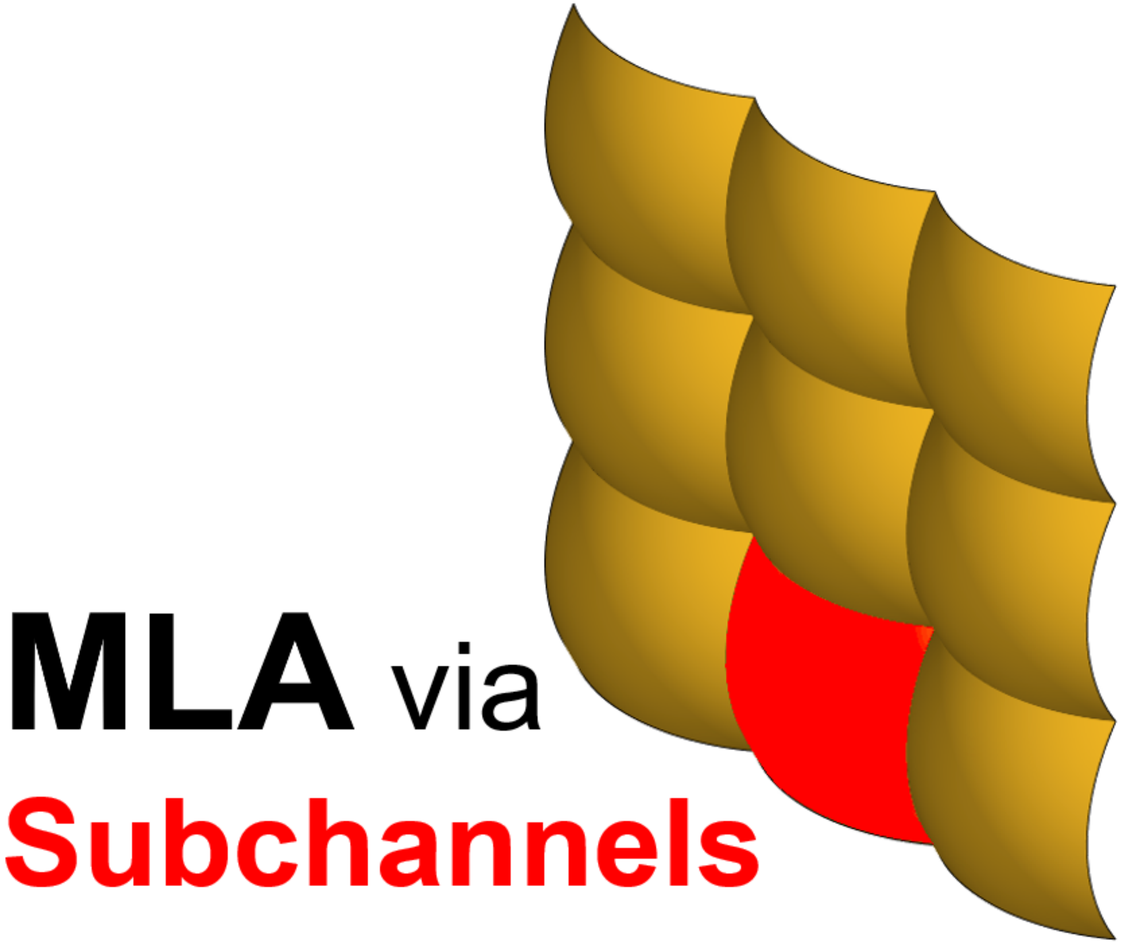
Advanced Simulation of Microlens Arrays

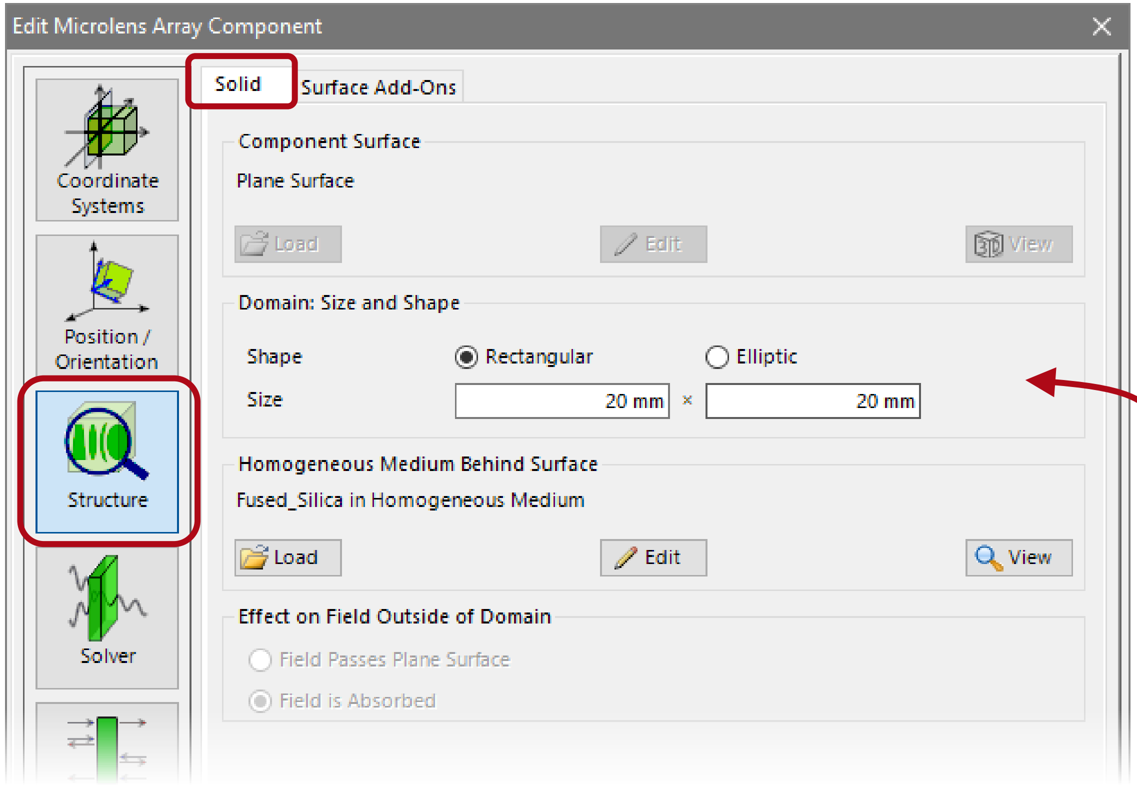
Abstract

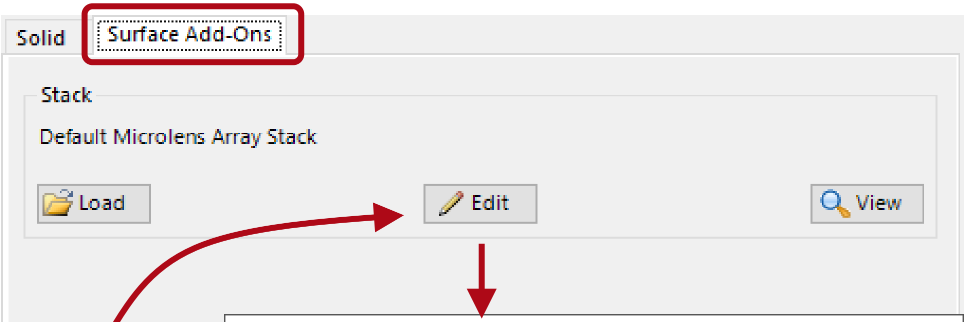


Microlens arrays (MLAs) are getting more and more attention in various opical applications, such as digital projectors, optical diffusers, and 3D imaging. VirtualLab Fusion allows to apply an advanced field tracing algorithm to analyze such array elements via a so-called multi-channel concept. In this use case, the configuration and usage of the Microlens Array component are introduced.

