Spatial Resolution of an X-ray Pinhole Camera using a Multi-layer Monochromator

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ABSTRACT

X-ray pinhole cameras are widely used for beam emittance monitoring at synchrotron light sources. Due to the reduction in beam emittance expected for the many fourth generation machine upgrades, the spatial resolution of the pinhole camera must be improved accordingly. It is well known that there are many contributions to the point spread function. However, a significant contribution arises from diffraction by the pinhole aperture. Given that diffraction is dependent on the spectral distribution of the incident synchrotron radiation, the spatial resolution can be improved by using a monochromatic beam. For optimal performance, the photon energy should be matched to the pinhole aperture size. Here we investigate the spatial resolution of the pinhole camera as a function of photon energy using a multi-layer monochromator.

X-RAY PINHOLE CAMERAS AT DIAMOND

Table 1: X-ray pinhole camera systems at Diamond.

PINHOLE CAMERA	DESCRIPTION
1	Used in the vertical emittance feedback system.
2	
3	Used for research and development.

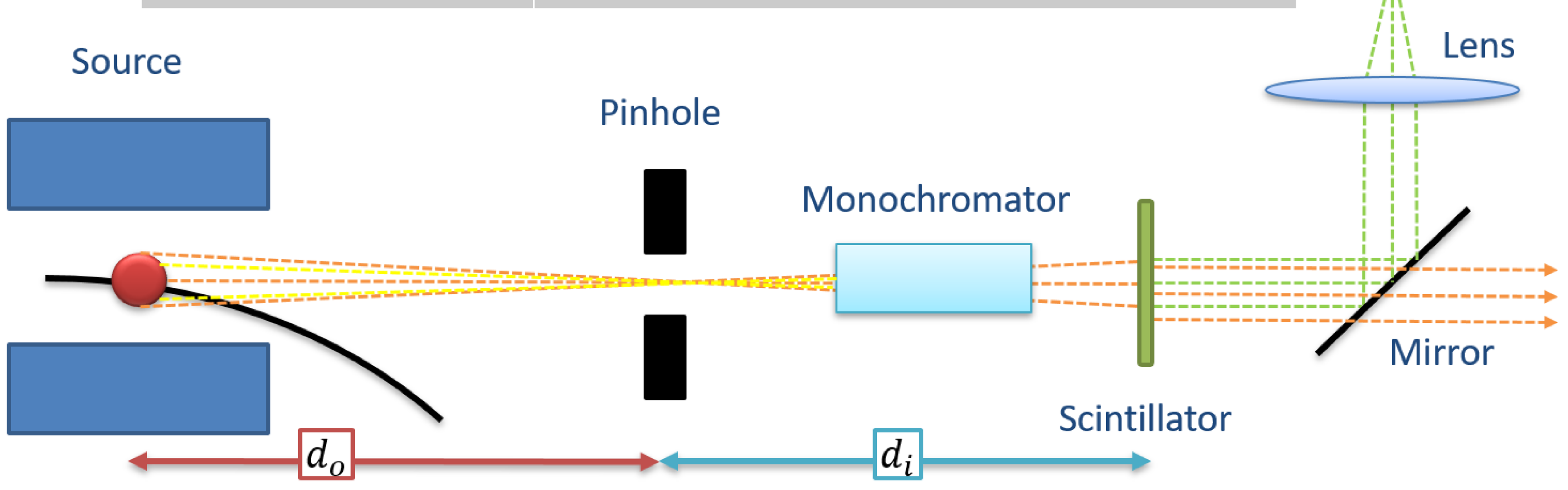


Figure 1: Schematic of the monochromatic X-ray pinhole camera system.

