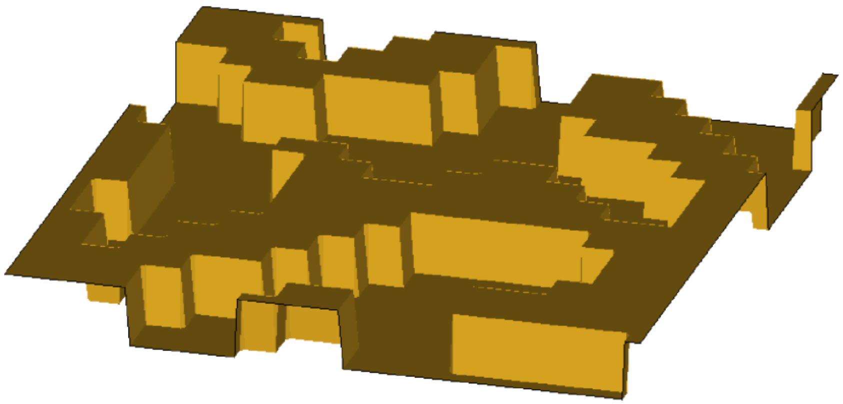
# Design and Rigorous Analysis of Non-Paraxial Diffractive Beam Splitter

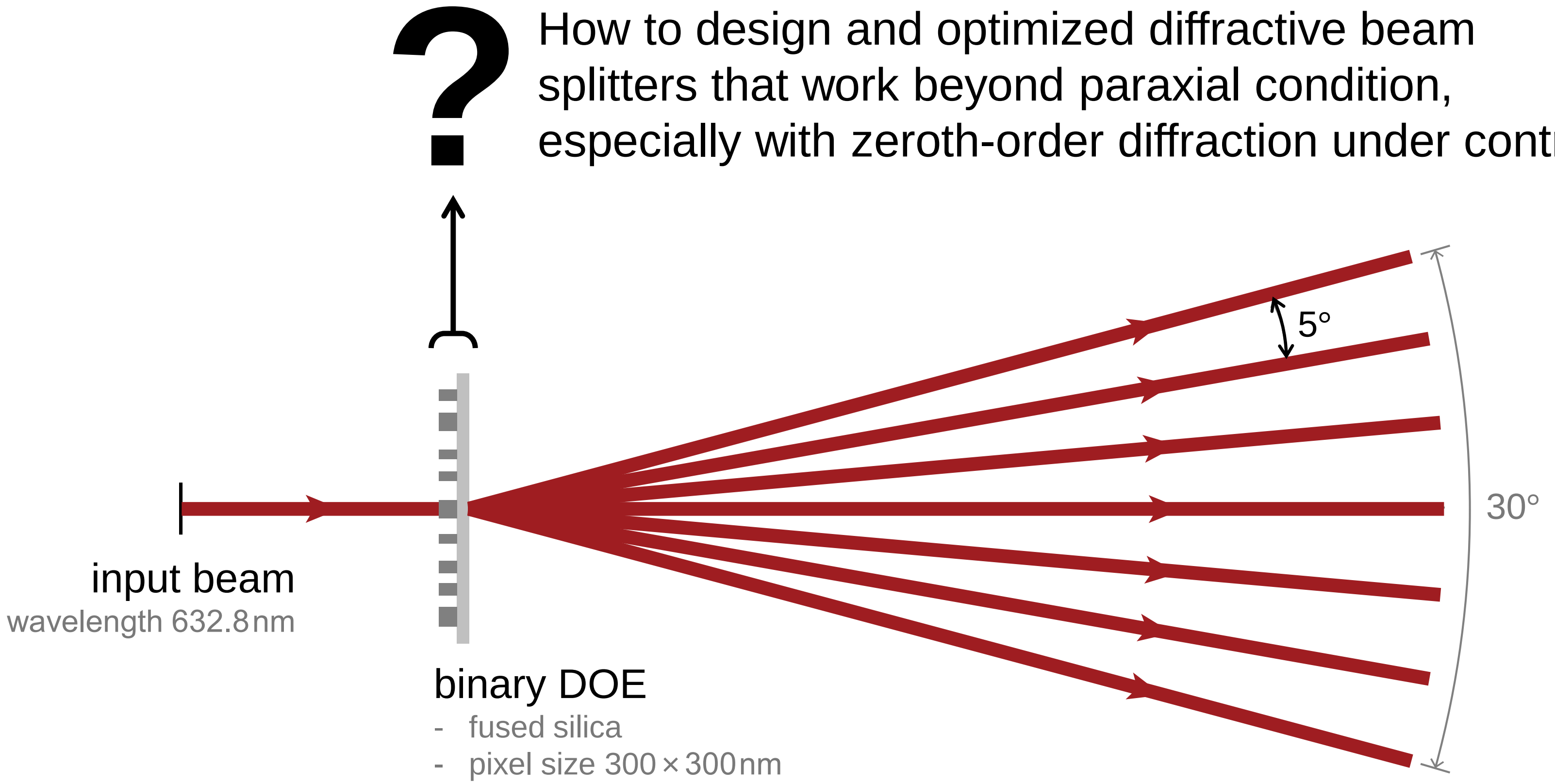
# Abstract



Direct design of a non-paraxial diffractive beam splitters is still challenging. Due to the relatively large splitting angle, the feature size of the element is equivalent to or smaller than the working wavelength. Thus, it is often beyond the paraxial modeling approaches. In this example, the iterative Fourier transfrom algorithm (IFTA) and thin-element approximation (TEA) are used for the initial design of the diffractive element structures, and Fourier modal method (FMM) is then applied for the rigorous performance evaluation.

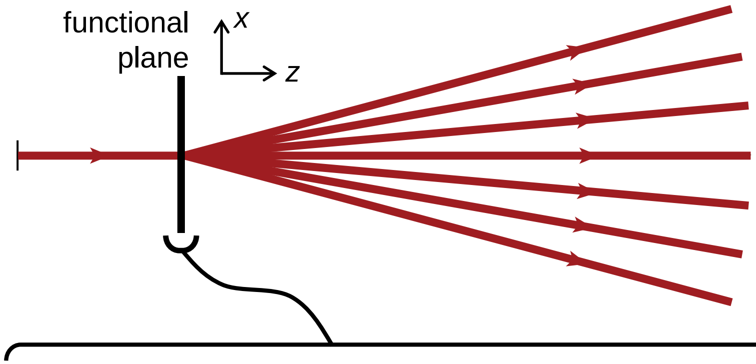
# Design Task

How to design and optimized diffractive beam splitters that work beyond paraxial condition, especially with zeroth-order diffraction under control?

