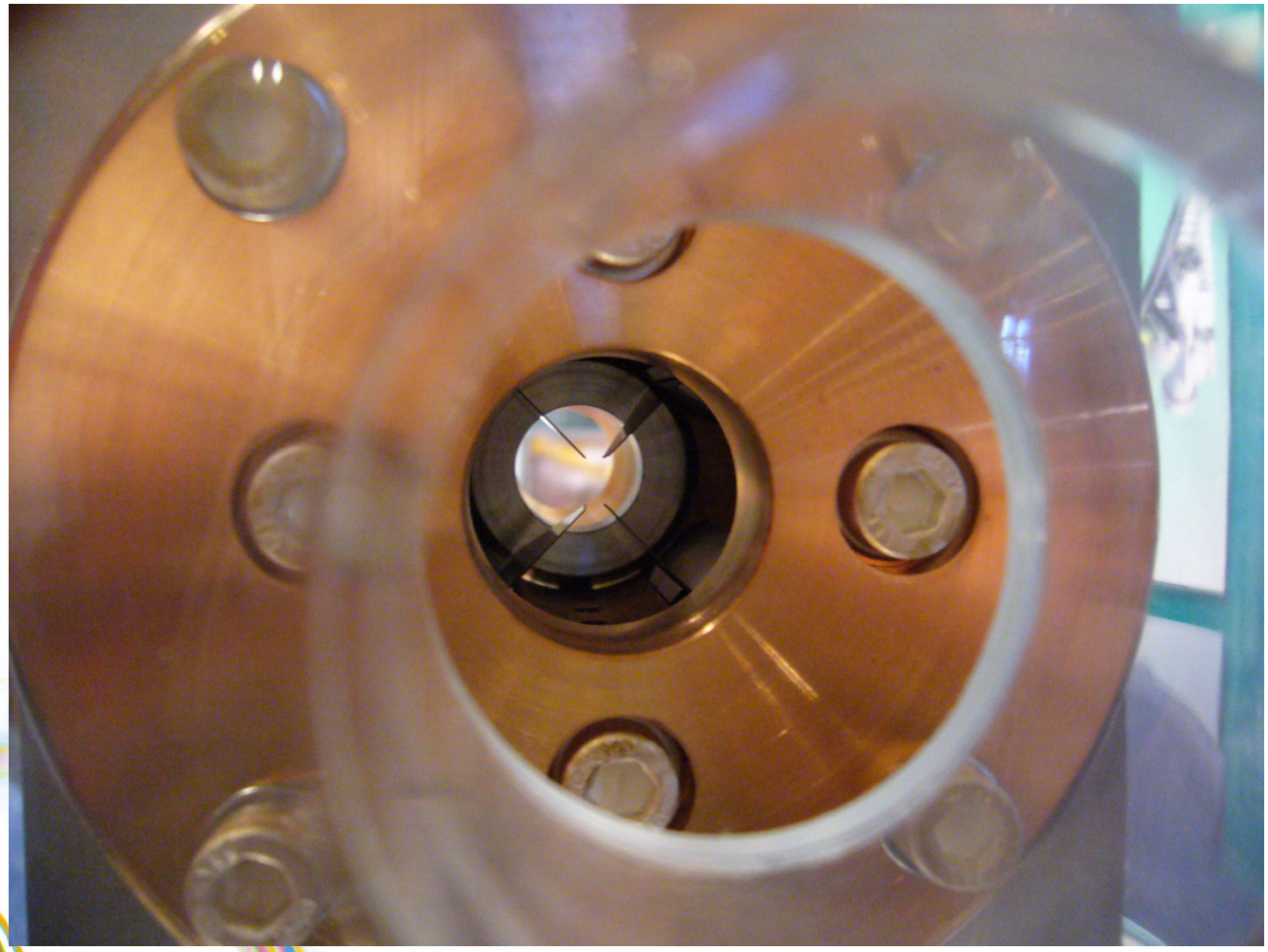
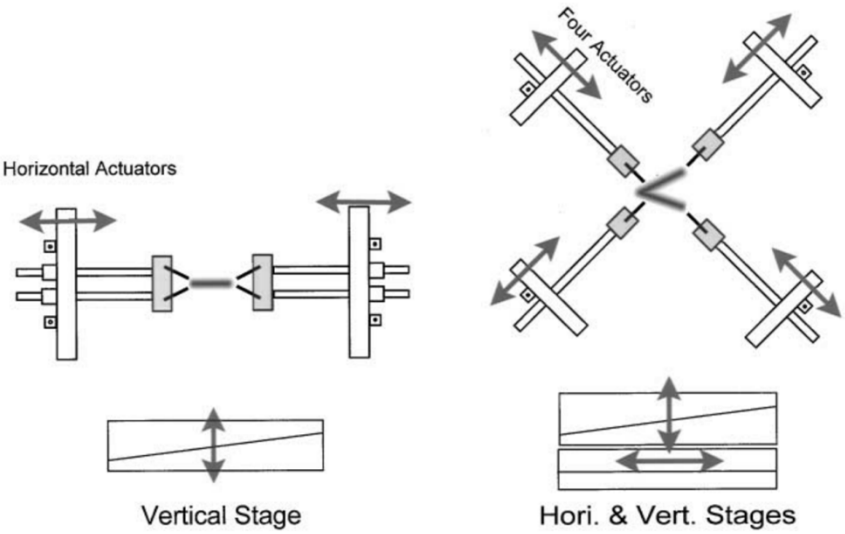
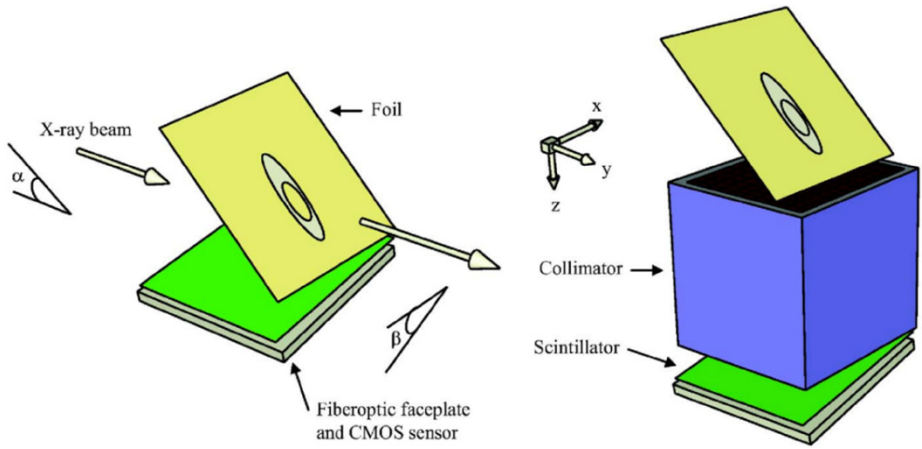
A four vane XBPM



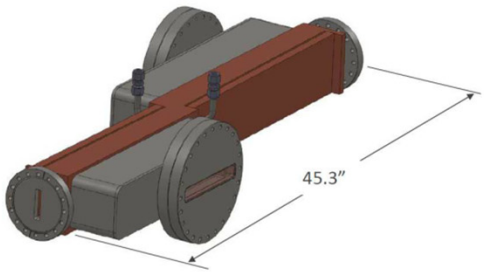
Attempts to profile the X-ray beam

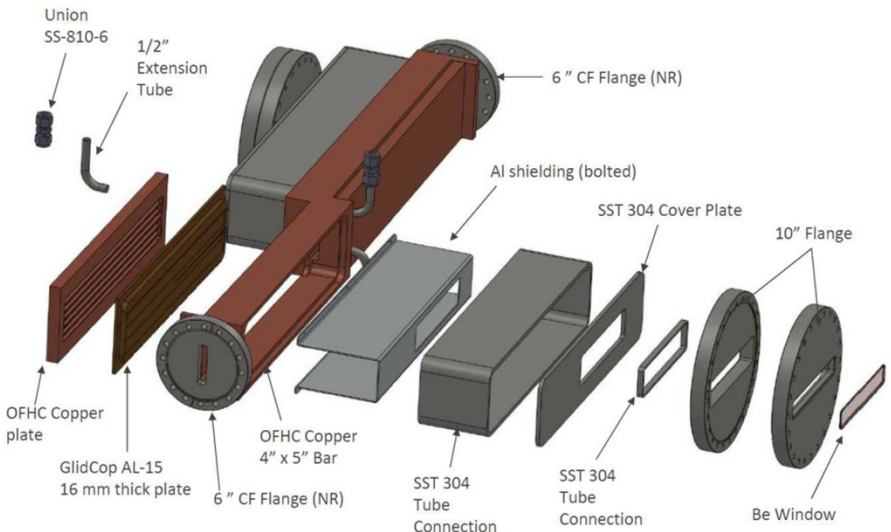


Aoyagi *et al*, SPRing8 (2001)



Kyele *et al*,
The University of Manchester (2007)





Lee *et al*, APS (2010)

