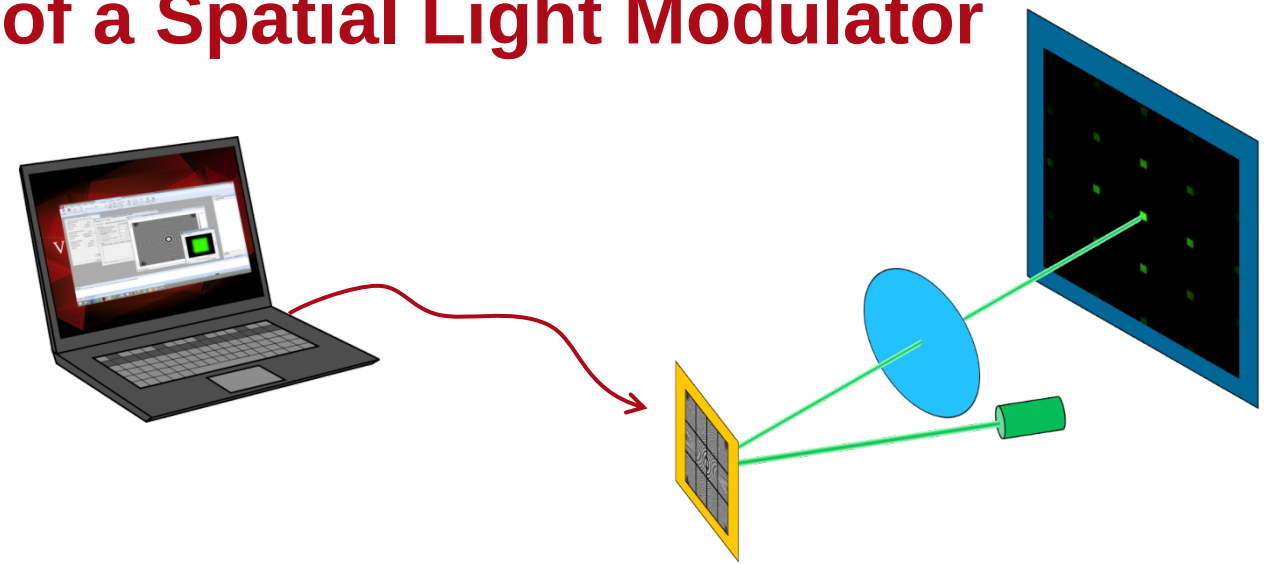
LightTrans

Spatial Light Modulator (SLM.0002 v1.0)

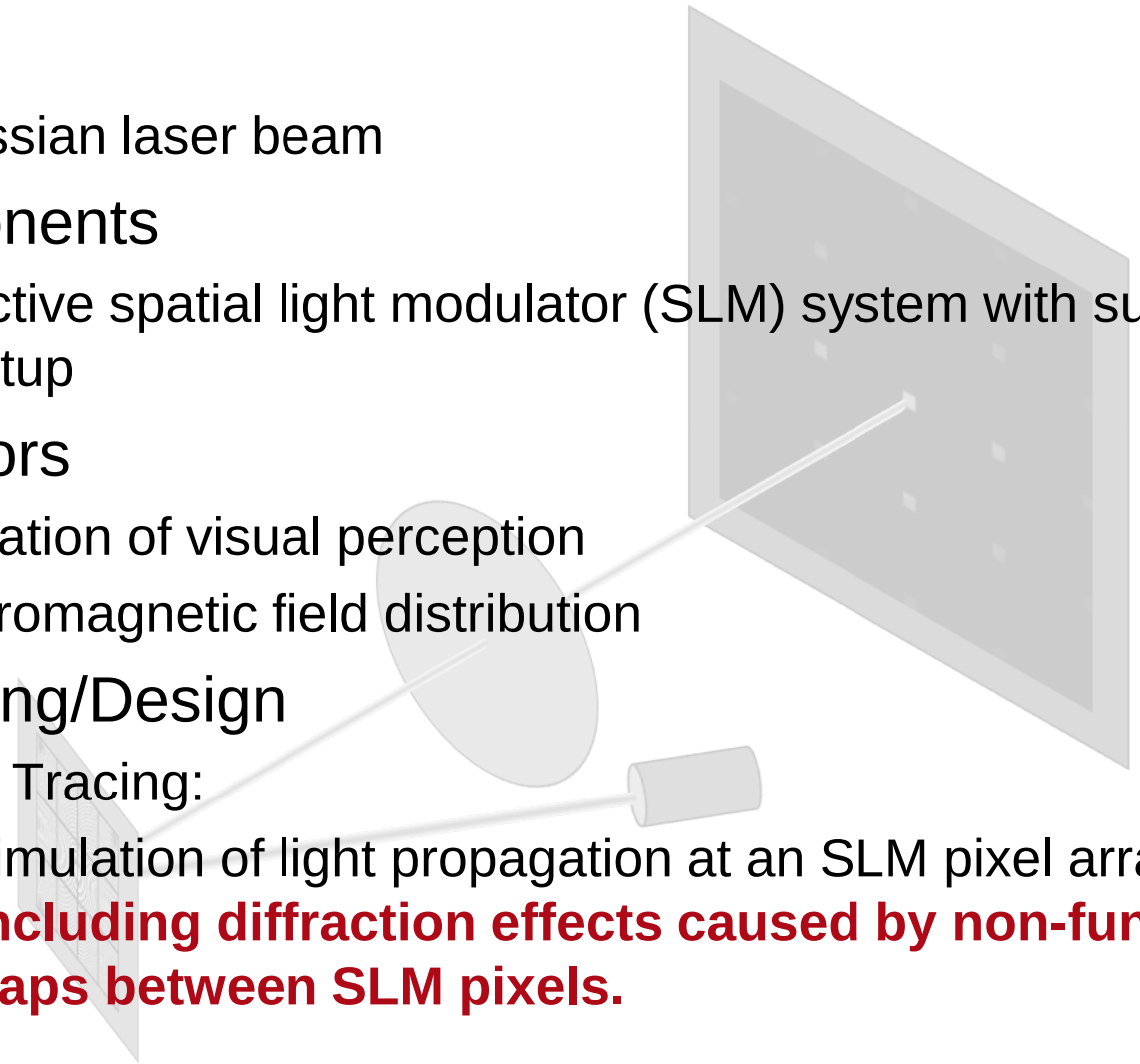
Simulation of Light Diffraction at Pixels of a Spatial Light Modulator



