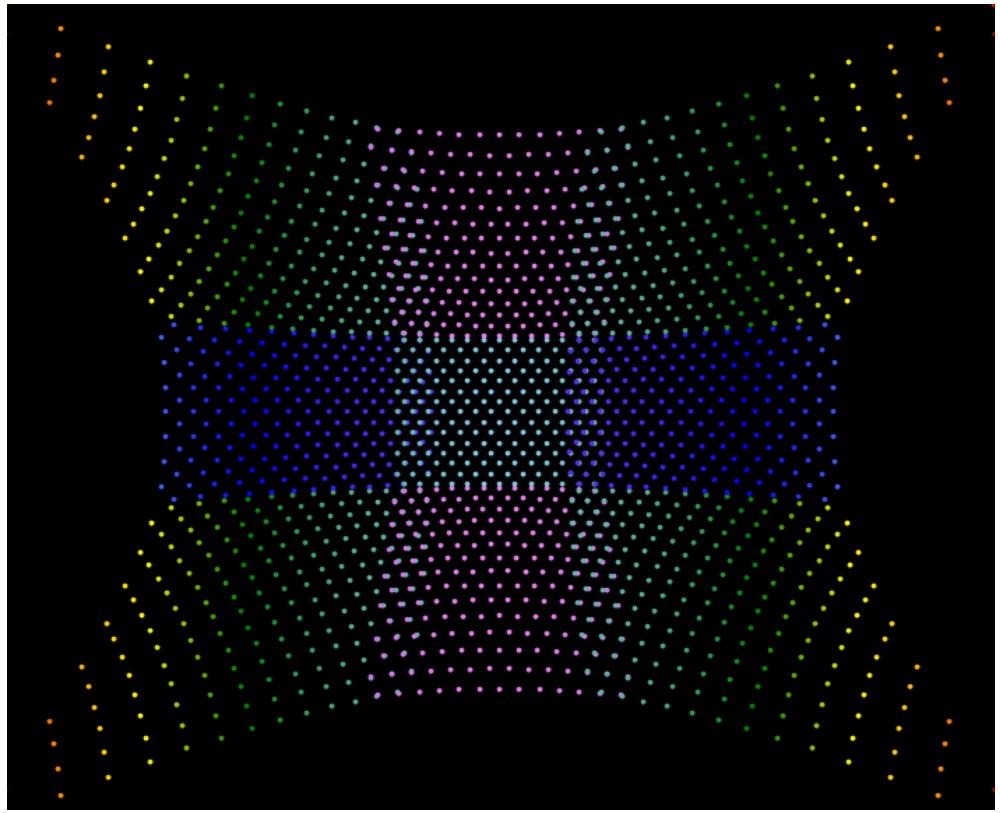
Design and Analysis of a 3x3 Beam Splitter

Abstract



A phase-only transmission function is designed using the iterative Fourier transform algorithm. Typically, the IFTA is designing a phase profile, which includes phase dislocations. As an additional step, a phase-only transmission is designed without any phase dislocations.

Design Task

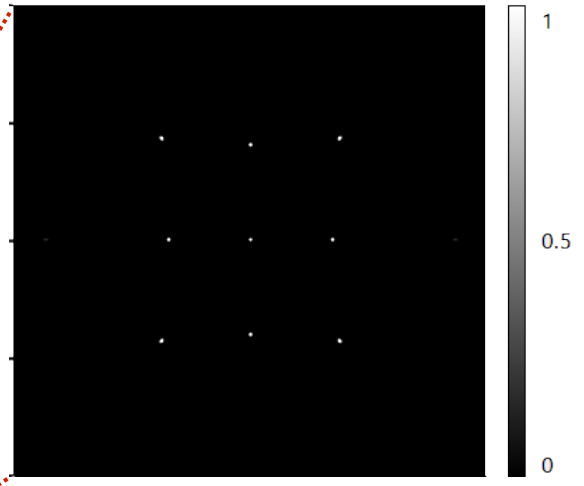
Source: VCSEL Array

design wavelength	940nm
VCSEL specification	
half-angle divergence (1/e²)	22°×22°
VCSEL mode	Laguerre Gaussian (0,0); (0,1); (0,2);
VCSEL array specification	
number of VCSELs	14×15
emitter distribution	hexapolar
pitch	36×38.5µm

