X-RAY PINHOLE CAMERA SPATIAL RESOLUTION USING HIGH ASPECT RATIO LIGA PINHOLE APERTURES

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ABSTRACT

X-ray pinhole cameras are employed to provide the transverse profile of the electron beam from which the emittance, coupling and energy spread are calculated in the storage ring of Diamond Light Source. Tungsten blades separated by shims are commonly used to form the pinhole aperture. However, this approach introduces uncertainties regarding the aperture size. X-ray lithography, electroplating and moulding, known as LIGA, has been used to provide thin screens with well-defined and high aspect ratio pinhole apertures. Thus, the optimal aperture size given the beam spectrum can be used to improve the spatial resolution of the pinhole camera. Experimental results using a LIGA screen of different aperture sizes have been compared to SRW-Python simulations over the 15-35 keV photon energy range. Good agreement has been demonstrated between the experimental and the simulation data. Challenges and considerations for this method are also presented.

X-RAY PINHOLE CAMERAS AT DIAMOND

The point spread function (PSF) from each optical element is assumed to be Gaussian such that the overall PSF is [1,2]:

$$\sigma^2_{PSF} = \sigma^2_{pinhole} + \sigma^2_{camera} \qquad (1)$$

$$\sigma^2_{pinhole} = \sigma^2_{diffraction} + \sigma^2_{aperture} \qquad (2)$$

$$\sigma^2_{camera} = \sigma^2_{screen} + \sigma^2_{lens} + \sigma^2_{sensor} \qquad (3)$$

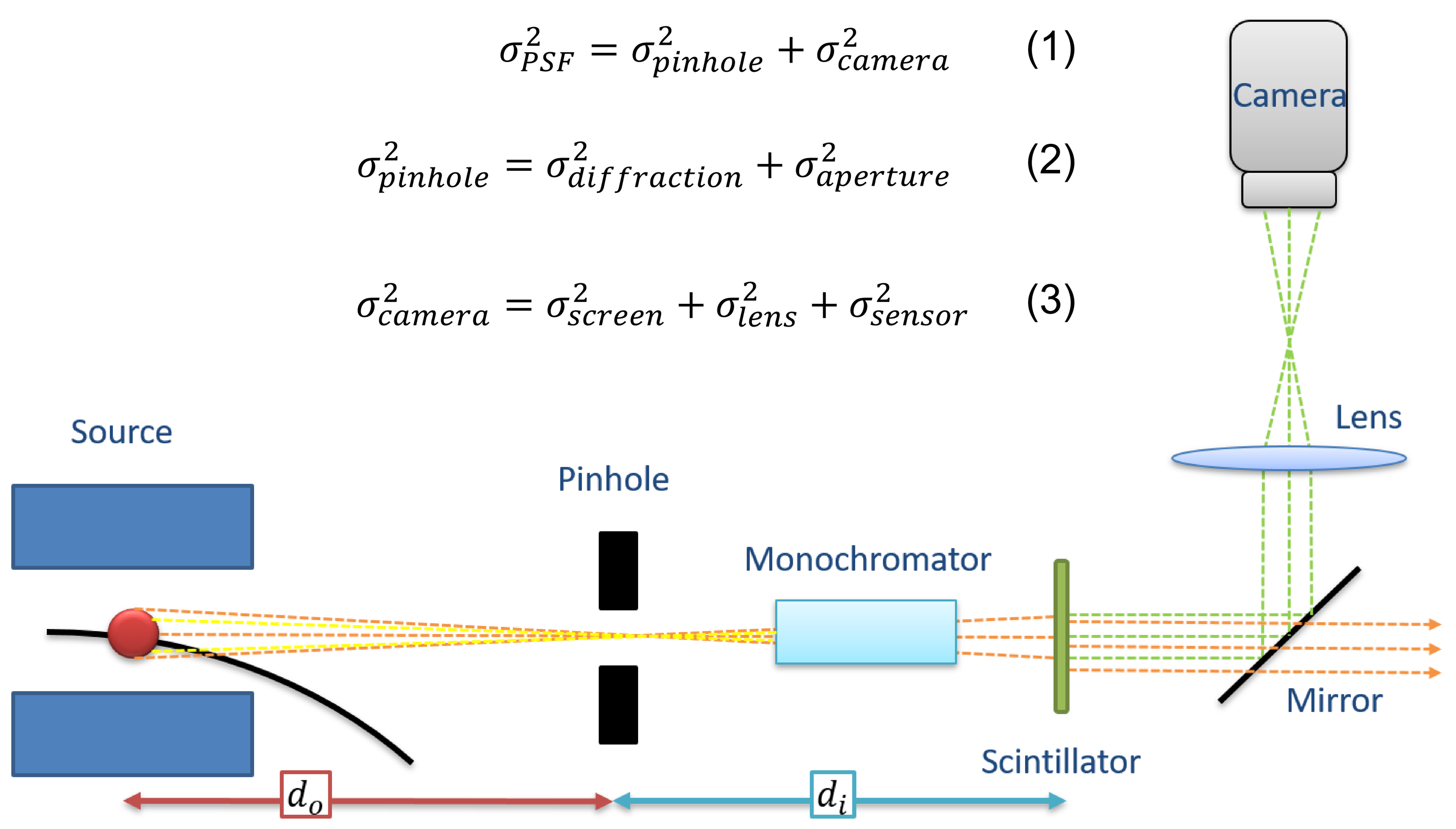
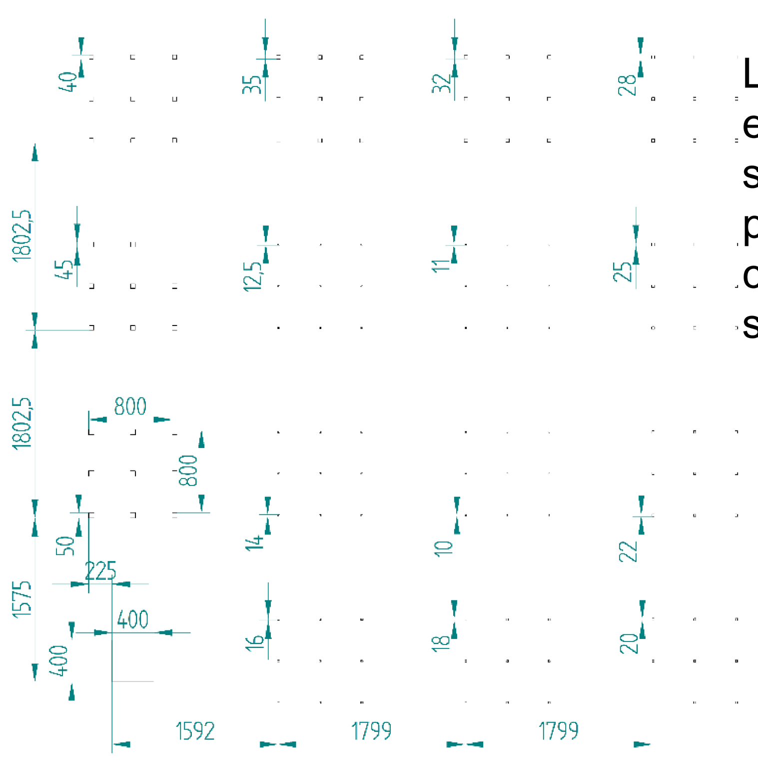