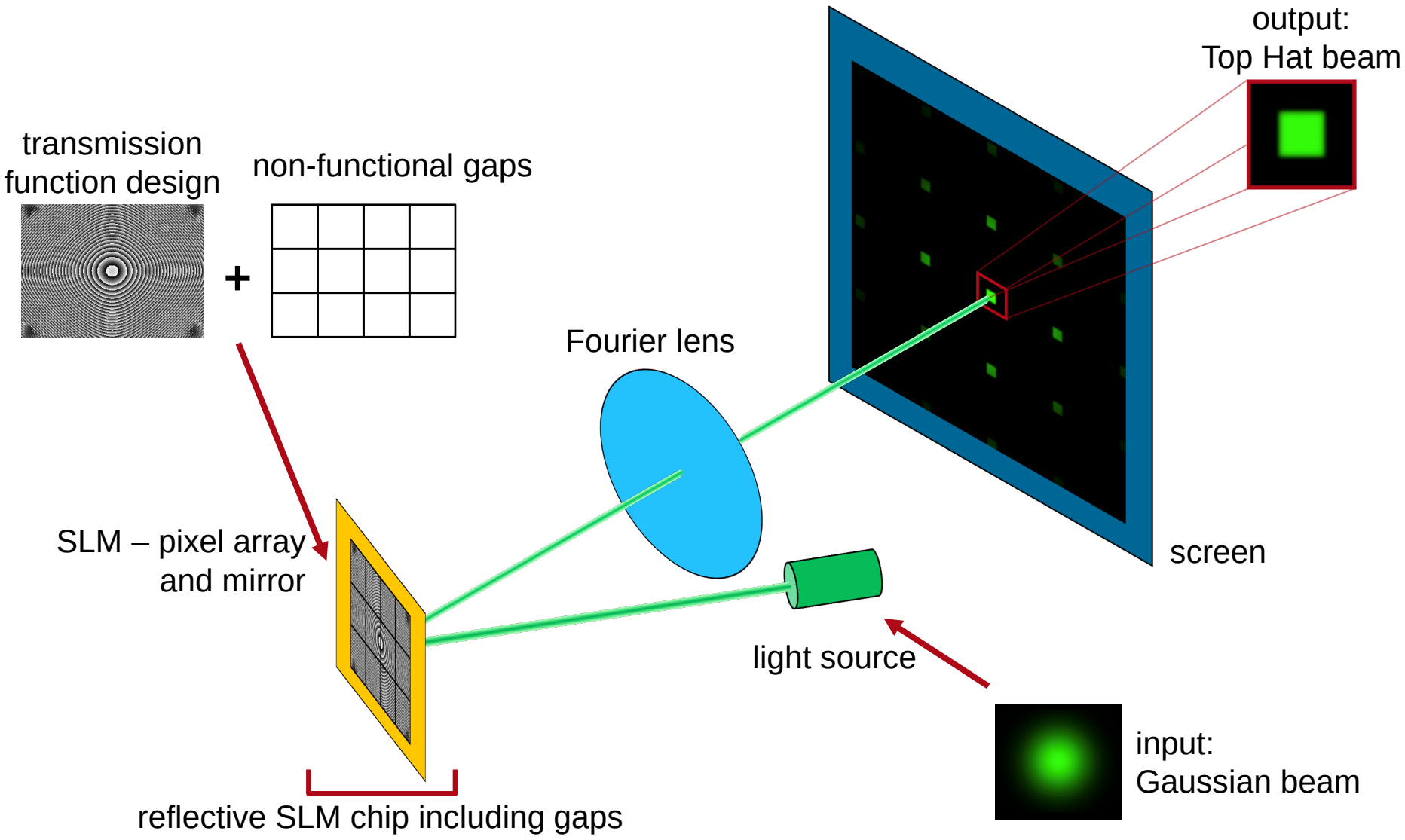
Application Example in a Nutshell

System Details

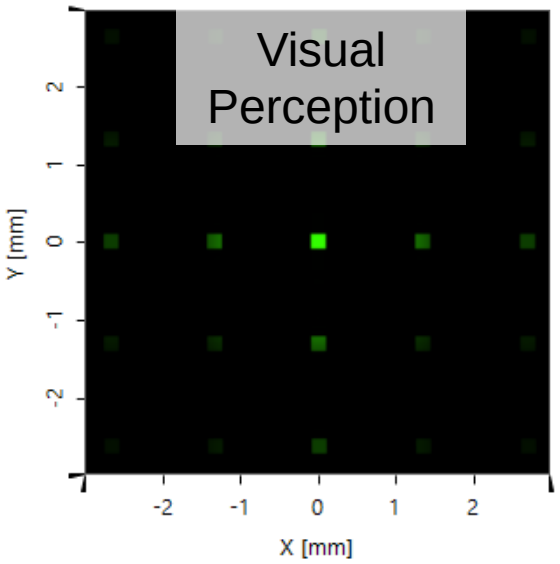
- Source
  - Gaussian laser beam
- Components
  - reflective spatial light modulator (SLM) system with subsequent 2f-setup
- Detectors
  - emulation of visual perception
  - electromagnetic field distribution
- Modelling/Design
  - Field Tracing:
    - ✓ simulation of light propagation at an SLM pixel array **including diffraction effects caused by non-functional gaps between SLM pixels.**

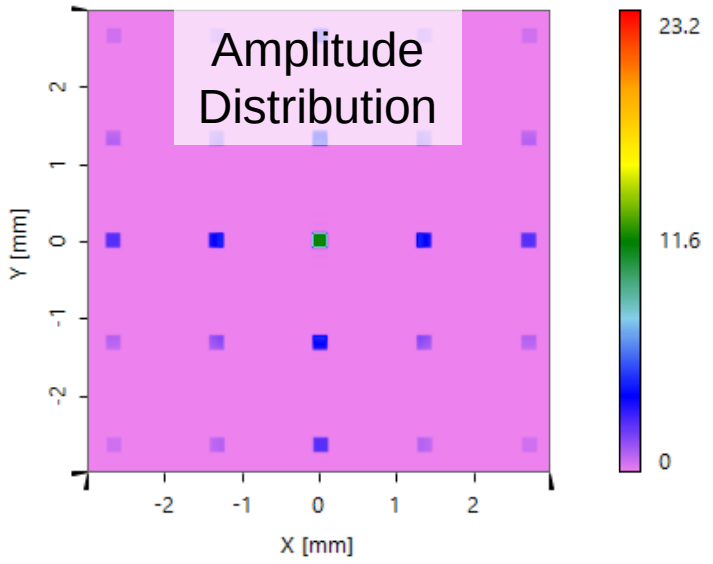


System Illustrations



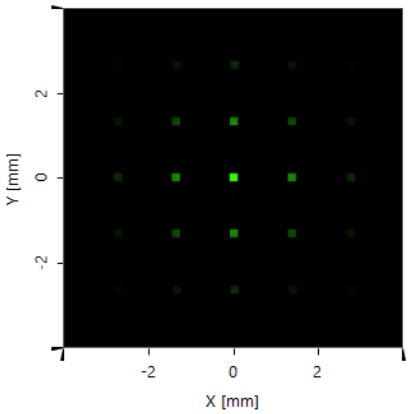
Modelling & Design Results



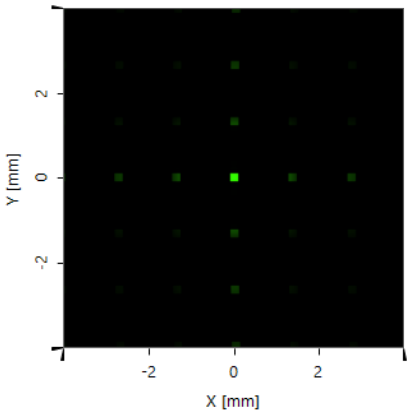


Results for different SLM area fill factors

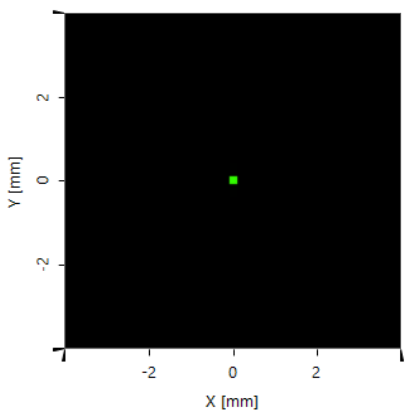
60%



80%



100%



Summary

Investigation of the performance of a spatial light modulator taking into account **the gaps between the SLM pixels**.

