CRL ray tracing, error simulations, wavefront propagation (SRW, HYBRID)

Rafael Celestre
rafael.celestre@synchrotron-soleil.fr

Groupe Optique, Division Expériences, Synchrotron SOLEIL

Luca Rebuffi
lrebuffi@anl.gov

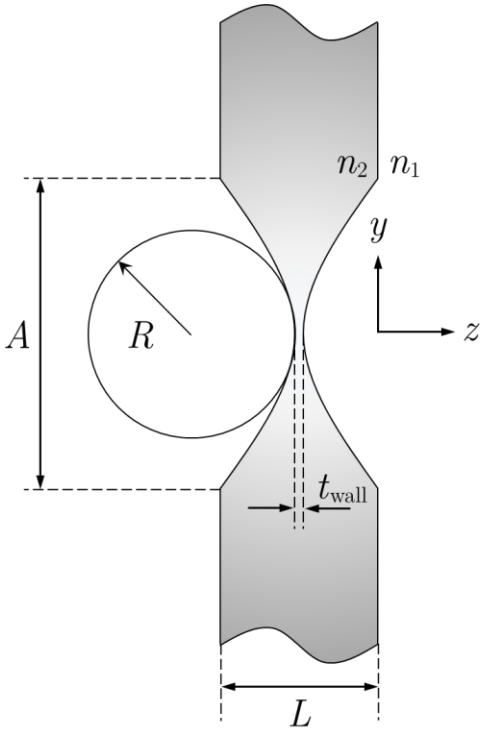
Optics Group, Advanced Photon Source

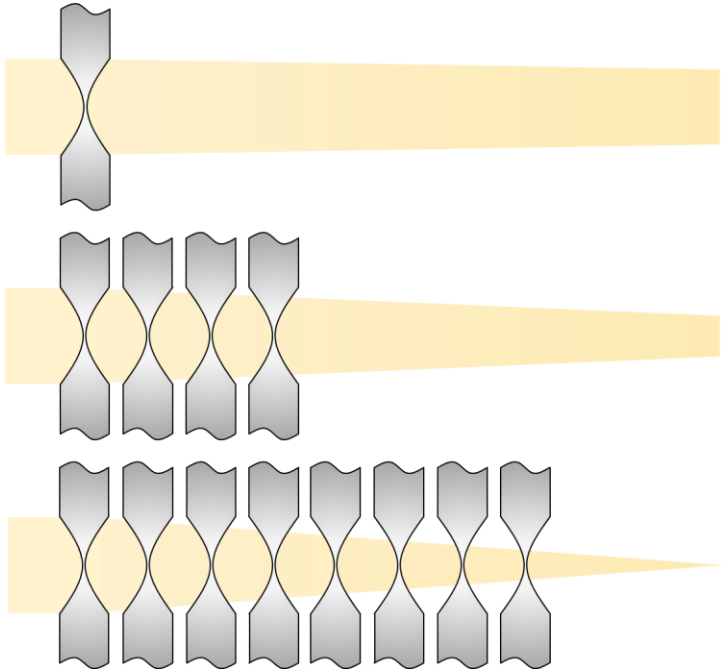
CRL ray tracing, error simulations, wavefront propagation

Outline:

- X-ray lens modelling
- Why x-ray lens modelling?
- Accurate simulation of x-ray lenses and CRL
- Live demo using OASYS

