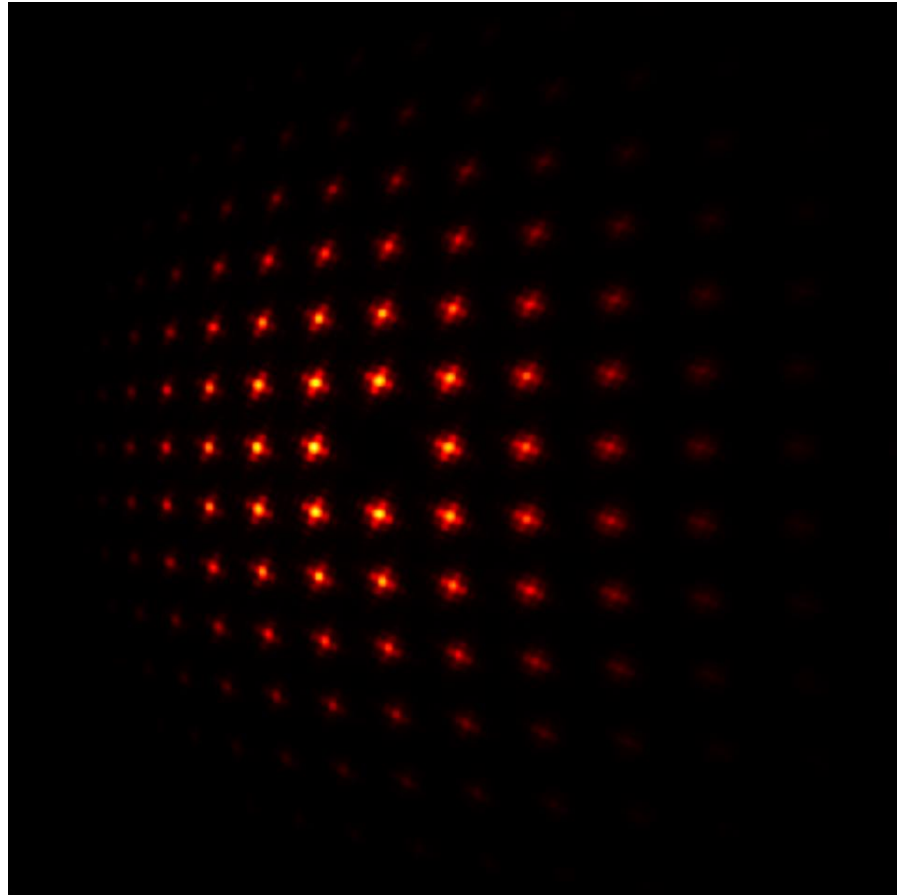


Hartmann Wavefront Sensor for X-Ray Optics

Abstract



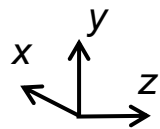
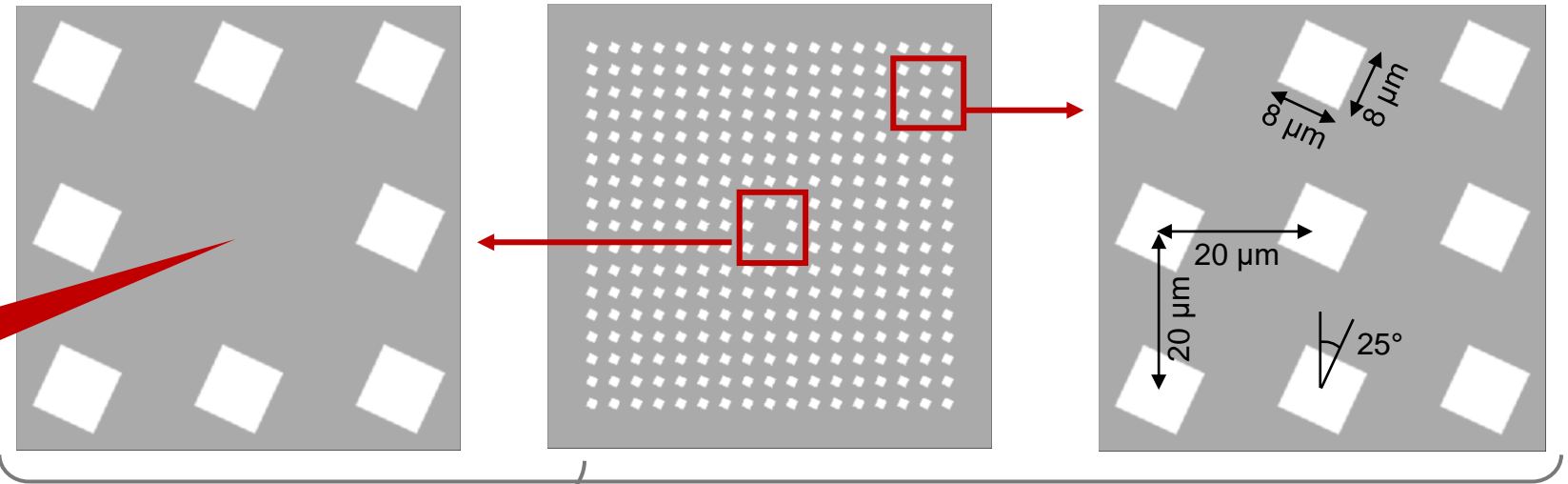
Hartmann sensors are a common tool to investigate the wavefront shape of an incoming X-ray beam, as they provide advantages like achromaticity and large dynamic ranges. In this use case, we follow the work of de La Rouchefouauld O. *et al.