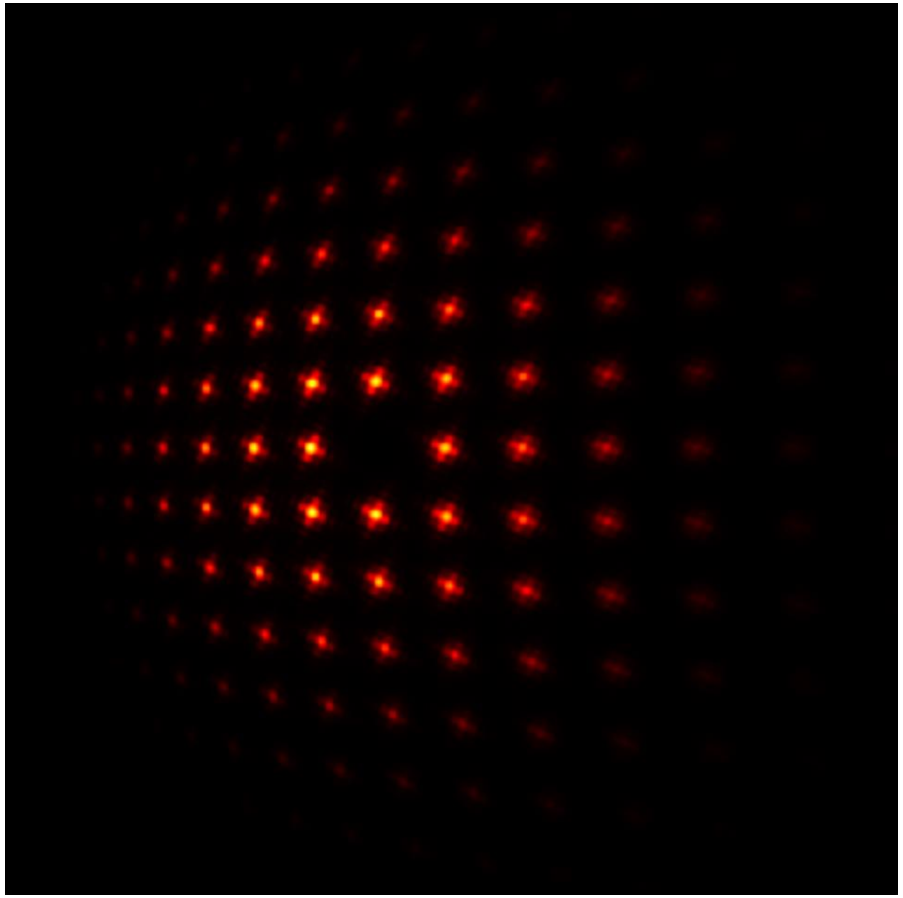
Hartmann Wavefront Sensor for X-Ray Optics