Figure 1: Schematic of the monochromatic X-ray pinhole camera system.

LIGA SCREEN



LIGA (X-ray lithography) technology [3] enables the fabrication of high-aspect ratio structures using high-Z materials such that the pinhole aperture size is known and controllable. The typical thickness of gold screens fabricated by LIGA is up to 250 μm.

Figure 2: Pinhole screen design of 3x3 arrays of square holes

PINHOLE APERTURE MEASUREMENTS

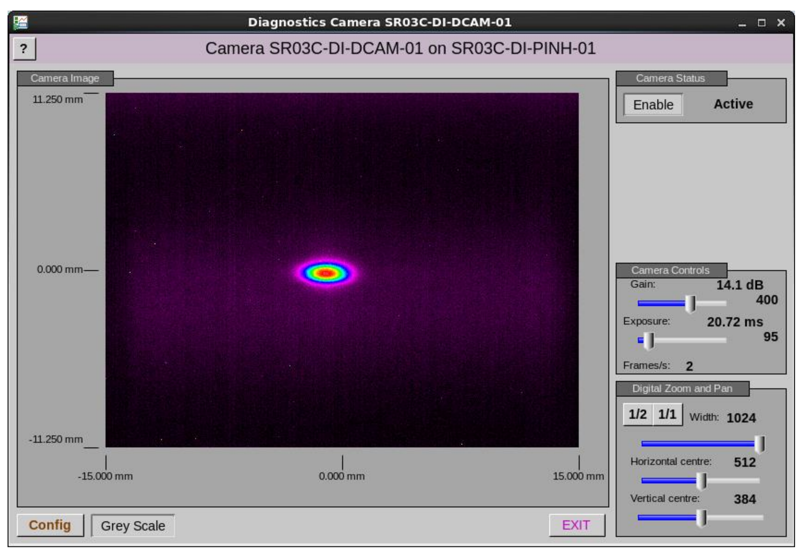


Figure 3: White beam image using LIGA screen.

