Wavefront sensing at an ellipsoidal mirror shell with a micron-sized soft X-ray source

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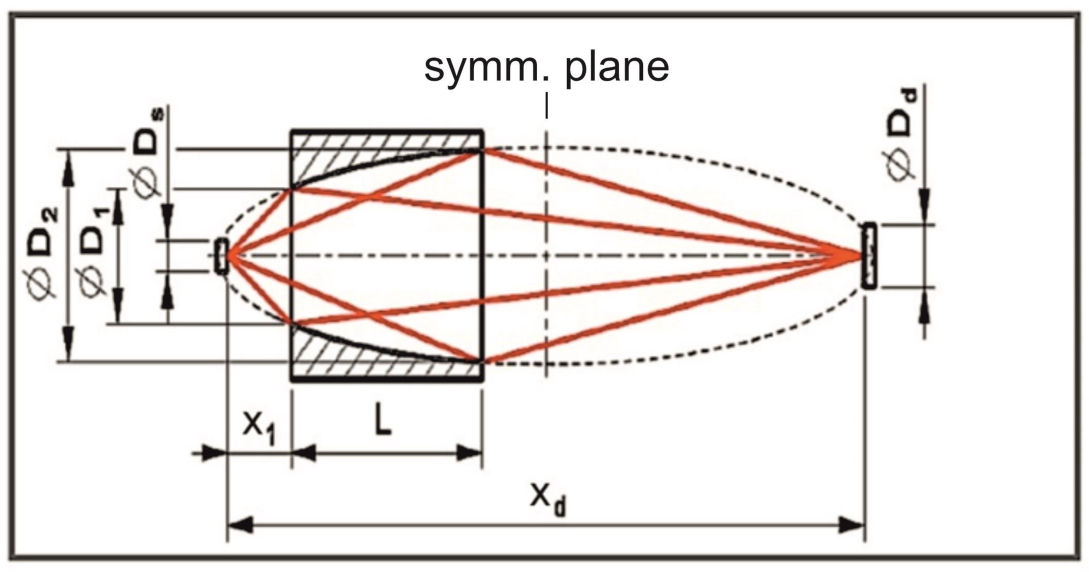
Schematic of the ellipsoidal mirror (not to scale) with parameters



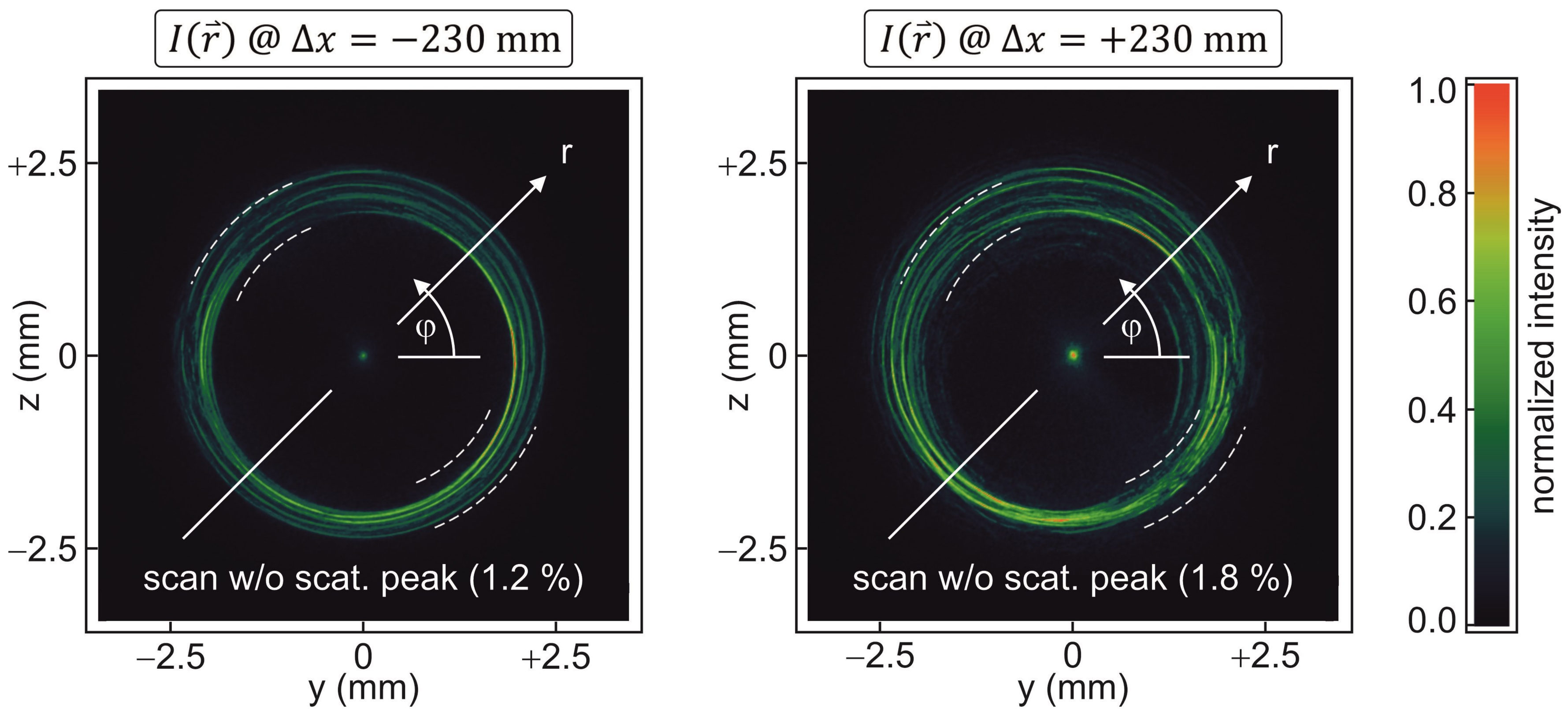
Major semi axis: a = 500.077 mm | minor semi axis: b = 8.75475 mm | focus: e = ± 500. mm