XXX

0.5 mm

Far Field
(1000 mm)



Desired Target Pattern

no. of spots	3×3
separation of orders (NA)	0.3797×0.4247
efficiency	> 75%
maximum relative straylight	< 15%

Beam Delivery Optics

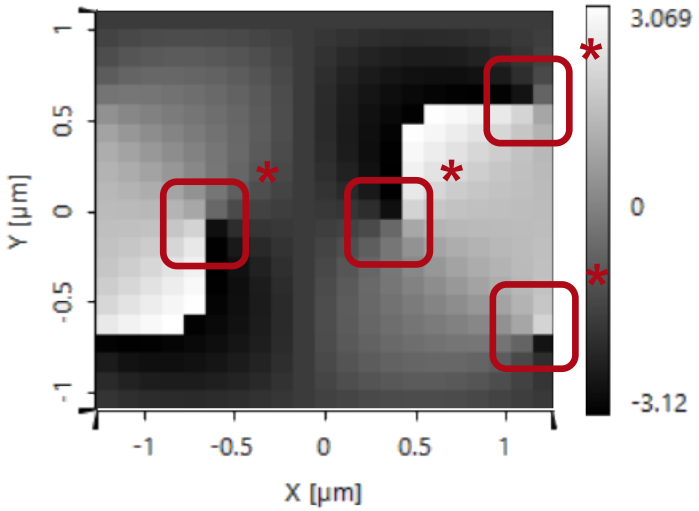
- Collimation lens f' X.XX mm

Light Shaping Element

- Single-sided layer with periodic surface height profile
- Quantized (preferred 2 steps)

Functional Design with Phase Dislocations (A)

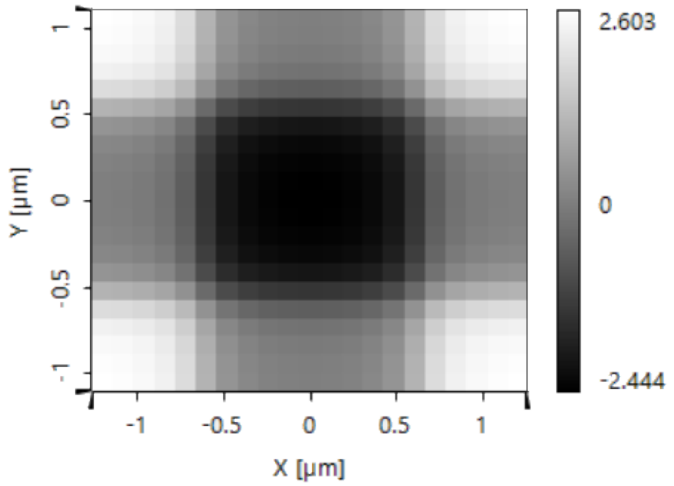
Design of Phase Function [rad]



First, a phase-only transmission function is designed using the iterative Fourier transform algorithm. Typically, the IFTA is designing a phase profile, which includes phase dislocations (*). These are disadvantageous for efficiency control after performing the structure design by the thin element approximation due to their scattering nature, which is even not predicted by this structure design method.

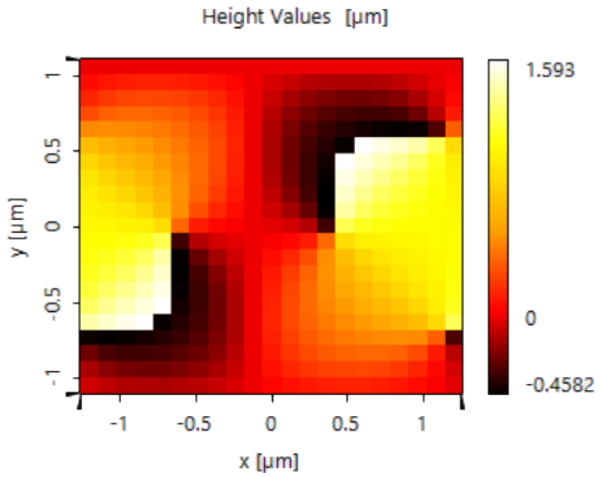
Functional Design without Phase Dislocations (B)