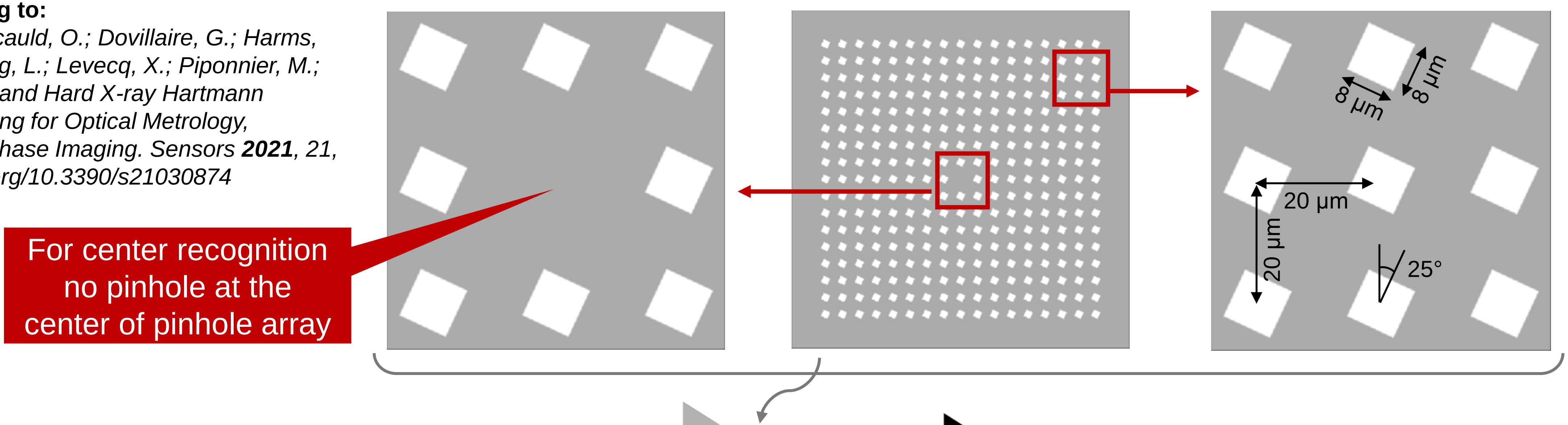
Abstract

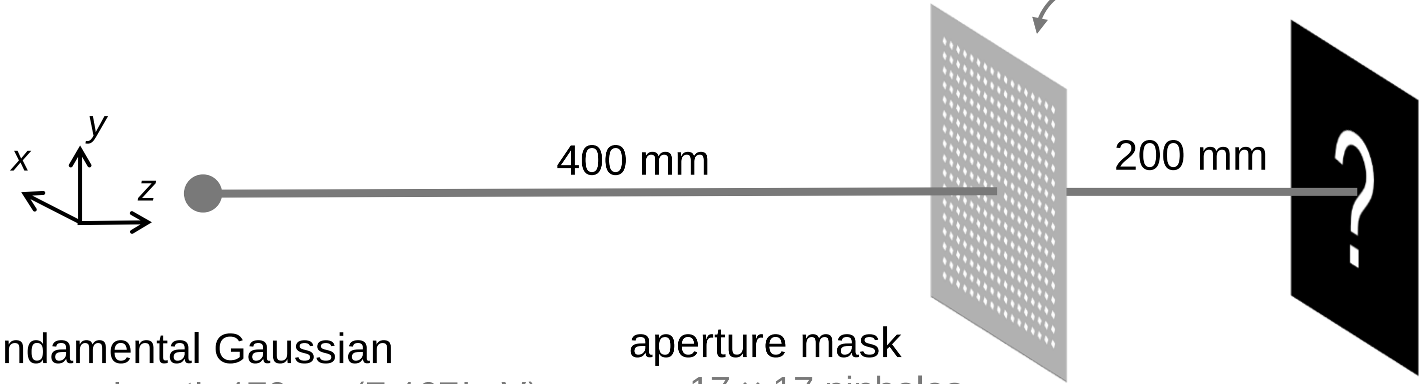


Hartmann sensors are a common tool to investigate the wavefront shape of an incoming X-ray beam, as they provide advantages like achromaticity and large dynamic ranges. In this use case, we follow the work of de La Rouchefouauld O. *et al*. [*Sensors* **2021**, *21*, 874.], to model the X-ray fields propagating through the Hartmann wavefront sensor, which is composed of a series of pinholes. The diffraction from each pinhole will lead to a shift at the detector plane which can be used to calculate the wavefront of the input.

Modeling Task

Setup according to:
de La Rochefoucauld, O.; Dovillaire, G.; Harms, F.; Idir, M.; Huang, L.; Levecq, X.; Piponnier, M.; Zeitoun, P. EUV and Hard X-ray Hartmann Wavefront Sensing for Optical Metrology, Alignment and Phase Imaging. Sensors ***2021****, 21, 874. https://doi.org/10.3390/s21030874*





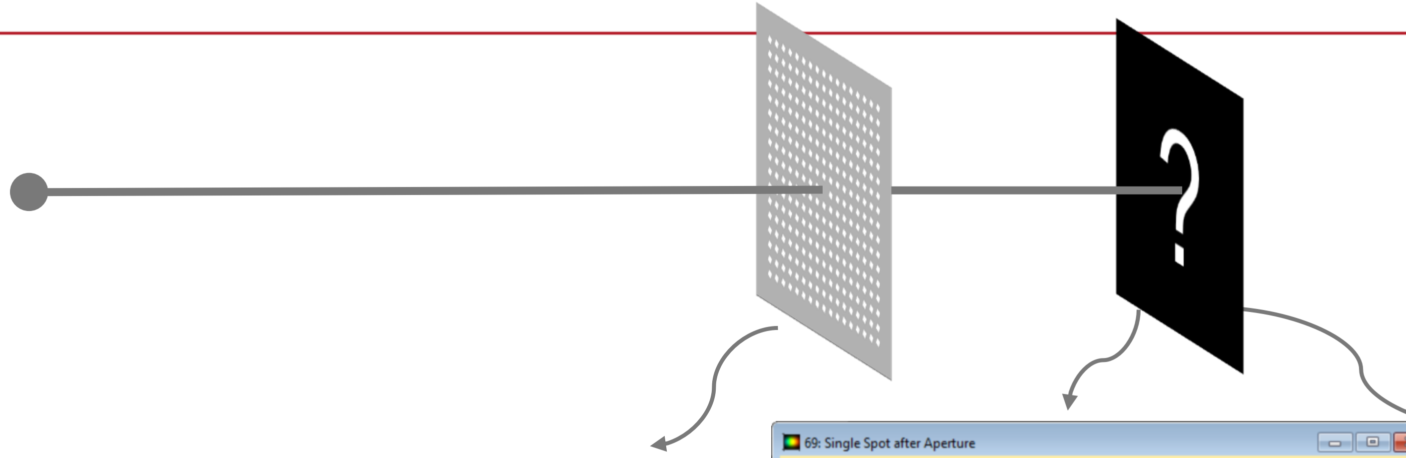
visualize the X-ray field through the Hartmann wavefront sensor