L	D_1	D_2	x_1	x_d
100 mm	13 mm	15.4557 mm	165 mm	1000 mm

geometrical solid angle for acceptance of source photons: 2.20 msr

Au coating → reflectivity (76.2 ± 2.6) % for σ = ± 1 nm (E = 277 eV)

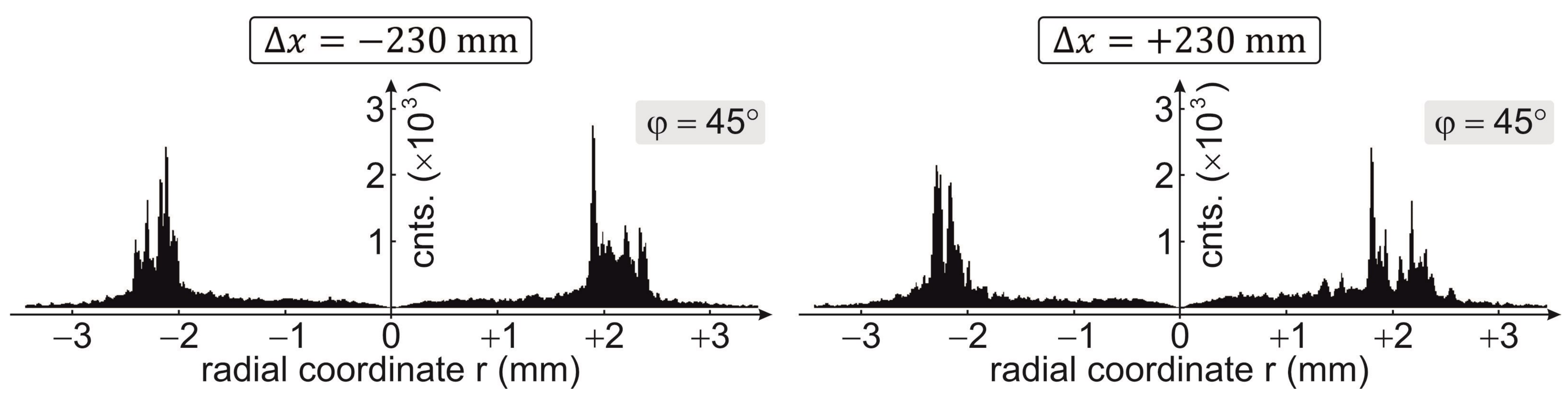
Experimental CCD images in defocus (940 × 940 pixels à 13.5 µm)