* [*Sensors* **2021**, *21*, 874.], to model the X-ray fields 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>

For center recognition
no pinhole at the
center of pinhole array



400 mm

200 mm

visualize the X-ray field
through the Hartmann
wavefront sensor

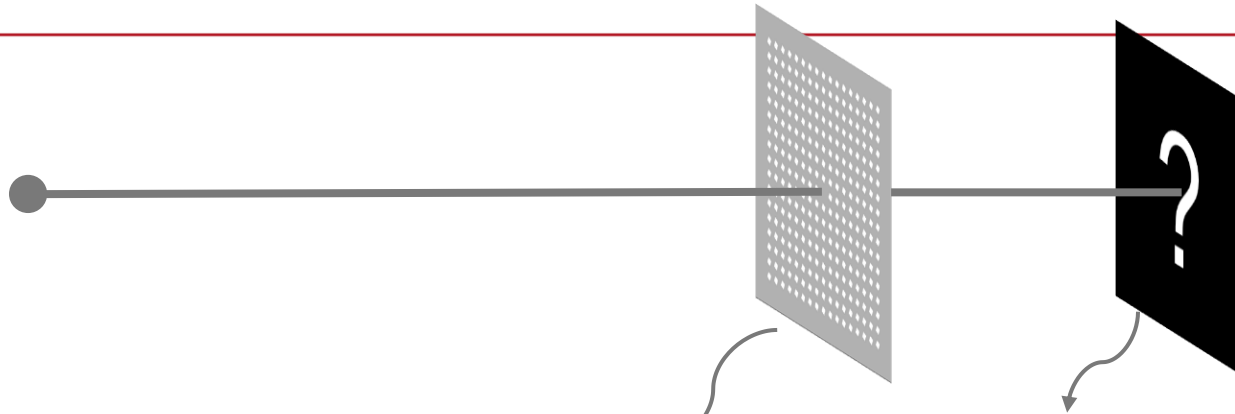
fundamental Gaussian

- wavelength 173pm (7.167keV)
- divergence angle $0.0012^\circ \times 0.0012^\circ$