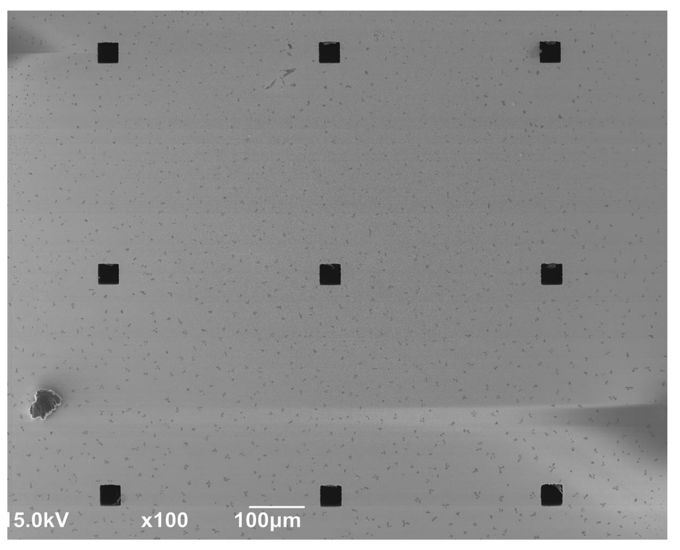
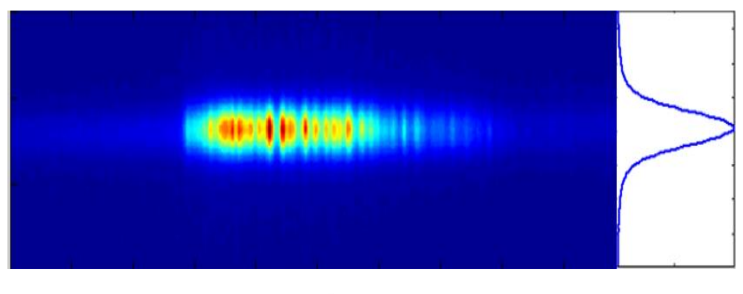


Figure 4: SEM image for the case of 34 μm aperture size.

To obtain the pinhole aperture size, SEM images were analysed. Some discrepancies of the range of few microns were revealed between the SEM measurements and the specification size.



The banding effect was introduced by the monochromator [4]. The image shows the preservation of the vertical beam size despite the stripe pattern the monochromator introduces.

Figure 5: Image from pinhole camera at 23 keV using 25 μm aperture.

SRW SIMULATION

The Synchrotron Radiation Workshop [5,6] in Python (SRW-Python) used to simulate:

- the partially coherent wavefront and its propagation by summing up the contributions of SR from 2000 individual electrons
- the image of the photon beam at the scintillator screen.