rotate radial scan I(r) in each plane for 0° ≤ φ ≤ 178°, increm. δφ = 2°

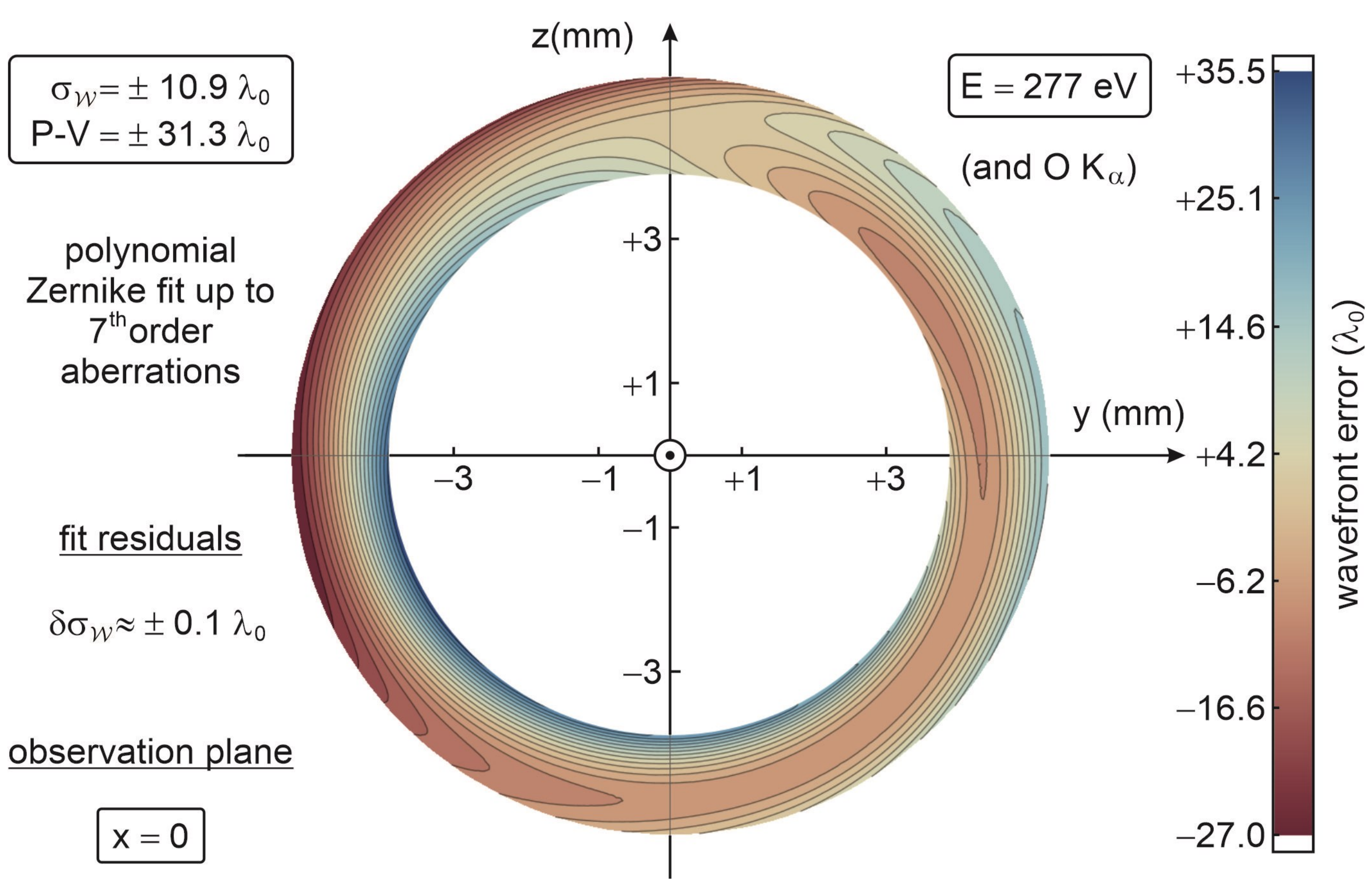
10 CCD planes within – 250 mm ≤ Δx ≤ + 250 mm → 5 eval. samples