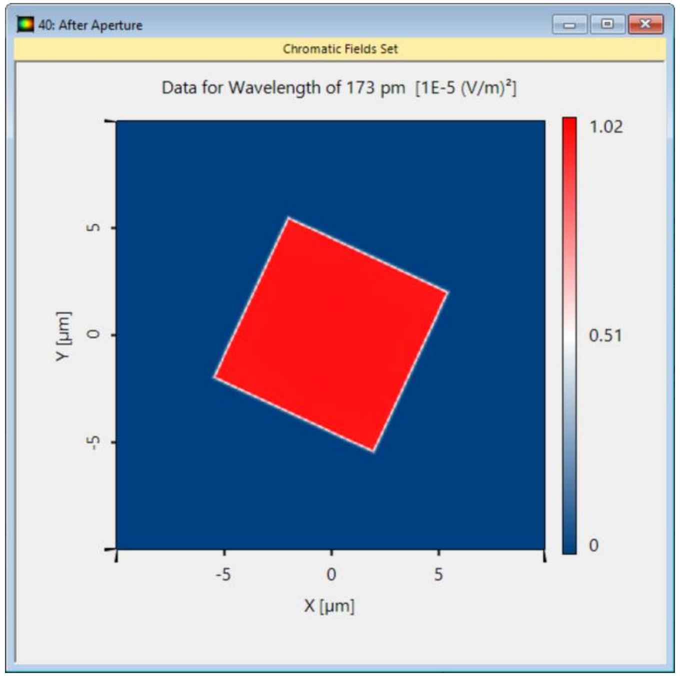
fundamental Gaussian
- wavelength 173 pm (7.167 keV)
- divergence angle 0.0012° × 0.0012°

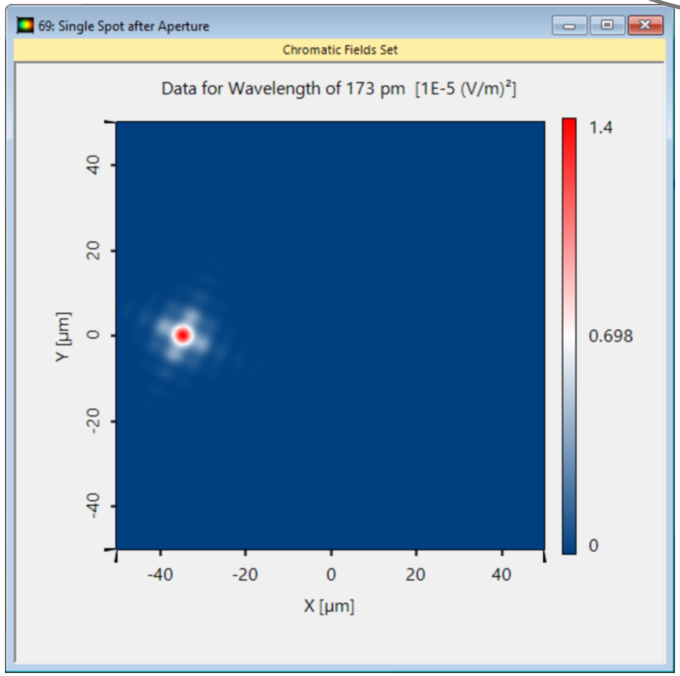
aperture mask
- 17 × 17 pinholes (central pinhole removed)

Simulation of an Individual Aperture

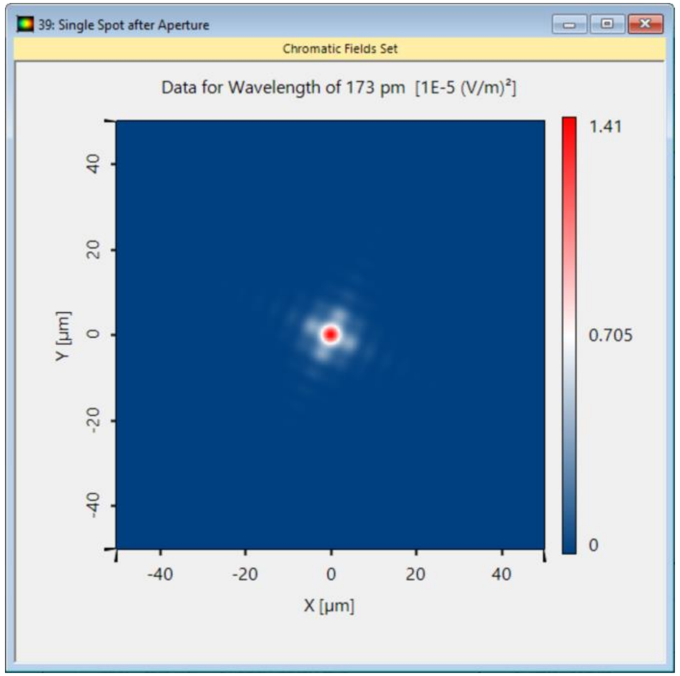
To investigate the effects, we can first set up the system with a single aperture. The effects of the coma on a single spot are already observable.