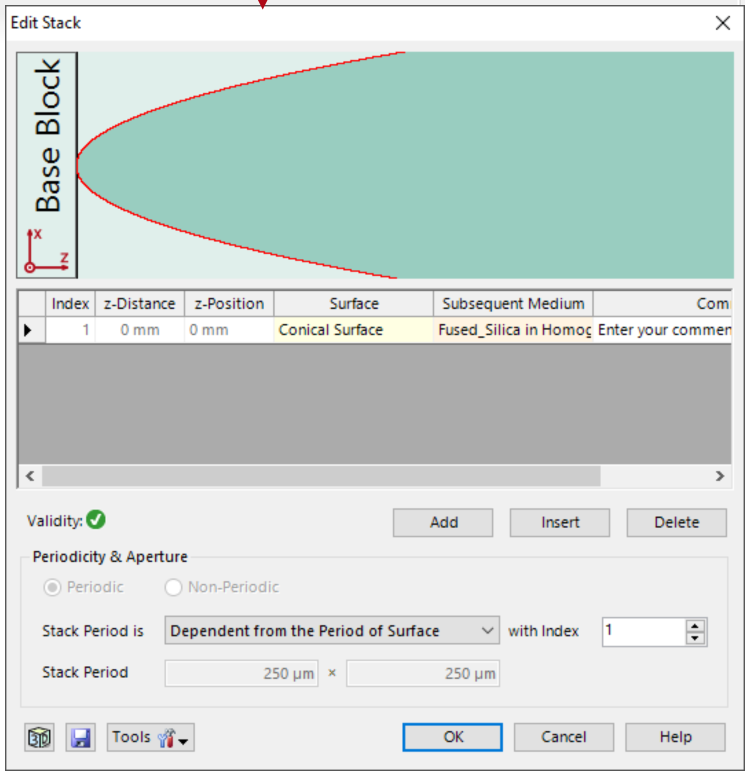
Structure Configuration of Microlens Array

The Microlens Array component is predestined to model elements that consist of periodic rectangular cells where each contains a smooth surface profile. More options are planned.



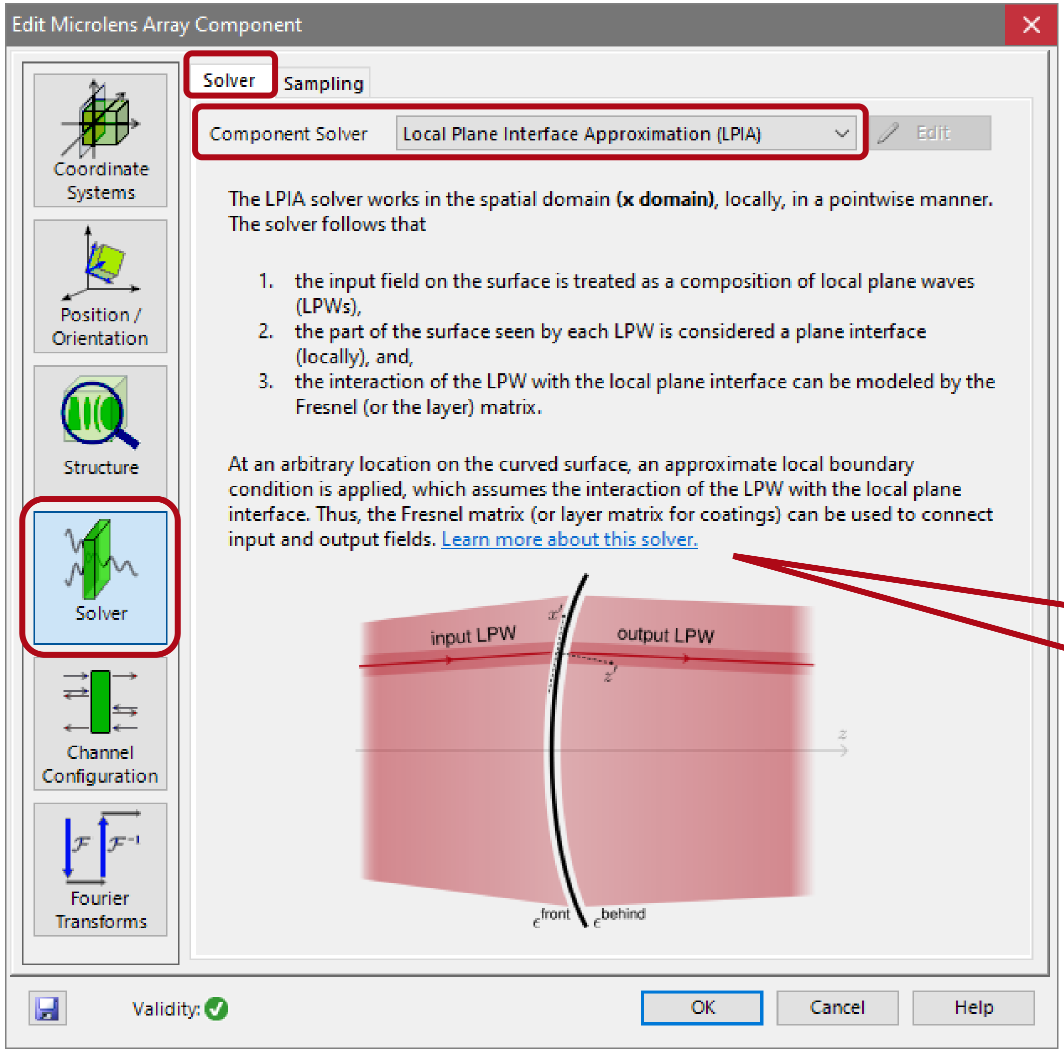


The surface profile used for each microlens cell is to be defined via VirtualLab's stack dialog via the Surface Add-Ons tab.



On the Solid tab of the Structure page, the shape and size of the whole array is to be defined as well as the material behind the surface.

By Which Method Is the Field Propagated through the MLA?