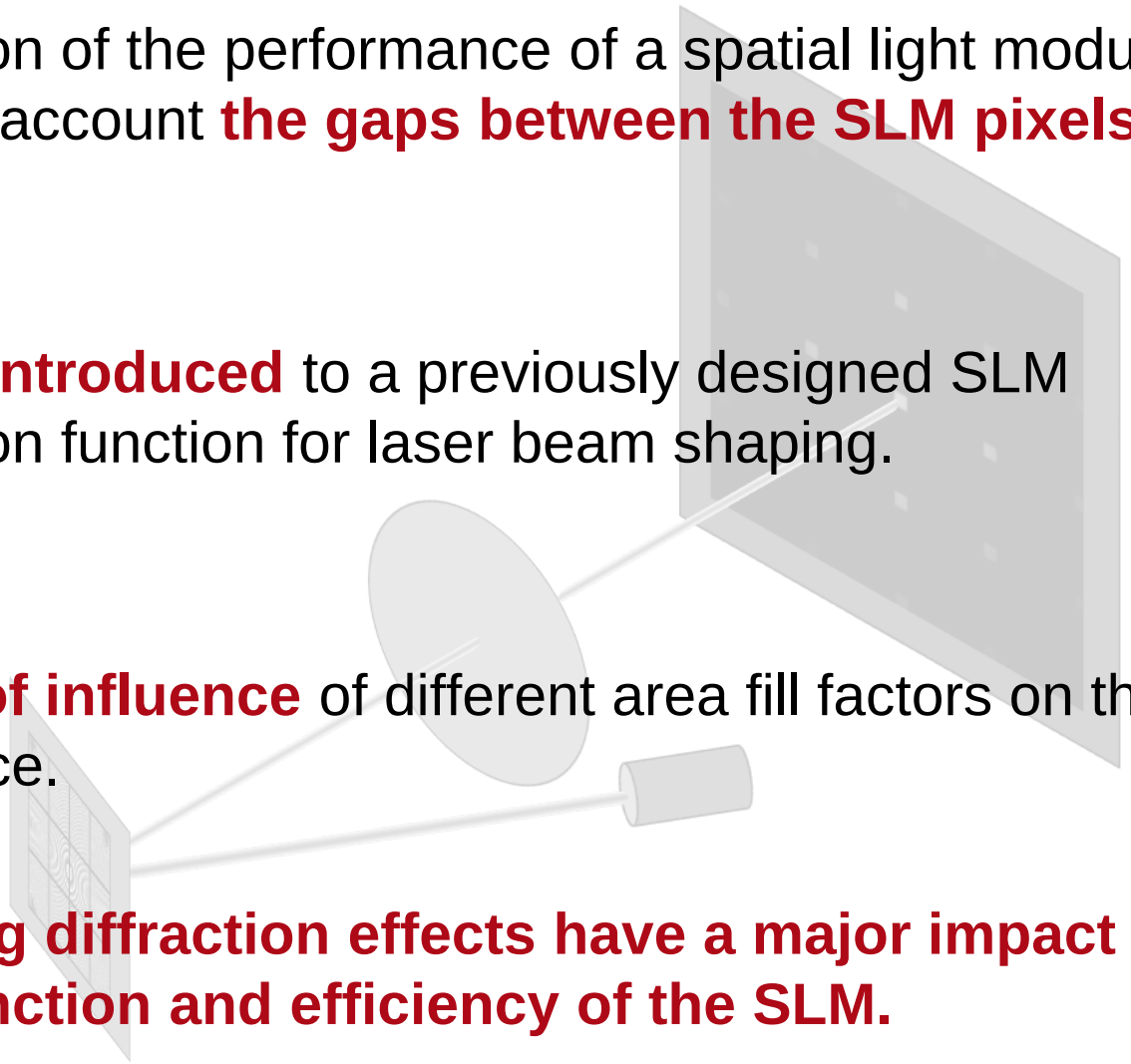
1st step

Gaps are introduced to a previously designed SLM transmission function for laser beam shaping.

2nd step

Analysis of influence of different area fill factors on the performance.

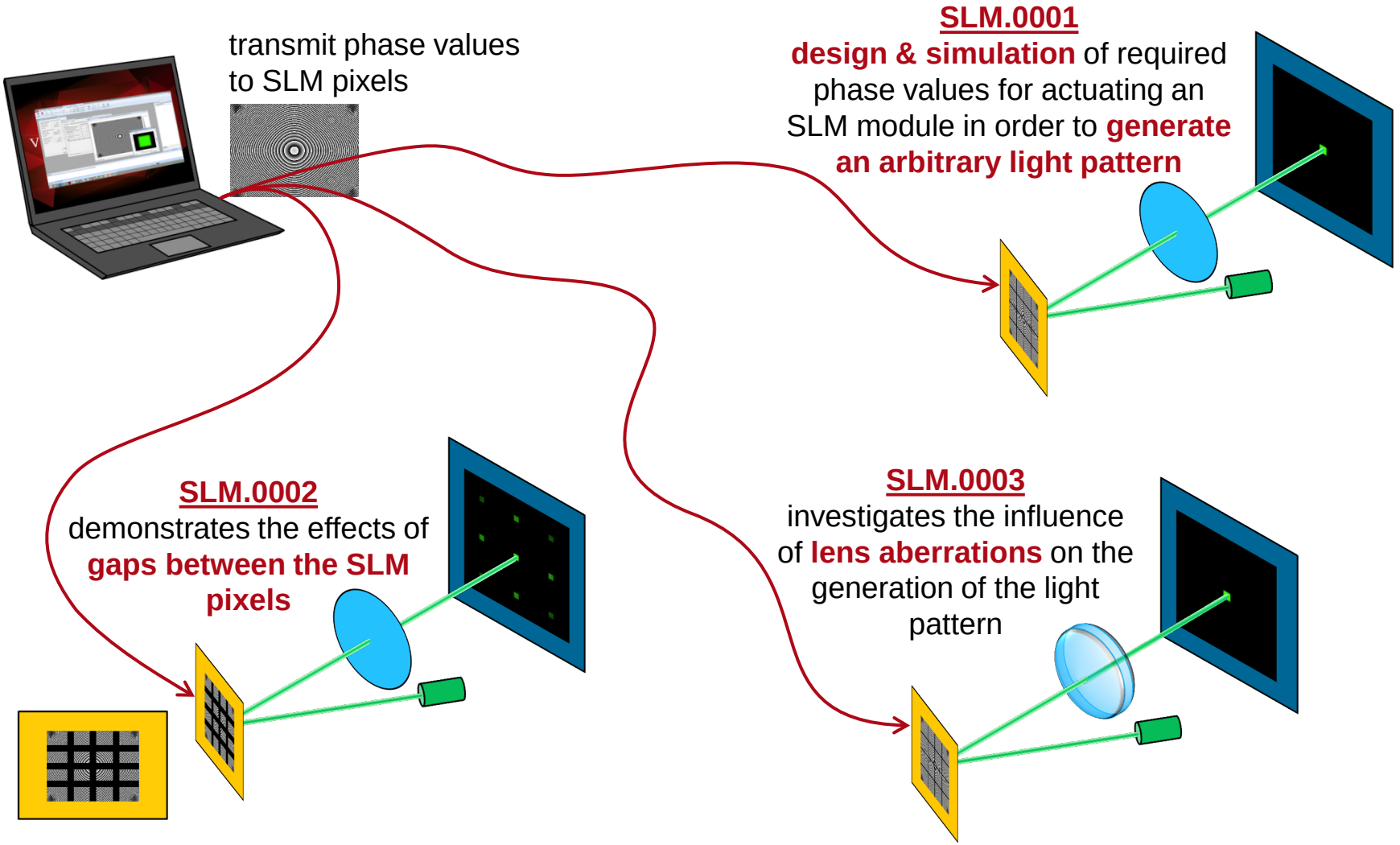
The arising diffraction effects have a major impact on the optical function and efficiency of the SLM.