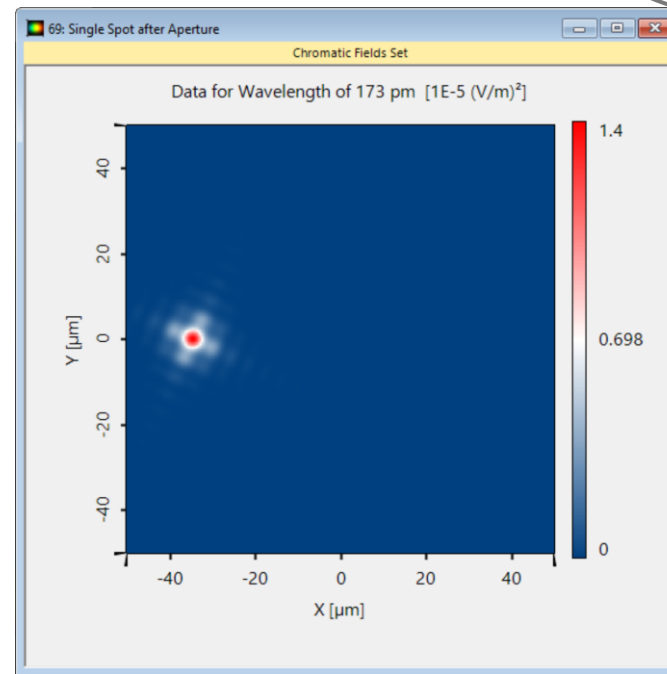
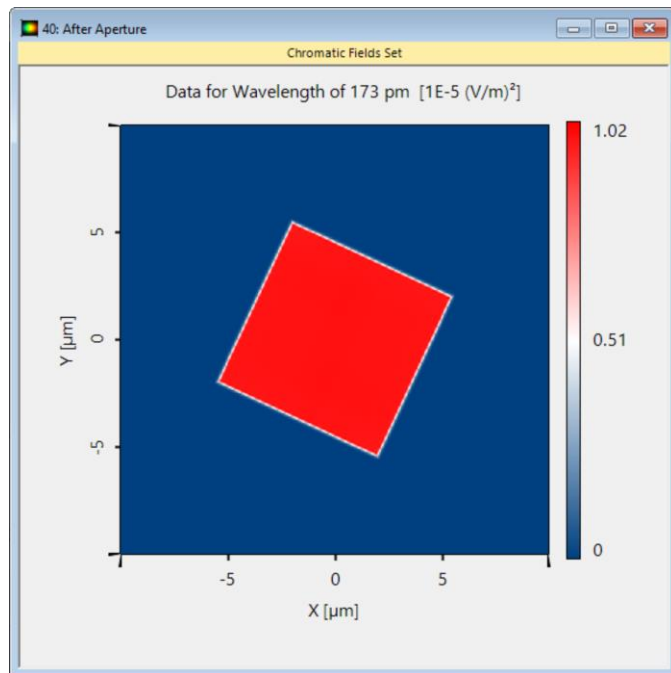
aperture mask

- 17×17 pinholes
(central pinhole removed)

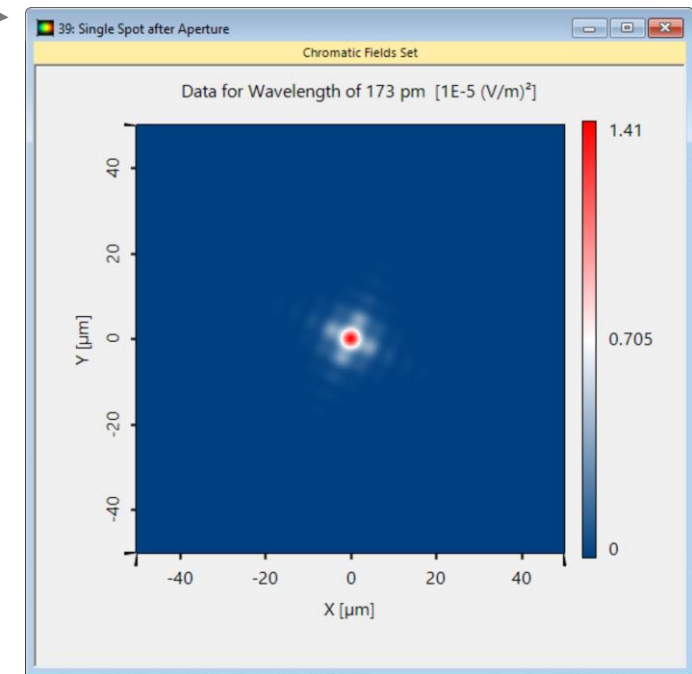
Simulation of an Individual Aperture



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.