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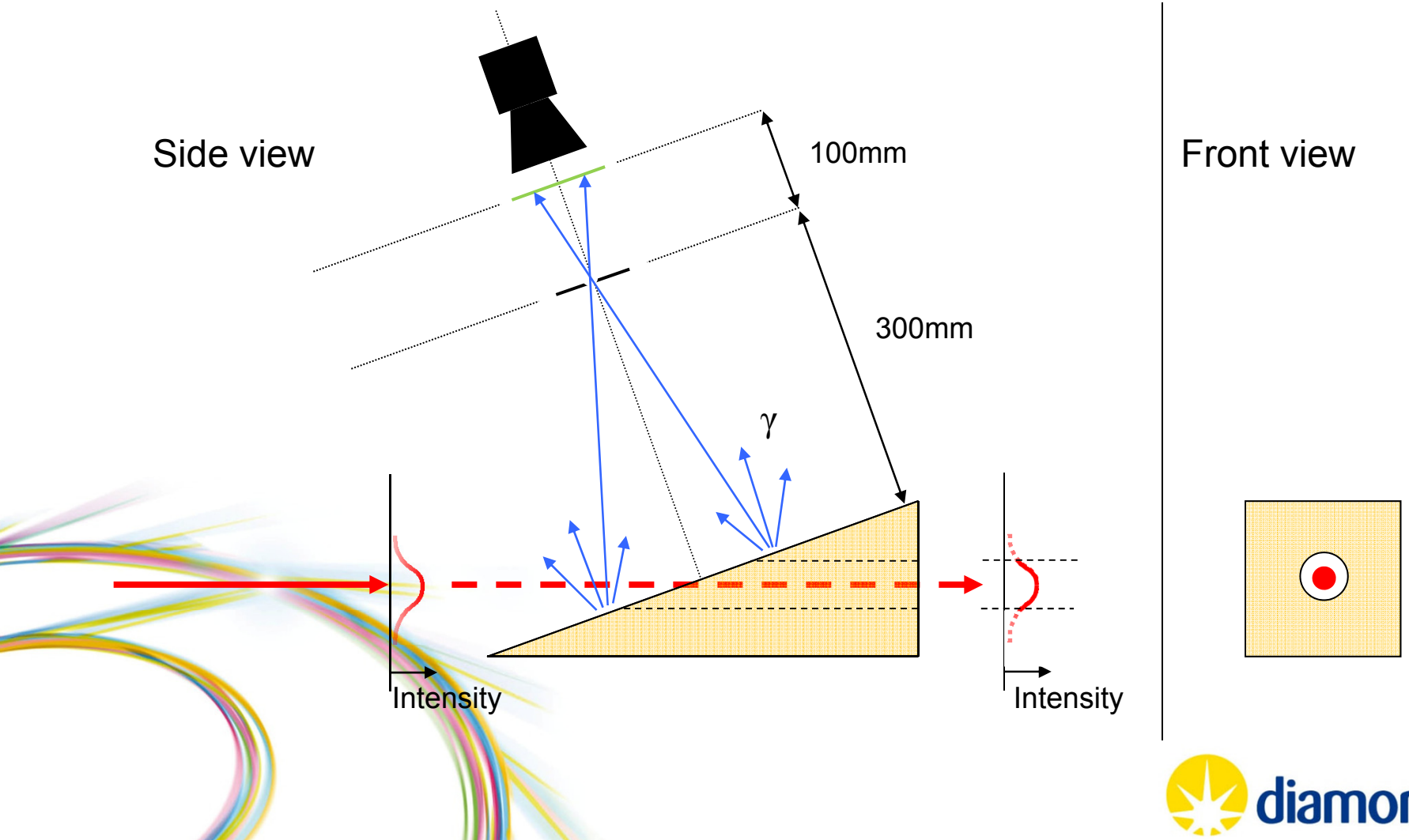
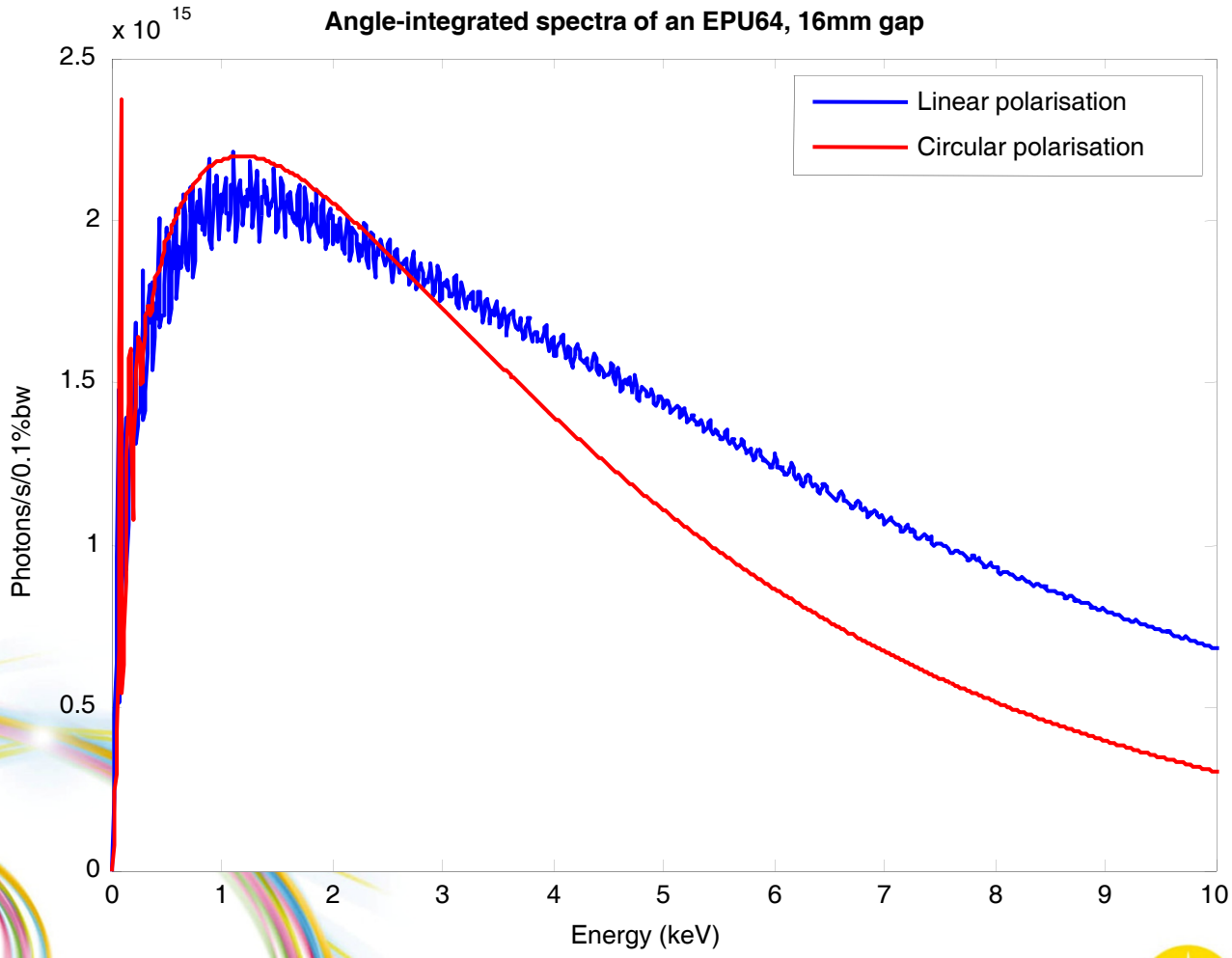
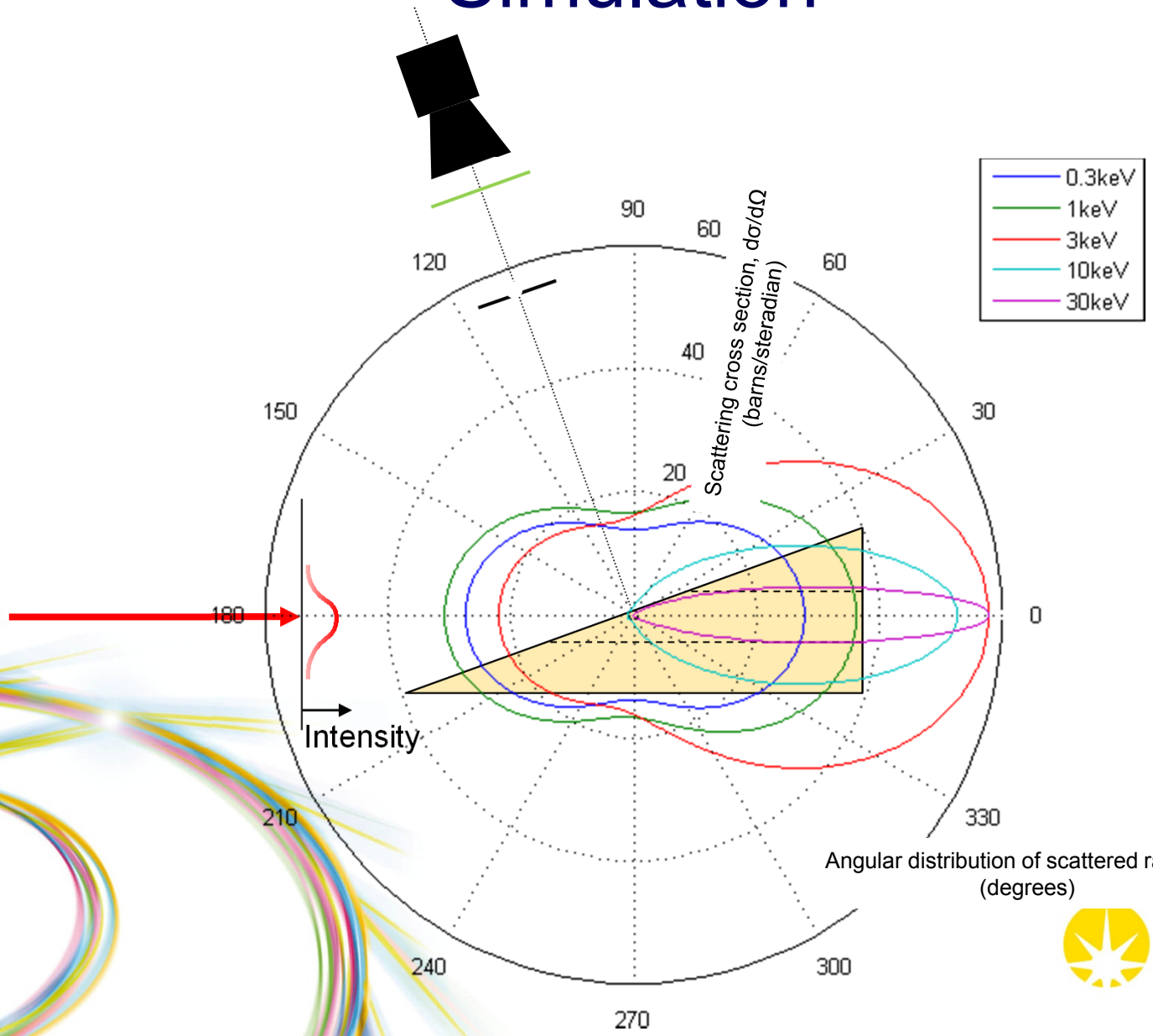
Using Backscatter from a Copper Aperture