Experimental 1-D radial cross section (r,φ) as ray density distribution

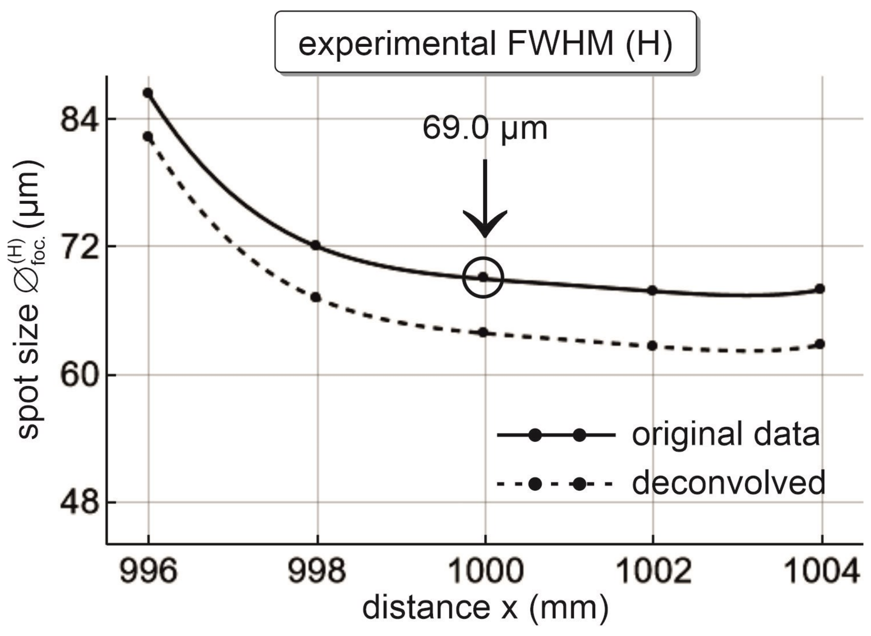


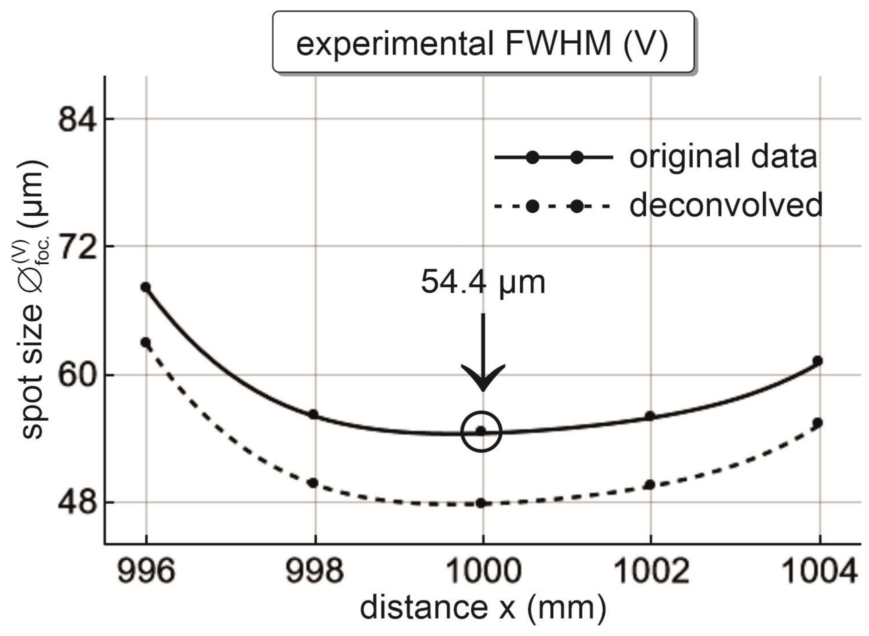
- no absorption: (re-)equalizing the sum of pixel entries in all planes
- no cross over: sorted list of rays along radial cross section line I(r)