X-ray lens modelling





$$n = 1 - \delta + i \cdot \beta$$

$$\Re(n) < 1 \qquad \Re(n) \approx 1$$

$$f = \frac{R}{2\delta N}$$

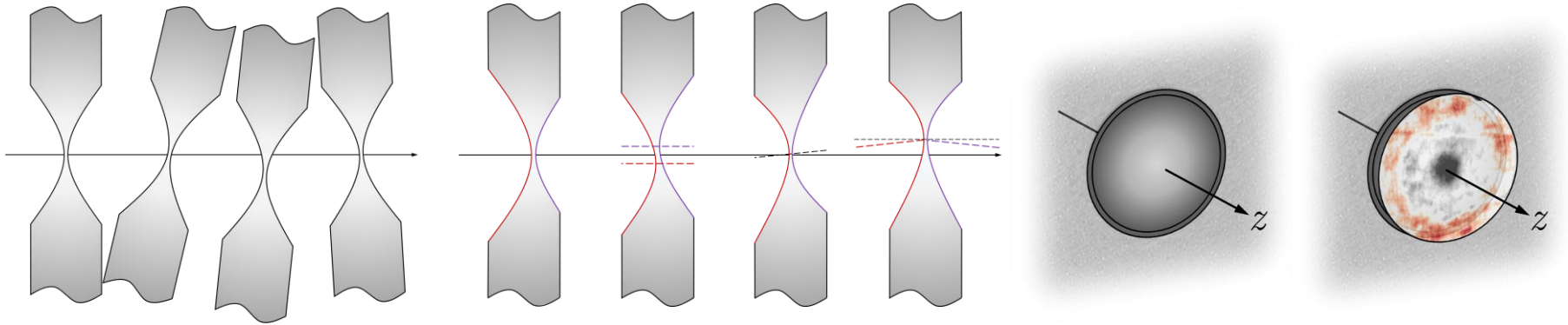
(left) sagittal cut of an x-ray lens; (right) stacking of lenses to reduce the focal length of the CRL

(δ: 10^{-8}~10^{-4}; β: 10^{-11}~10^{-5})

X-ray lens modelling

The complex transmission operator representing a single x-ray lens:

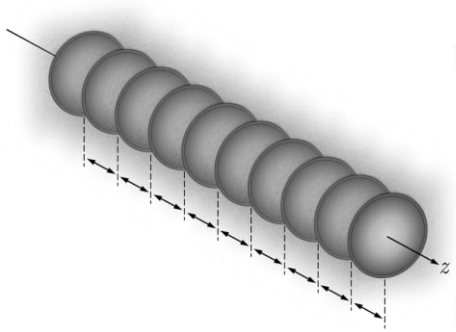
$$\mathrm{T}_{\mathrm{x-ray\ lens}}(x,y)\bullet = \exp\left[-k\beta\cdot\Delta_{\mathrm{x-ray\ lens}}(x,y)\right]\cdot\exp\left[-ik\delta\cdot\Delta_{\mathrm{x-ray\ lens}}\,(x,y)\right]\bullet$$