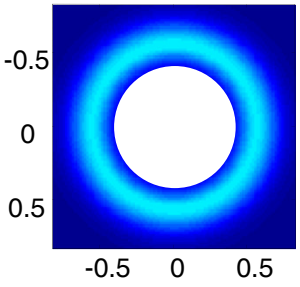
Simulation


Angle-integrated spectra of an EPU64, 16mm gap
x 10 15
Linear polarisation
Circular polarisation
Photons/s/0.1%bw
Energy (keV)
0
0.5
1
1.5
2
2.5
0
1
2
3
4
5
6
7
8
9
10

Simulation

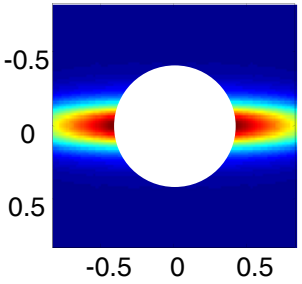

0.3keV
1keV
3keV
10keV
30keV
Scattering cross section, dσ/dΩ
(barns/steradian)
90
60
120
60
40
150
30
20
180
0
Intensity
210
330
240
300
270
Angular distribution of scattered radiation
(degrees)

Design



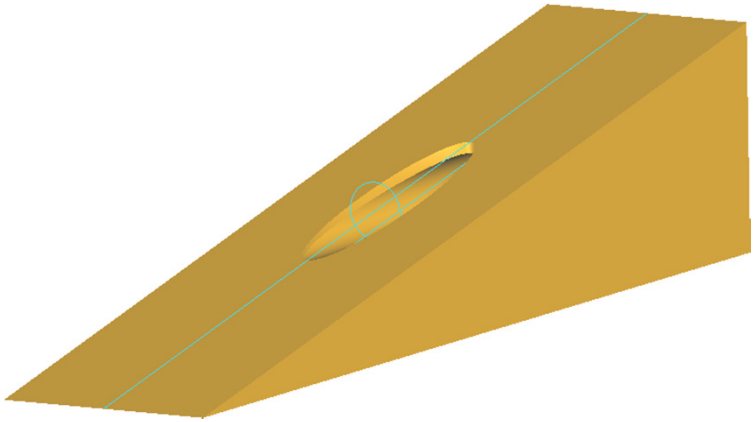
