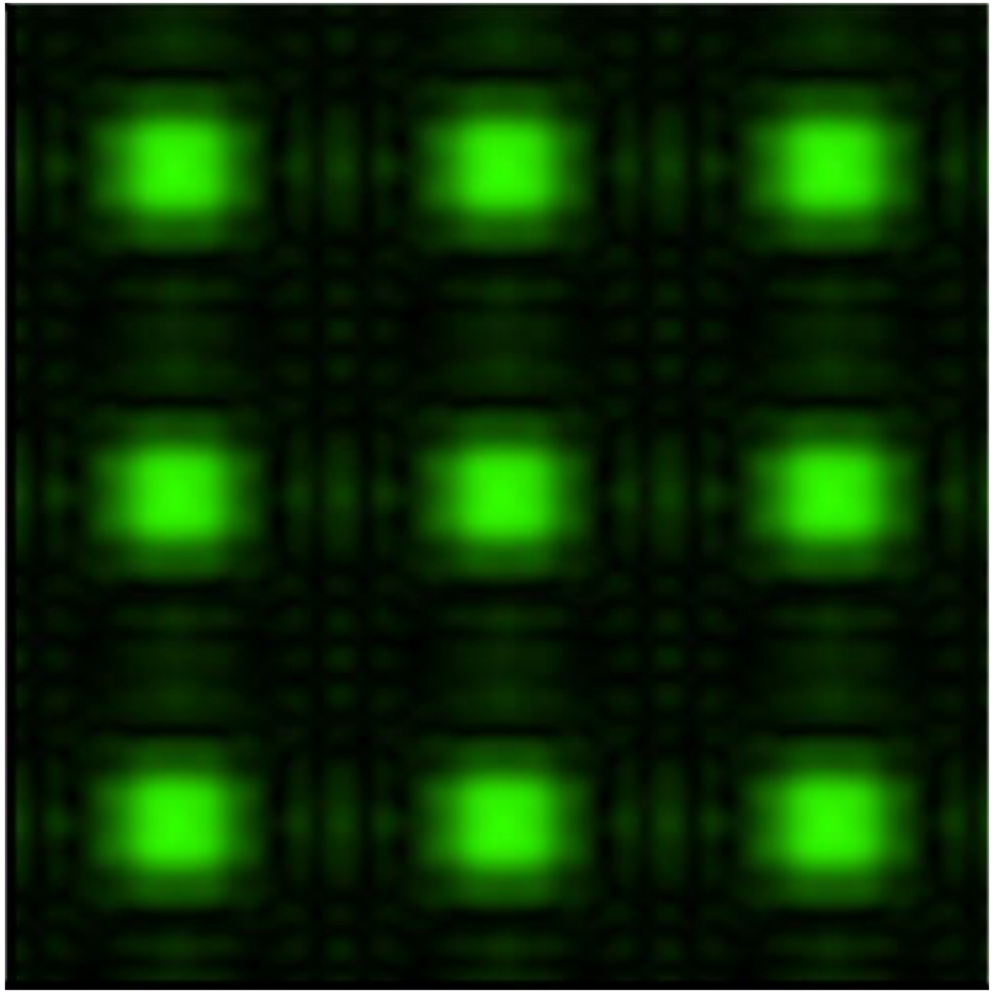
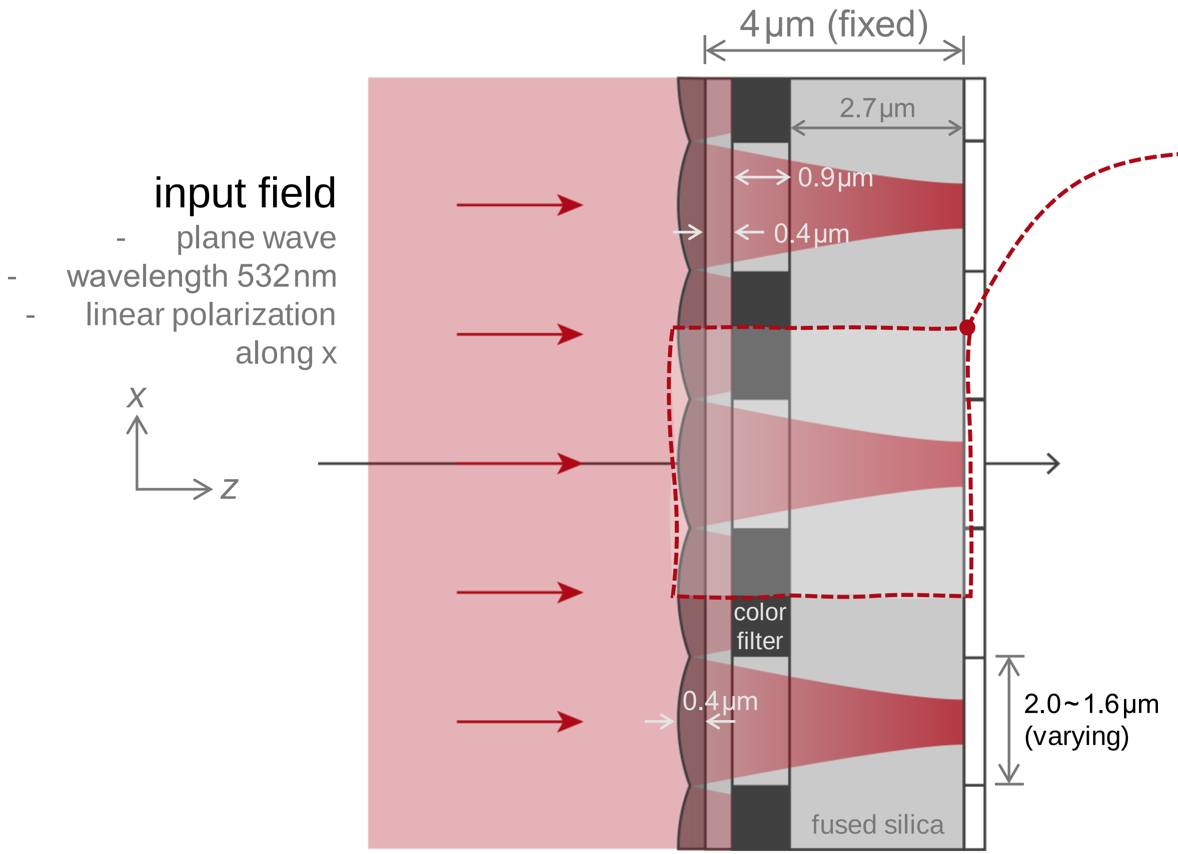
Analysis of CMOS Sensors with Microlens Array

