

#### **Advanced Simulation of Microlens Arrays**

#### Abstract

# MLA via **Subchannels**

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 Surface Add-Ons Solid elements that consist of periodic rectangular cells where each Stack Default Microlens Array Stack contains a smooth surface profile. More options are planned. 🚰 Load / Edit Q View Edit Microlens Array Component Edit Stack Solid Surface Add-Ons The surface profile used Block Component Surface for each microlens cell is Coordinate Plane Surface Base to be defined via Systems 🖂 Load 30 View 🖉 Edit VirtualLab's stack dialog Domain: Size and Shape via the Surface Add-Ons Position / ○ Elliptic Index z-Distance z-Position Surface Subsequent Medium Com Shape Rectangular Orientation tab. 0 mm 0 mm Conical Surface Fused Silica in Homoc Enter your commer Size 20 mm 20 mm Homogeneous Medium Behind Surface On the Solid tab of the Structure Fused\_Silica in Homogeneous Medium Structure page, the < | Q View 🚰 Load 🥖 Edit Validity: shape and size of the Add Insert Delete Periodicity & Aperture Effect on Field Outside of Domain whole array is to be Periodic Solver Field Passes Plane Surface defined as well as the Dependent from the Period of Surface with Index ÷ Stack Period is Field is Absorbed Stack Period 250 µm × 250 µm material behind the surface. 🛐 🛃 Tools 資 🗸 OK Cancel Help

# By Which Method Is the Field Propagated through the MLA?

Edit Microlens Array Component	×
Solver Sampling Component Solver Local Plane Interface Approximation (LPIA)	As solver for the propagat Local Plane Interface App
Coordinate Systems       The LPIA solver works in the spatial domain (x domain), locally, in a pointwise manner. The solver follows that         Position / Orientation       1. the input field on the surface is treated as a composition of local plane waves (LPWs),         2. the part of the surface seen by each LPW is considered a plane interface (locally), and,         3. the interaction of the LPW with the local plane interface can be modeled by the Fresnel (or the layer) matrix.         At an arbitrary location on the curved surface, an approximate local boundary condition is applied, which assumes the interaction of the LPW with the local plane interface. Thus, the Fresnel matrix (or layer matrix for coatings) can be used to connect	Solver page of the edit dia Component).
input and output fields. Learn more about this solver.	If you want to learn more about this solver, please follow our info link.
Fourier Transforms Validity: ♥ OK Cancel Help	

r the propagation through the surfaces the Interface Approximation (LPIA) is used (see of the edit dialog of the Microlens array

# **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.



## **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**



# **Region Boundary Management**

Edit Microlens Array Component X		
Â.	Master Channels         Sub-Channels: X-Domain         Sub-Channels: K-Domain           Region Boundary Management         Channel Mode Management	
Coordinate Systems	Master Region & Complement	
Resition (	<ul> <li>Outer Soft Boundary</li> <li>Shared Soft Boundary</li> </ul>	
Orientation	<ul> <li>○ Relative Soft Edge</li> <li>1 %</li> <li>③ Absolute Soft Edge</li> <li>15 µm</li> </ul>	
Structure	Sub-Channel Regions (x-domain only)	
3 min	O Uter Soft Boundary O Outer Soft Boundary Shared Soft Boundary	
Solver	Relative Soft Edge     10 %     Absolute Soft Edge     15 µm	
→ ↔ Channel Configuration		
Fourier Transforms	Learn more about region boundary management.	
Validi	ty: 🗸 OK Cancel Help	

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

#### Light Source

- Wavelength: 640nm
- Truncated ideal plane wave
- Shape & size: rect. 1mm × 1mm
- Soft edge width: 5%
- Linearly polarized (E<sub>x</sub>)



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

#### **Far Field Detectors**

- Type: Camera Detector
- Evaluated quantity: energy density of E<sub>x</sub>
- Distance: 1 m from back surface
- Detector window: 700mm × 700mm

#### 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**



# **Field Tracing Results: Near Field's Energy Densities**



without 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.

 $\rightarrow$  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)



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