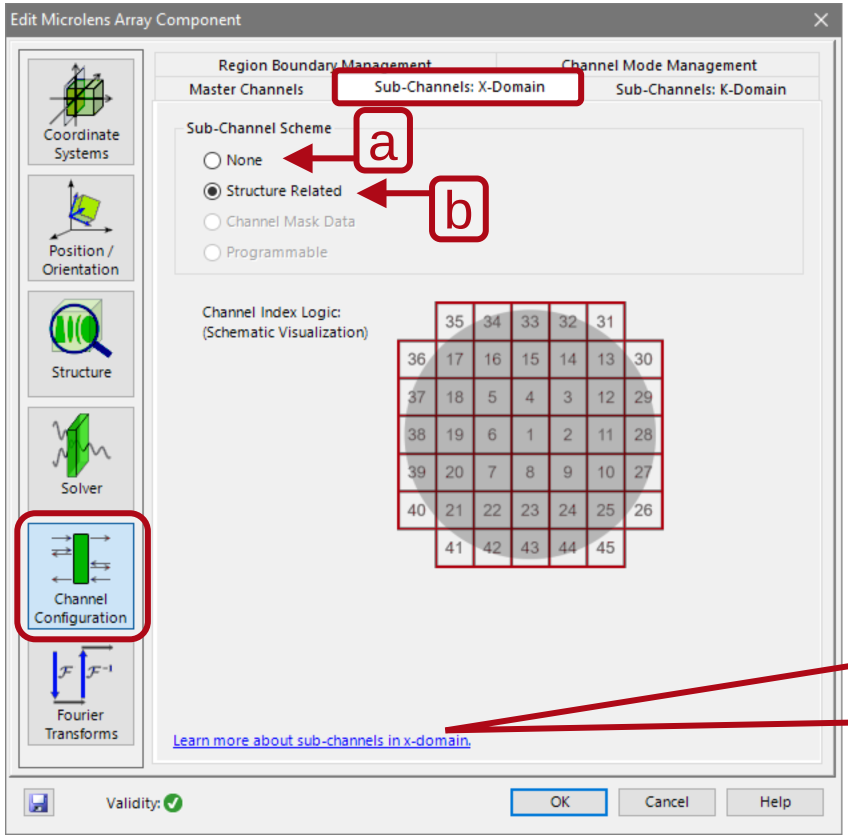


As solver for the propagation through the surfaces the Local Plane Interface Approximation (LPIA) is used (see Solver page of the edit dialog of the Microlens array Component).

If you want to learn more about this solver, please follow our info link.

Sub-Channel Decomposition

- The speciality of this MLA component is, that the user can choose if the simulation is done by propagating the full field through multiple microlenses in one step (a) or by decomposing the field before, so that each microlens is evaluated individually, and the output field of each of these so-called sub-channels is then processed further through the subsequent system whereupon all fields are suitably put together (b).

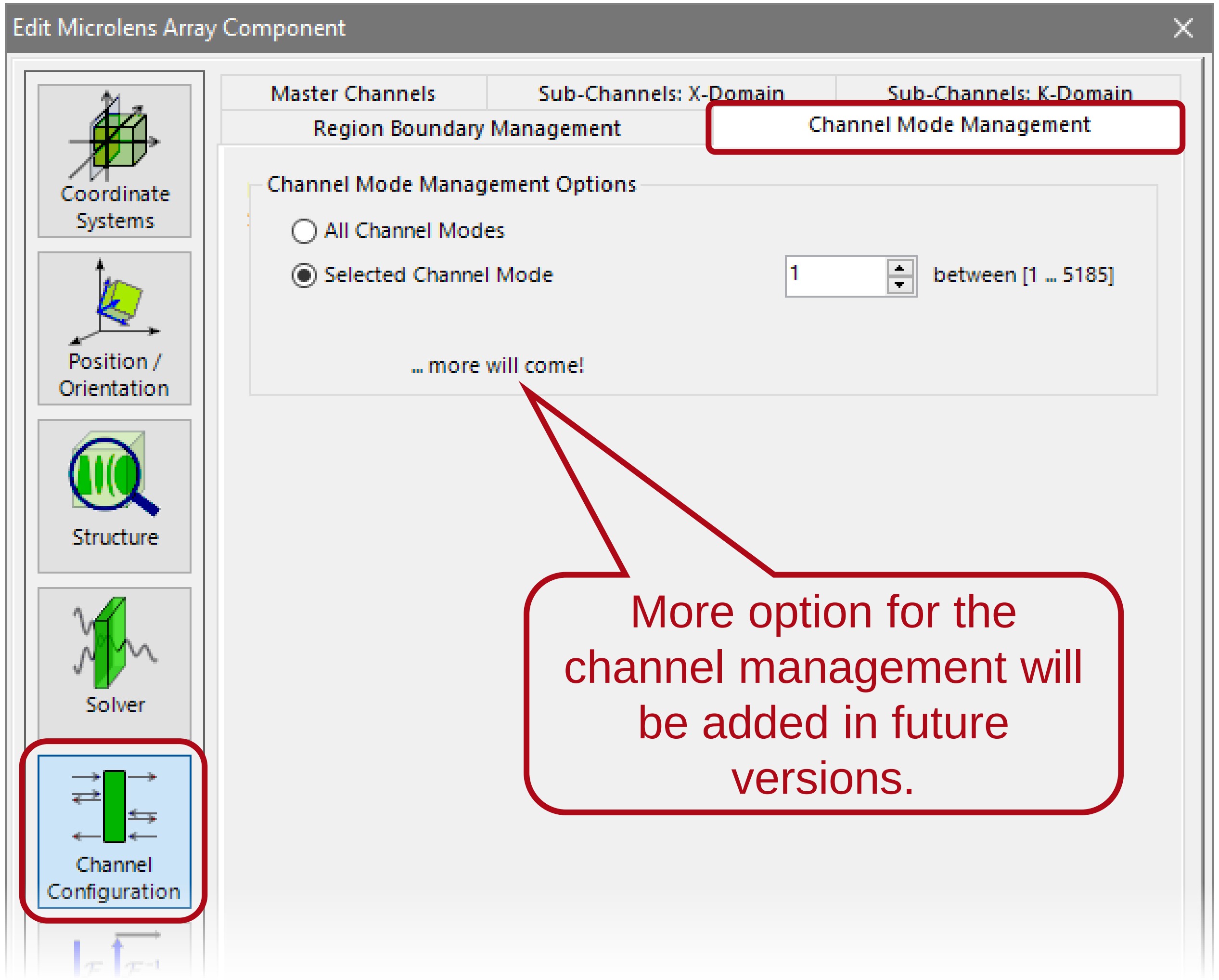


- The subchannel simulation is more accurate, but might take longer. Which option is more suitable depends on diverse factors. E.g. the number of microlenses, how strong the surface modulation is, where the field behind the lens is evaluated (near field, focus, far field). So it is best to test both options.
- For the configuration please go to the "*Sub-Channels: X-Domain*" tab on the *Channel Configuration* page.

If you want to learn more about this sub-channel concept please follow our info link.