Abstract

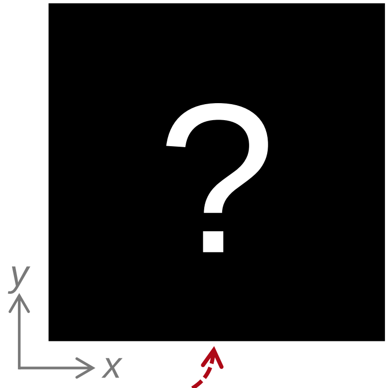


In the recent decades, the pixel size of CMOS sensors has scaled from more than 10µm to 2µm or even smaller. By decreasing the pixel size, higher spatial resolution has been achieved. At the same time, it brings questions to the functionality of the microlenses sitting on top of each pixel. In this example, we investigate the performance of CMOS sensor with pixel size equal to or below 2µm. The rigorous FMM / RCWA is employed for the simulation to check the effectiveness of the microlenses.

Modeling Task



How does the field behind the microlens array behave – is the focusing function still valid?



What is the field distribution like on the final pixel array?

geometry parameters adapted from Y. Huo, *et al*., Opt. Express 18, 5861-5872 (2010)

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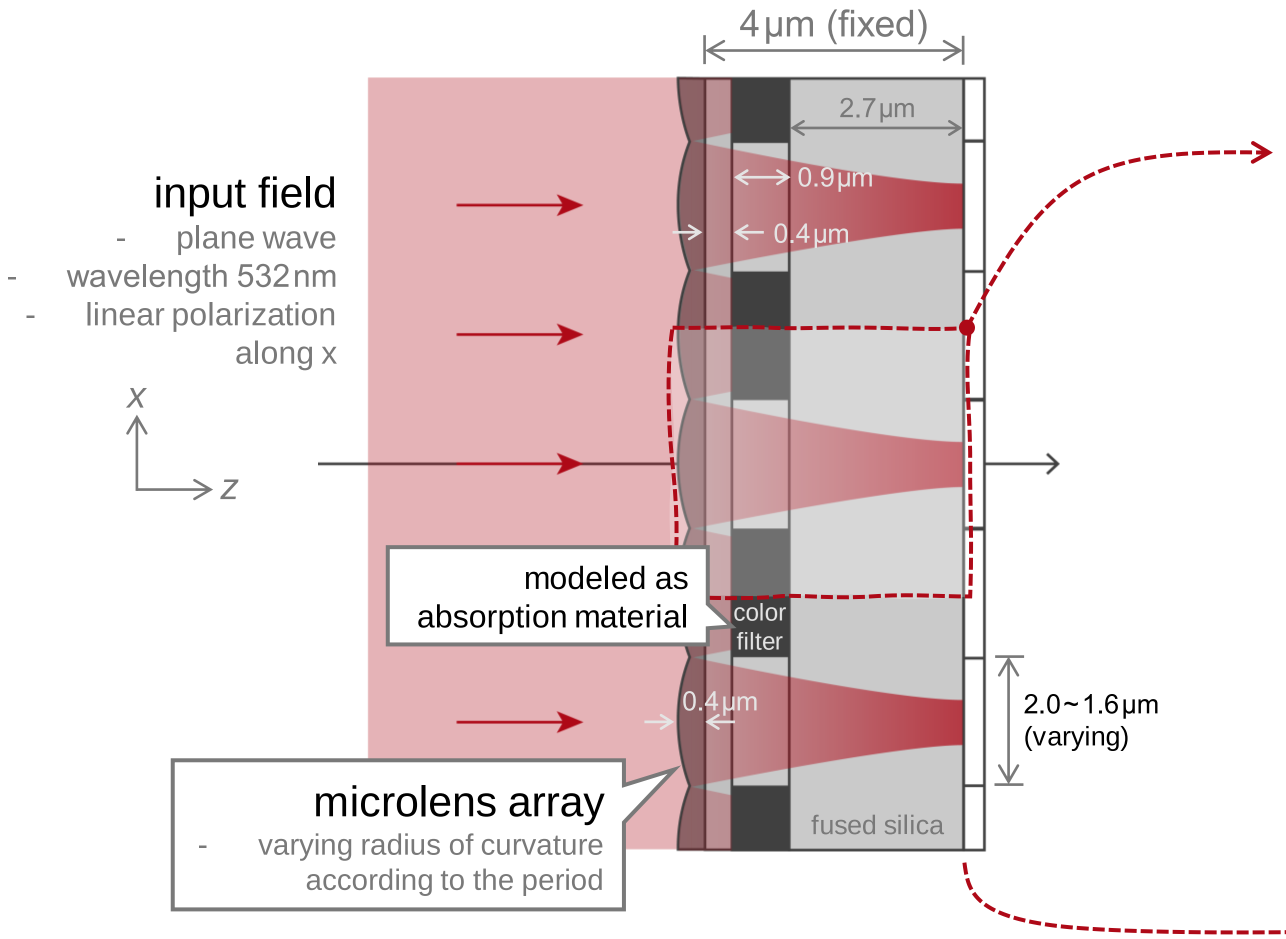

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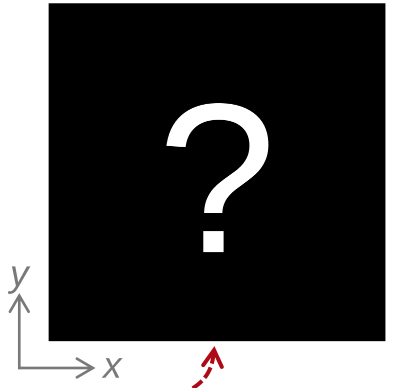