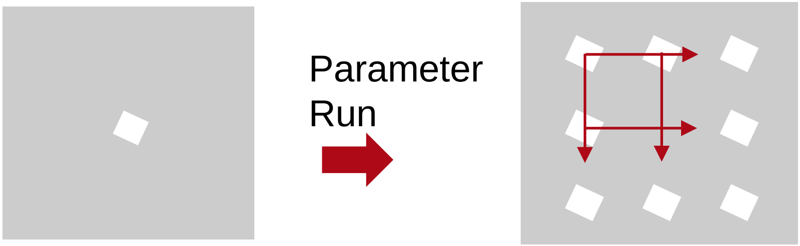


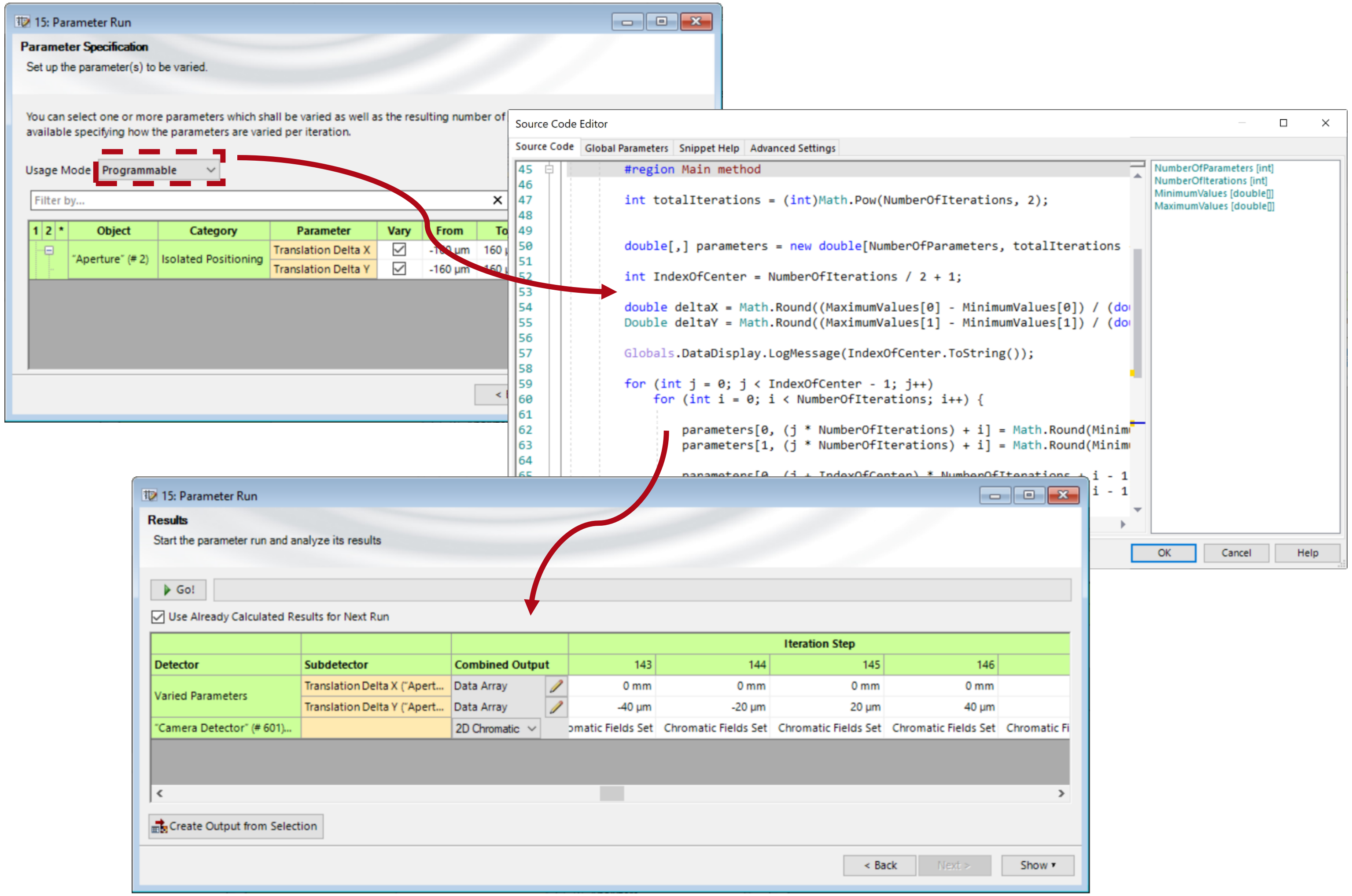
With Coma



Without Coma

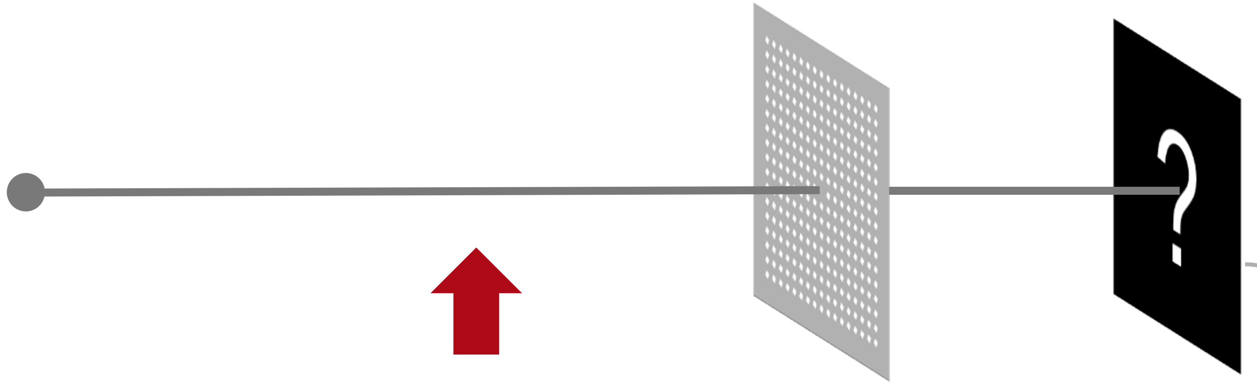
Construction of Array through Programmable Parameter Run

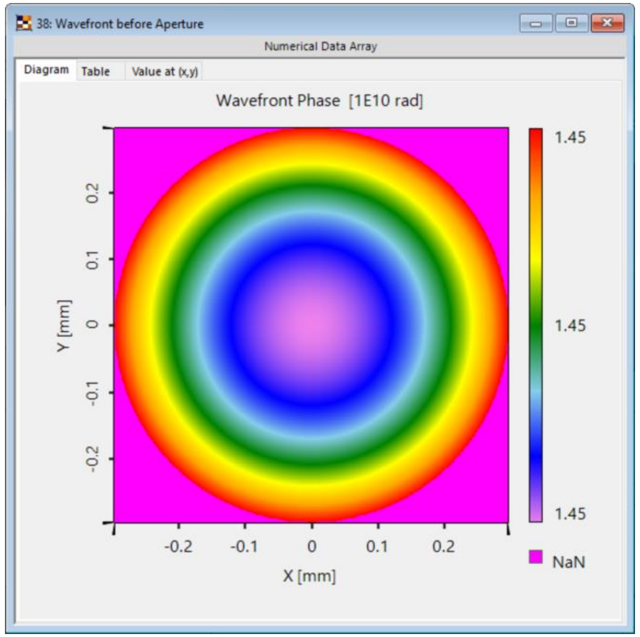


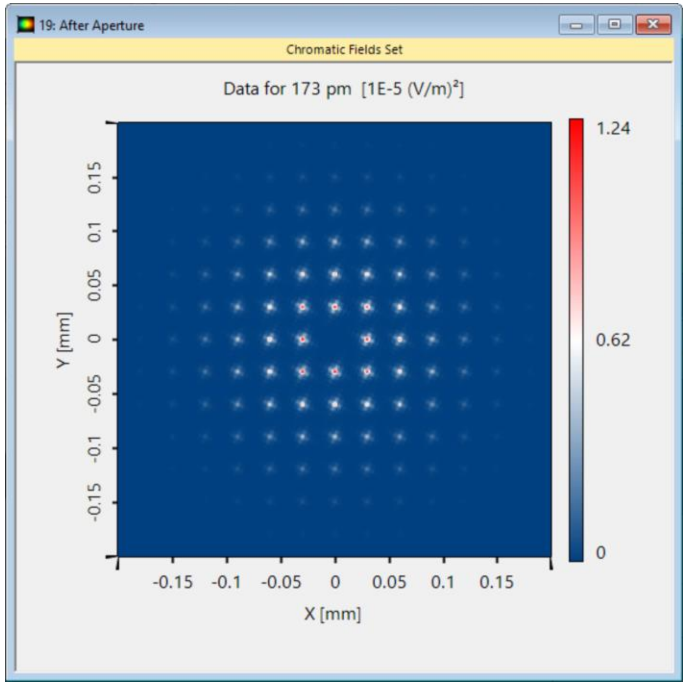


With the help from the programmable Parameter Run tool of VirtualLab Fusion we can construct the entire array according to the specifications by placing each aperture at its position. The result can then be calculated and the results of the individual apertures are automatically combined into a single document.