MULTILAYER MONOCHROMATOR

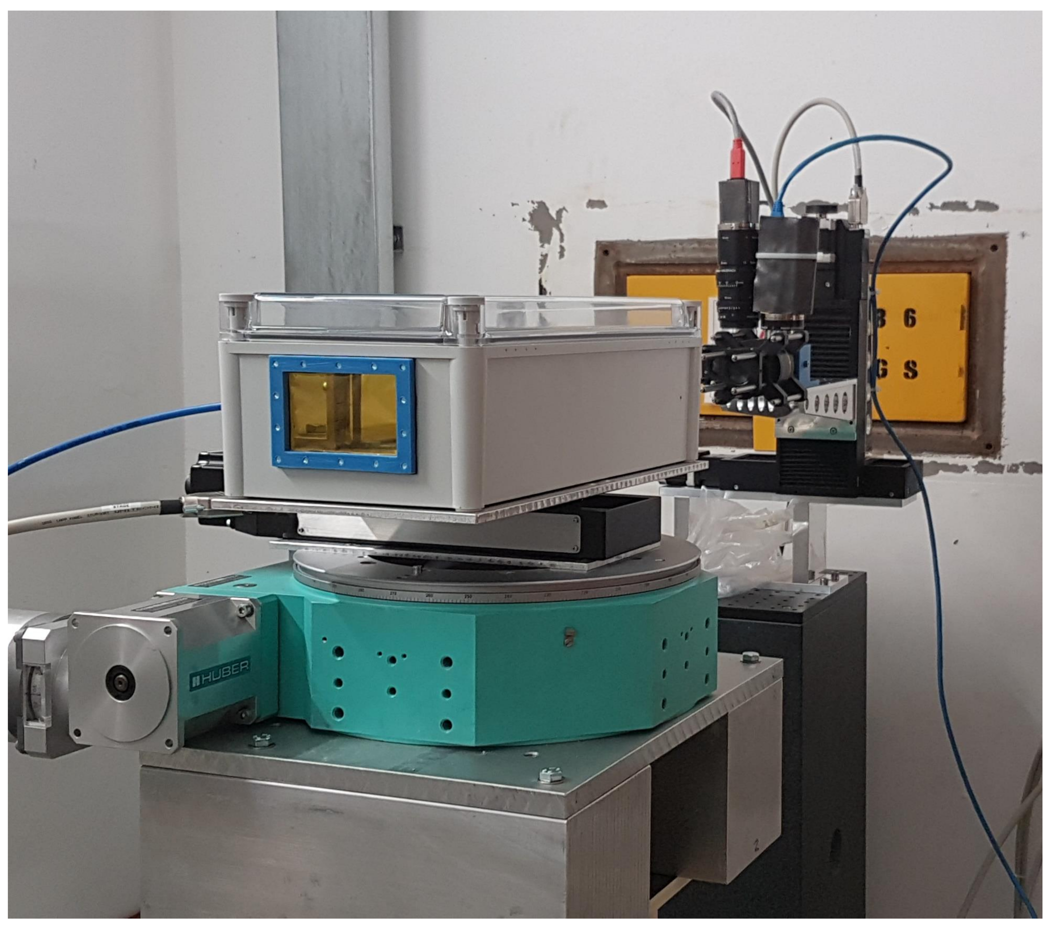


Figure 2: Photograph of the monochromator.

Mo/Si on float glass substrate

300 mm x 50 mm

4.8 nm d-spacing

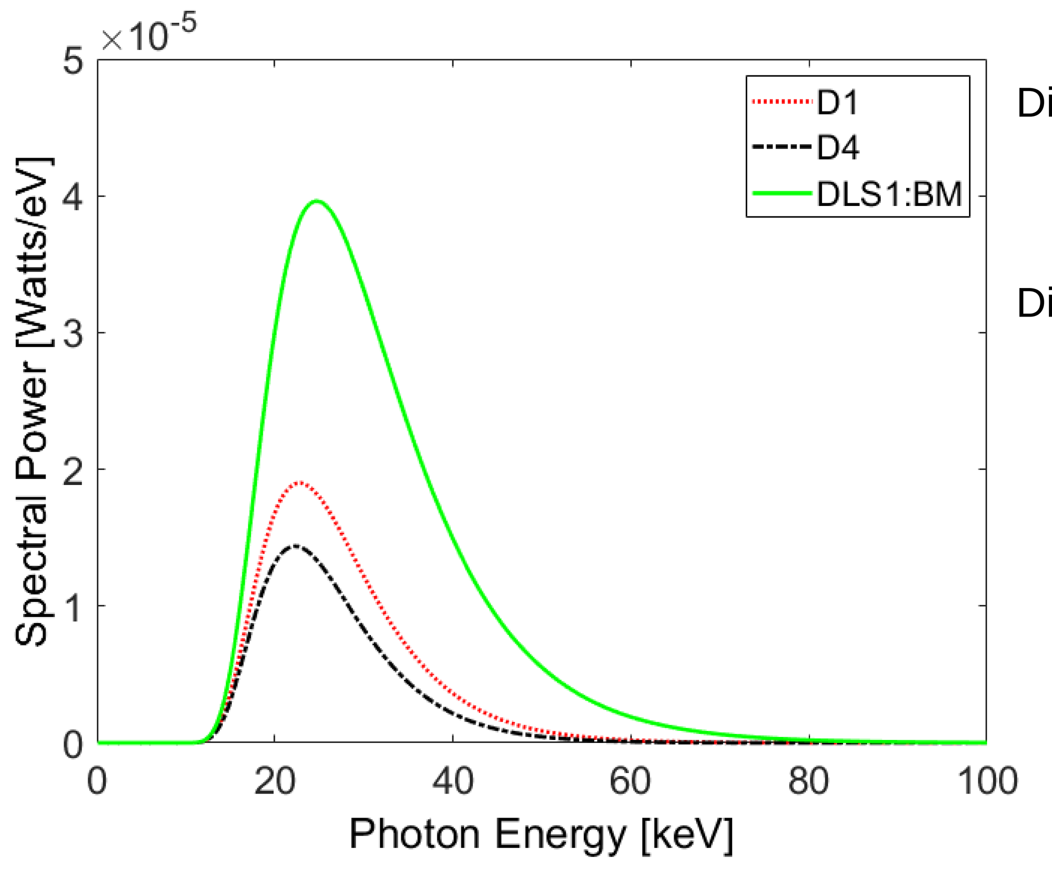
Bandwidth $\frac{\Delta E}{E} \approx 2\%$