Design of Phase Function [rad]

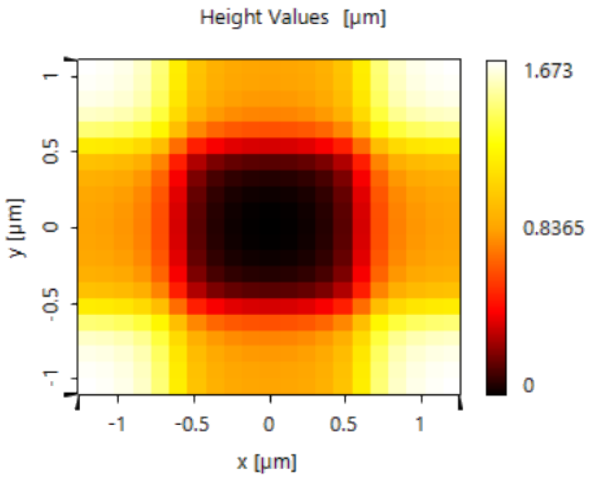


As an additional step, a phase-only transmission is designed without any phase dislocations. These special kinds of phase-only transmissions are supposed to have better performance after designing a height profile to be manufactured using the thin element approximation.

Structural Design based on Functional Embodiment



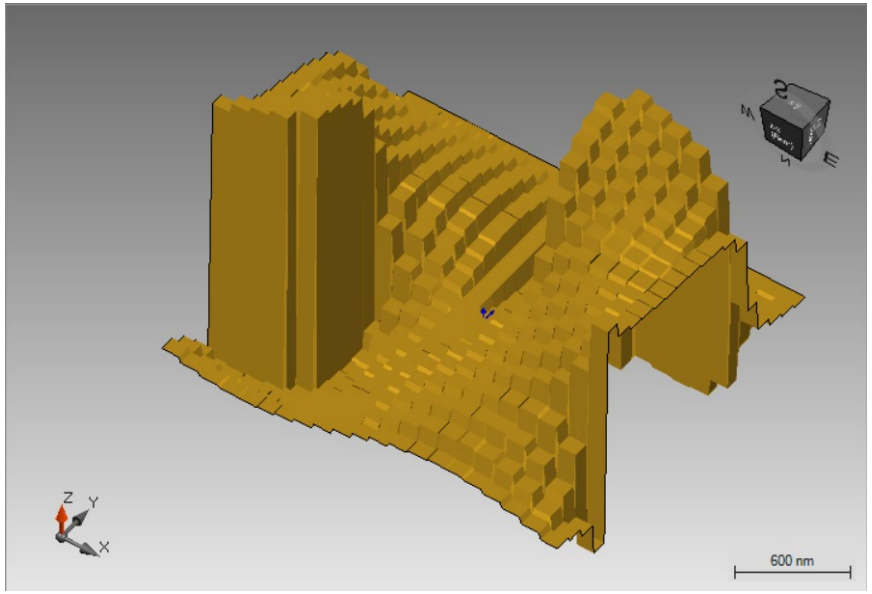
(A) Calculated height profile of the phase-only transmission function with phase dislocations