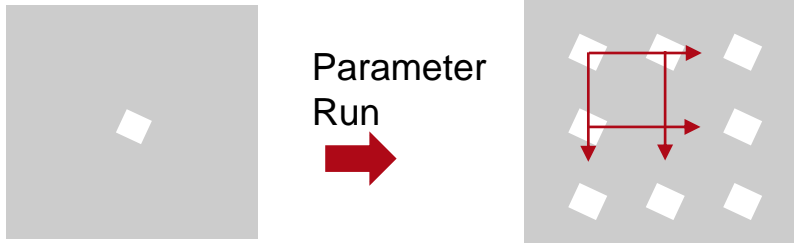


With Coma



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.

Parameter Specification

Set up the parameter(s) to be varied.

You can select one or more parameters which shall be varied as well as the resulting number of available specifying how the parameters are varied per iteration.

Usage Mode: Programmable

1	2	*	Object	Category	Parameter	Vary	From	To
			"Aperture" (# 2)	Isolated Positioning	Translation Delta X	<input checked="" type="checkbox"/>	-160 µm	160 µm
					Translation Delta Y	<input checked="" type="checkbox"/>	-160 µm	160 µm

Source Code Editor

```
#region Main method
45
46 int totalIterations = (int)Math.Pow(NumberOfIterations, 2);
47
48 double[,] parameters = new double[NumberOfParameters, totalIterations]
49
50 int IndexOfCenter = NumberOfIterations / 2 + 1;
51
52 double deltaX = Math.Round((MaximumValues[0] - MinimumValues[0]) / (double)totalIterations);
53 Double deltaY = Math.Round((MaximumValues[1] - MinimumValues[1]) / (double)totalIterations);
54
55 Globals.DataDisplay.LogMessage(IndexOfCenter.ToString());
56
57 for (int j = 0; j < IndexOfCenter - 1; j++)
58     for (int i = 0; i < NumberOfIterations; i++) {
59         parameters[0, (j * NumberOfIterations) + i] = Math.Round(MinimumValues[0] + (double)i * deltaX);
60         parameters[1, (j * NumberOfIterations) + i] = Math.Round(MinimumValues[1] + (double)i * deltaY);
61     }
62
63     parameters[0, (j * NumberOfIterations) + i] = Math.Round(MinimumValues[0] + (double)i * deltaX);
64     parameters[1, (j * NumberOfIterations) + i] = Math.Round(MinimumValues[1] + (double)i * deltaY);
65
66 }
```

Results

Start the parameter run and analyze its results

Go!