Remote translation in/out of beam

Remote rotation to select photon energy

Calibration using 0.1 mm Mo (k-edge is 20 keV).

SYNCHROTRON RADIATION SOURCEPOINTS IN DIAMOND-II

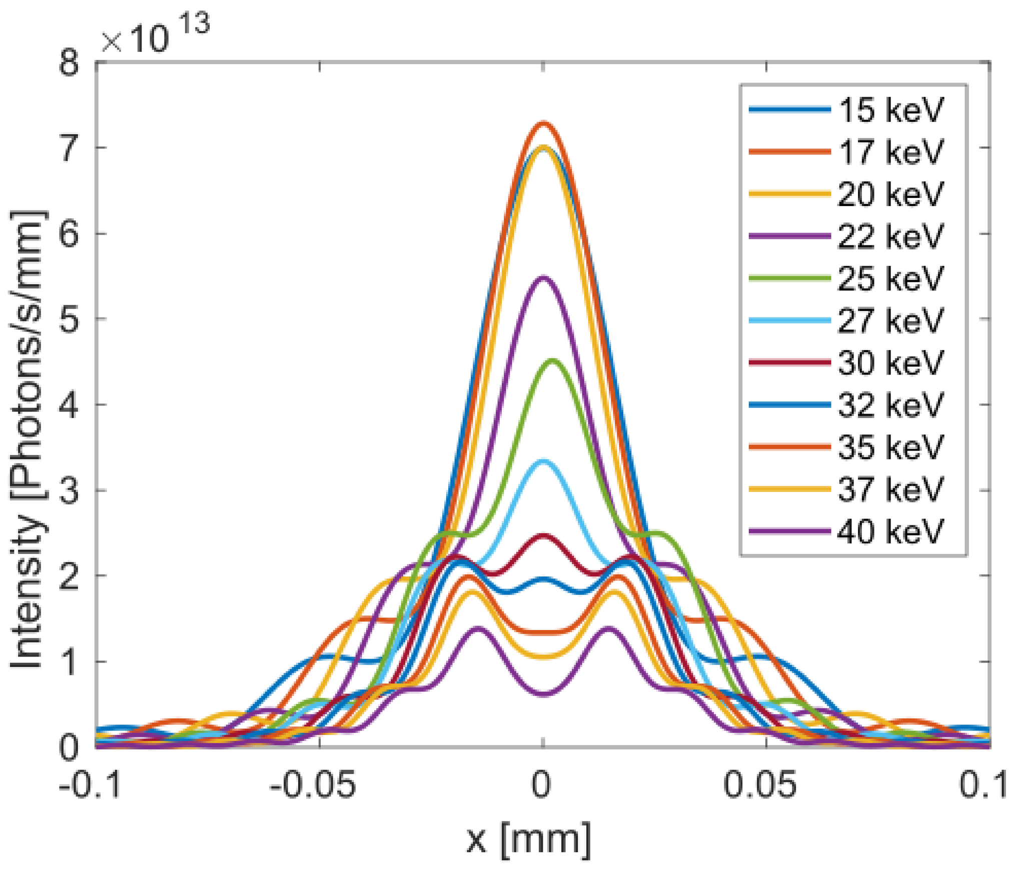


Diamond-I :
E = 3 GeV
B = 1.4 T

Diamond-II [1]:
E = 3.5 GeV
B_{D1} = 0.76 T
B_{D4} = 0.70 T

Figure 3: Comparison of the spectral power distributions using XOP, after 1mm aluminium and 10m air, of the bending magnet source points of Diamond-II (D1 and D4) with Diamond-I (DLS1:BM).

POINT SPREAD FUNCTION SIMULATION



The point spread function (PSF) from each optical element is assumed to be Gaussian such that the overall PSF is [2,3]:

$$\sigma_{PSF}^2 = \sigma_{pinhole}^2 + \sigma_{camera}^2 \quad (1)$$

with

$$\sigma_{pinhole}^2 = \sigma_{diffraction}^2 + \sigma_{aperture}^2 \quad (2)$$

and

$$\sigma_{camera}^2 = \sigma_{screen}^2 + \sigma_{lens}^2 + \sigma_{sensor}^2 \quad (3)$$

Figure 4: SRW simulation of the vertical PSF from a 25 µm pinhole aperture for different photon energies. This simulation does not include the attenuation of the X-rays from the 1 mm aluminium window and 10 m air.