Application Example in Detail

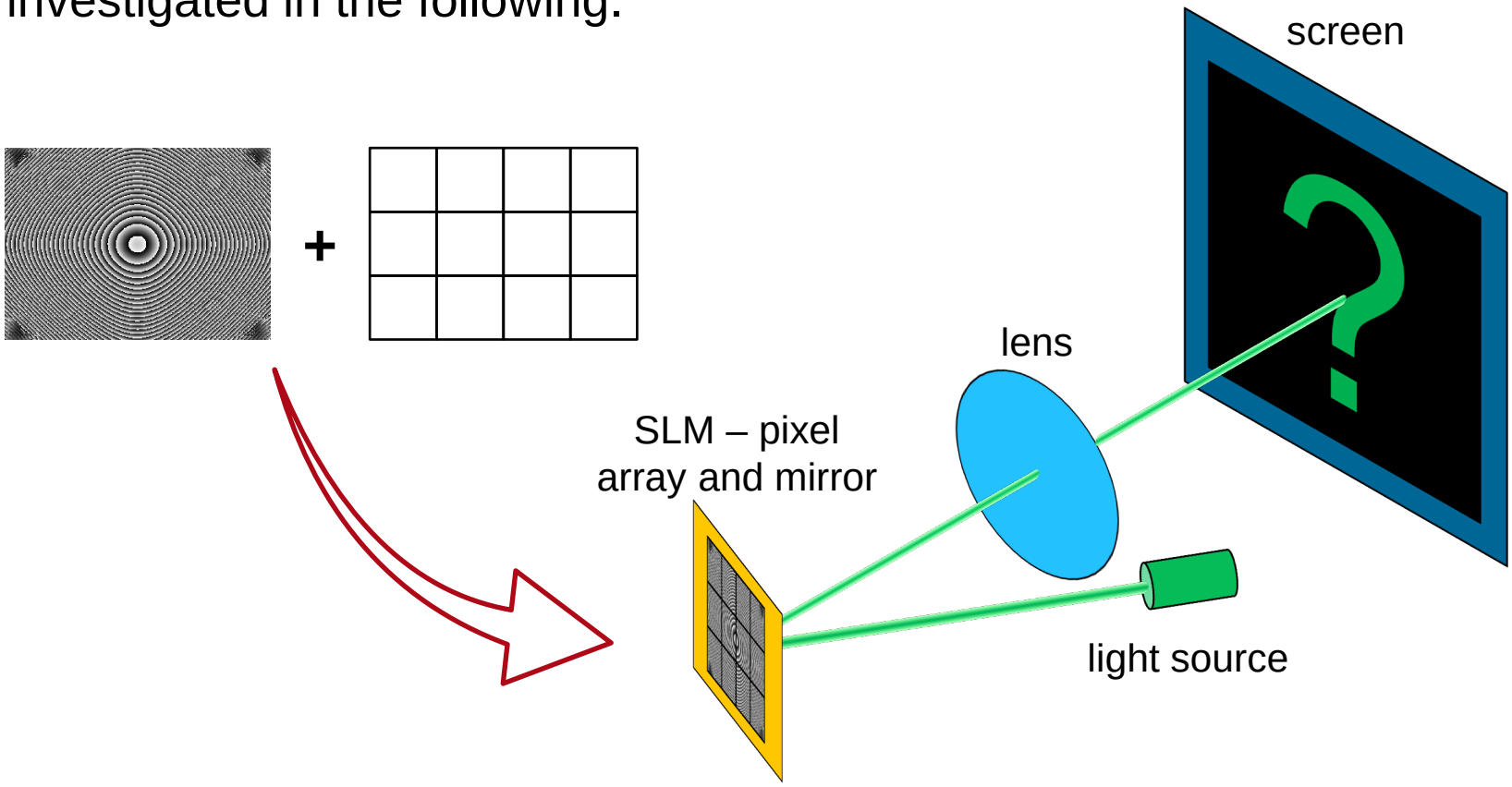
System Parameter

Context of This Application Example

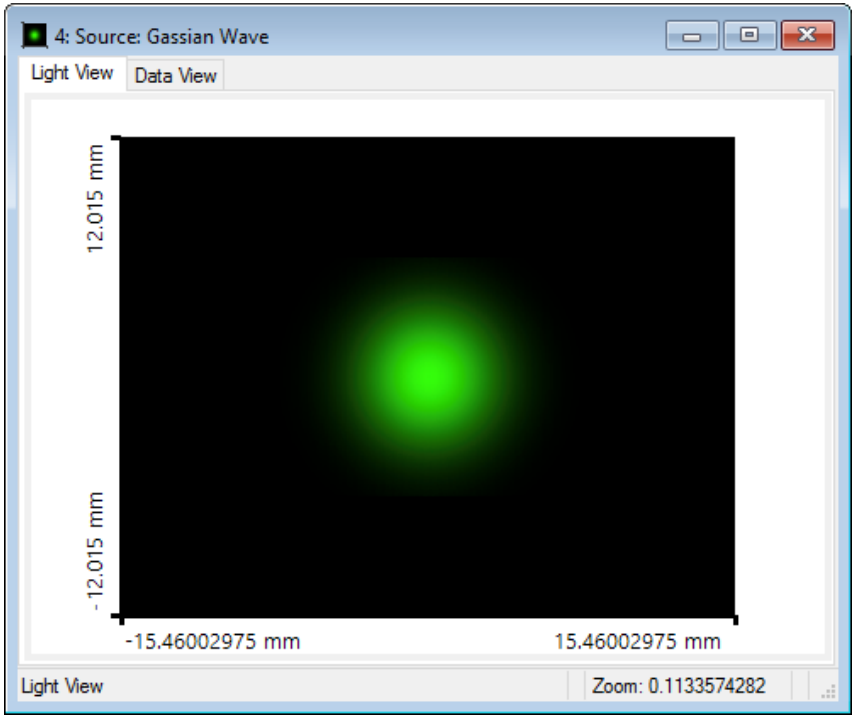


Simulation Task

Due to fabrication and technological issues **non-functional gaps** are located between all pixels. These characteristic gaps have an **diffractive effect on the optical performance** of the SLM and will be investigated in the following.



Specs: Almost collimated Input Laser Beam



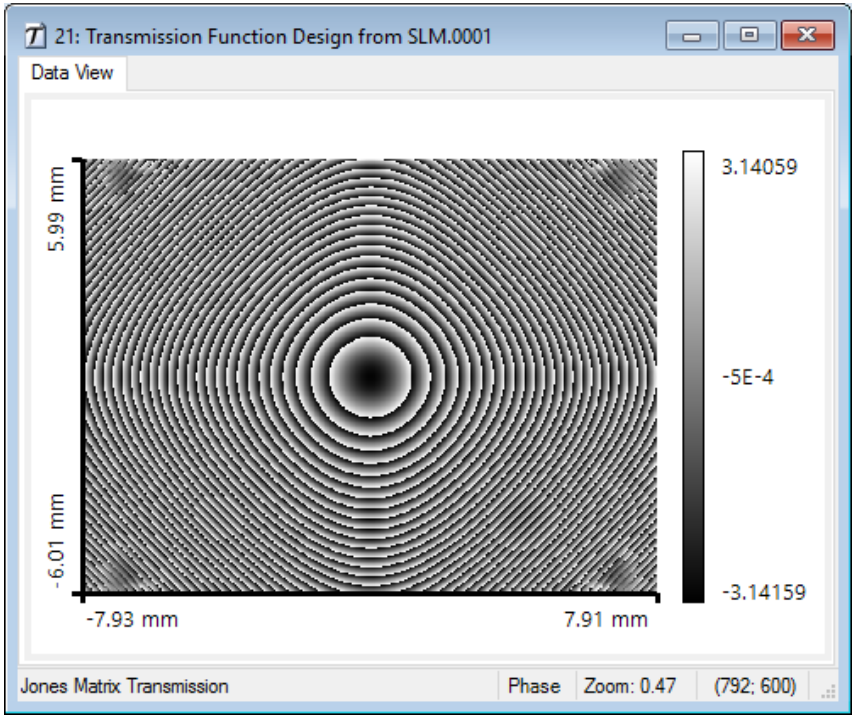
Single Mode Laser

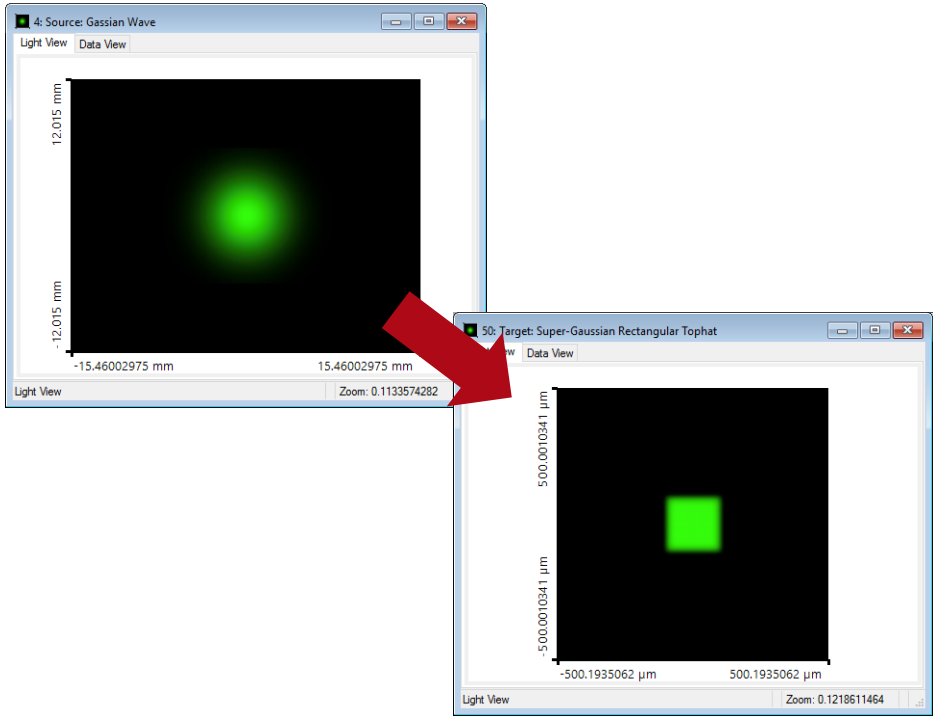
Parameter	Value & Unit
wavelength	532 nm
beam radius ($1/e^2$)	3.3 mm
divergence angle of beam intensity	0.003° x 0.003° (full angle $1/e^2$)
M^2-value	1