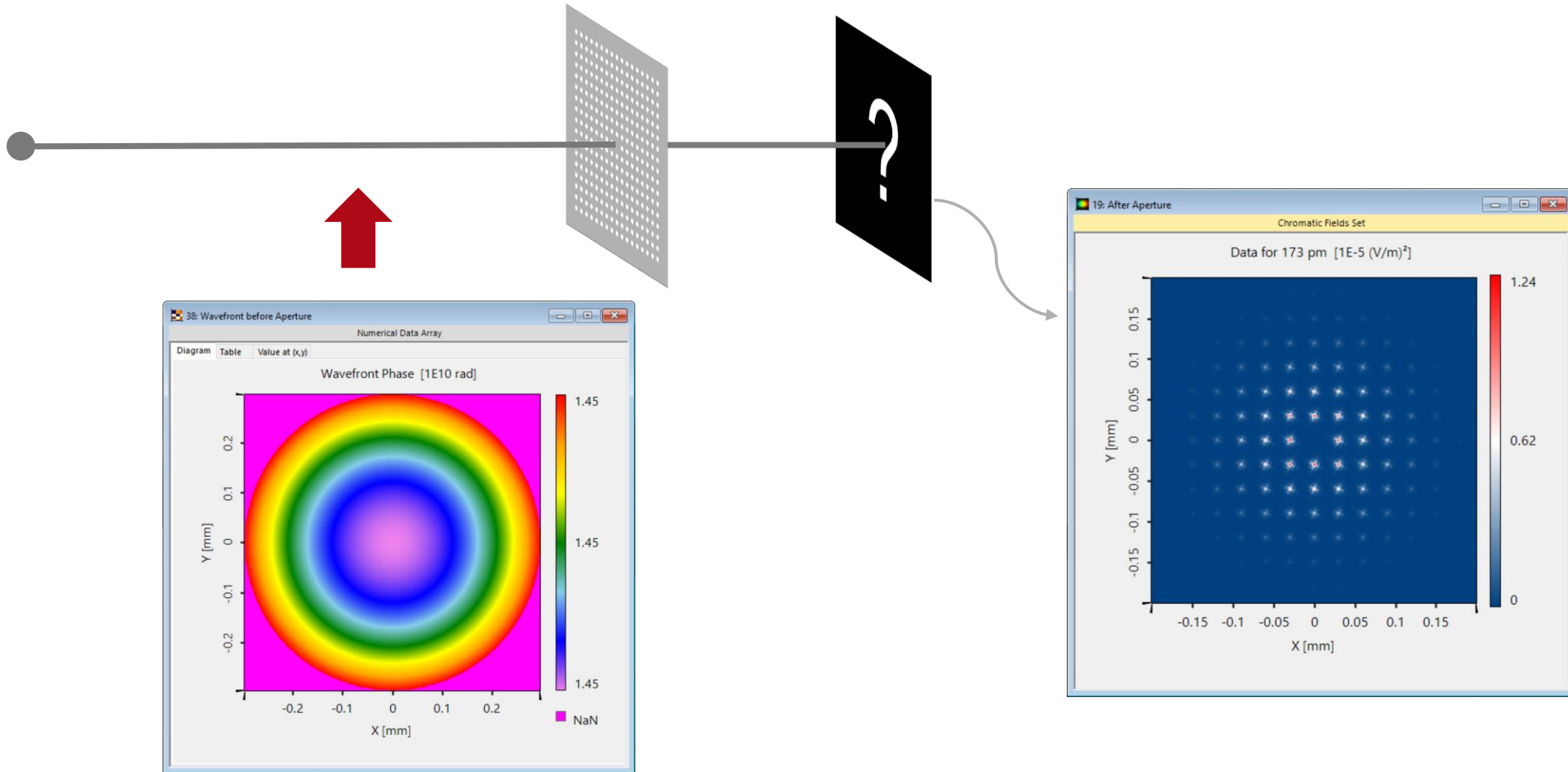
Use Already Calculated Results for Next Run

Detector	Subdetector	Combined Output	Iteration Step	143	144	145	146
Varied Parameters	Translation Delta X ("Apert...	Data Array		0 mm	0 mm	0 mm	0 mm
	Translation Delta Y ("Apert...	Data Array		-40 µm	-20 µm	20 µm	40 µm
"Camera Detector" (# 601)...		2D Chromatic		Chromatic Fields Set	Chromatic Fields Set	Chromatic Fields Set	Chromatic Fields Set