RESULTS

The PSF of the X-ray pinhole camera is calibrated using the Touschek lifetime for white beam [4]. The true vertical beam size at the scintillator screen was measured as 30.1 µm. From knife-edge measurements the PSF from the scintillator screen, lens and camera is 8 µm. With the Gaussian approximation and using the SRW simulations, the simulated vertical beam size at the scintillator screen is

$$\sigma_{Meas\_simulation}^2 = \sigma_{true}^2 + \sigma_{camera}^2 + \sigma_{pinhole\_SRW}^2 \quad (4)$$

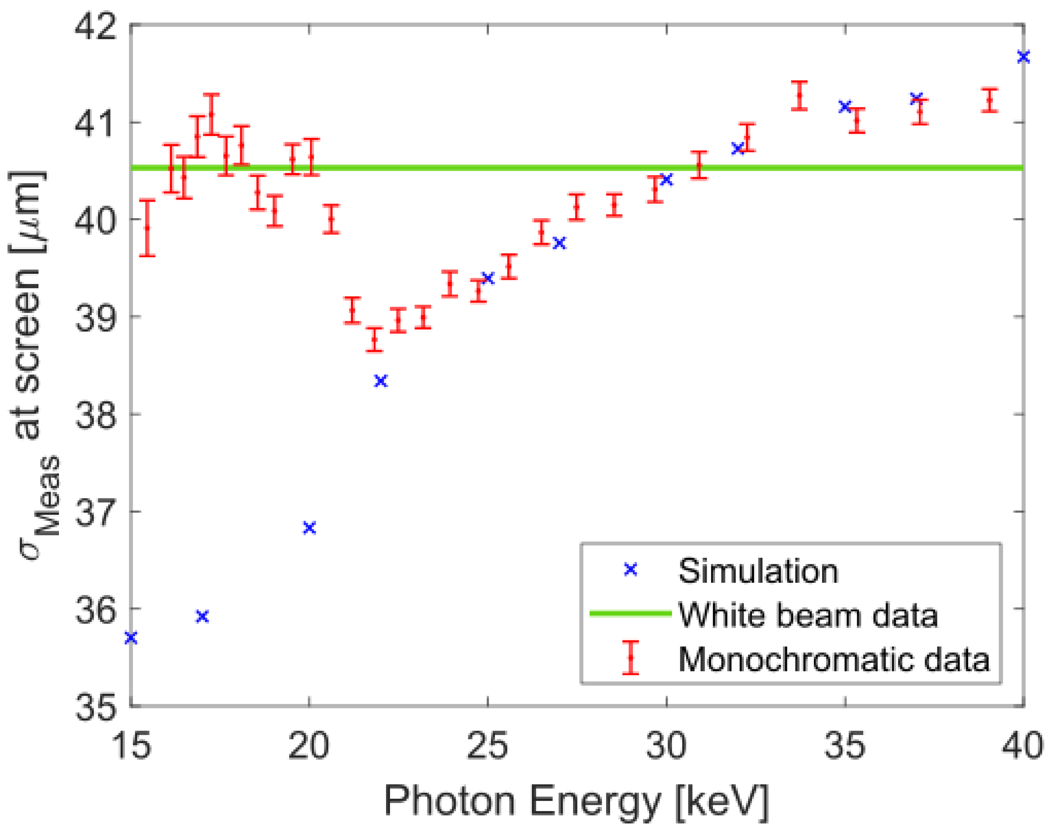


Figure 5: A comparison of the vertical beam size at the screen from measurement and simulation.

CONCLUSION

It has been demonstrated that the contribution from the aperture of the X-ray pinhole camera to the overall point spread function can be reduced by using monochromatic light. These first measurements with the recently installed multilayer monochromator have shown a good agreement with SRW simulations above 22 keV.

Further investigations are planned to improve the monochromatic X-ray pinhole camera. These studies will include testing a different multilayer monochromator and improving the capture efficiency of the photon yield using the microscope imager described in [5].

For Diamond-II the suitability of a monochromatic X-ray pinhole camera must be assessed. A lower flux is expected due to the weaker dipole field, thus a higher efficiency imaging system or direct X-ray detection will be needed especially for emittance feedback. Alternatively, the monochromator could be used for a complementary high resolution beam size monitor using X-ray interferometry. These options will also be investigated.

ACKNOWLEDGEMENTS

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