Circular polarisation

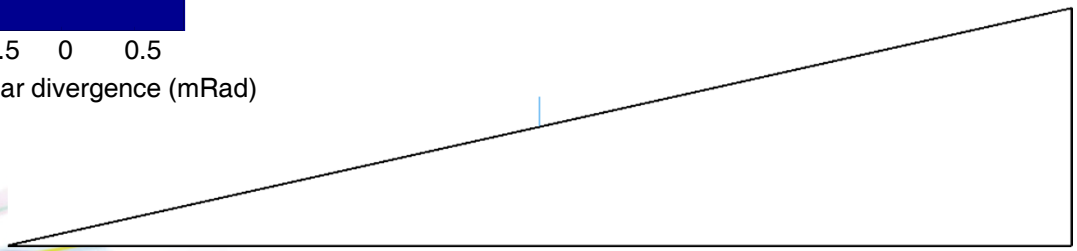
Power striking aperture = 1.97kW

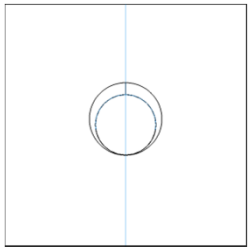


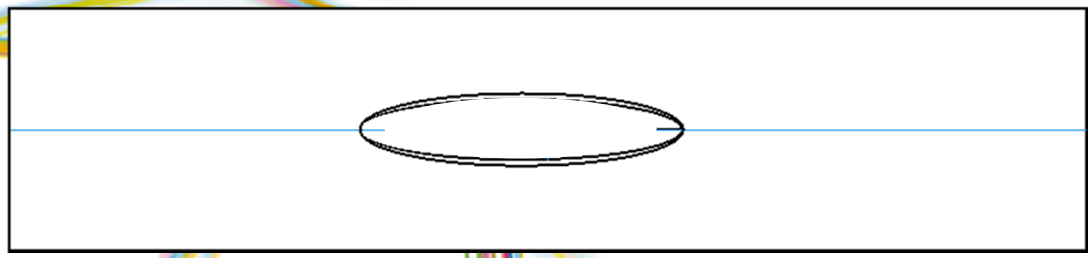
Linear polarisation

Power striking aperture = 1.28kW

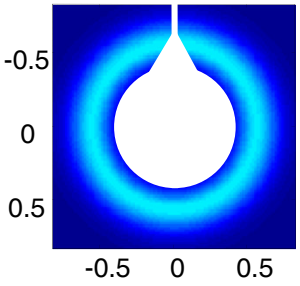






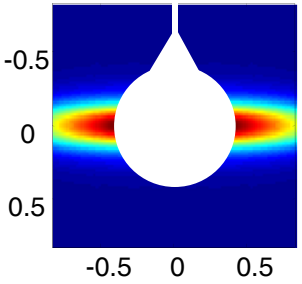


Design



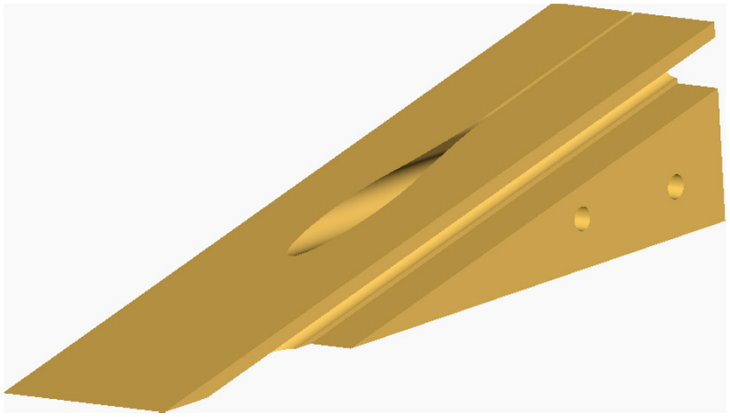
Circular polarisation

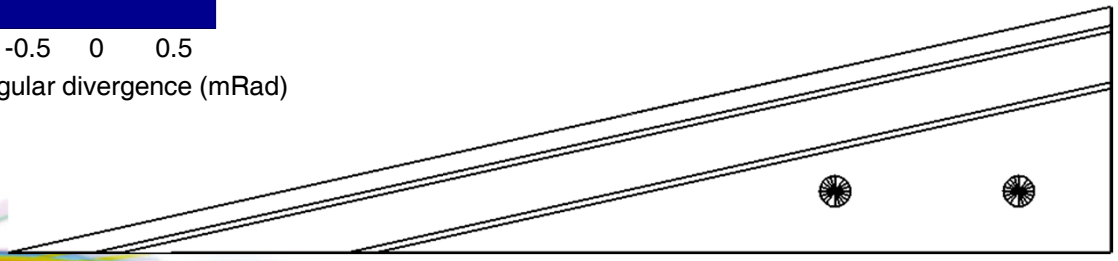
Power striking aperture = 1.91kW

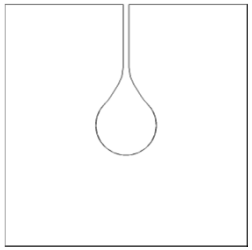