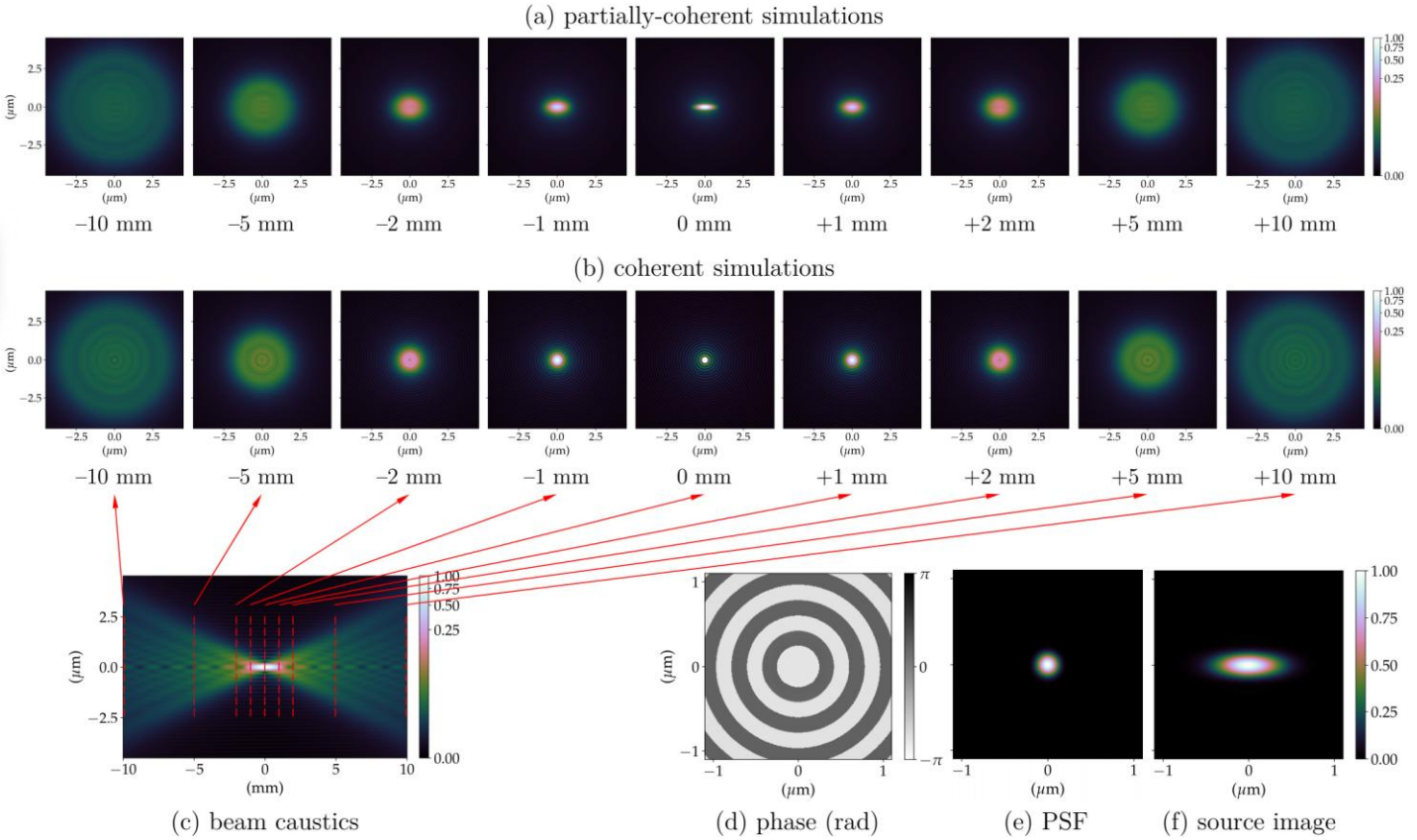


(left) typical lens misalignment; (middle) idealised lens fabrication errors; (right) lens with metrology data added to it

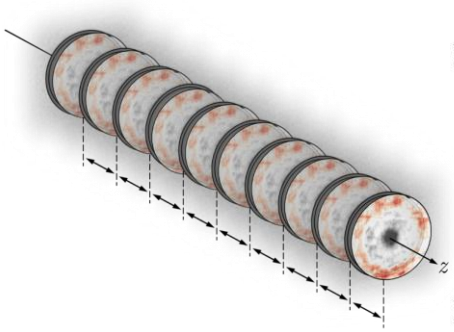
$$\mathrm{T}_{\mathrm{imperfect\ lens}}(x,y)\bullet = \mathrm{T}_{\mathrm{figure\ error}}(x,y)\cdot\mathrm{T}_{\mathrm{ideal\ lens}}(x,y)\bullet$$