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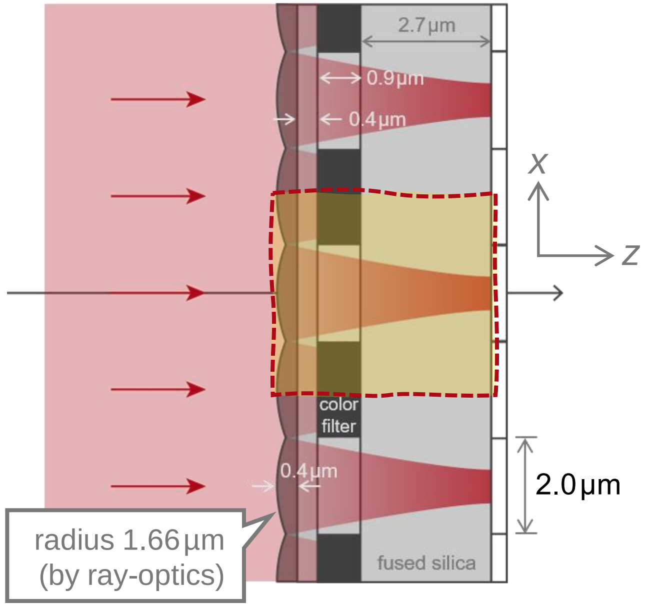
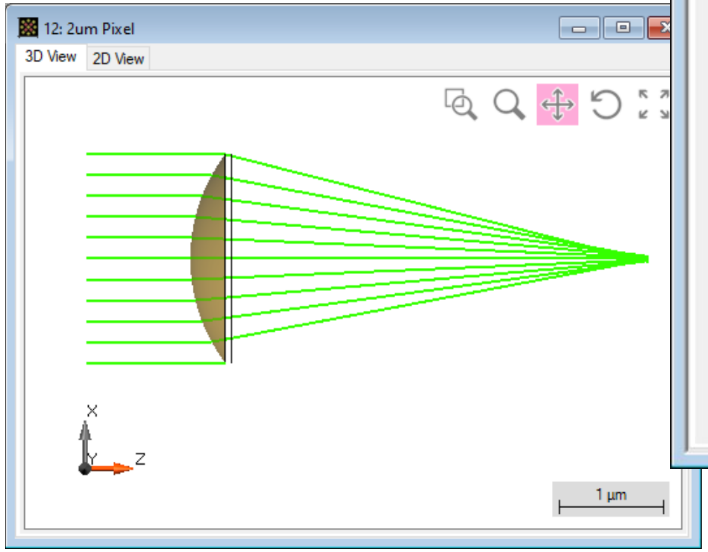
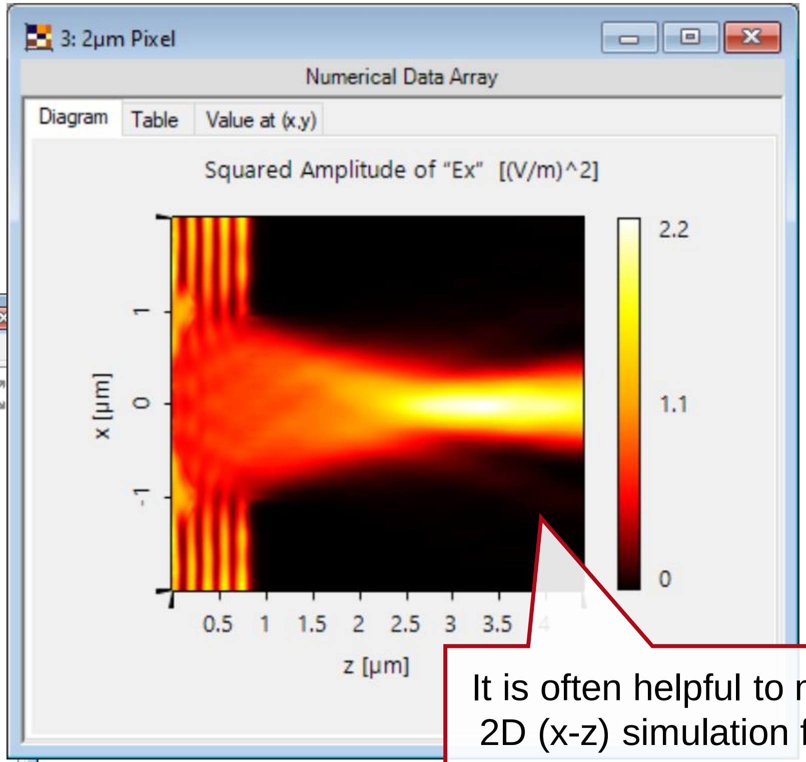
Microlens for 2 µm Pixel (x-z Simulation)



ray-optics design

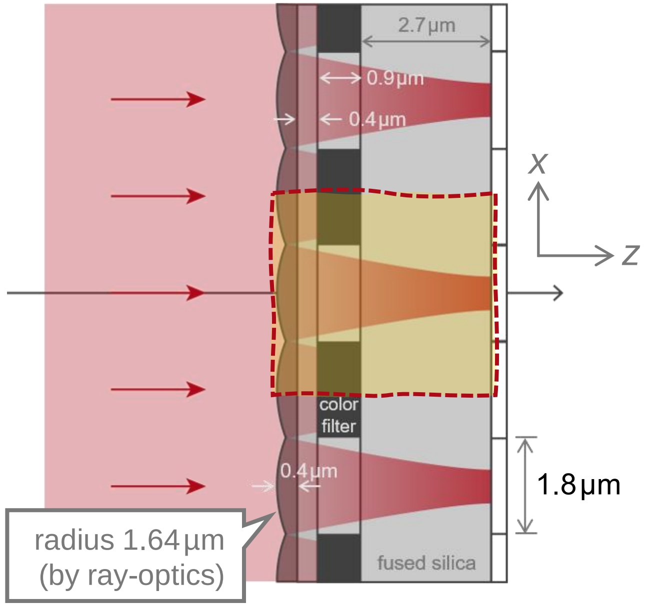


FMM / RCWA simulation (x-z)