identical to SLM.0001

Specs: SLM Transmission Function

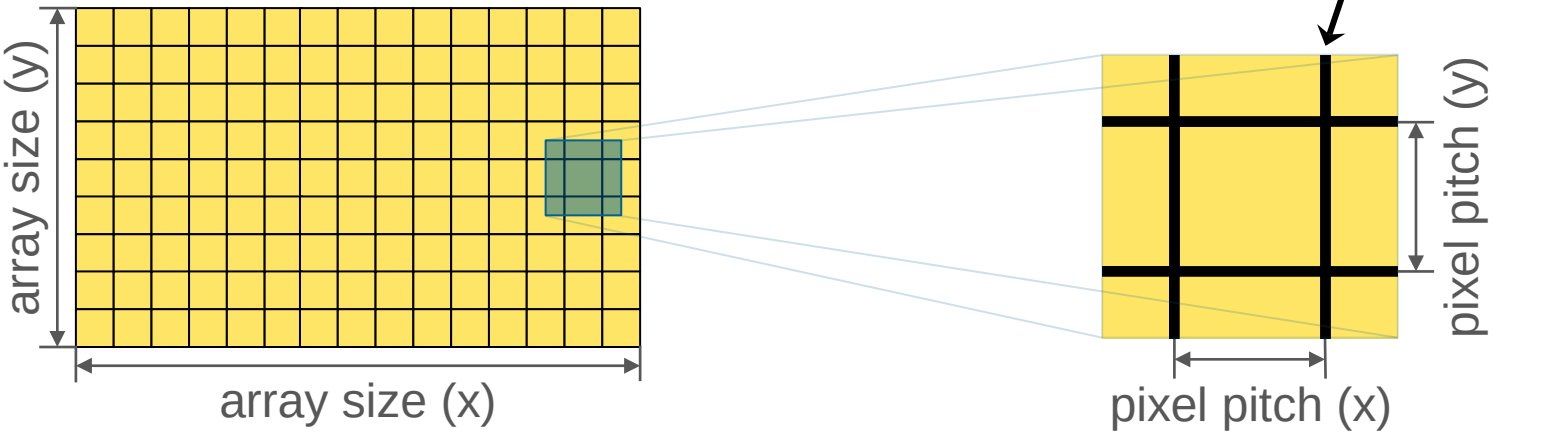
Transmission function to retrieve the desired Top Hat beam shape (designed in *SLM.0001*).





Specs: SLM Pixel Array

SLM pixel array top view:



Hamamatsu X10468	Value & Unit
array size	792 x 600 pixels
pixel pitch	20 µm x 20 µm
area size	15.84 mm x 12.0 mm
area fill factor	98%
element tilt with respect to optical axis	10°

"Area Fill Factor":

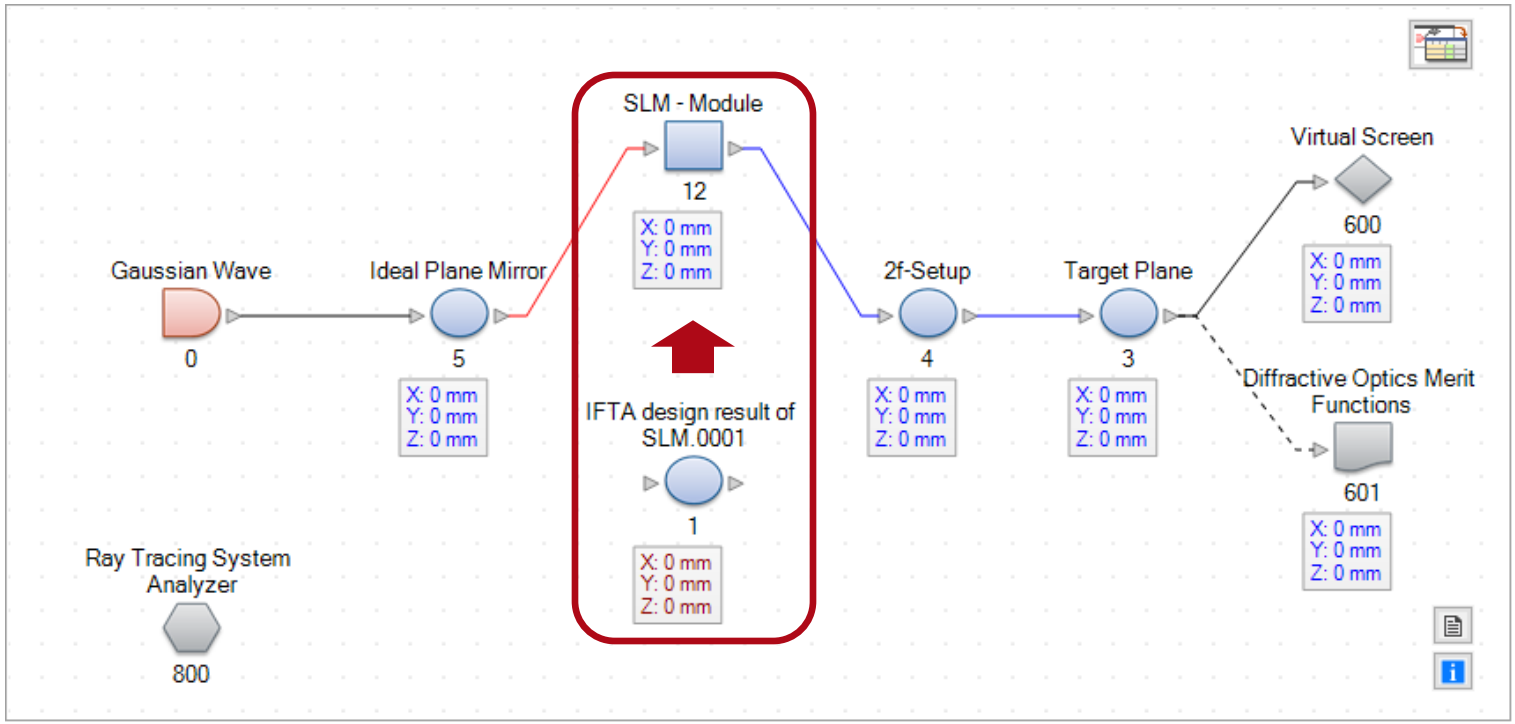
$$f = \frac{\text{effective area}}{\text{array area}}$$

Application Example in Detail

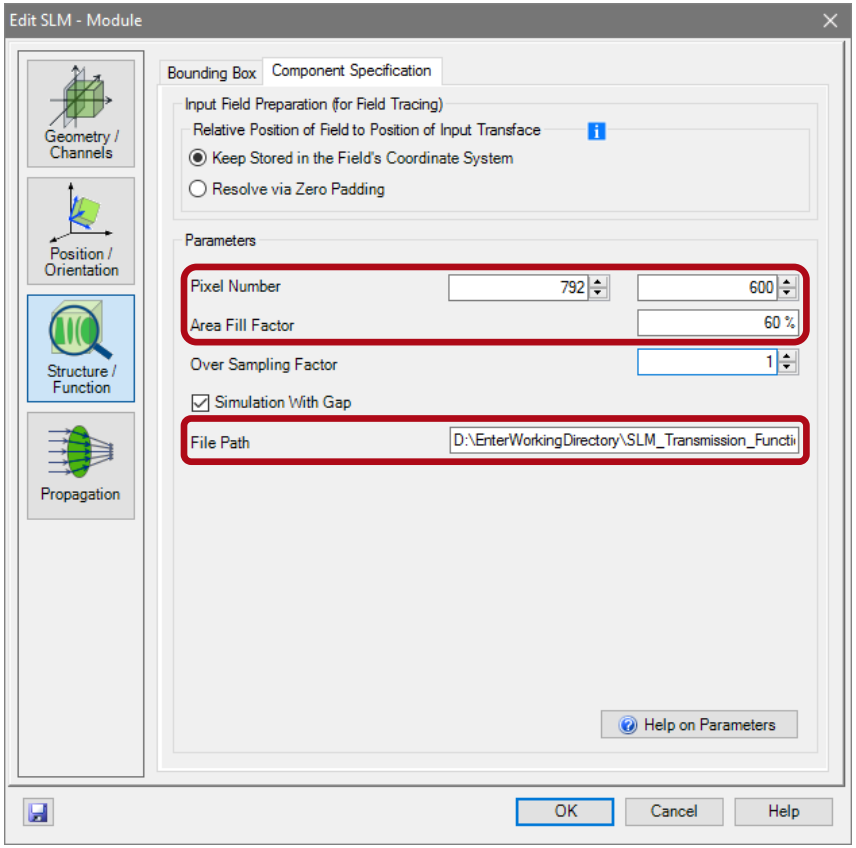
Simulations & Results

Simulation of SLM including Gaps in VirtualLab

- Due to embedded components, VirtualLab allows for an easy realization of the **reflective setup** (e.g. mirrors, 2f-Setup, etc.).
- The provided **SLM-Module** provides an automatic conversion from simple transmission function to an **array containing pixels and gaps**.