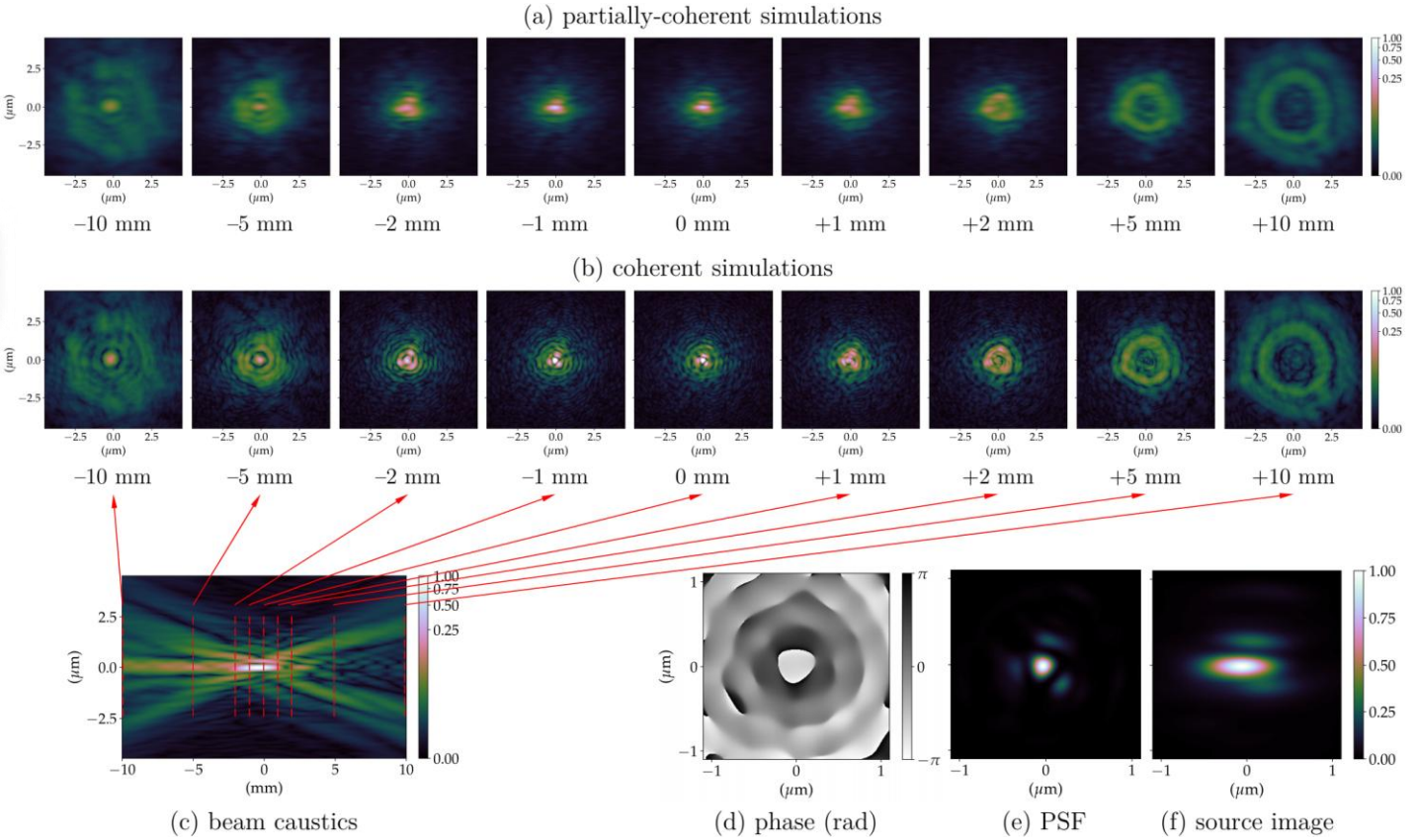
X-ray lens modelling



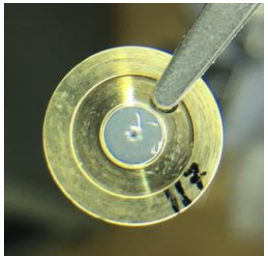


X-ray lens modelling

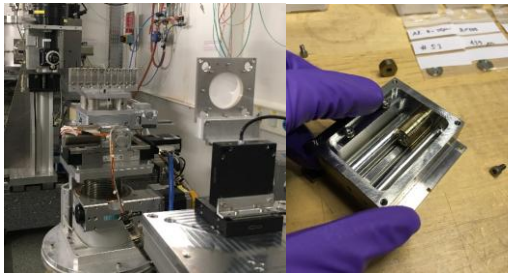




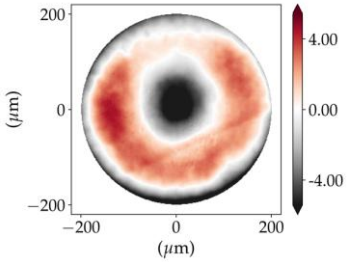
Why x-ray lens modelling?