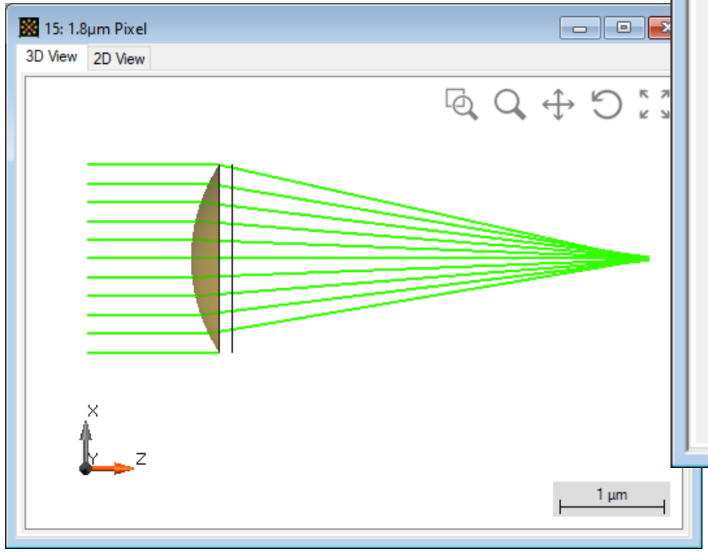


It is often helpful to make a 2D (x-z) simulation first so to get a fast understanding of the situation.

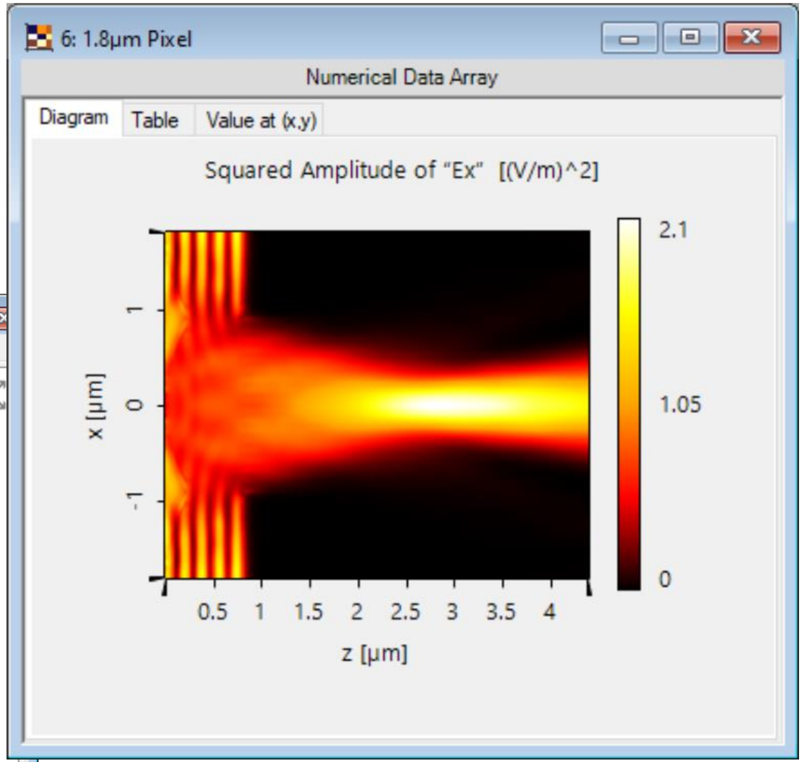
Microlens for 1.8 µm Pixel (x-z Simulation)



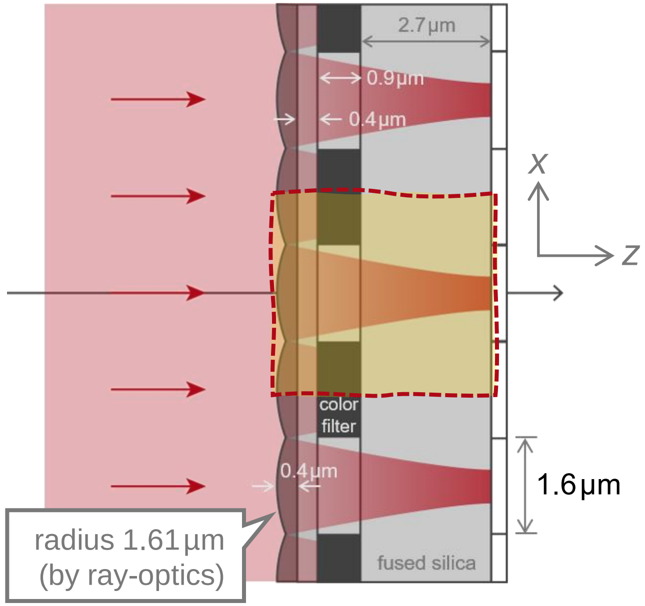
ray-optics design



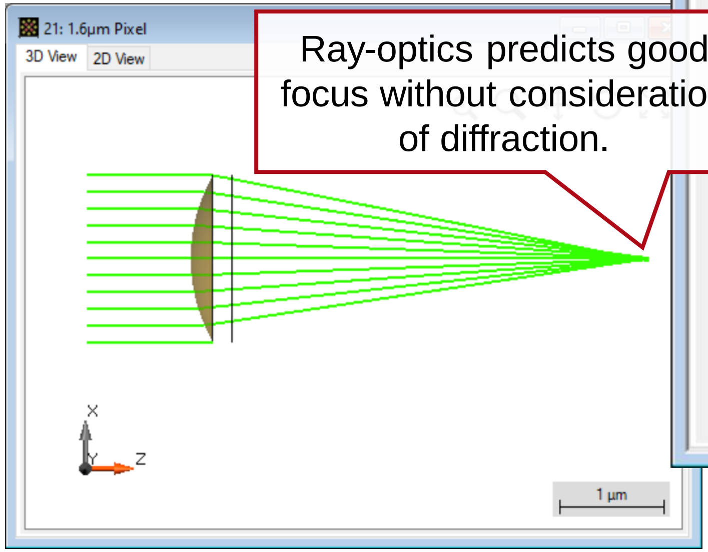
FMM / RCWA simulation (x-z)