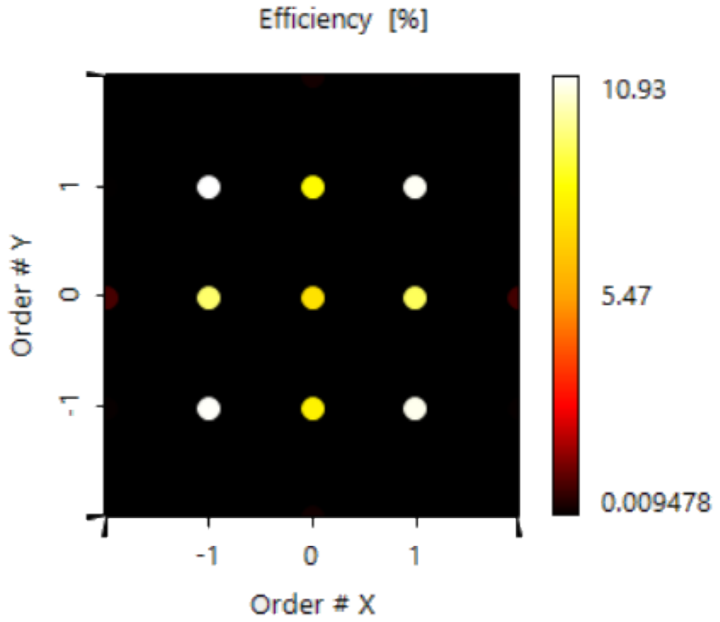


(B) Calculated height profile of the phase-only transmission function without phase dislocations

The thin element approximation is a common method to calculate the height profile of a phase function, which is accurate for feature sized which are larger than ~5 times the wavelength. Due to the need of the high diffraction angles, the feature size (~100 nm) are below the wavelength and hence, this method can only be used for the initial calculation of the height profile.

Analysis of the Structure (A) by TEA

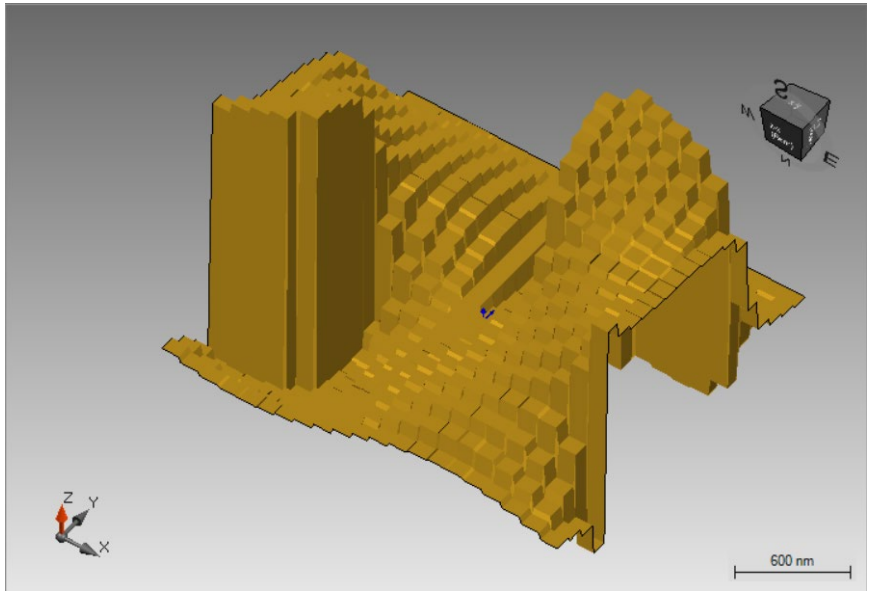


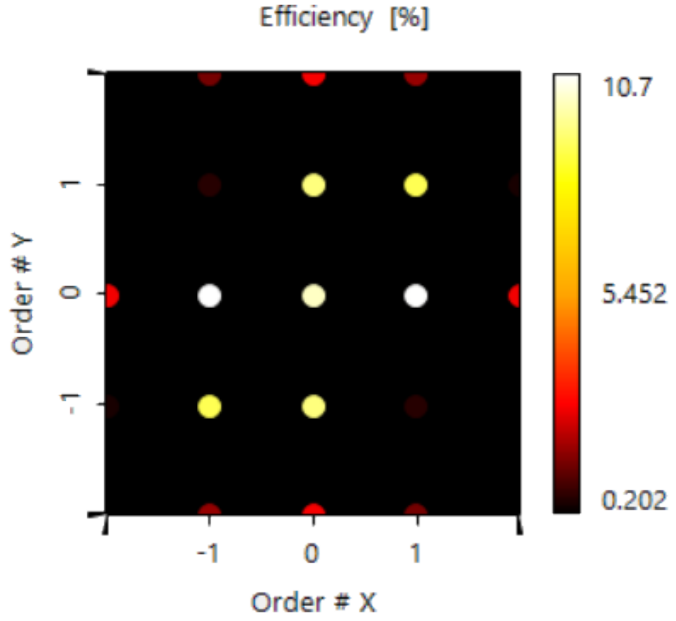


First, the thin element approximation is used for the analysis of the height profile to show the design conditions.