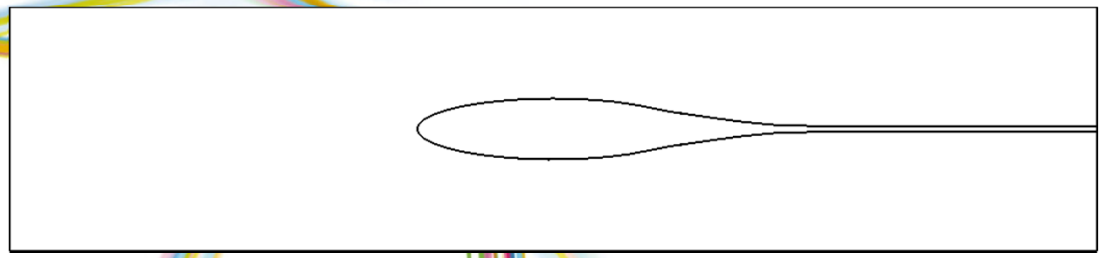
Linear polarisation

Power striking aperture = 1.27kW

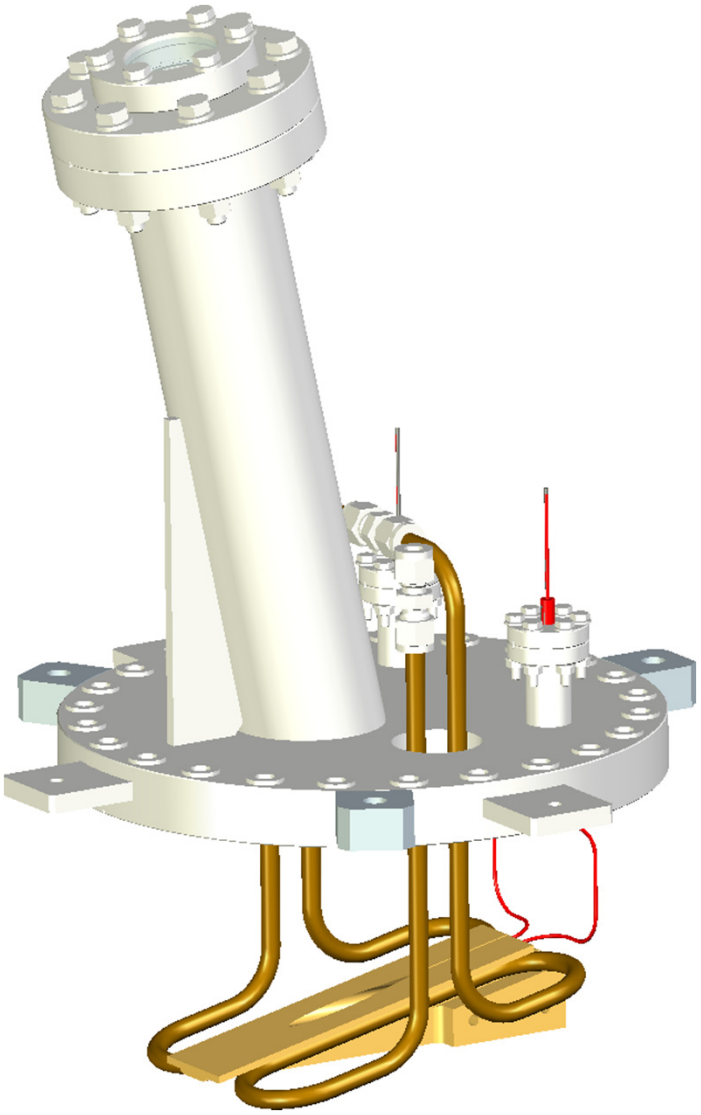


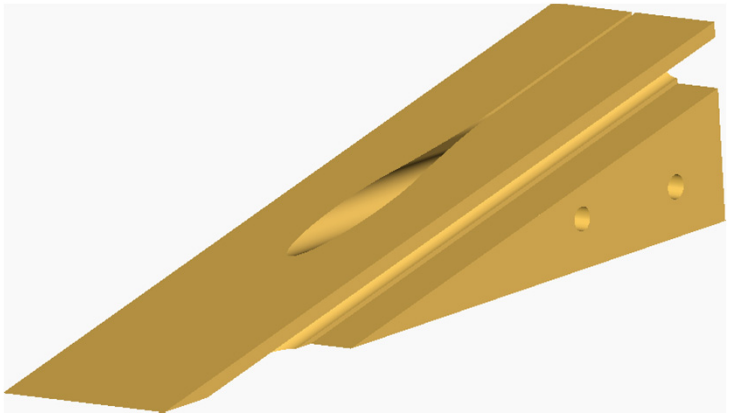




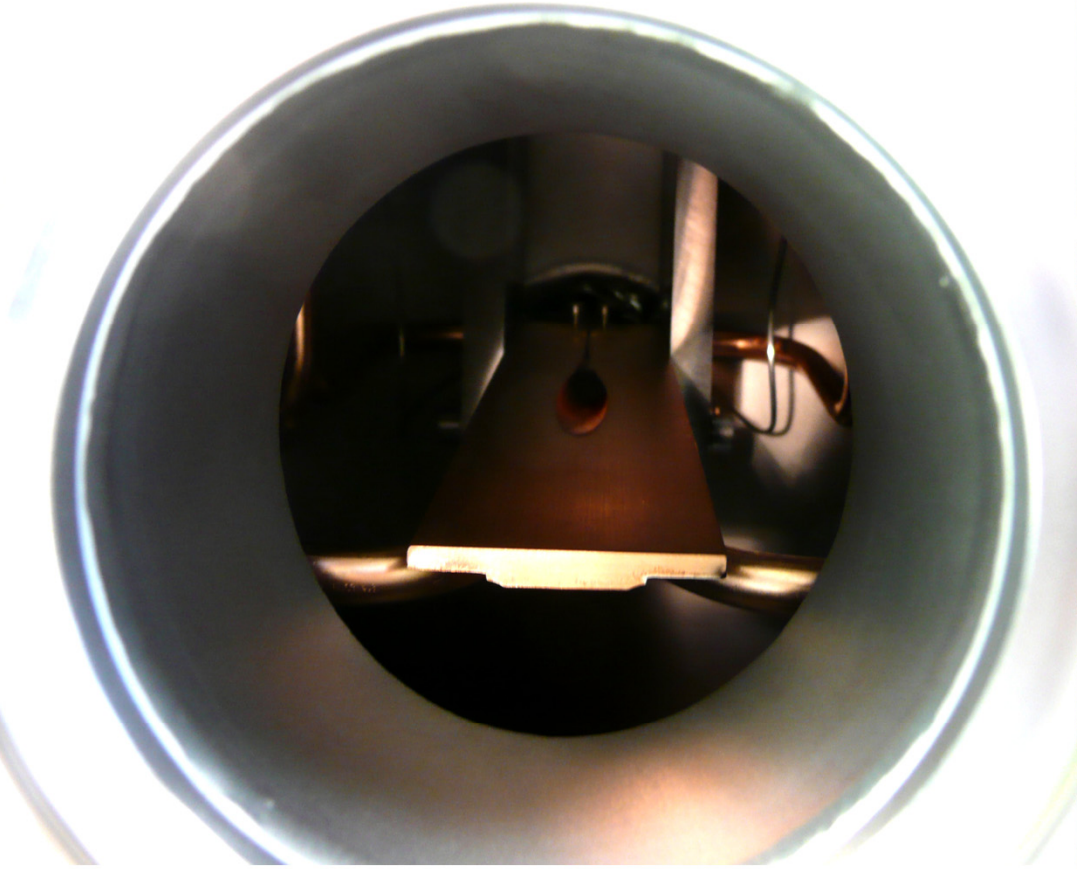


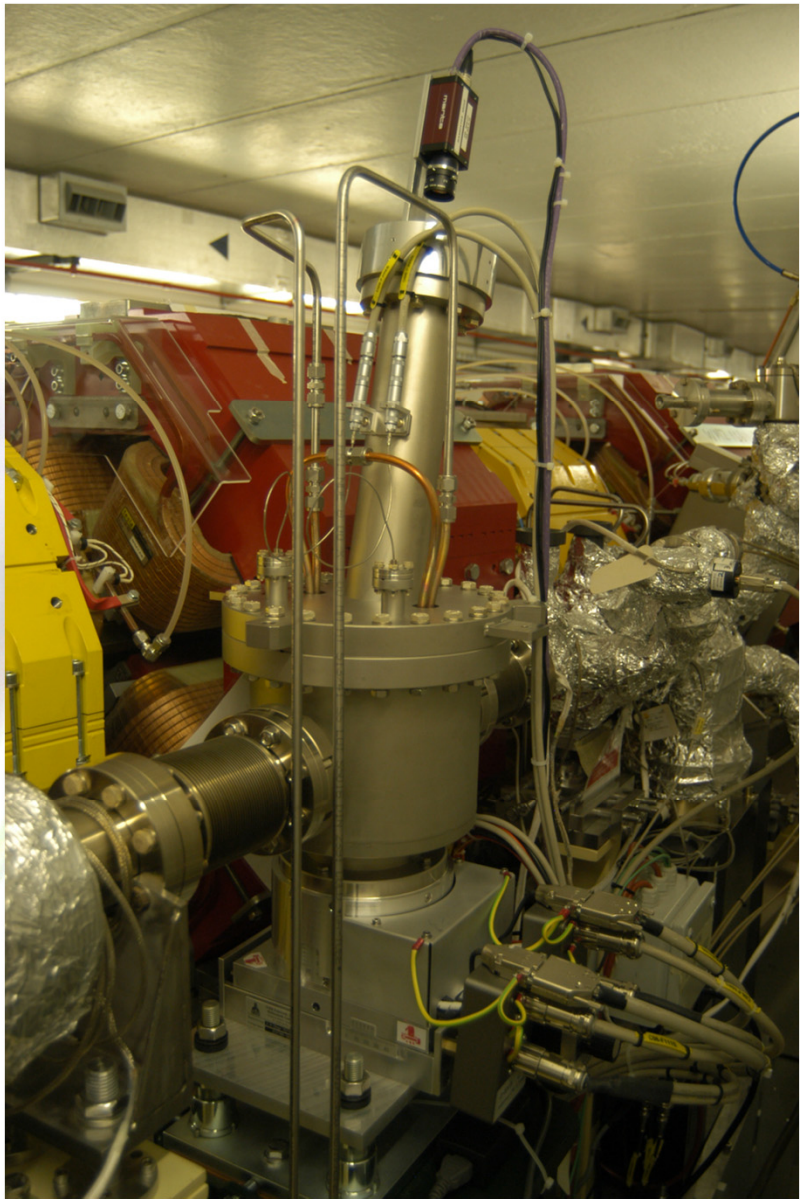
Design



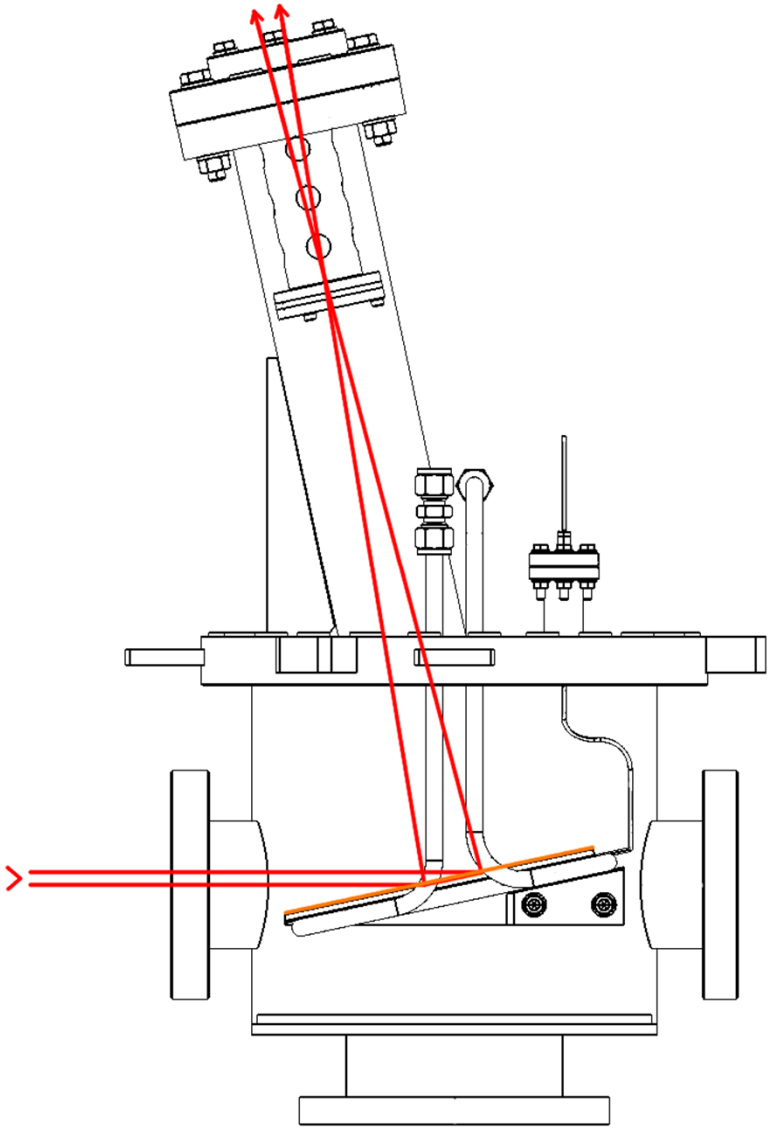


Design

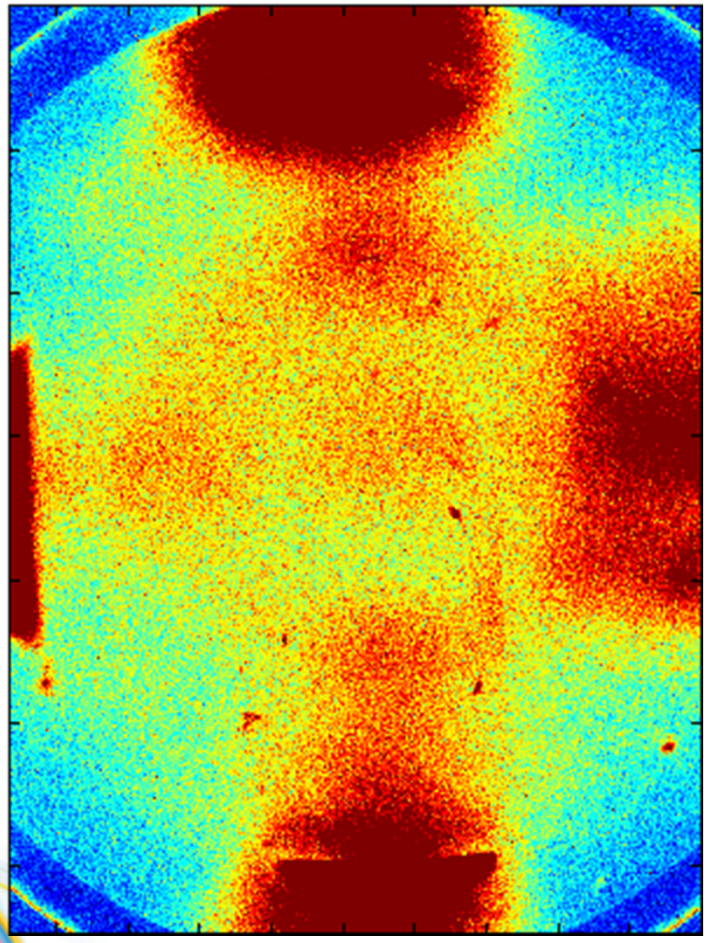




Design

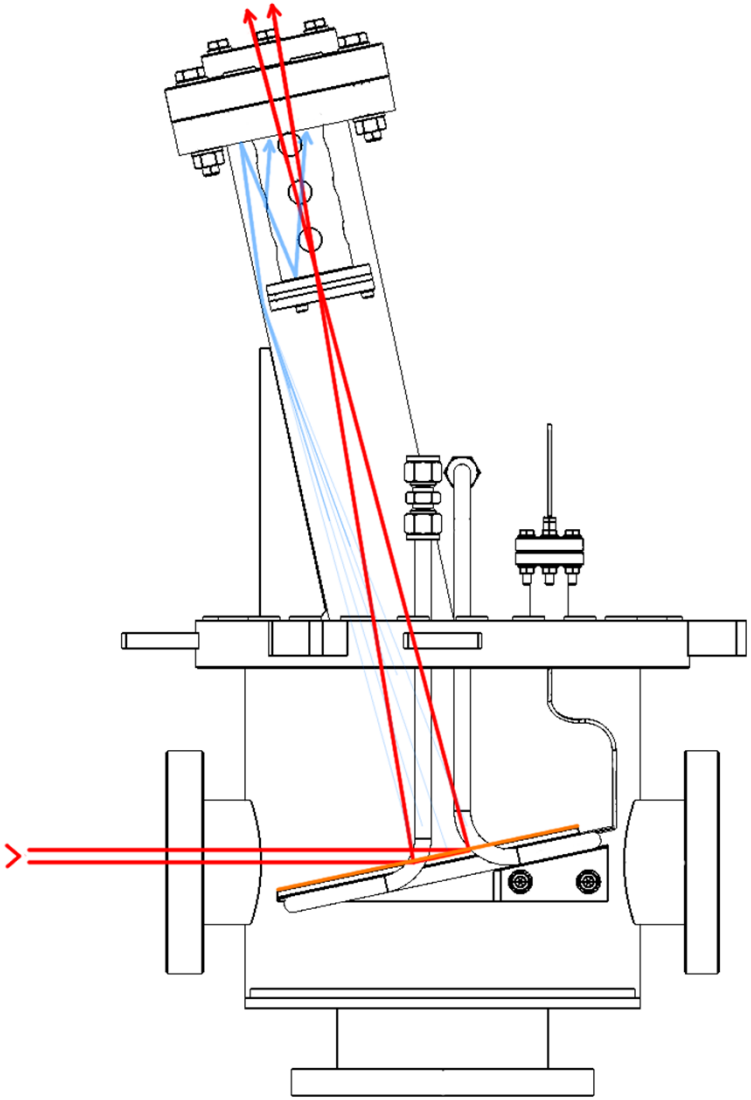


First Results

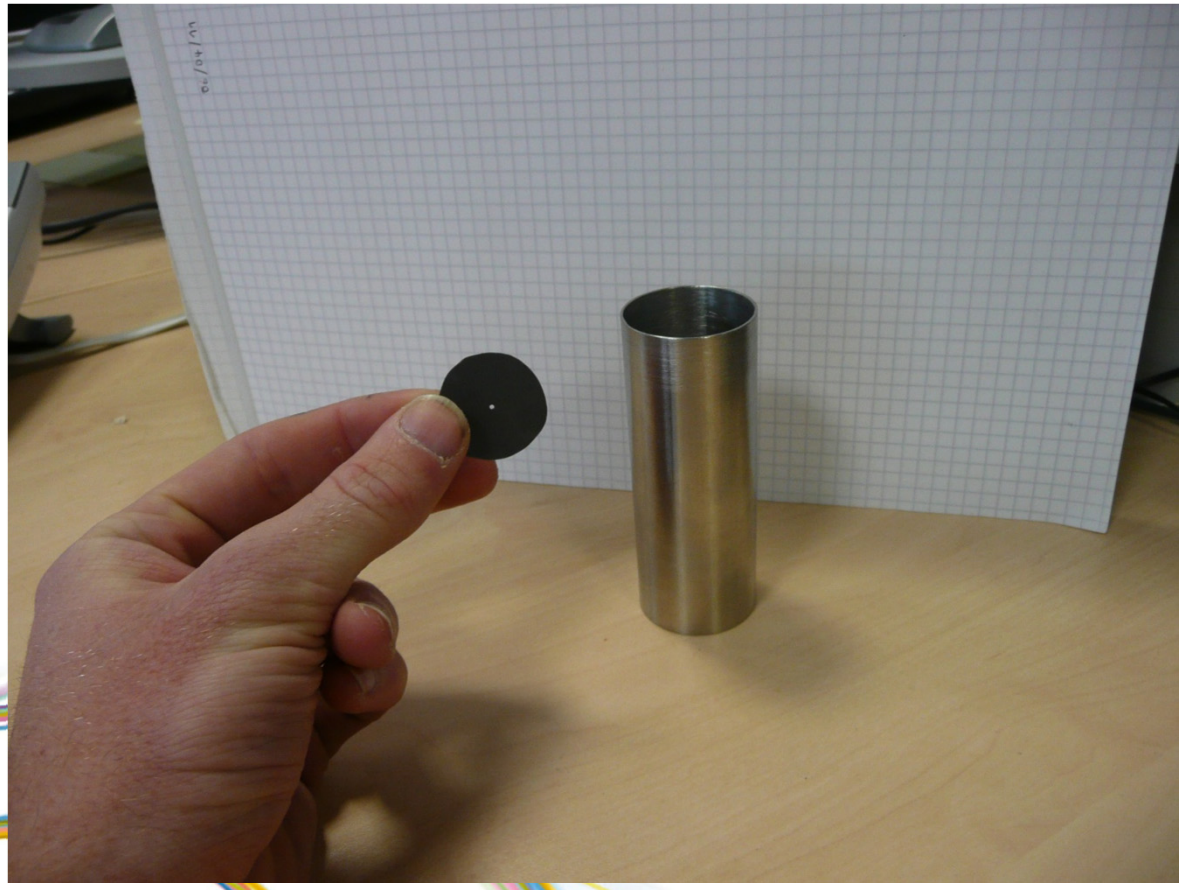


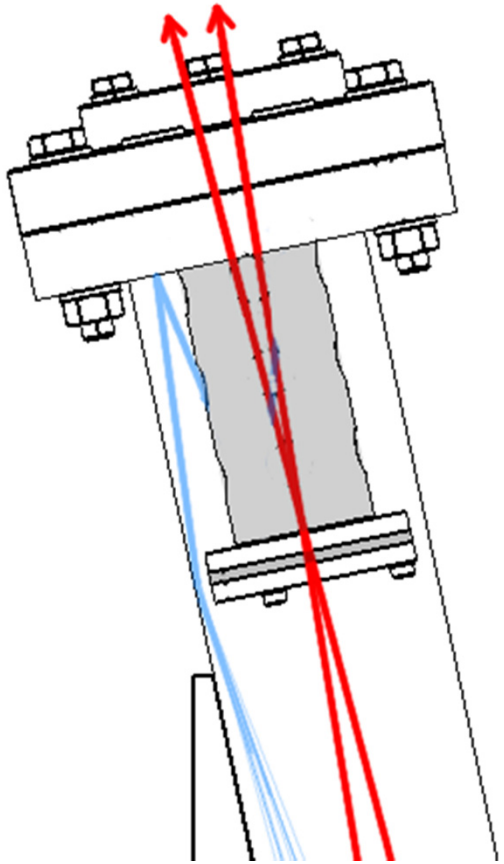