Microlens for 1.6µm Pixel (x-z Simulation)

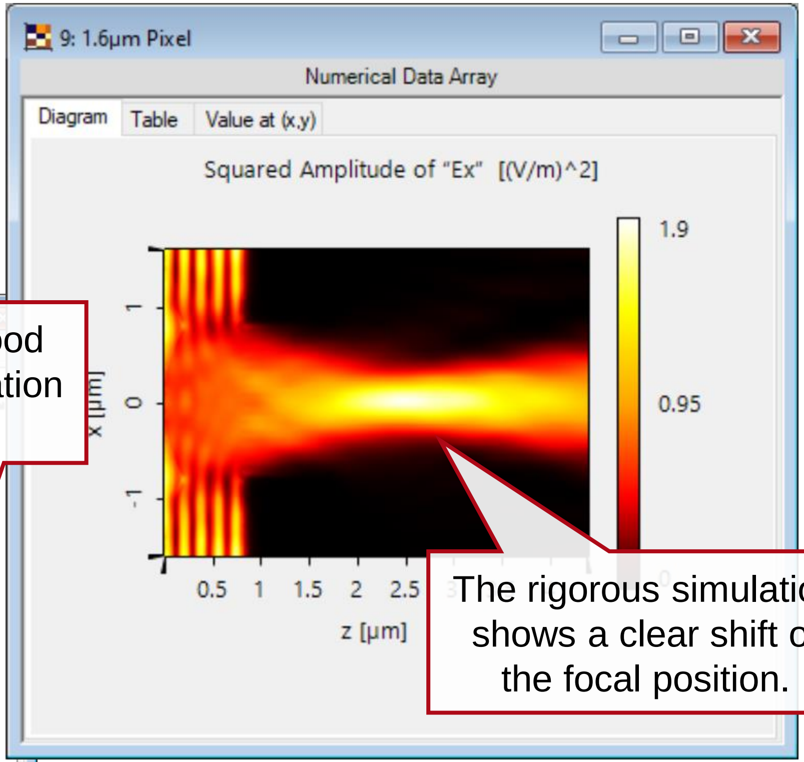


ray-optics design



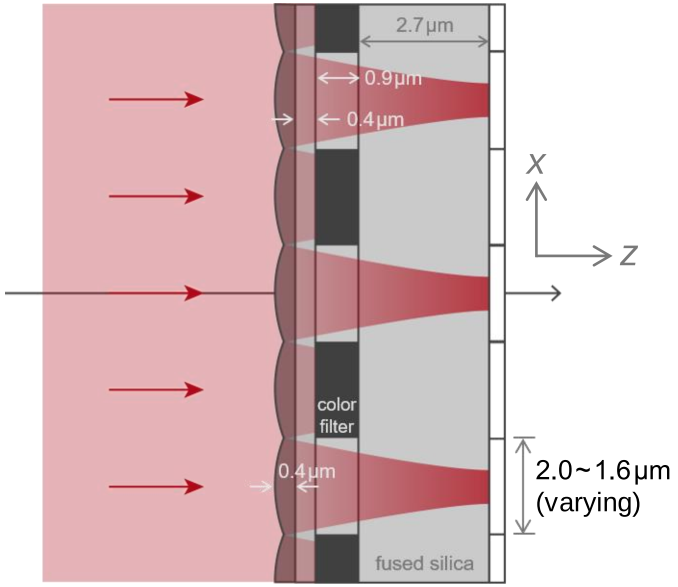
Ray-optics predicts good focus without consideration of diffraction.

FMM / RCWA simulation (x-z)