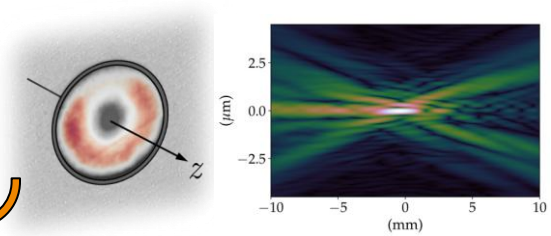
(a) lens (stack)



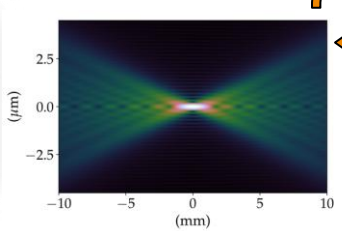
(b) at-wavelength metrology



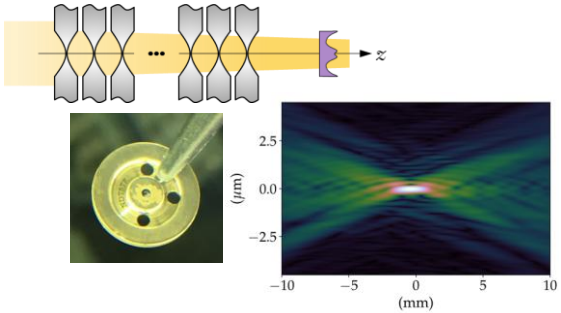
(c) error profile



(d) “realistic” modelling

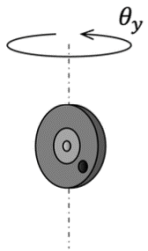


(e) ideal modelling

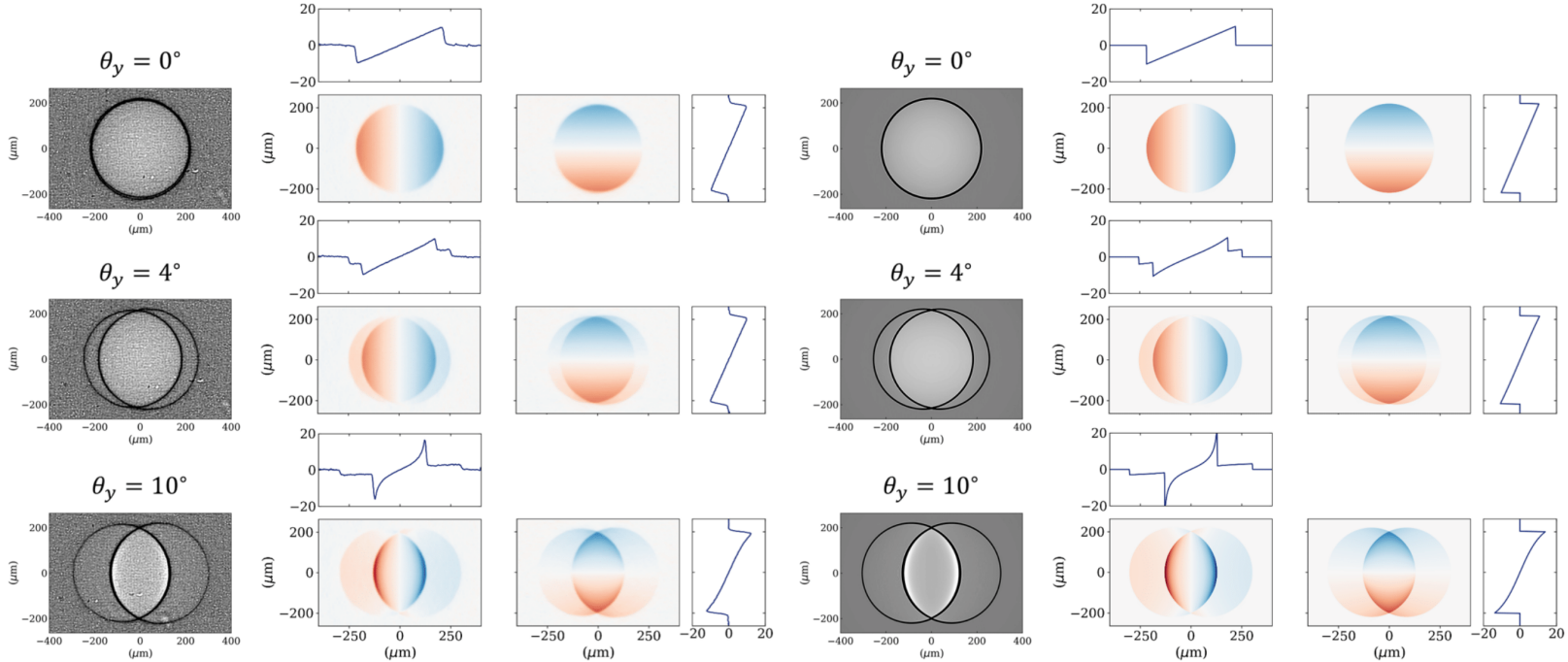