(Failure!)

Visible light leaking in

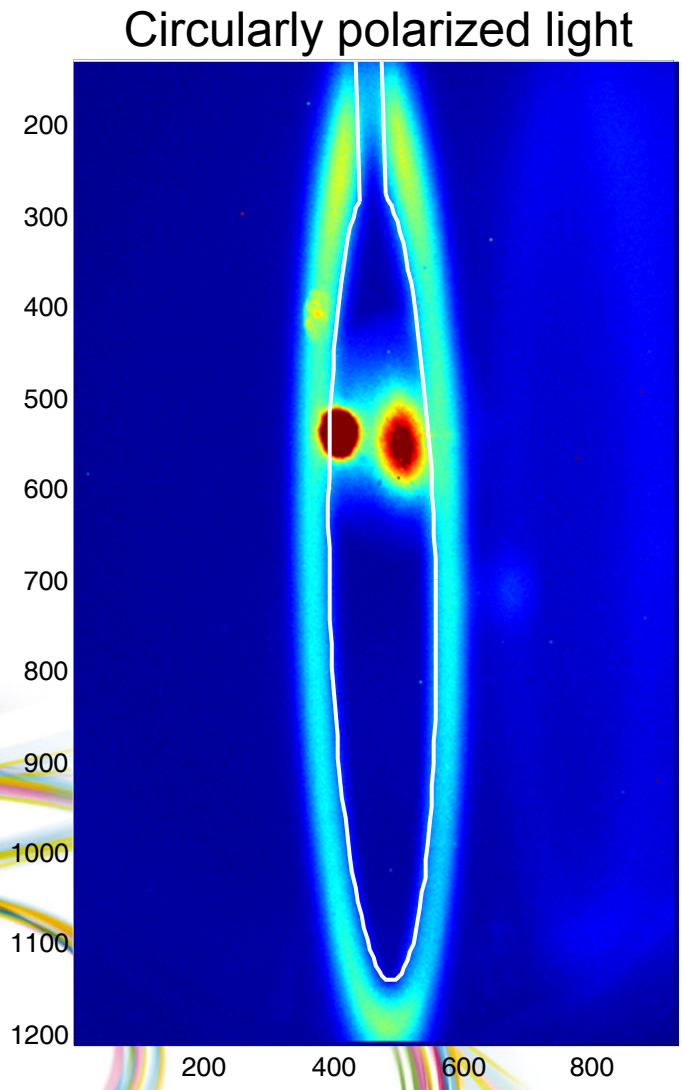


Modification





Results



- The image is elongated by a ratio of 1:5, corresponding to the slope of the aperture.
- Two very bright spots appear in the centre, almost certainly an out-of-focus image of the pinhole itself, and a reflection.
- The shape of the EPU beam can clearly be seen though.

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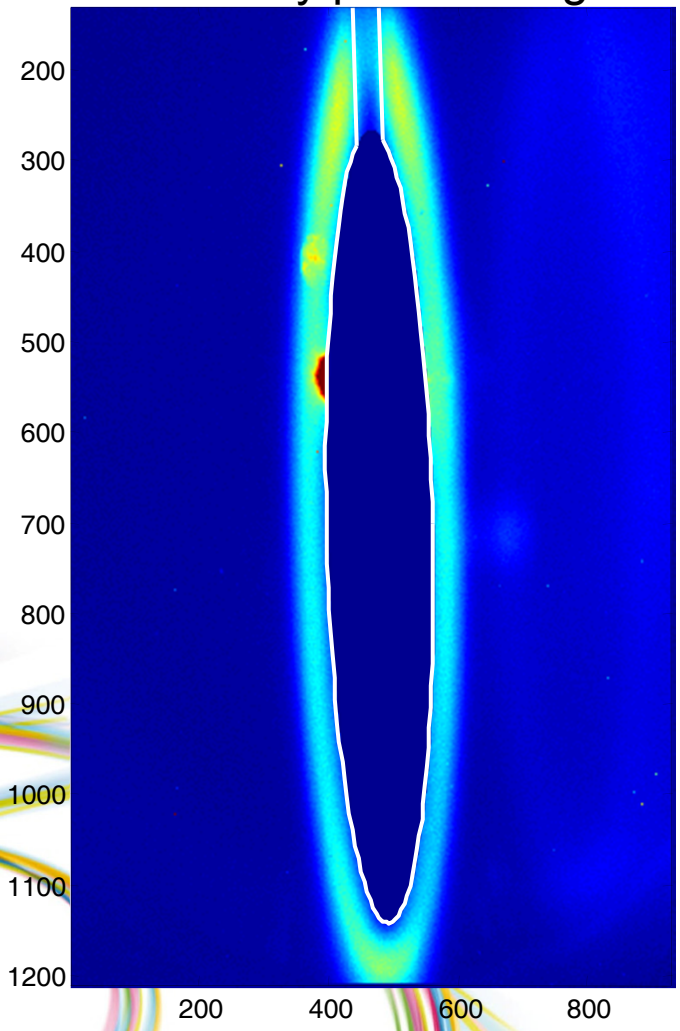
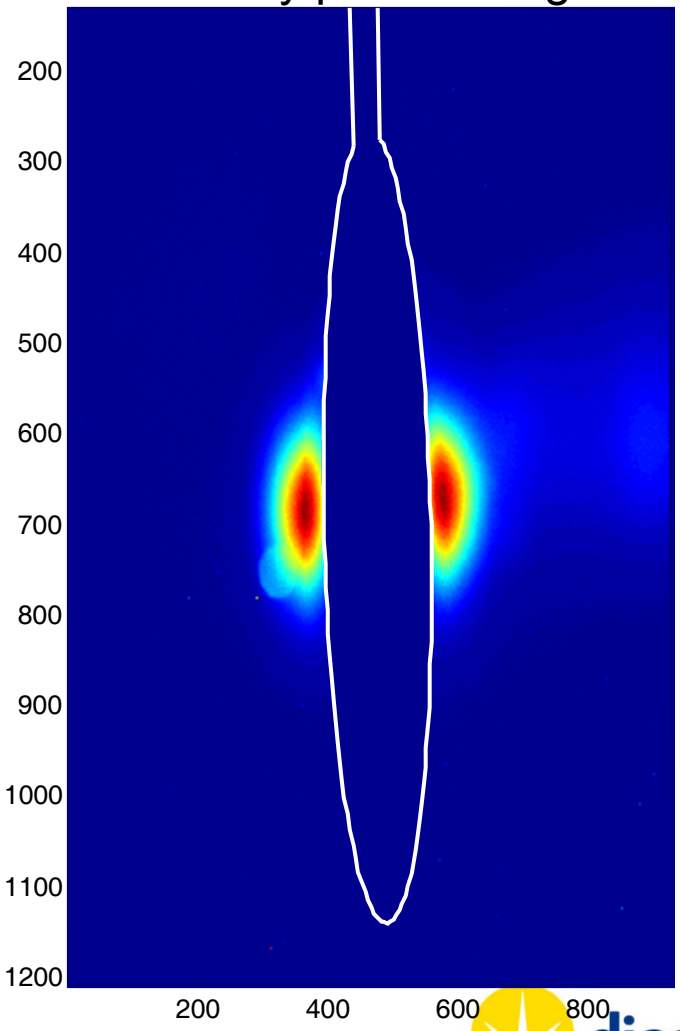
Results