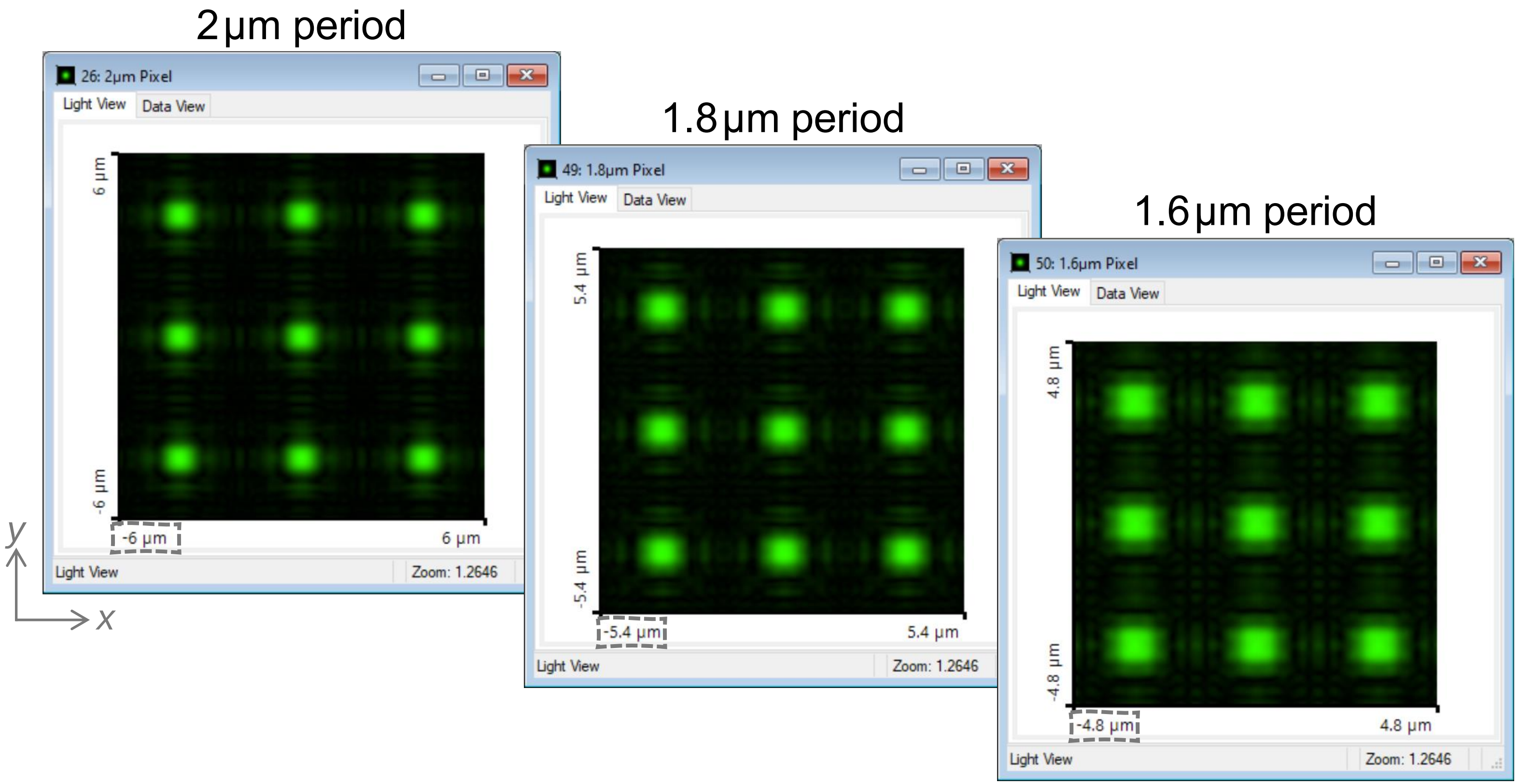


The rigorous simulation shows a clear shift of the focal position.