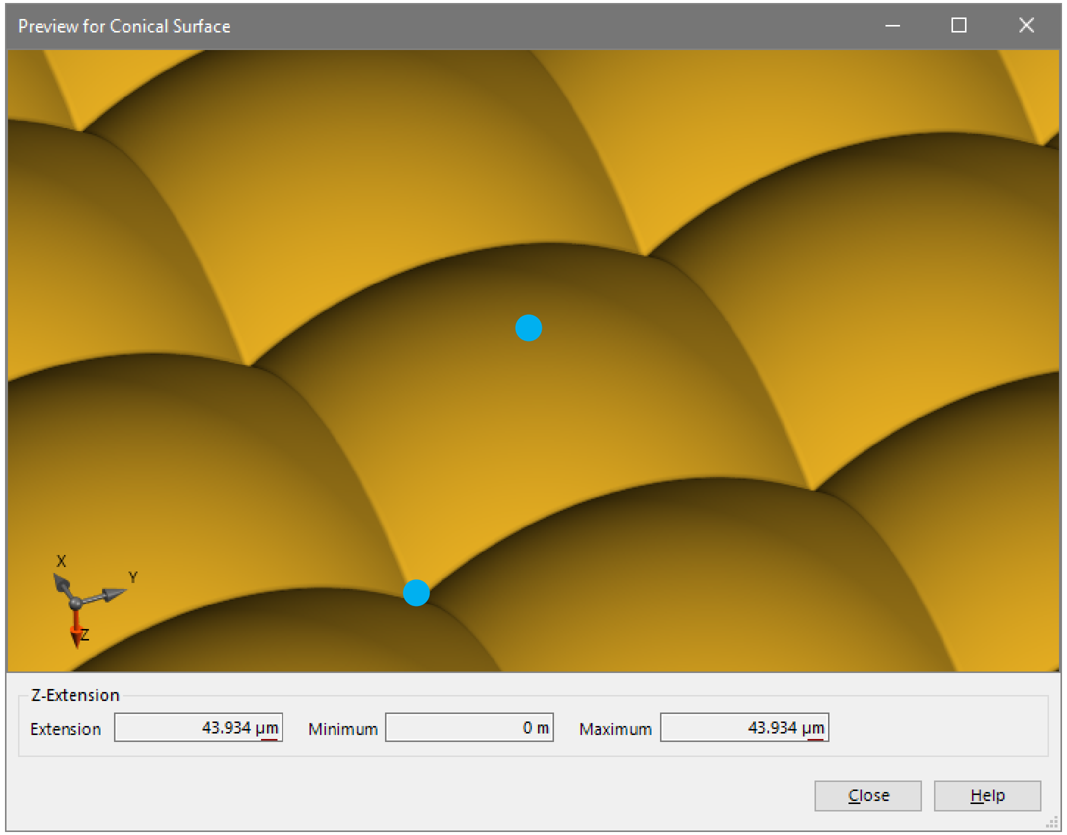
More Info about Subchannel Concept

Sub-Channel Evaluations



- VirtualLab Fusion allows also to evaluate the results of each microlens separately.
- On the "*Channels Mode Management*" tab the channel modes can be selected via their index.

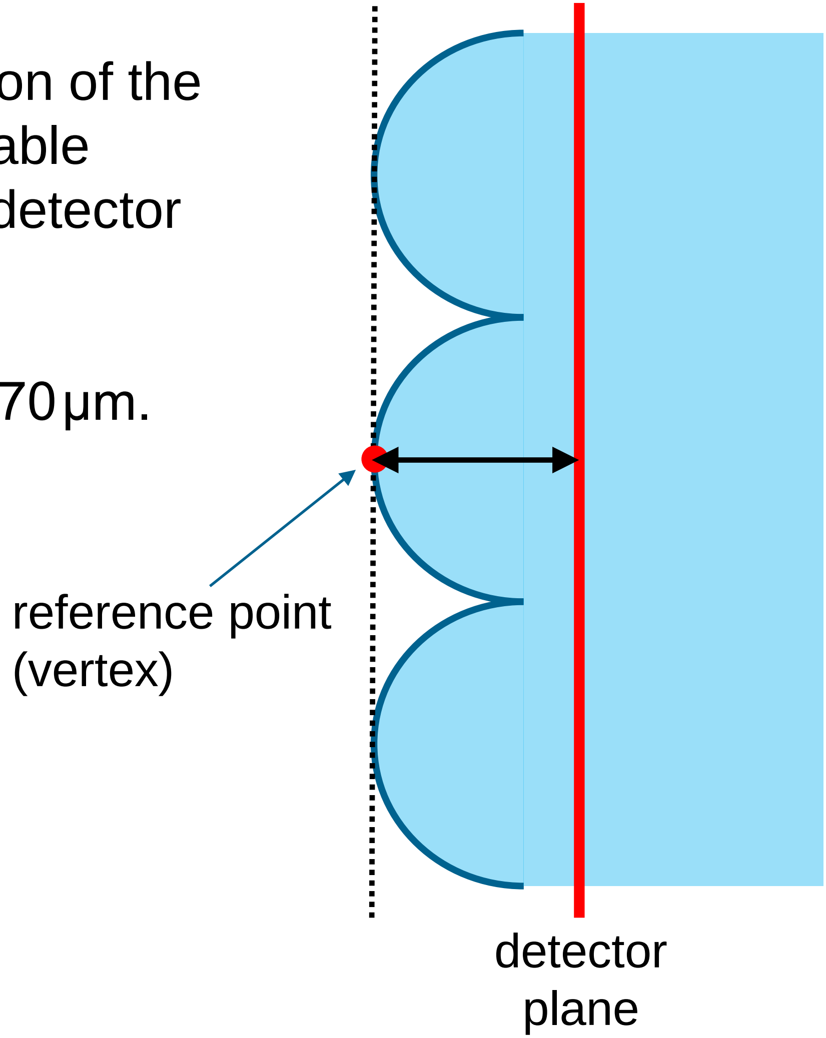
Positioning of Detector for Near Field Evaluation