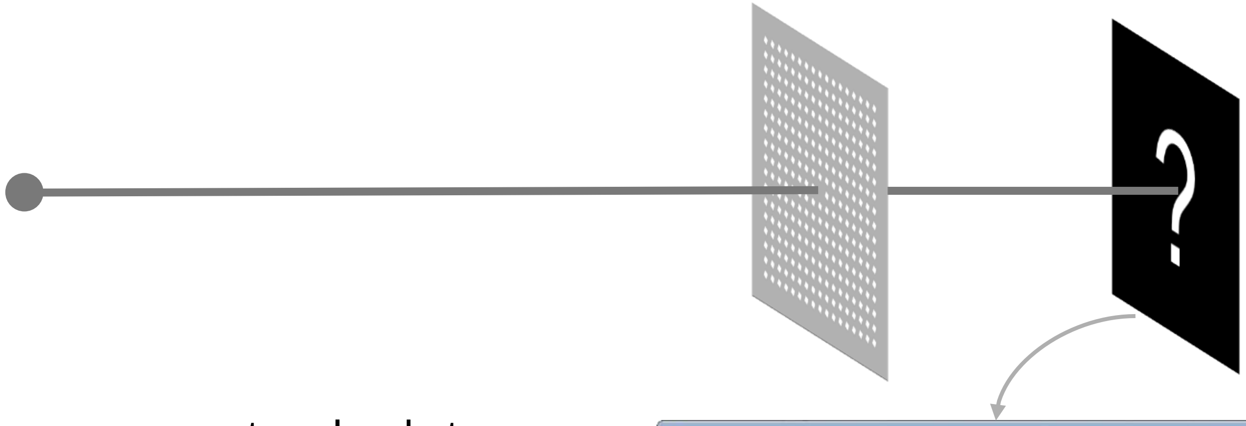
Simulation of Fundamental Gaussian Wavefront