(f) manufactured correction

Accurate simulation of x-ray lenses and CRL - I

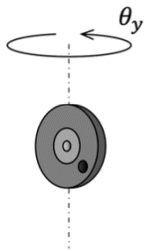


Tilting refractive x-ray lenses for fine-tuning of their focal length

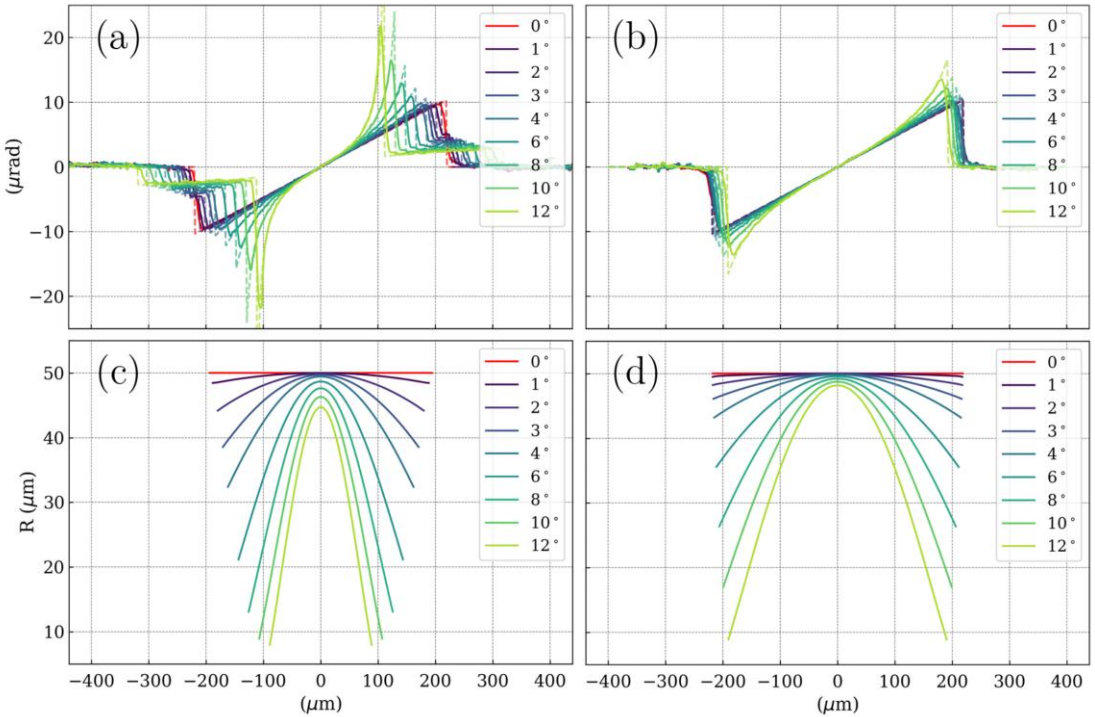


(a) experimental data (radiograph and wavefront gradient) (b) simulations using barc4ro (available through OASYS)