EXPERIMENT – SIMULATION COMPARISON RESULTS

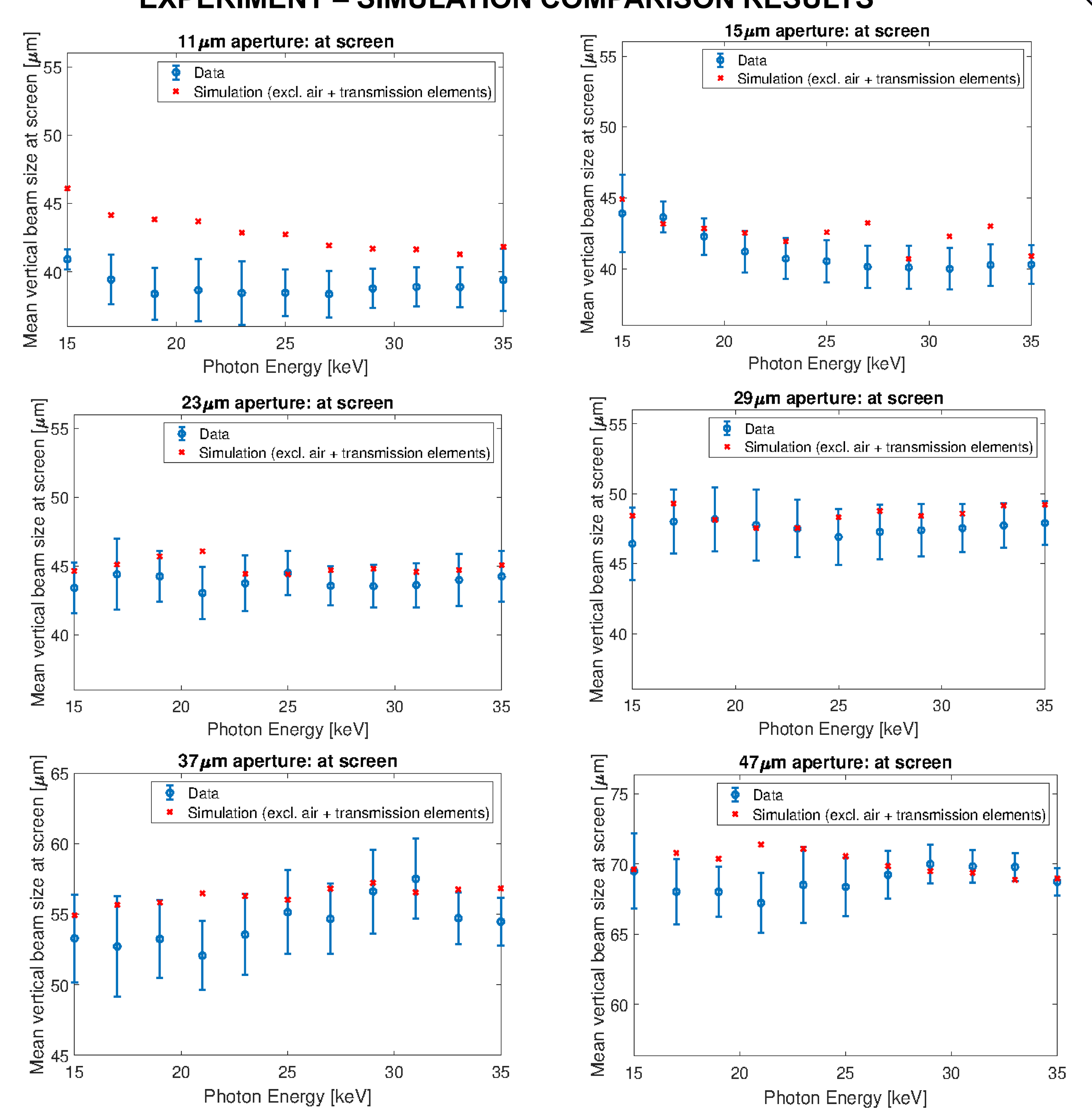


Figure 6: Experimental and simulation data for a range of different pinhole apertures

CONCLUSIONS

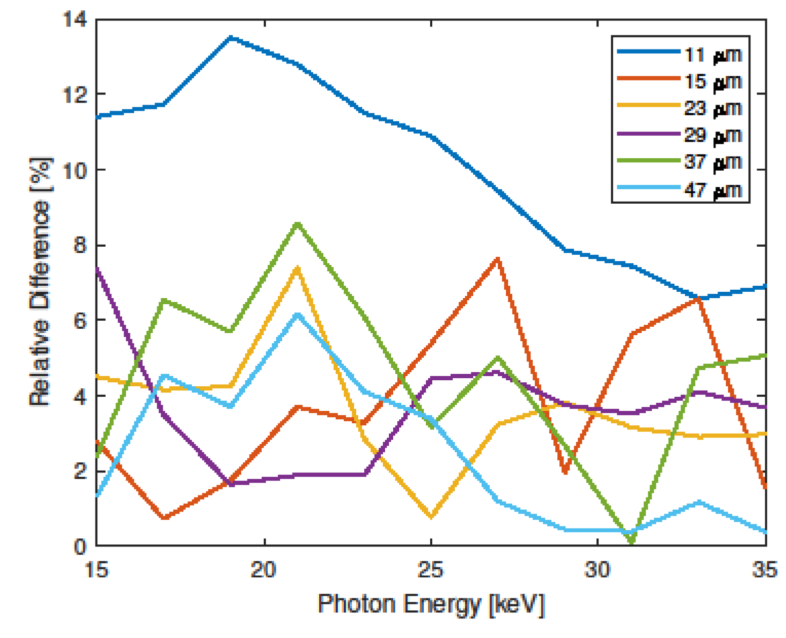


Figure 7: Relative difference between the simulated and measured beam sizes over a range of photon energies for each aperture size.

LIGA offered the possibility to control the pinhole aperture size and to compare the theory with the experiment with a good agreement (≤ 8%) excl. 11 μm aperture.
Given the white beam spectrum peaks at 23 keV, the optimal aperture size from simulation and experiment for this pinhole camera is approximately 15 μm.
The smallest vertical beam sizes were obtained from pinhole apertures in the range of 11 − 23 μm
SEM measurements were important to validate the accuracy of the specified aperture size and eventually to achieve a good agreement between the experiment and the simulation.
A new approach where the PSF of the system can be provided from the simulation, without the need for direct measurements of PSF, like Touschek calibration, can be explored in the future.

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