VirtualLab's SLM-Module

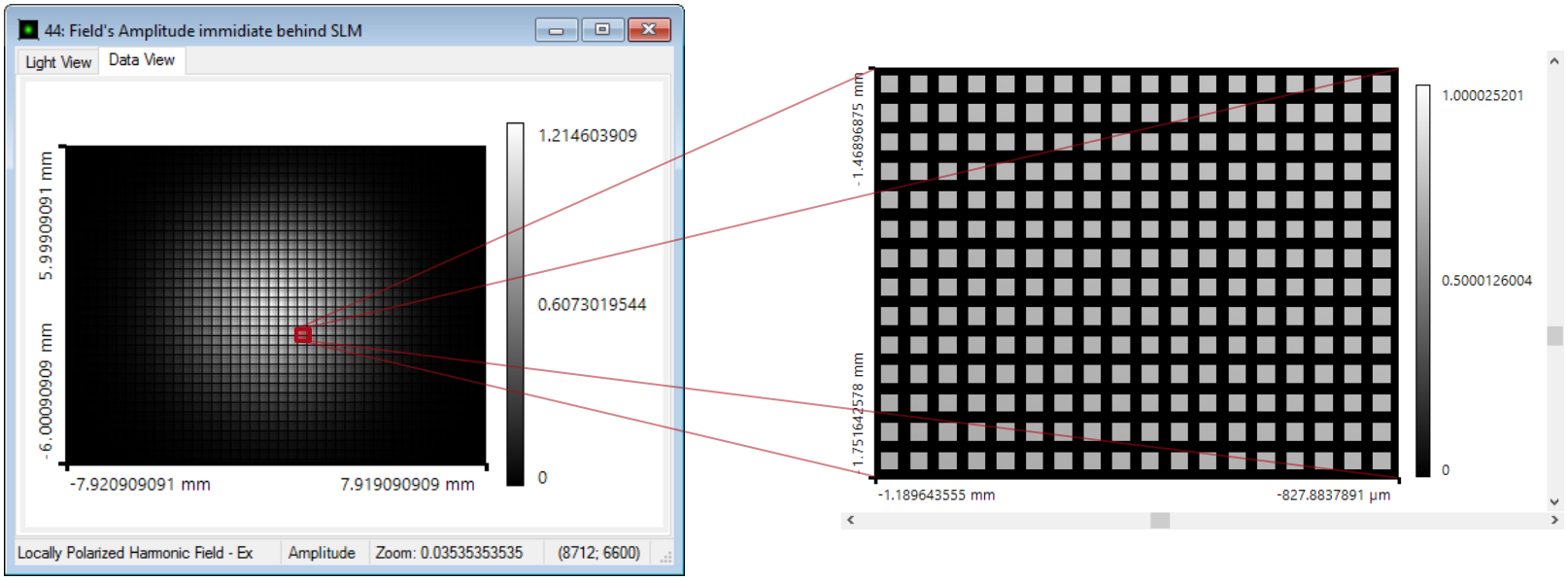


- In order to setup the pixel array, the **array size** and **area fill factor** have to be entered.

- The **designed transmission function** of the SLM has to be set. Therefore, the Path of the File *SLM_Transmission_Function.ca2* needs to be entered.

Optical Function of SLM

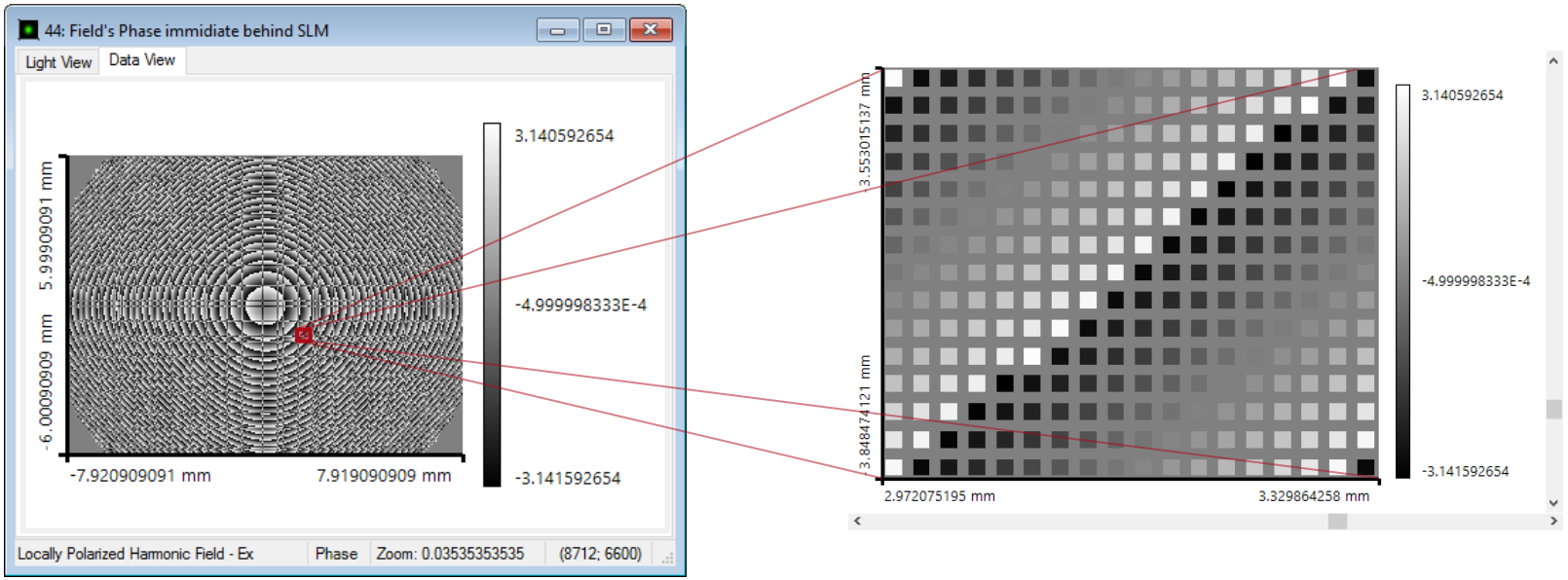
- In a first step, we investigate the electromagnetic **field directly behind the SLM**.
- For this purpose, an **area fill factor of 60%** is used.
- First, the **amplitude** of the field (E_x component) is depicted, which shows the influence of the SLM-pixels and of the gaps, respectively.



file used: SLM.0002_Diffraction_Pixels_SLM_01_Nearfield.lpd

Optical Function of SLM

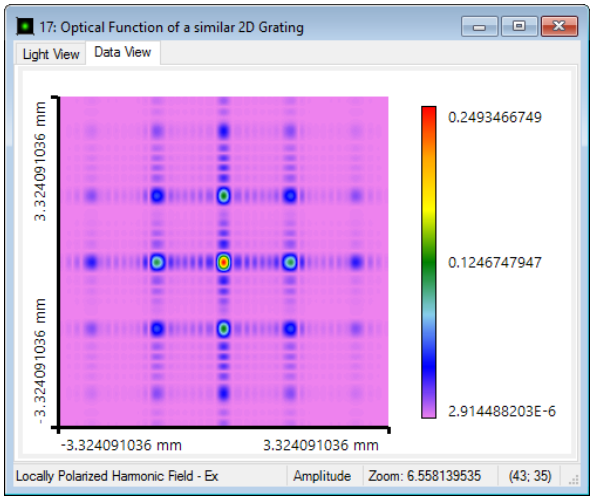
- Here, the (wrapped) **phase** of the field (E_x component) is shown, which exhibits a constant value in all of the gaps.



file used: SLM.0002_Diffraction_Pixels_SLM_02_2DGrating.lpd

Comparison: Optical Function of a Grating

- The demonstrated pixelation effect can be compared with the optical function of a similar 2D periodic structure.
- The shown function (**amplitude of E_x**) is comparable to an SLM, whose pixels provide a **constant phase** function.

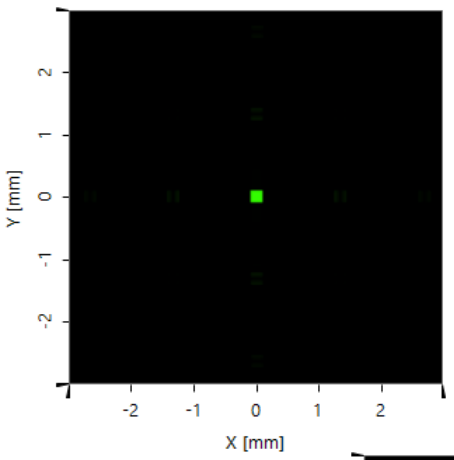


- Such grating diffracts the light into **several diffraction orders**, which are distributed in x- and y-direction (due to 2D periodical structure).
- The amplitude (and intensity) for higher orders decays very fast, so only the 0^{th}, 1^{st} and 2^{nd} orders contribute major parts of light.
- This means, for the SLM we expect also **higher orders of our desired light distribution** (e.g. Top Hat), whose **intensities are determined by the area fill factor**.