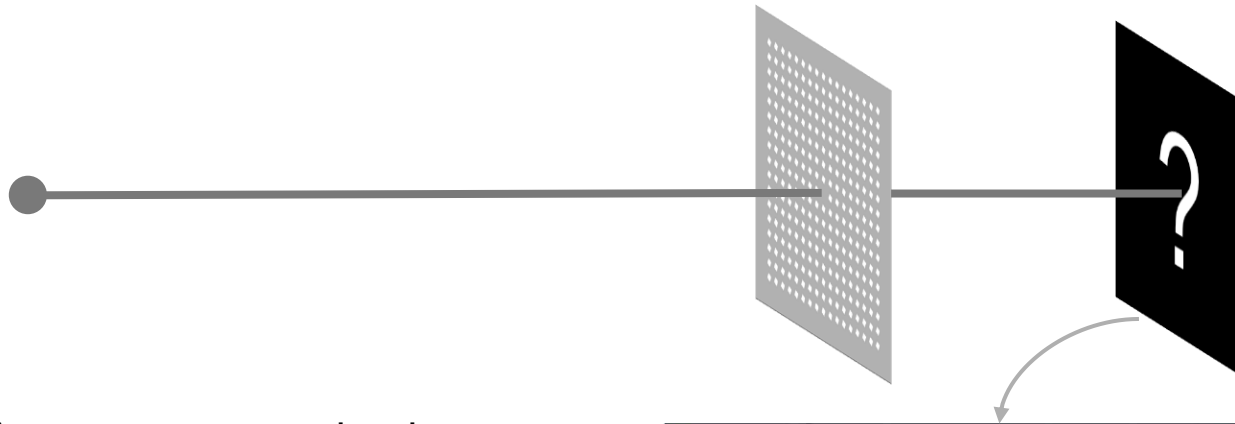
Create Output from Selection

< Back Next > Show

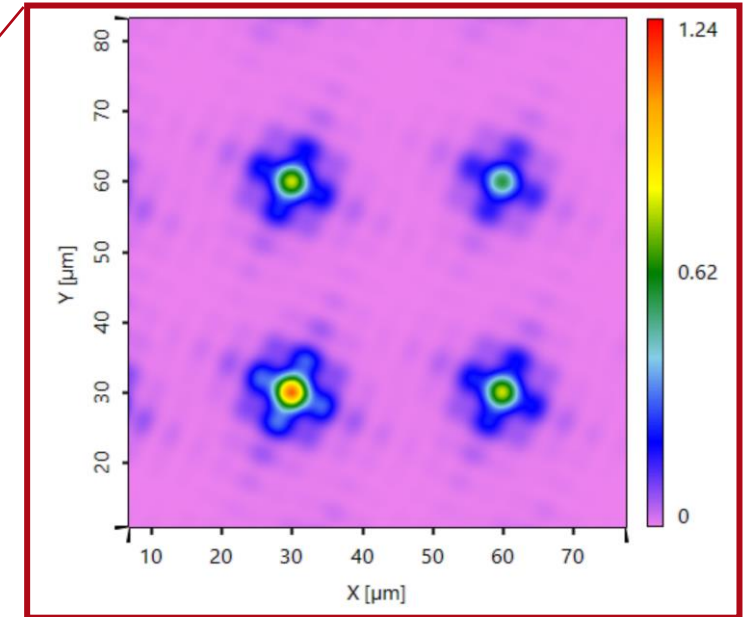
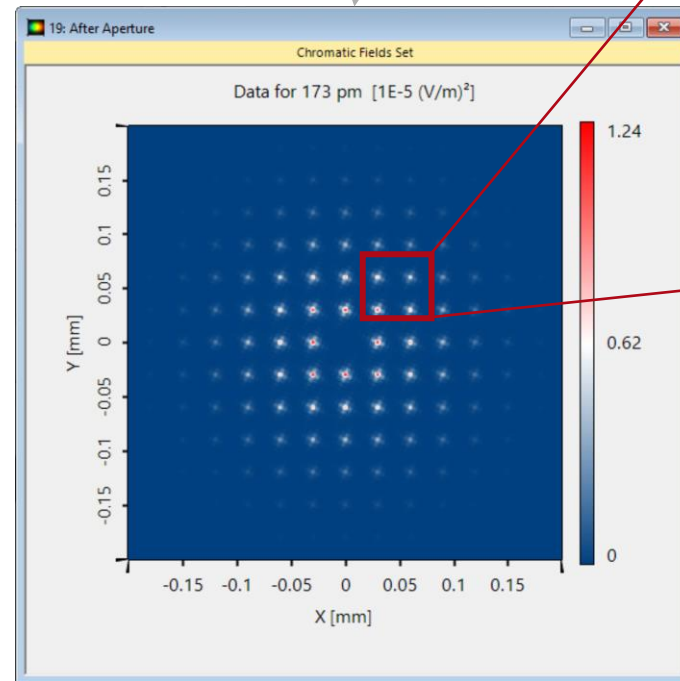
Simulation of Fundamental Gaussian Wavefront