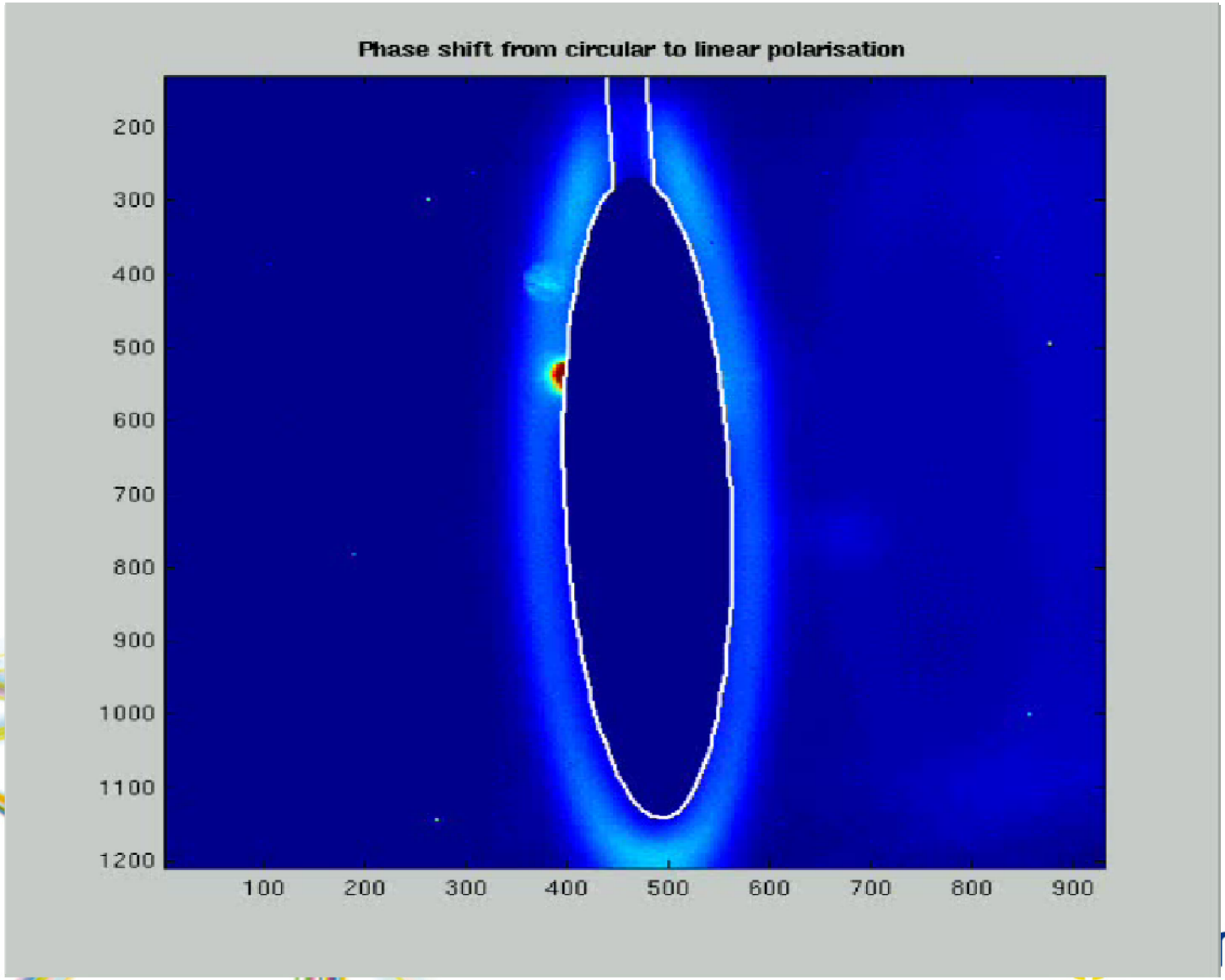
Circularly polarized light



Linearly polarized light

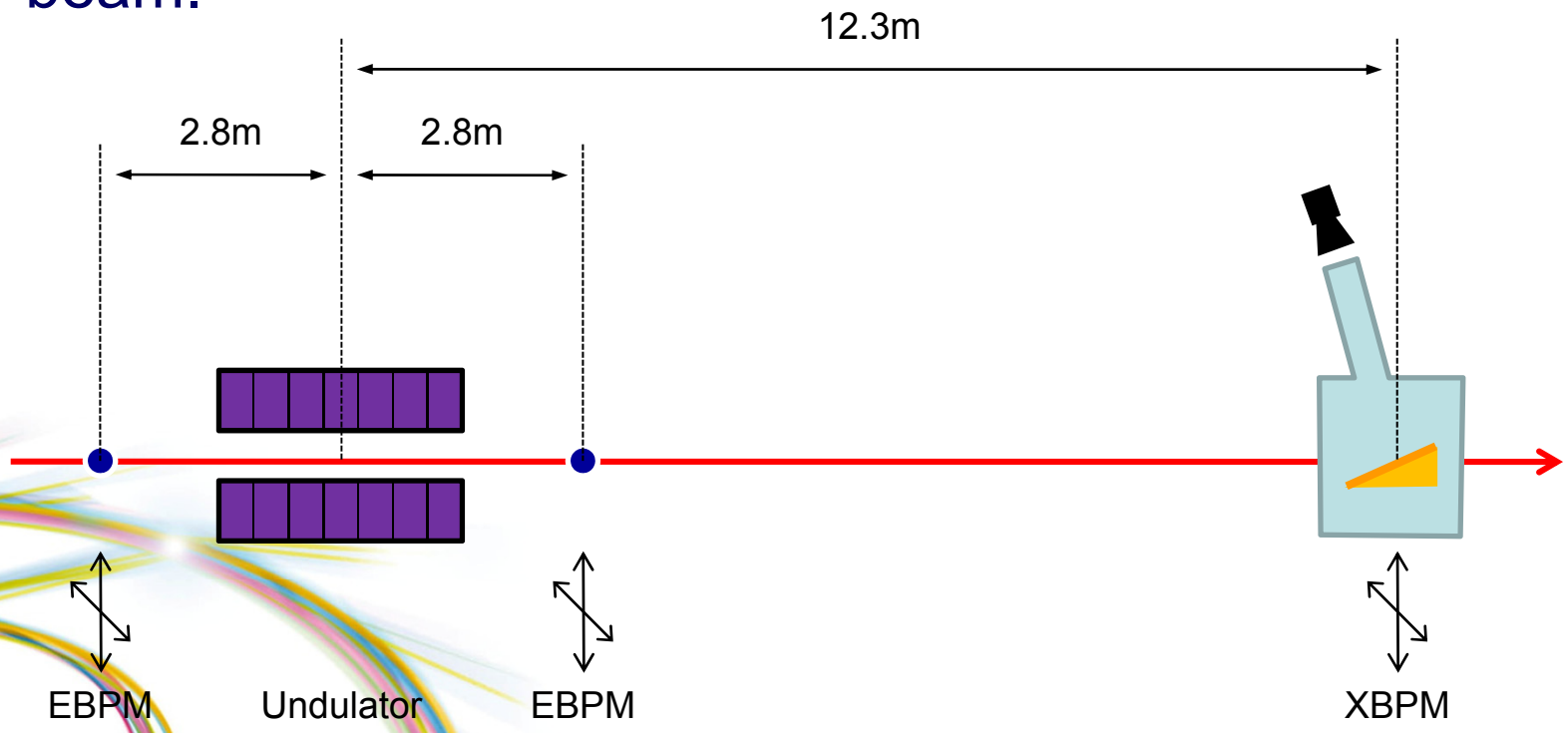


diamond

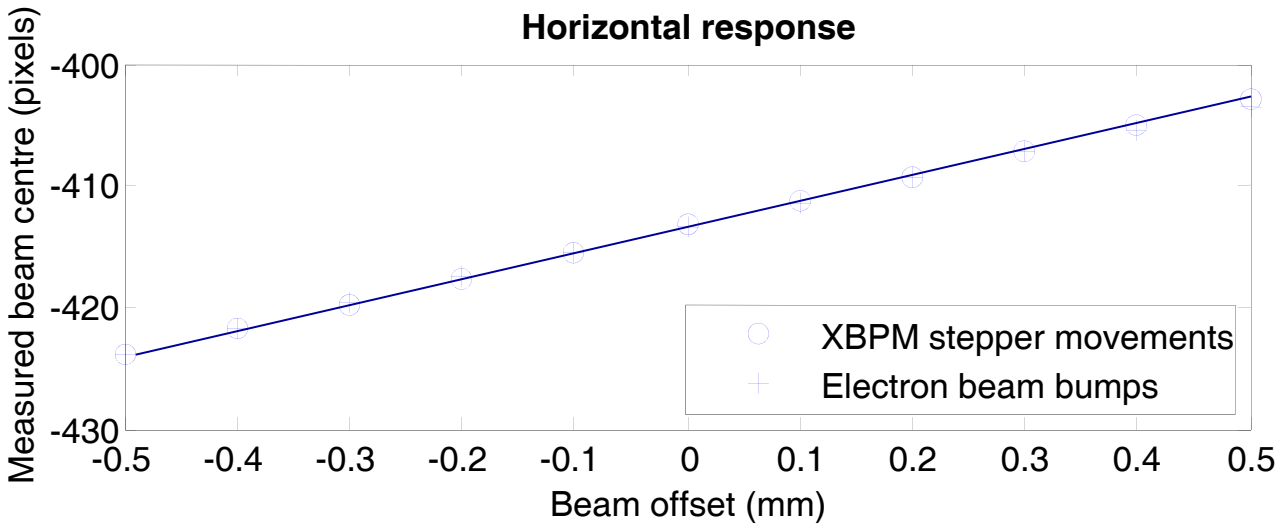

Phase shift from circular to linear polarisation
200
300
400
500
600
700
800
900
1000
1100
1200
100
200
300
400
500
600
700
800
900