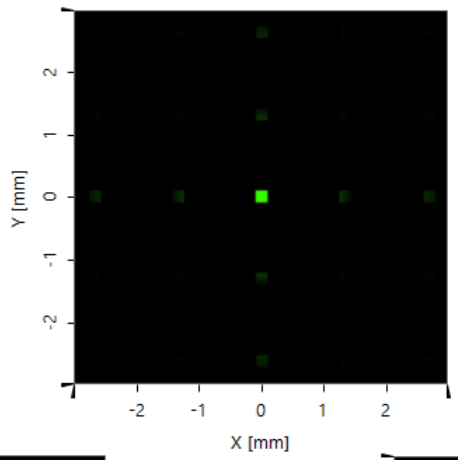
Optical Function of the SLM with Gaps

Now, we are able to investigate the optical function of the SLM in the Fourier plane, **depending on the area fill factor** of the pixel array.

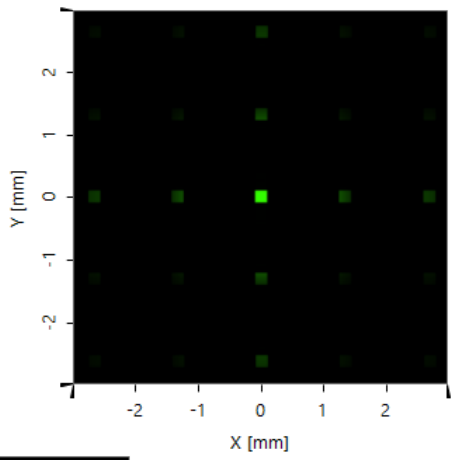
100%



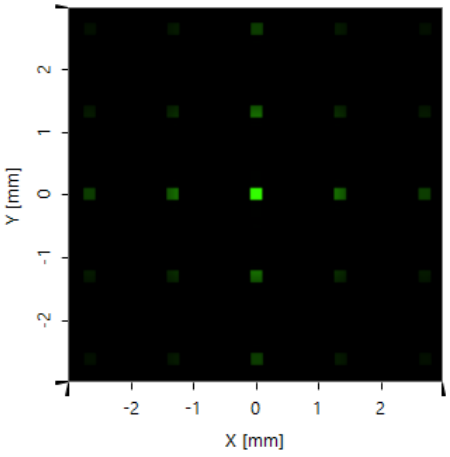
90%



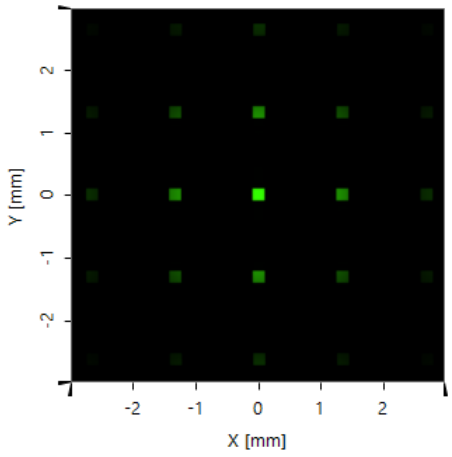
80%



70%



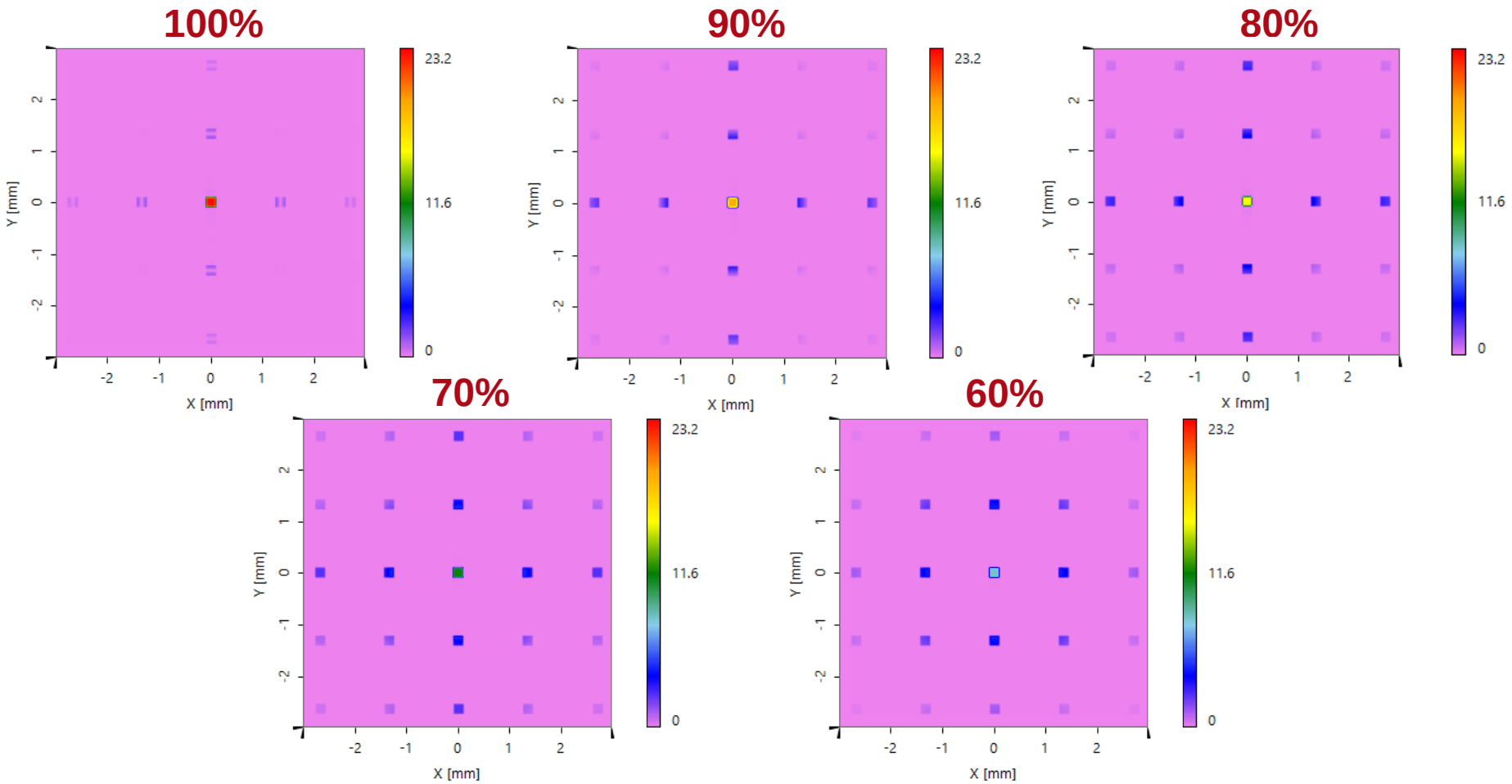
60%



file used: SLM.0002_Diffraction_Pixels_SLM_03_Farfield.lpd

Optical Function of the SLM with Gaps

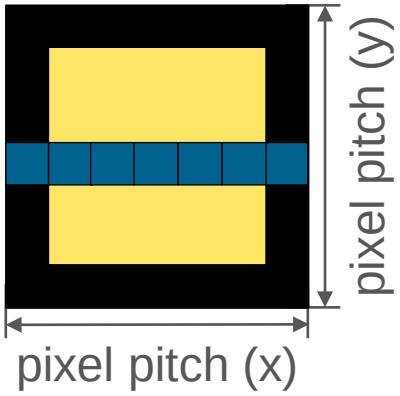
Now, showing the light distributions, but with **same amplitude scaling** (E_x-component).