Effect of the Tilted Square Apertures

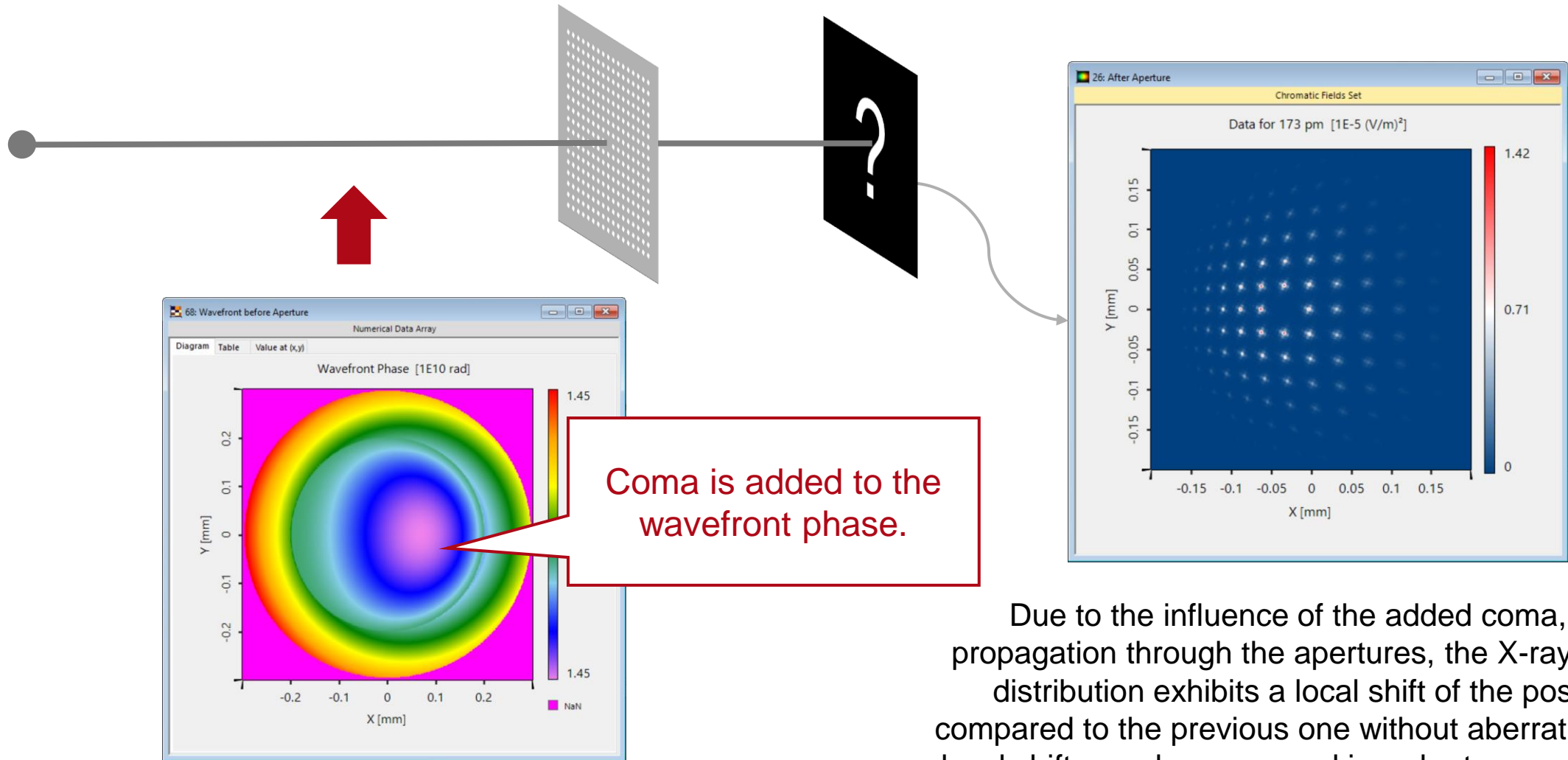


A square aperture leads to a diffraction pattern with four distinct directions. Through the tilt of the square apertures these side lobes no longer overlap, which decreases the cross-talk allowing for denser aperture arrays.