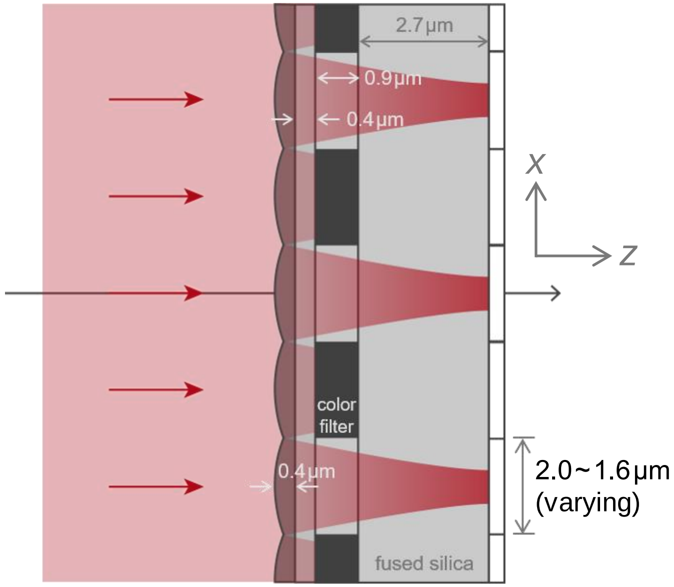
3D Simulation and Results Comparison



check the results on this plane

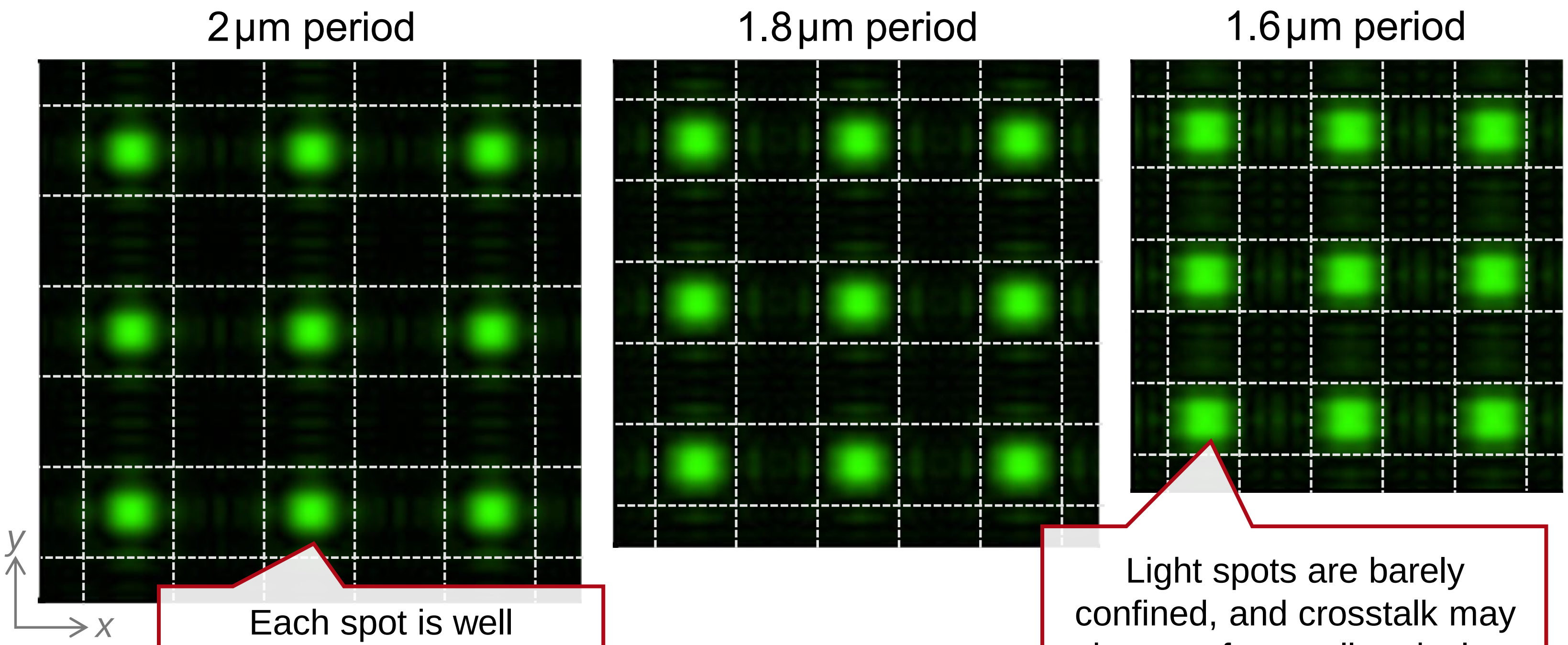


3D Simulation and Results Comparison



check the results on this plane

same scaling for all the result pictures

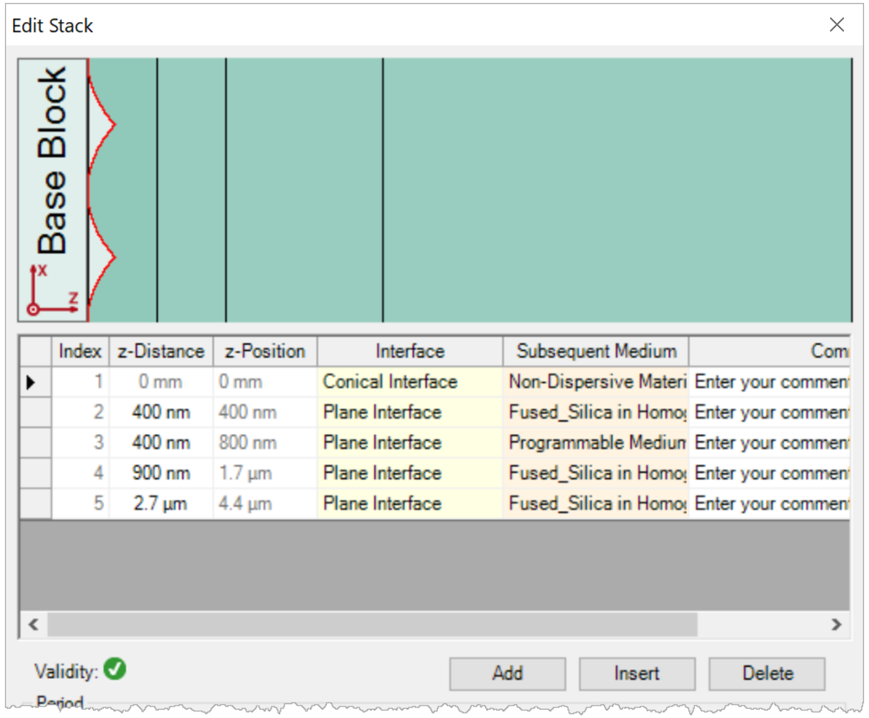


Each spot is well confined within the corresponding pixel area.

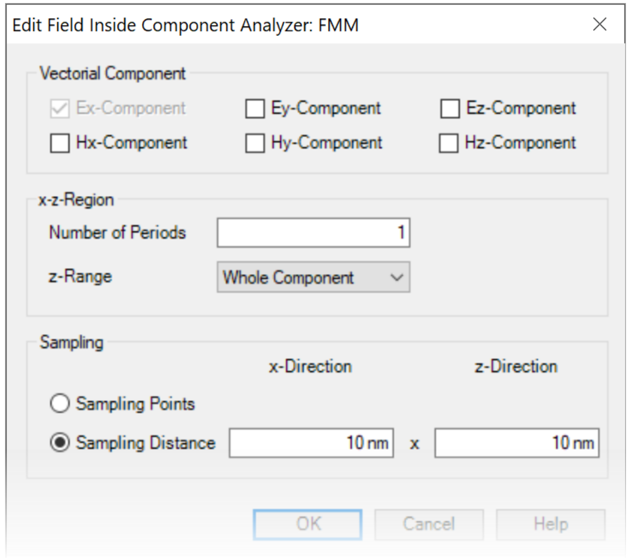
Light spots are barely confined, and crosstalk may happen for smaller pixels.