Accurate simulation of x-ray lenses and CRL - I



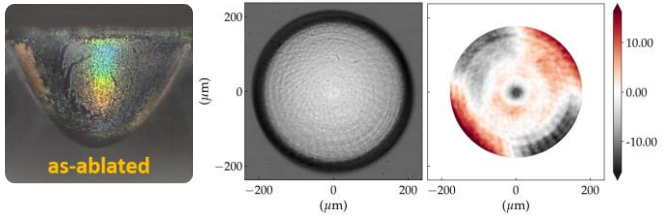
Tilting refractive x-ray lenses for fine-tuning of their focal length



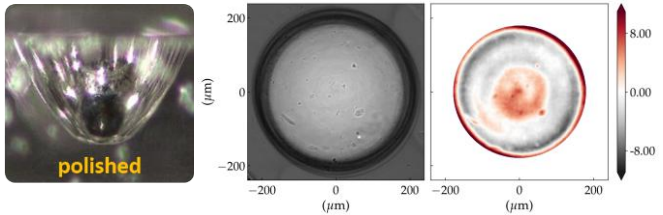
(a) horizontal and (b) vertical gradient cuts comparison for the simulation (dashed line) and experimental data (continuous line) for a 2D Be lens with R=50 μm at E=17 keV. Calculated (c) horizontal and (d) vertical apparent radius of curvature.

Accurate simulation of x-ray lenses and CRL - II

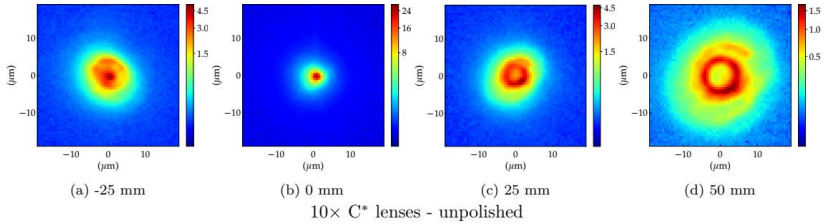
Partially coherent simulations of 10x 2D diamond lens stack focusing:

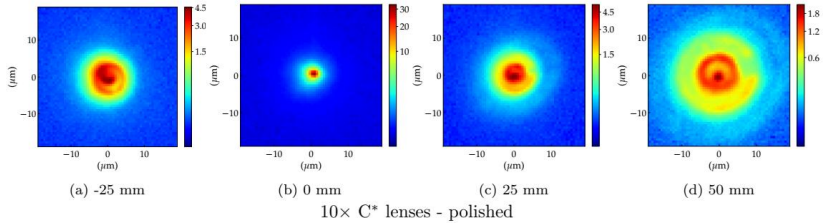


(a) unpolished stack

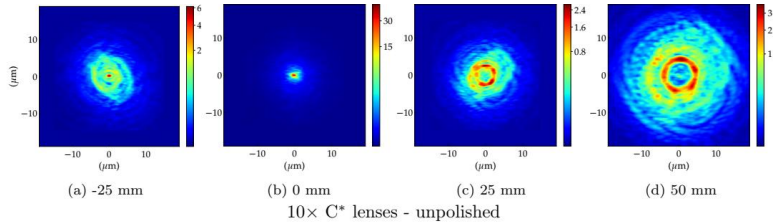


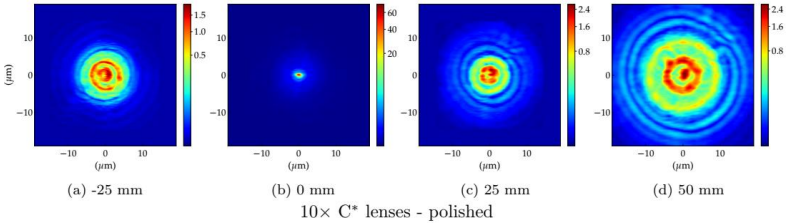
(b) polished stack





(c) experimental data (ID06)