Parameter	Value & Unit
Zeroth Efficiency	7.35%
Average Efficiency	9.47%
Total Efficiency	85.26%

Analysis of the Structure (A) by FMM

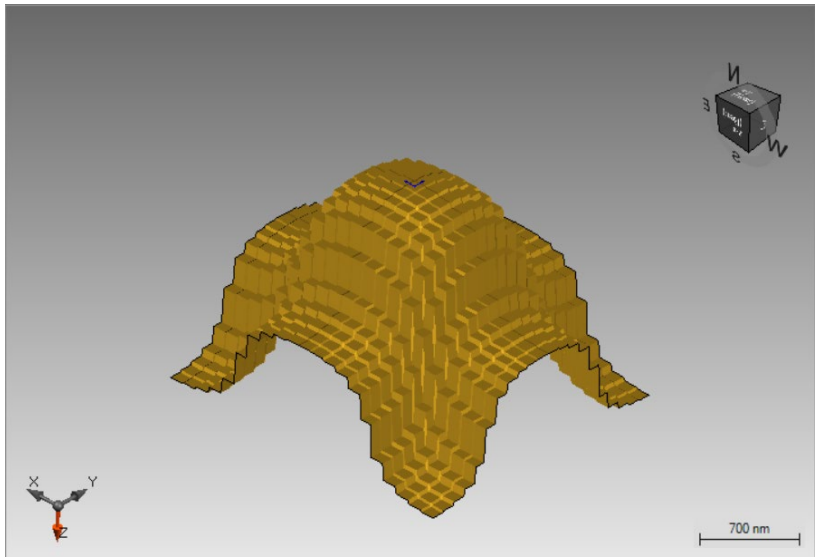




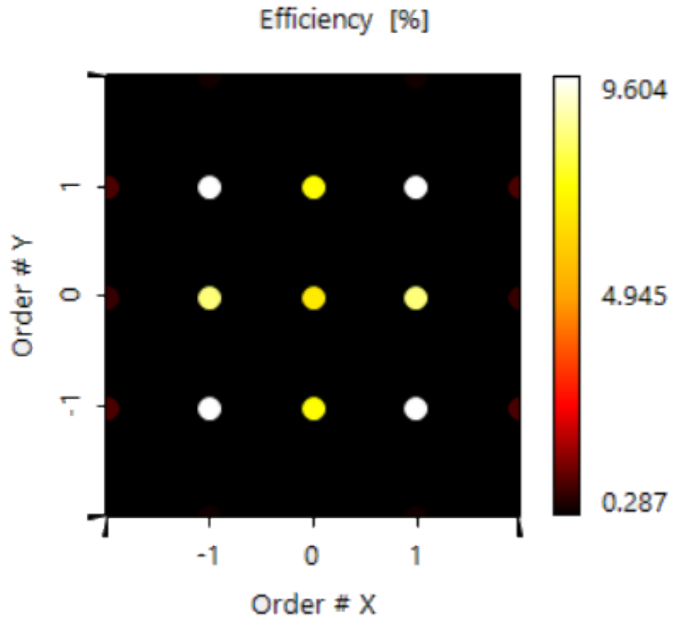
Second, the Fourier modal method is used for the rigorous analysis of the height profile and to predict the performance of the beam splitter accurately.

Parameter	Value & Unit
Zeroth Efficiency	10.01%
Average Efficiency	7.70%
Total Efficiency	69.32%