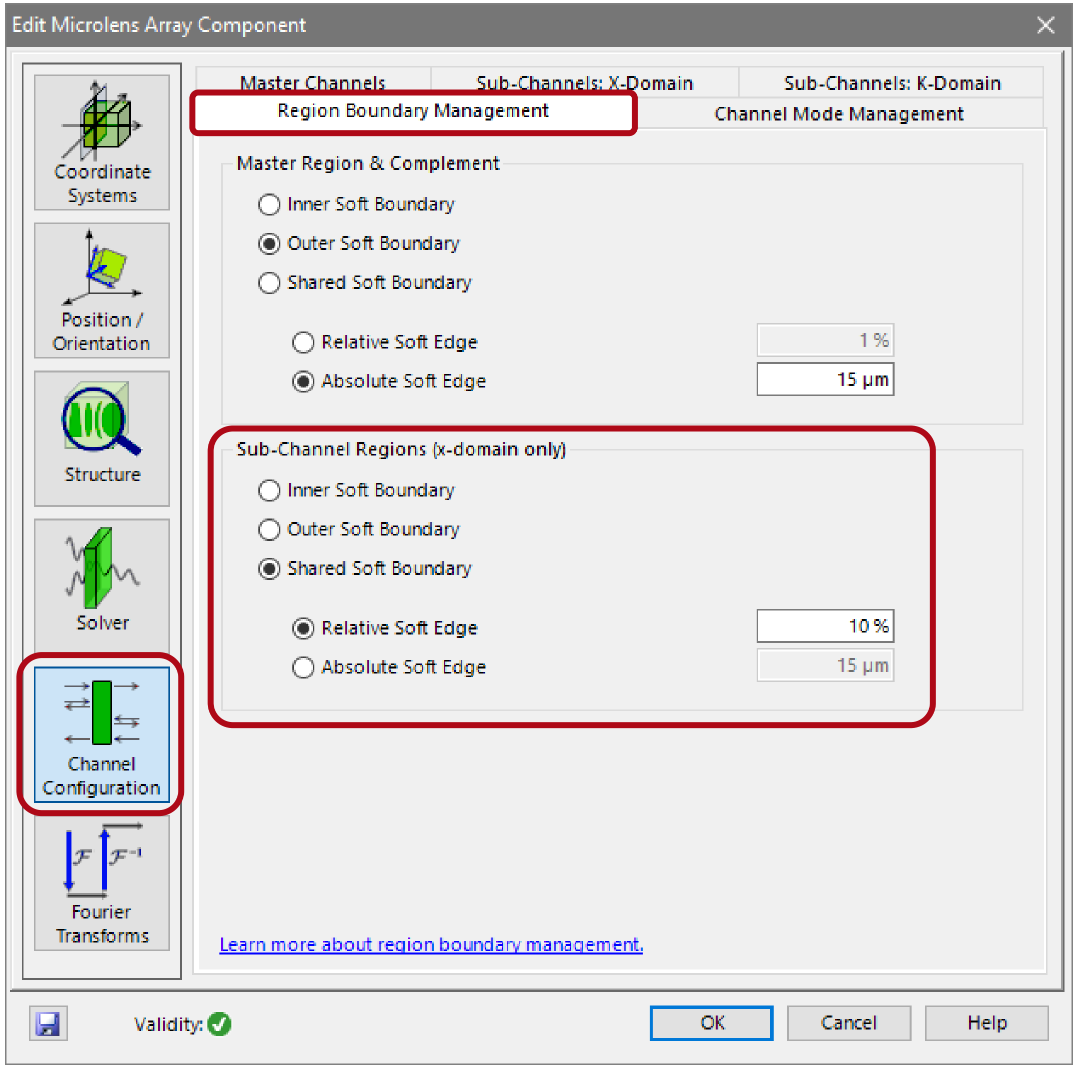
The absolute height of the MLA structure is ~43.9 µm.
(lowest and highest point of MLA is indicated by blue marker)

For the evaluation of the near field a suitable distance of the detector has to be set.

Here we chose 70 µm.

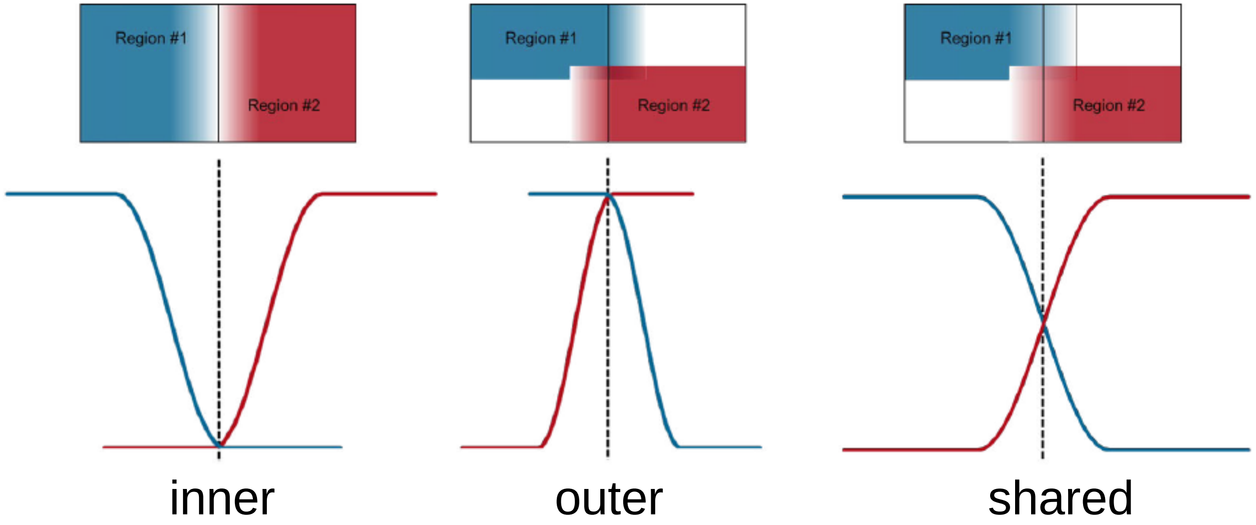


Region Boundary Management



- By using the subchannel option the numerically critical edges of each microlens can be handled with much more care.
- For each such subchannel region a soft edge should be applied. VirtualLab Fusion allows to specify these soft edges in different ways.

→ **For standard simulations we recommend to use the shared soft bondary setting for the subchannel regions.**
[The other options might be of interest e.g. for special display options, but lead to less ealistic results.]



Demonstrational Scenario

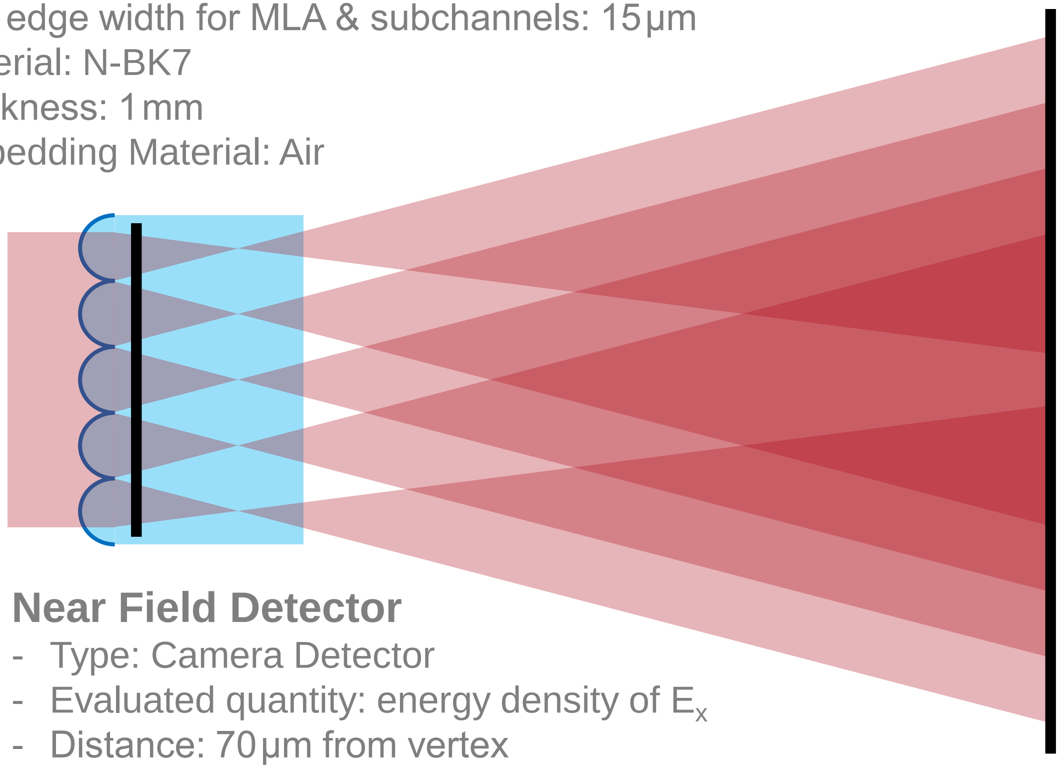
Configuration of Demonstrational Example