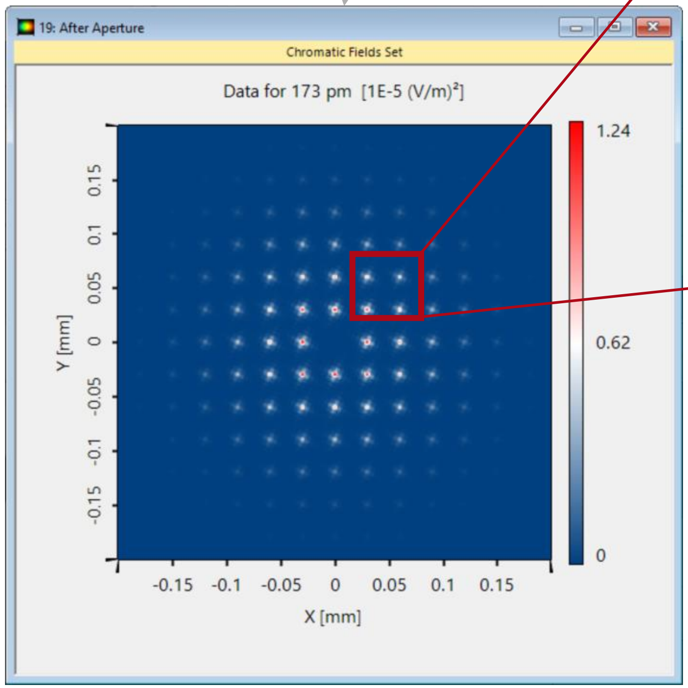


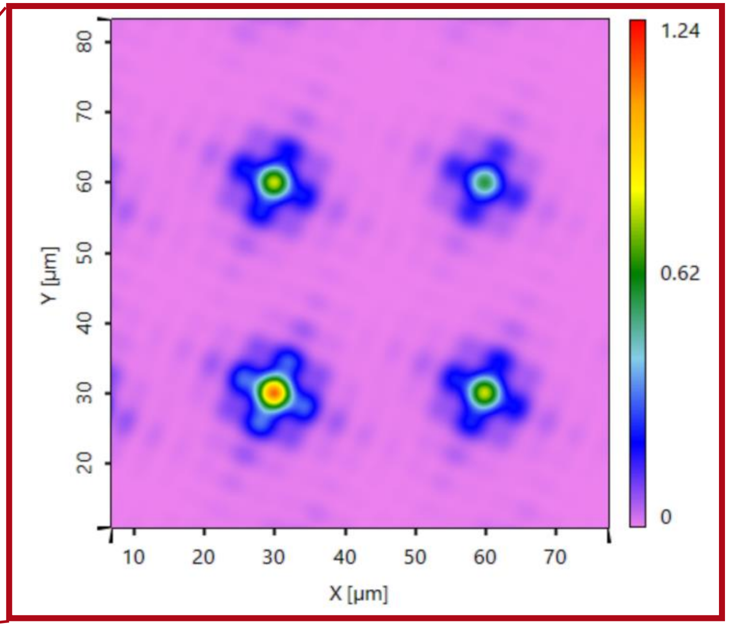


Effect of the Tilted Square Apertures



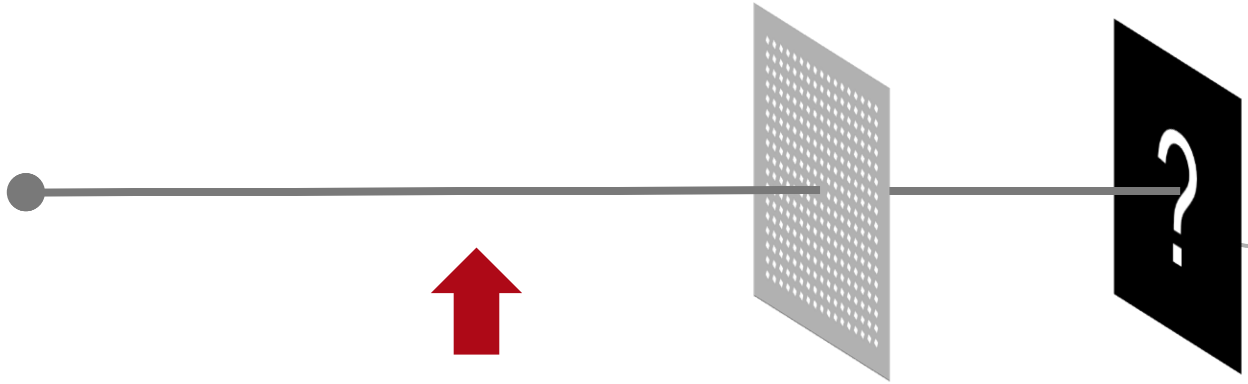
A square aperture leads to a diffraction pattern with four distinct directions. Through the tilt of the square apertures these side lobes no longer overlap, which decreases the cross-talk allowing for denser aperture arrays.

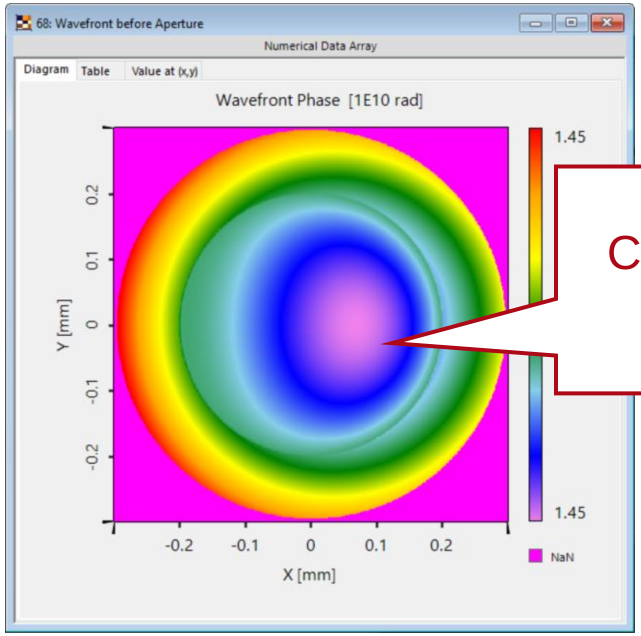




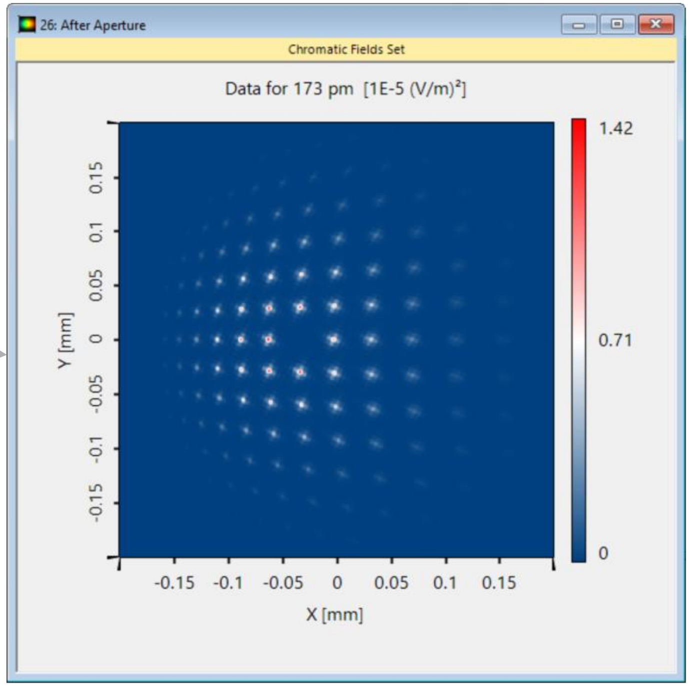
Note: VirtualLab Fusion allows on-the-fly swaps of color palettes for most detector results to better highlight certain effects without the need of recalculation.