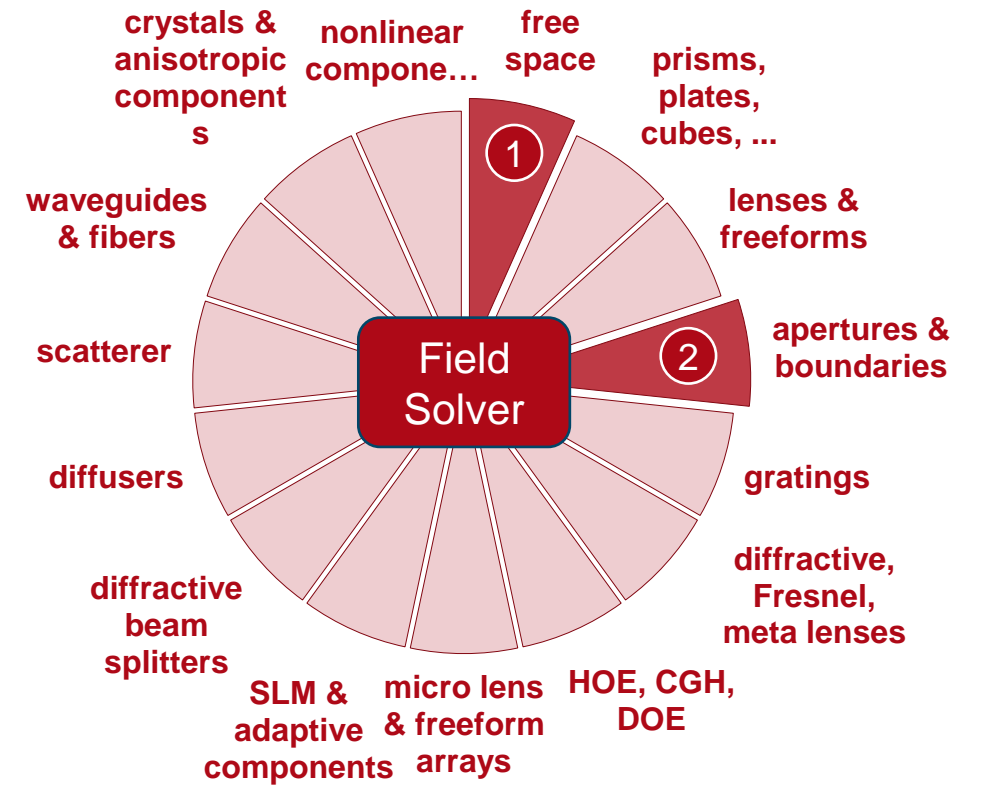
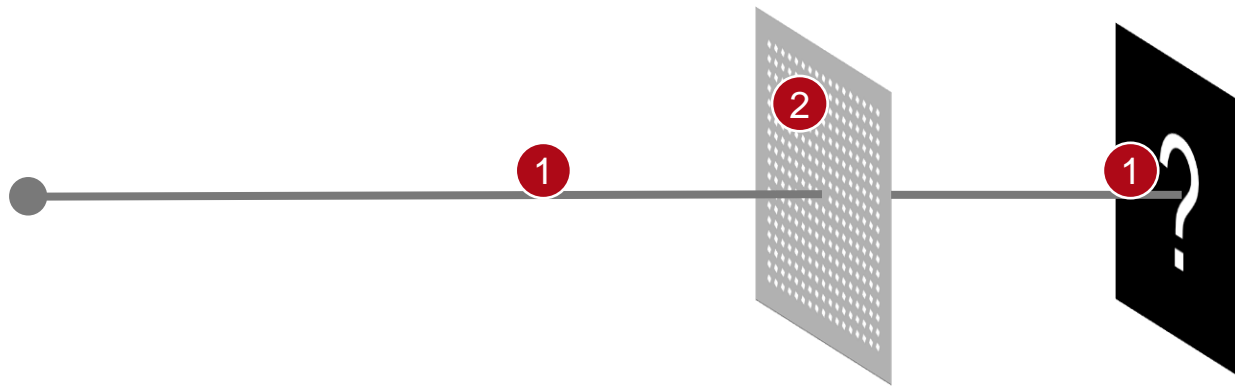


Note: VirtualLab Fusion allows on-the-fly swaps of color palettes for most detector results to better highlight certain effects without the need of recalculation.

Simulation Including Coma Aberration



VirtualLab Fusion Technologies



Document Information

title	Hartmann Wavefront Sensor for X-Ray Optics
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further reading	<ul style="list-style-type: none">- Single Grating Interferometer for X-Ray Imaging- Grazing-Incidence Focusing Mirrors for X-Ray Beams