Microlens Array

- Shape & Size: rect. 1.5 mm × 1.5 mm
- Conical surface (convex first surface)
- Radius of curvature: 150 µm
- Period: 150 µm × 150 µm
- Soft edge width for MLA & subchannels: 15 µm
- Material: N-BK7
- Thickness: 1 mm
- Embedding Material: Air

Light Source

- Wavelength: 640 nm
- Truncated ideal plane wave
- Shape & size: rect. 1 mm × 1 mm
- Soft edge width: 5%
- Linearly polarized (E_x)



Near Field Detector

- Type: Camera Detector
- Evaluated quantity: energy density of E_x
- Distance: 70 µm from vertex
- Detector window: 1.2 mm × 1.2 mm

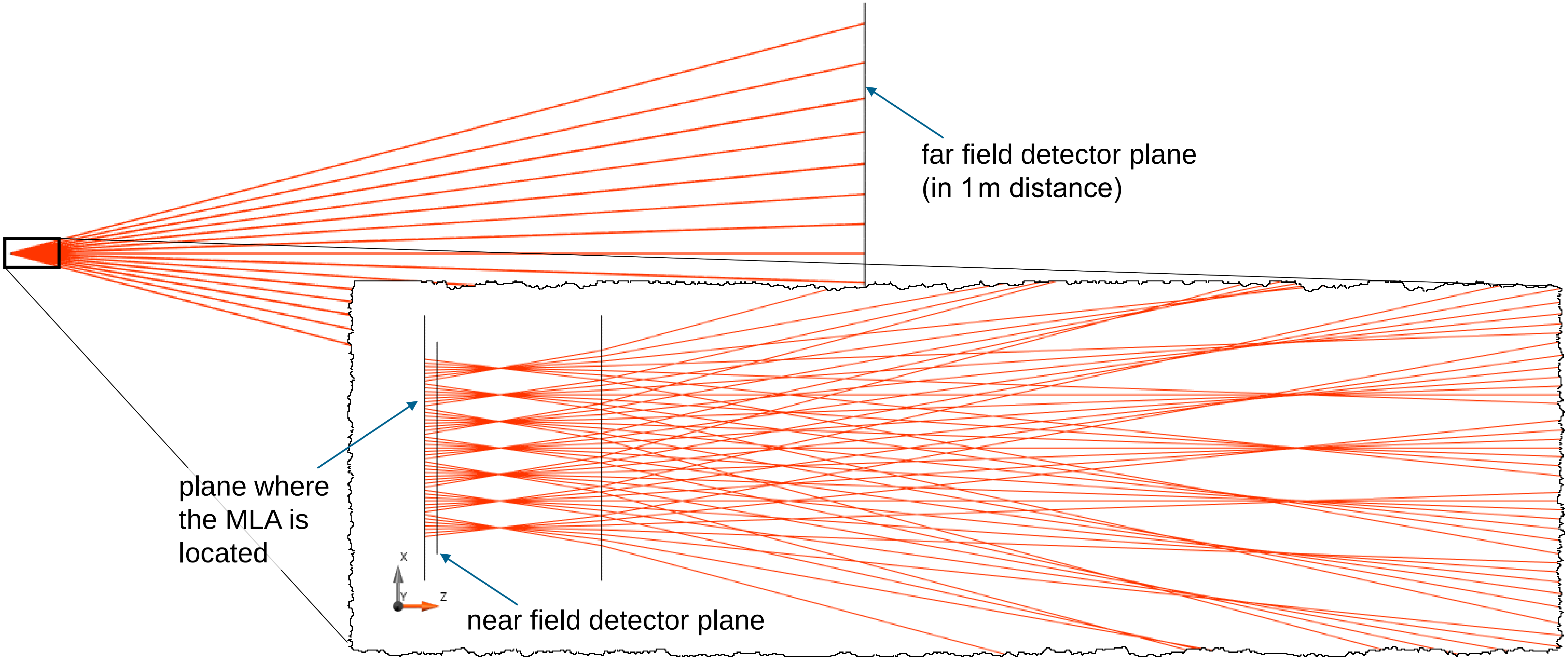
Far Field Detectors

- Type: Camera Detector
- Evaluated quantity: energy density of E_x
- Distance: 1 m from back surface
- Detector window: 700 mm × 700 mm