Simulation Including Coma Aberration



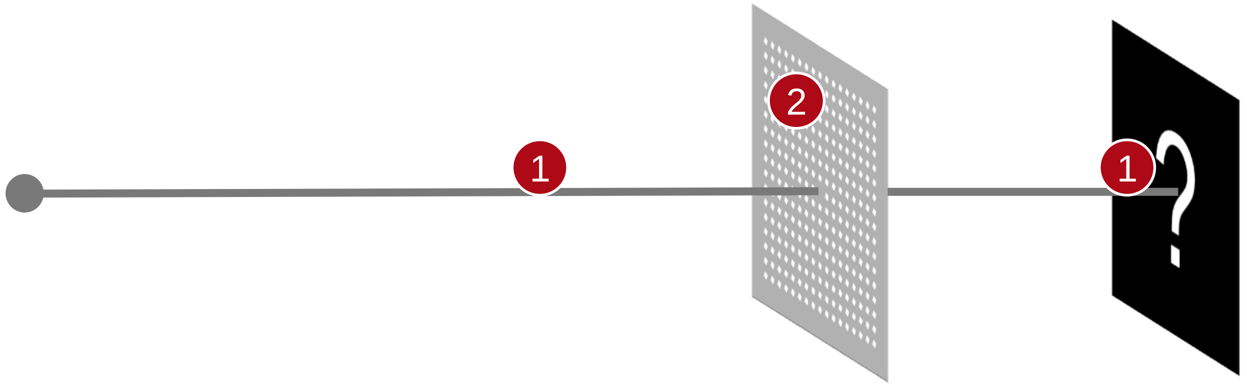


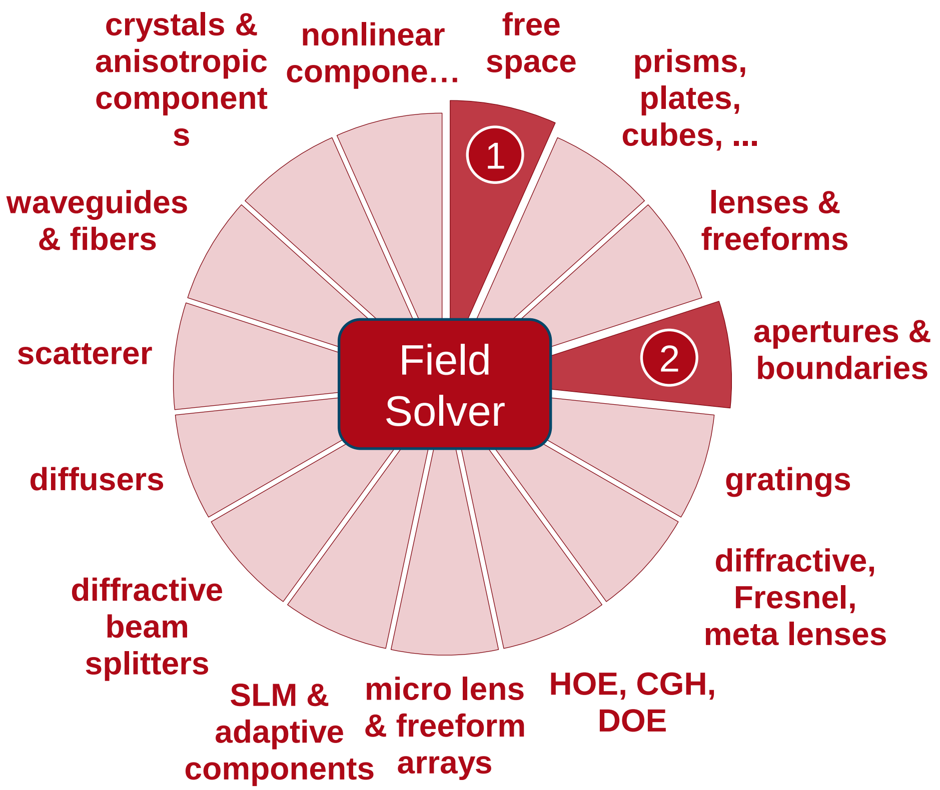
Coma is added to the wavefront phase.



Due to the influence of the added coma, after propagation through the apertures, the X-ray intensity distribution exhibits a local shift of the positions, compared to the previous one without aberration. These local shifts can be measured in order to reconstruct the original wavefront phase.

VirtualLab Fusion Technologies





Document Information

title	Hartmann Wavefront Sensor for X-Ray Optics
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version	1.0
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software version	2021.1 (Build 1.180)
category	Application Use Case
further reading	- Single Grating Interferometer for X-Ray Imaging - Grazing-Incidence Focusing Mirrors for X-Ray Beams