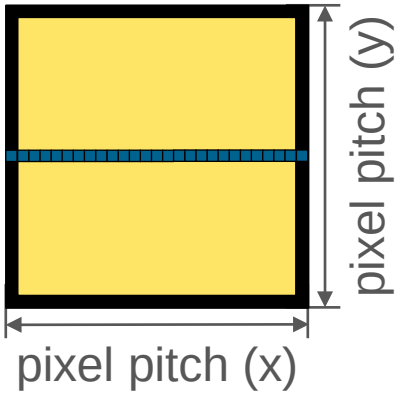
file used: SLM.0002_Diffraction_Pixels_SLM_03_Farfield.lpd

Reducing the Computational Effort

60% area fill factor



90% area fill factor



Required sampling:

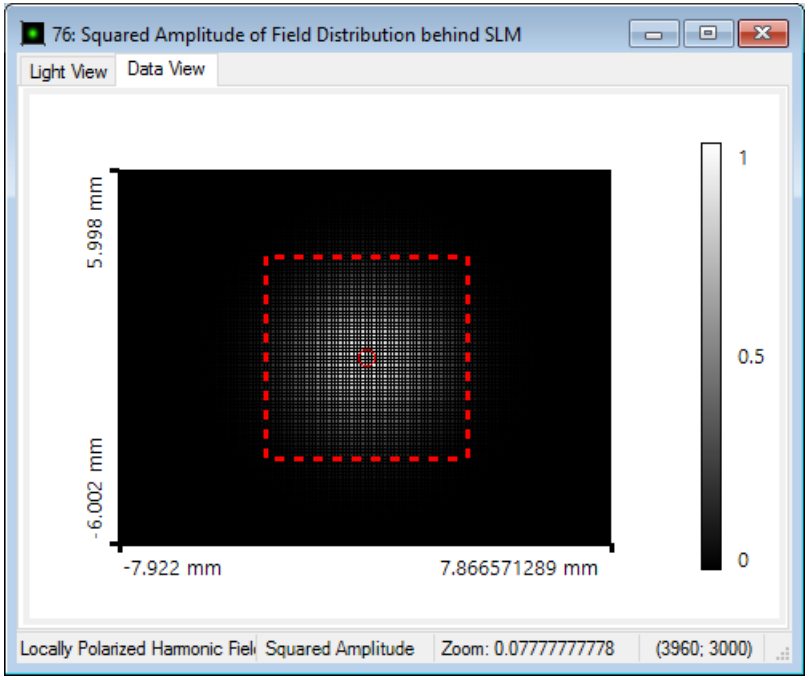
- at least 1 point in gap (per side)
- For e.g. user specified 60% fill factor the module calculates an equidistant sampling of 5 x 5 points in active area

Required sampling:

- again, at least 1 point in gap
- in case of 90% area fill factor 25 x 25 sampling points in active area
- **Sampling increases rapidly if regarding large fill factors**

Reducing the Computational Effort

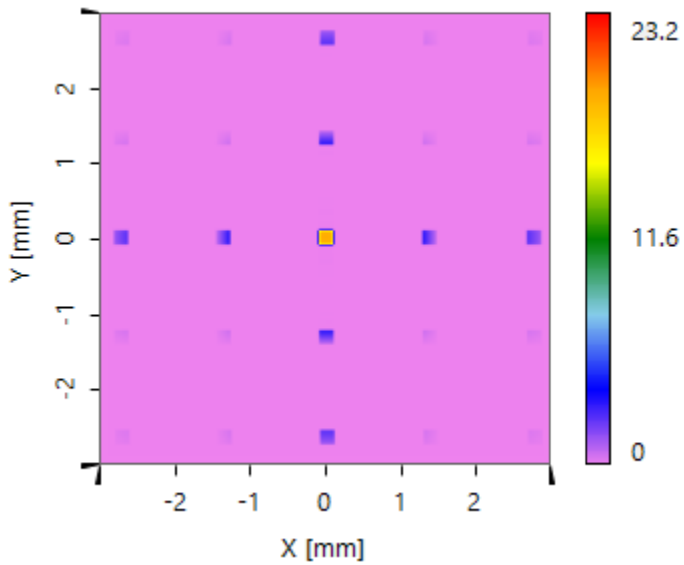
- In order to optimize the computational effort in case of large fill factors, it could be useful to **reduce the regarded array size**.
- This simplification is especially appropriate if the illuminated area is smaller than the array size (the **marked area contains 90% of the intensity**).



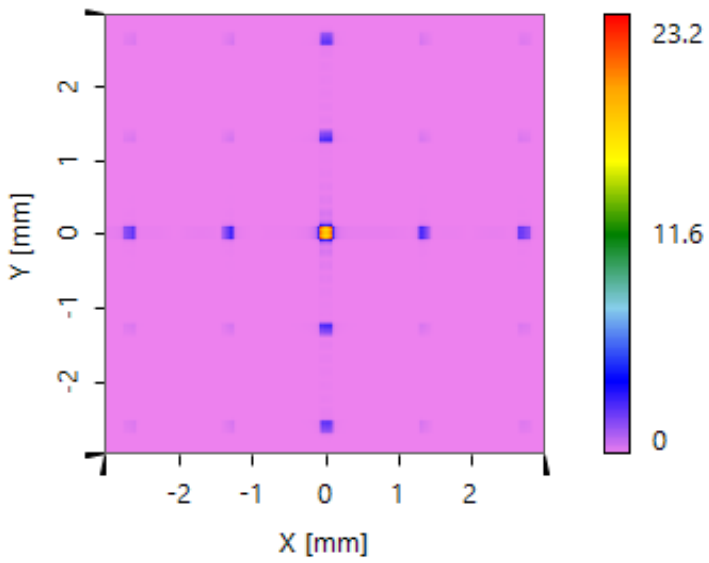
- If just the marked region is considered, only **320 x 320 pixels** of the SLM pixels have to be taken into account. (the SLM-Module automatically cuts the borders of the transmission function).
- Due to this optimization, the computational effort is reduced by the **factor of 4.7**.

Reducing the Computational Effort

90% area fill factor (full array)



90% area fill factor (reduced array size)

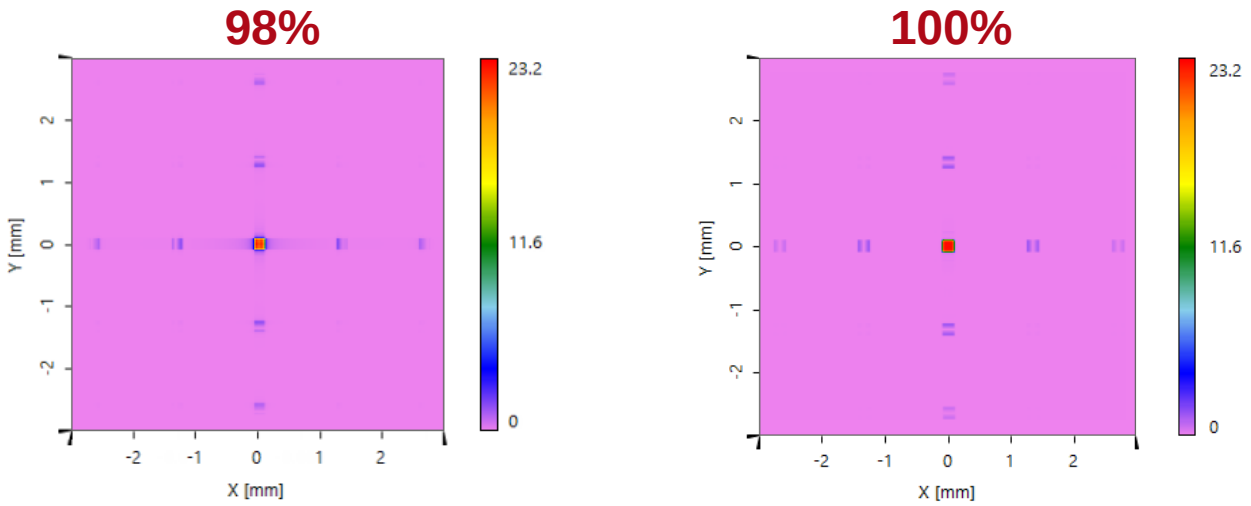


The reduction of the considered SLM array region delivers almost the same result for the amplitude distribution of the electromagnetic field!

Simulation of the specified Area Fill Factor

- The computation of the **specified area fill factor of 98%** of Hamamatsu's X10468 needs considerably more sampling points, due to the very narrow gaps.
- The full array size of 792 x 600 pixels would require 79992 x 60600 sampling points and therefore a very high computational effort.
- Thus, it is appropriate to **reduce the array size** to 320 x 320 pixels, resulting in a sampling of 32320 x 32320 points.
- With the help of this optimization, the specified area fill factor can be investigated (this simulation still requires about 256GB of RAM).

Result:



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Investigation of the performance of a spatial light modulator taking into account **the gaps between the SLM pixels**.

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Gaps are introduced to a previously designed SLM transmission function for laser beam shaping.

2nd step

Analysis of influence of different area fill factors on the performance.

The arising diffraction effects have a major impact on the optical function and efficiency of the SLM.

Further Readings

Further Readings

- Get Started Videos:
  - Introduction to the Light Path Diagram

- Documents Correlated with This Application Examples
  - SLM.0001: Design of SLM Phase Modulation for Top Hat Generation
  - SLM.0003: Investigation of Lens Aberrations in an SLM-based Beam Shaping Setup