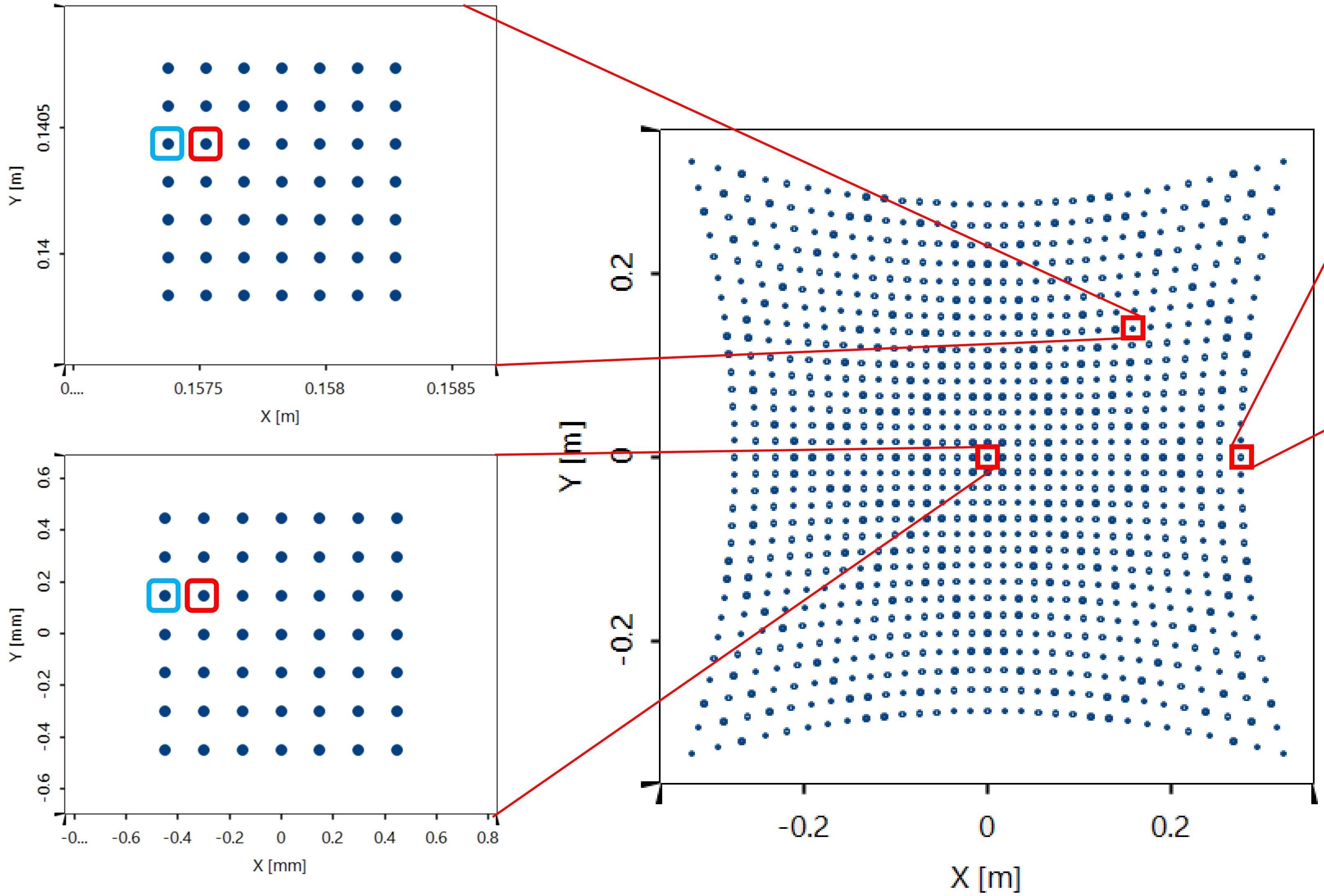
Simulation Settings

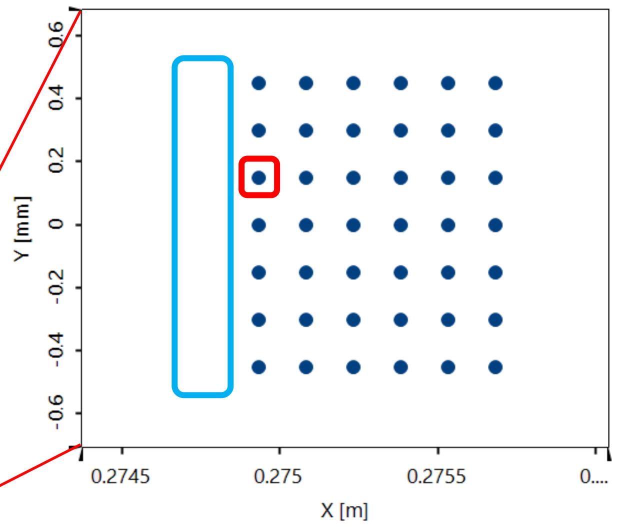
- ***With subchannels***
  Oversampling Factor Gridless Data: 1
- ***Without subchannels***
  Oversampling Factor Gridless Data: 10

Ray Tracing Result: Overview



Ray Tracing Results: Far Field





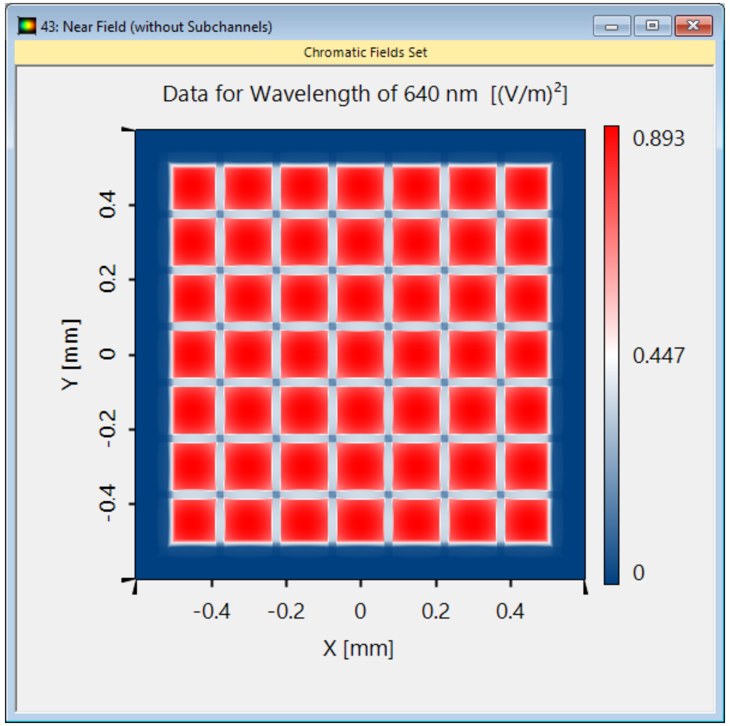
Each rectangular microlens generates a pin cushion distorted pattern. They all are slightly shifted to each other.

dot from border microlens

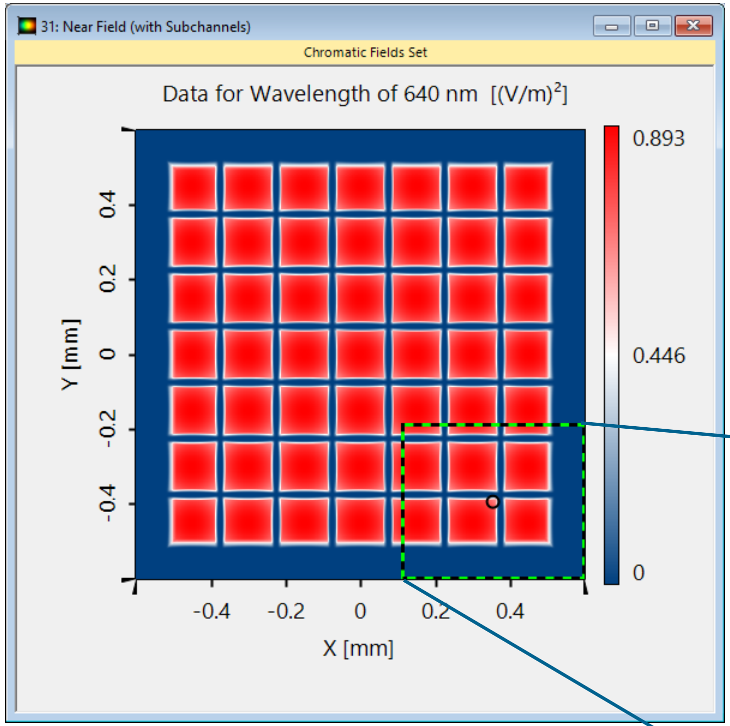
dot from inner microlens

Missing dots (see above) are due to partially illuminated border microlenses. (see near field evaluation on later pages)