Analysis of the Structure (B) by TEA

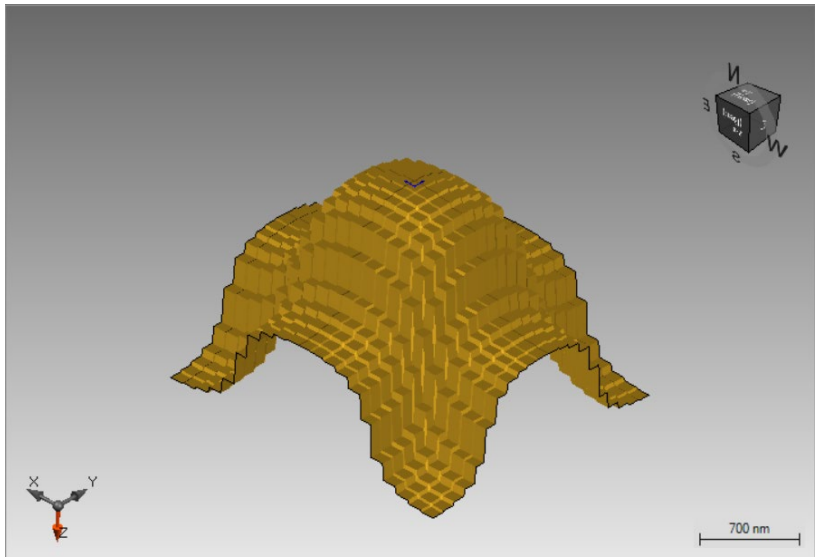


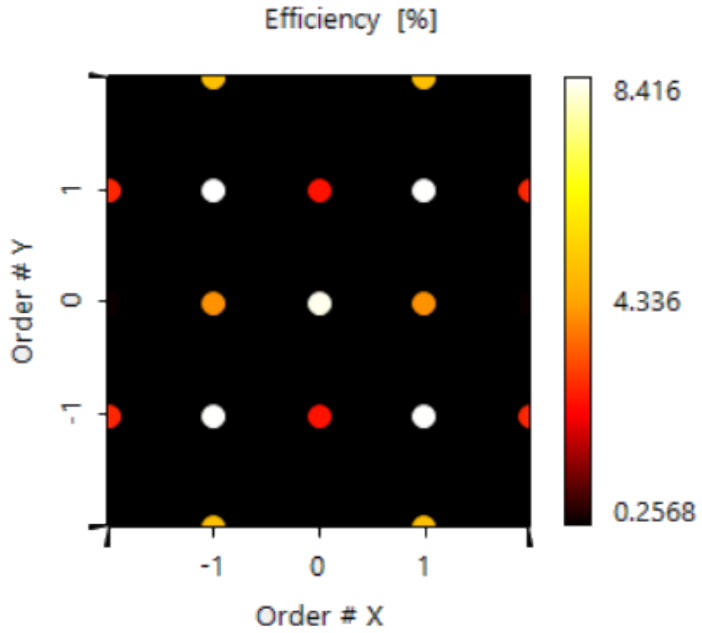
In comparison to the dislocation afflicted height profile, the dislocation free height profile has worse total efficiency and more visible stray light. However, the smooth height profile, provides better performance in real world, which is shown by a rigorous analysis …



Parameter	Value & Unit
Zeroth Efficiency	6.78%
Average Efficiency	8.51%
Total Efficiency	76.58%