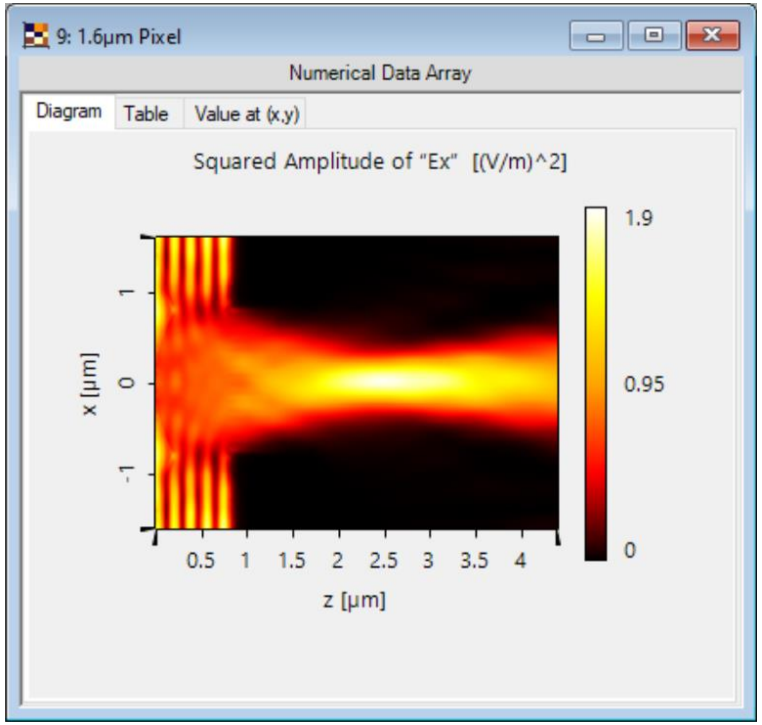
Peek into VirtualLab Fusion

flexible definition of micro-/nanostructures



convenient setting and visualization of field inside structrue

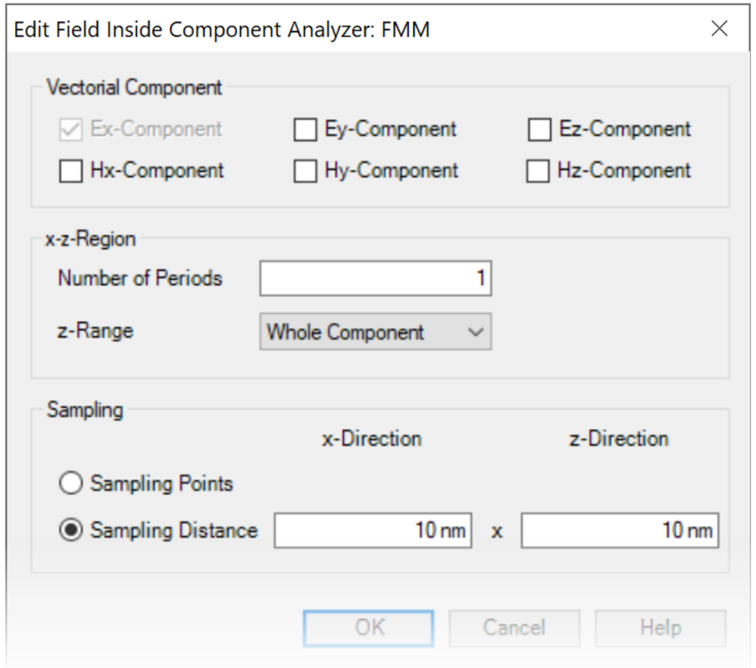




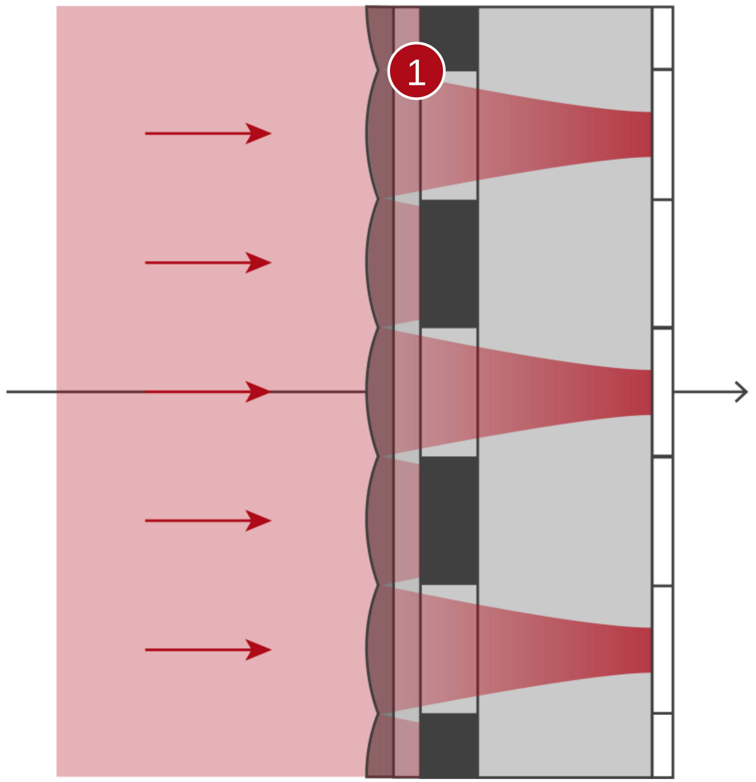
Workflow in VirtualLab Fusion

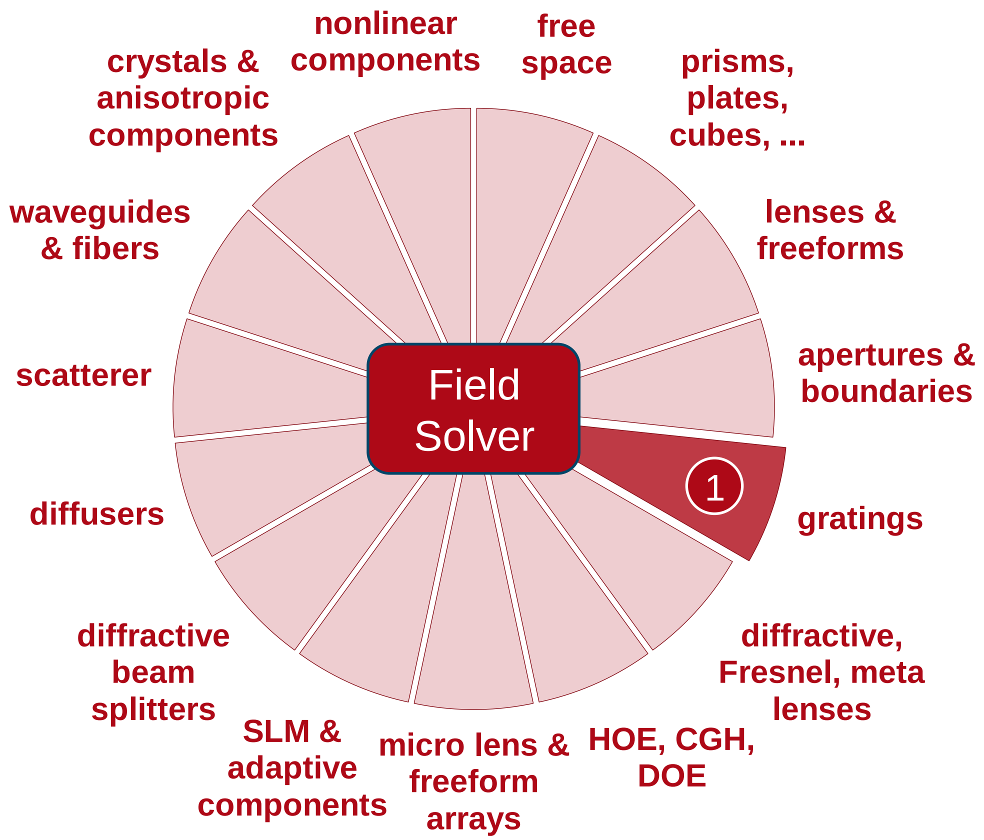
- Construct grating structure
  - [Configuration of Grating Structures by Using Interfaces] [Use Case]
  - [Configuration of Grating Structures by Using Special Media] [Use Case]

- Calculate field inside grating structure



VirtualLab Fusion Technologies





Document Information

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further reading	- Ultra-Sparse Dielectric Nano-Wire Grid Polarizers - Configuration of Grating Structures by Using Interfaces - Configuration of Grating Structures by Using Special Media