Field Tracing Results: Near Field's Energy Densities

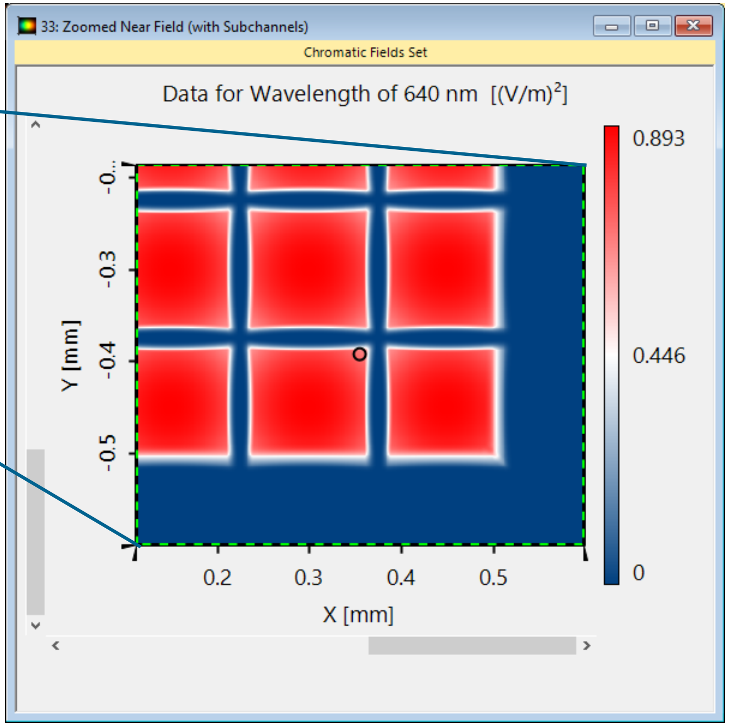


without subchannels



with subchannels

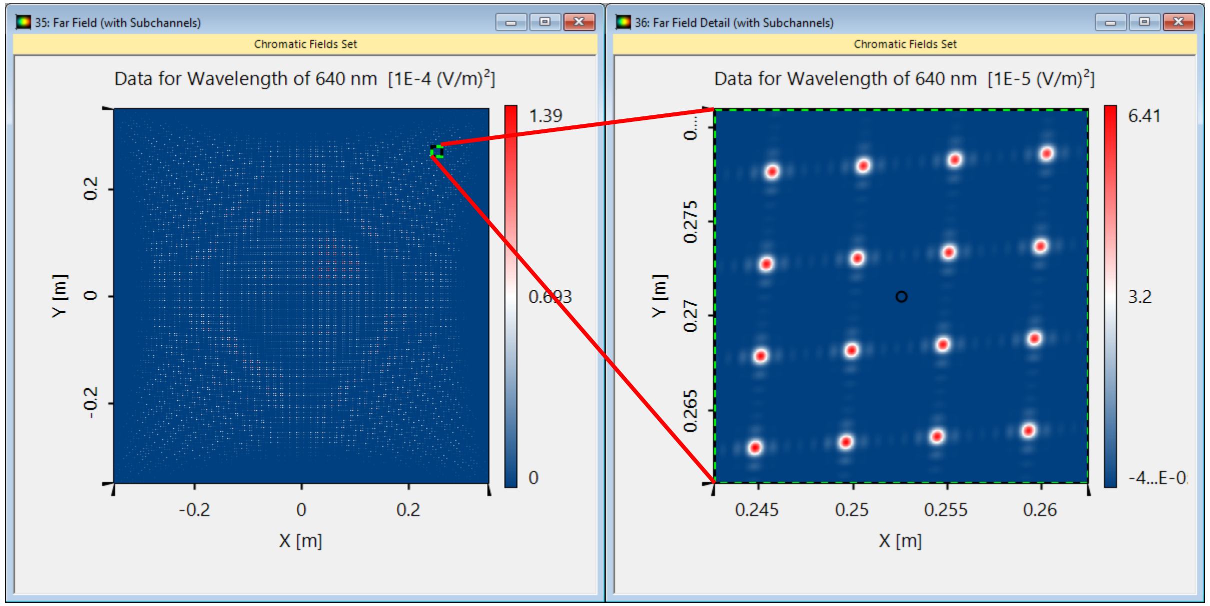
The near fields from the outer microlenses seem somewhat truncated. This is due to the fact that these lenses are not fully illuminated.



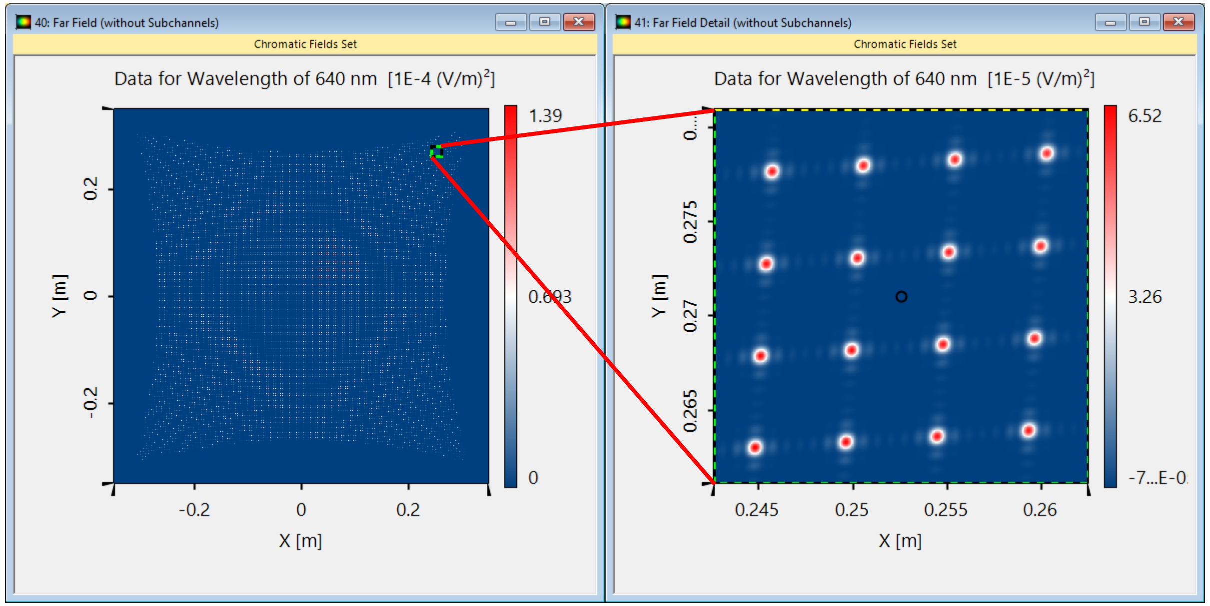
Without subchannels, the critical sampling of the area where the microleses meet yield some numerical artefacts that have a stronger effect on the near field's evaluation.

→ **With subchannels, the result is more accurate.**

Field Tracing Results: Far Field's Energy Densities



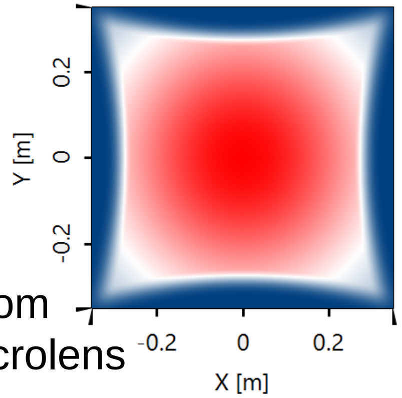
with subchannels



without subchannels

Here the numerical artefacts that turn up for the simulation without subchannels have a lower impact on the far field. Thus the temporal benefit of not using the subchannels might be arguable:

Simulation time with subchannels: ~70s
Simulation time without subchannels: ~25s (with Oversampling Factor Gridless Data = 10)



far field from center microlens

Document Information

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