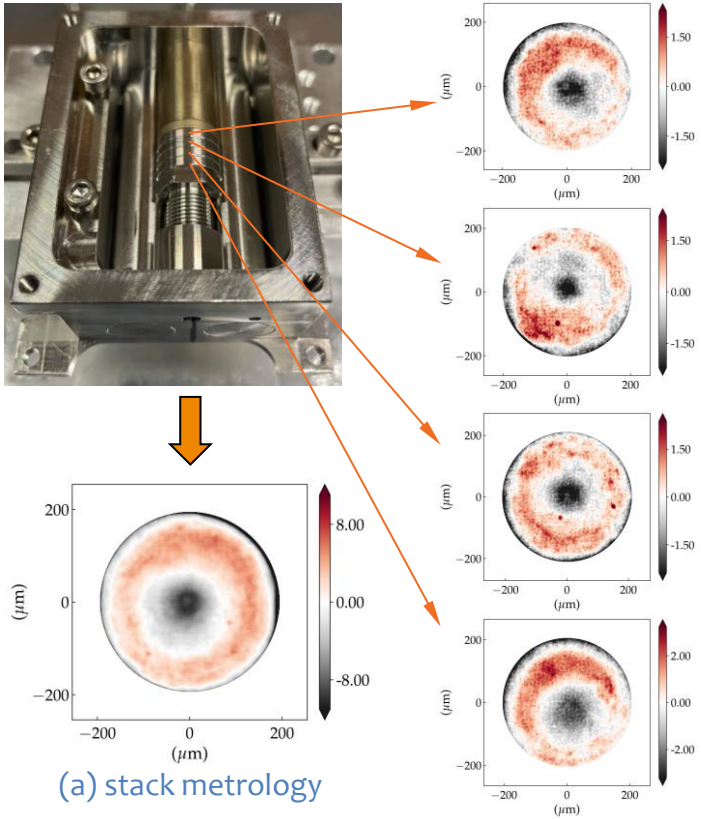




(d) simulations using SRW

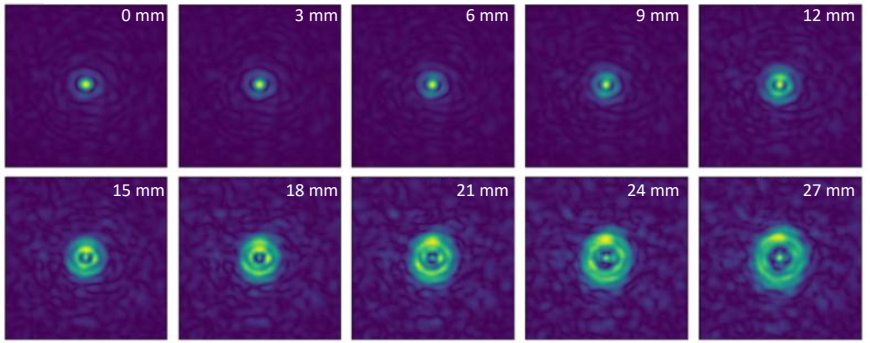
Accurate simulation of x-ray lenses and CRL - III

Coherent simulations of 4x 2D Be lens stack focusing:

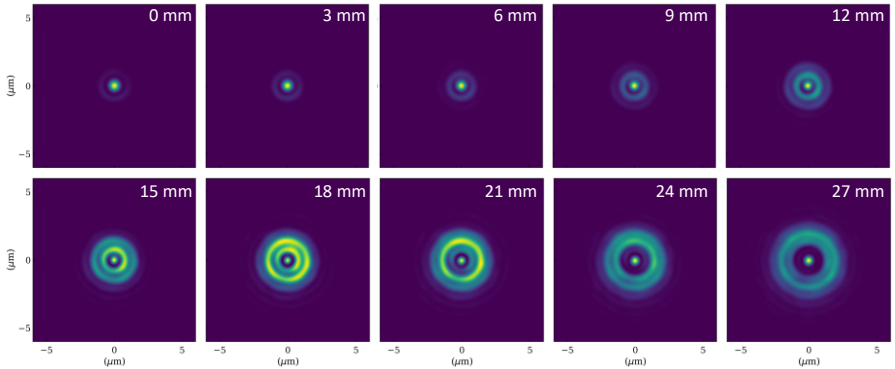


(a) stack metrology

Exp. data courtesy of E. Bellec & S. Leake (ESRF-ID01)



(b) ptychographic data reconstruction



(c) simulations using SRW

Examples

Live demo using OASYS…

Thank you!