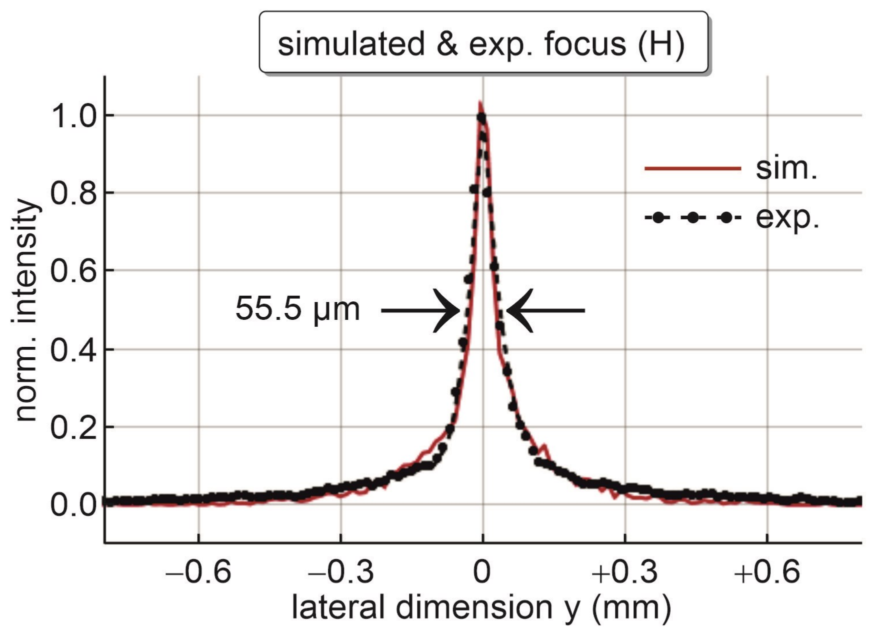
Wavefront retrieval at 277 eV and fit using Zernike polynomials