Analysis of the Structure (B) by FMM

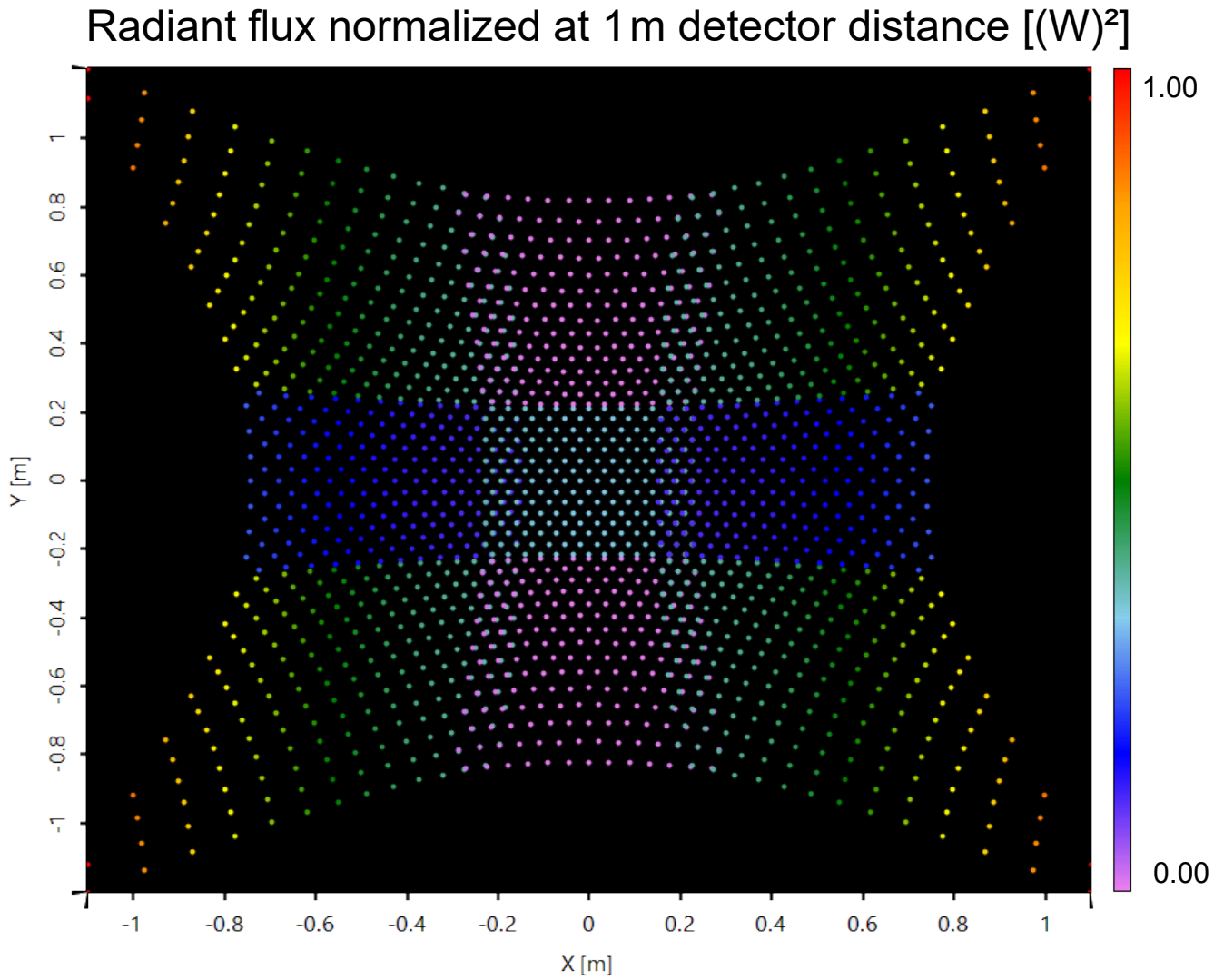




A rigorous analysis of the structure shows that total efficiency for the operating orders and the efficiency distribution is much better than for the dislocation afflicted height profile.

Parameter	Value & Unit
Zeroth Efficiency	8.28%
Average Efficiency	6.14%
Total Efficiency	55.22%

Analysis of the Complete Setup (B)



The generated dot pattern using the combination of the collimated VCSEL array and the 3x3 beam splitter (B) at 1 m distance is shown on the left.

There is a strong overlap along the x-direction. There are two options to correct that overlap:

- adjust design parameters of the beam splitter (NA_x)
- adjust the FOV of the VCSEL array by adjusting the beam delivery optics

Outlook

- Due to the smooth nature of the dislocation free phase function, the calculated height profile is advantageous for parametrization of the height profile, which can be used for post-processing optimization of the height profile to reduce the zeroth order strength.

- As a further step, quantization has to be investigated and optimization strategies have to be developed to optimize a 2- or 4-level smooth height profile to achieve the best performance.

- It is recommended to investigate a 5x5, 7x7 and/or 9x9 beam splitter in addition because it might be possible that these beam splitters provide better performance than a 3x3 beam splitter.

Document Information

title	Design of a 3x3 Beam Splitter
document code	Demo.1
version	1.0
VL version used for simulations	VirtualLab Fusion Summer Release 2019 (7.6.1.18)
category	Demo
further reading	- Design and Rigorous Analysis of Non-Paraxial Diffractive Beam Splitter - 7x7 Beam Splitter in 2f Setup with a VCSEL Source