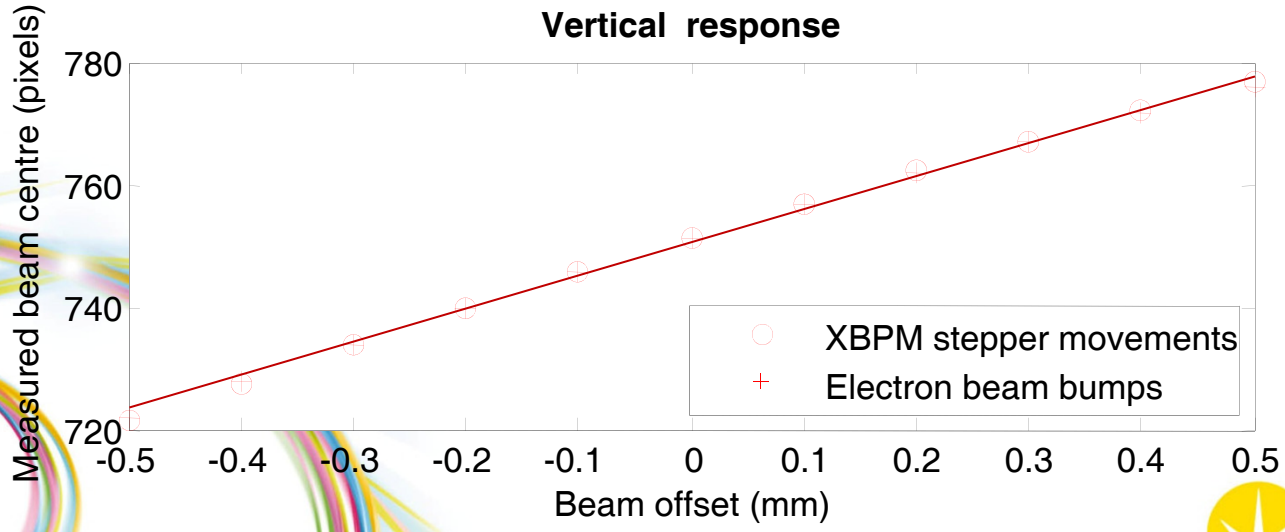
The Beamline Layout

- The EBPMs can be used to steer the X-ray beam.
- The XBPM stepper motor can be used to offset the beam.



Results





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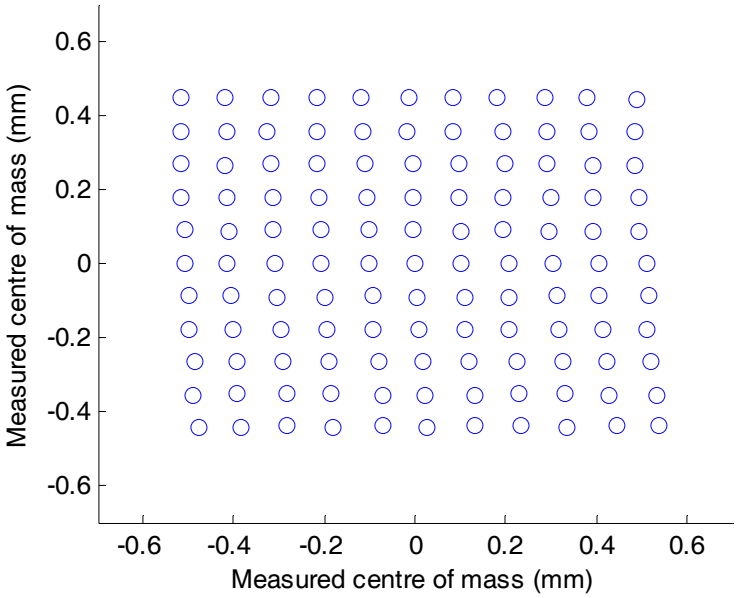
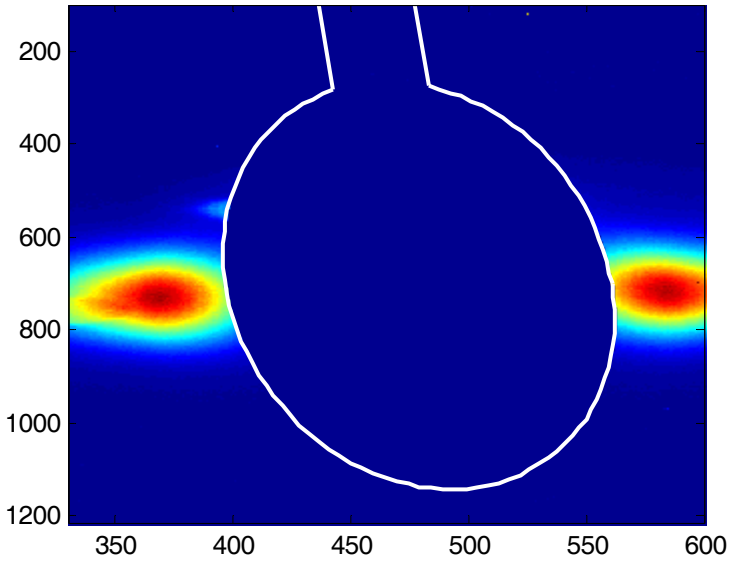
Results

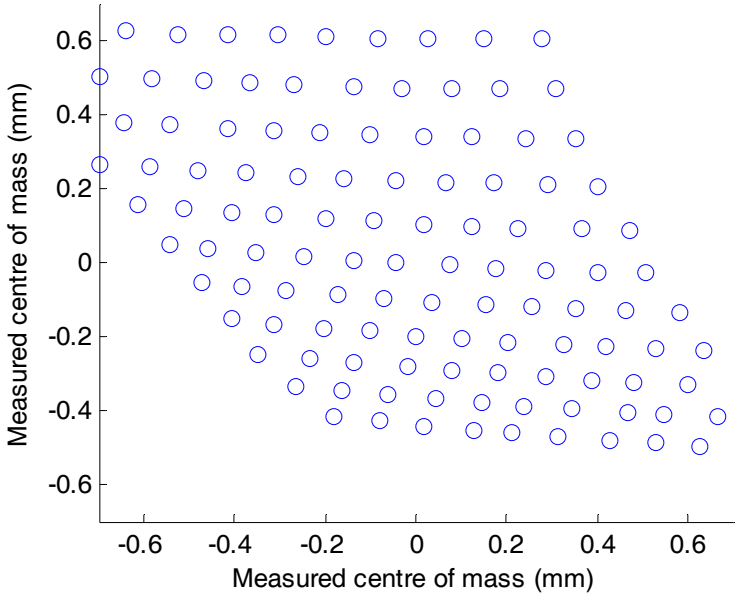
Linear polarisation, 16mm gap

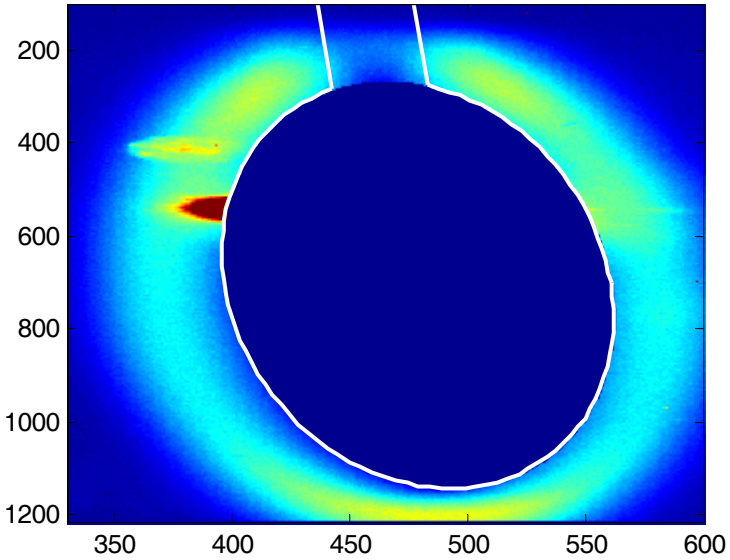




Results

Circular polarisation, 16mm gap





Further Improvements

- The 10mm diameter central aperture used to allow user photons through could be significantly reduced in size, increasing the scattering area and increasing the number of detected photons.
- At the moment >1.0s integration time is needed. This is sufficient to monitor slow drifts, but not fast enough to monitor beam vibrations. A larger lens or more sensitive detector could help improve this.
- Aluminium foil could be used with the fluorescent screen to block visible light from reaching the camera.

Conclusions

- Compared to tungsten vane XBPMs the spatial resolution afforded by this monitor provides far more information about the photon beam distribution.
- The in-vacuum pinhole design with an out-of-vacuum detector is a very simple solution compared to other monitors that use in-vacuum detectors.
- The size of the XBPM and its simplicity make it an excellent substitution for Front Ends where existing XBPMs have so far been unsuitable.

Acknowledgements

Richard Smith for the initial drawings

Callum Ide for the aperture design

FMB for the manufacture of the XBPM

And the Diamond Vacuum group for their patience and interventions!