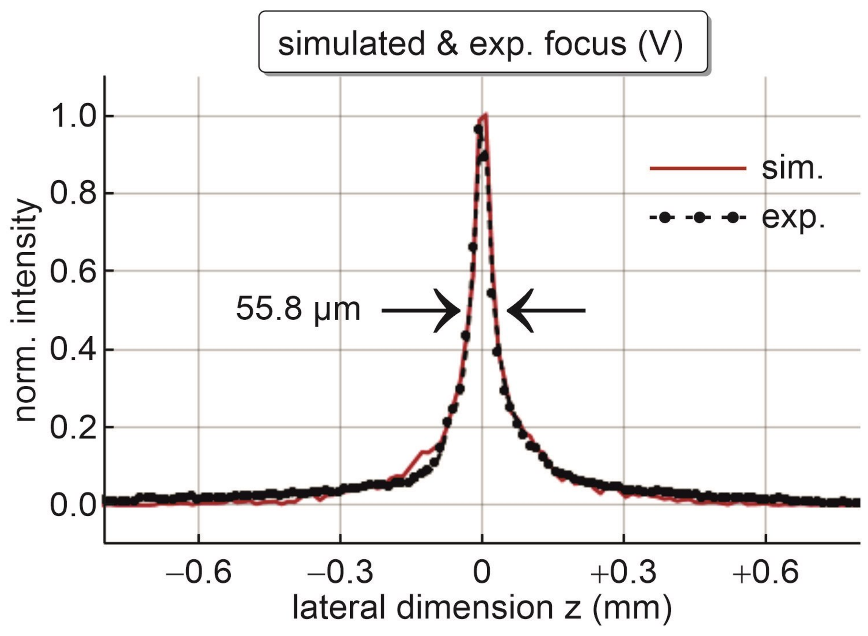


What we can learn from the measured and simulated focal spot size





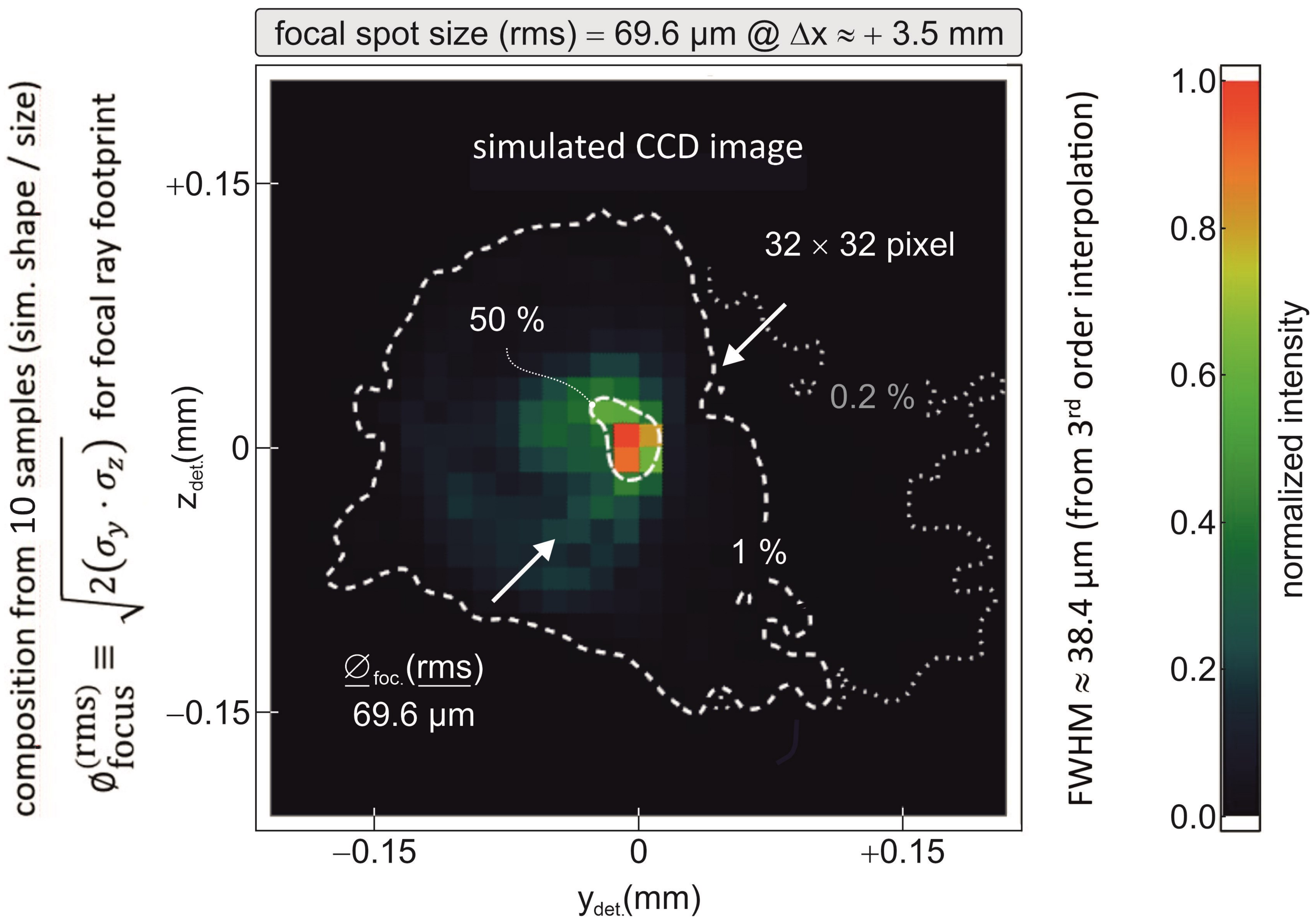




mirror simulated with normal distribution of geometrical slope errors measured (pseudo Voigt fit) vs. simulated (interpol.) 1-D intensities:

experiment ≈ ray tracing for statist. slope error σ = ± 8.8 arcsec (rms)

Reconstructed focal intensity distribution by WF slope propagation



Reconstructed figure error of the ellipsoid by WF error mapping

deformation $\delta r(x,\varphi)$ related to WF error $WFE_{fig.}$ and inc. angle $\theta(x)$

$$WFE_{fig.} = -2\,\lambda^{-1}\delta r(x,\varphi)\,\sin\theta(x)$$

averaged over full mirror surface: $\langle \delta r(x,\varphi) \rangle_{x,\varphi} \approx \pm\, 1.14\ \mu\text{m (rms)}$

Reference

J. Probst, H. Löchel, T. Krist, C. Braig, and C. Seifert, "Soft X-ray spectroscopy in the lab with an ellipsoidal mirror and a wavefront corrected reflection zone plate," Proc. SPIE **12576**, 125760C (2023).

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