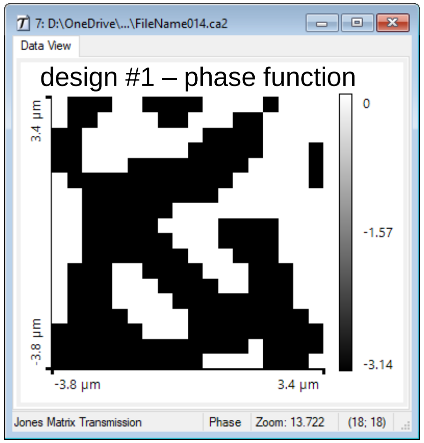


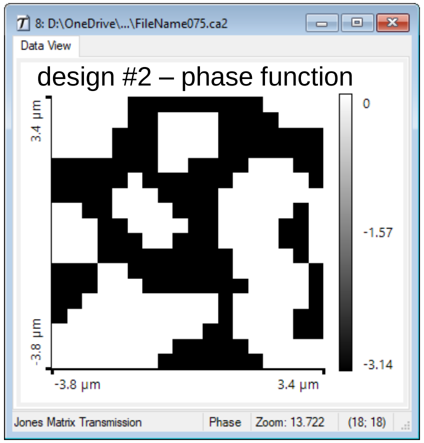
# Results

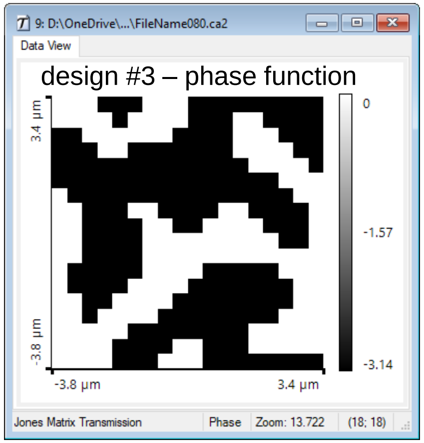
- Phase-only transmission design
  [with iterative Fourier transform algorithm (IFTA)]




With differently random phase distributions as starting points, IFTA calculates different possible design results. 3 designs are selected out of 100 according to customized criteria.

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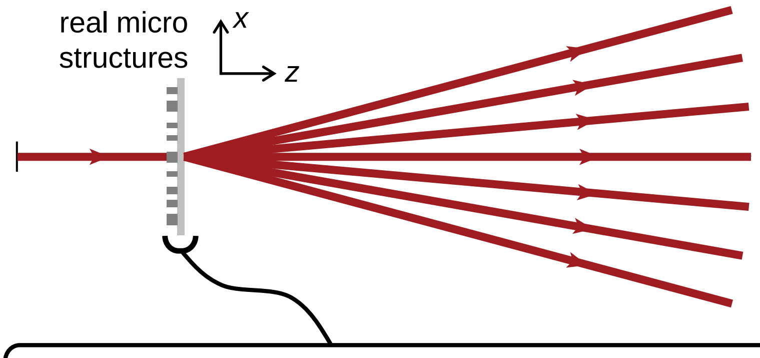
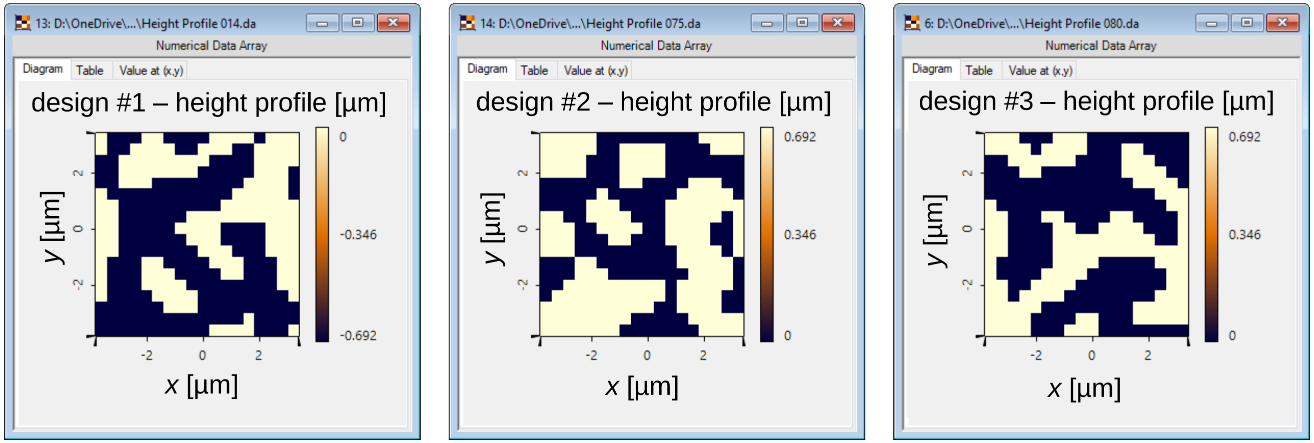
delivery of 100 designs within 20 seconds!

# Results

- Structure design
  [with thin-element approximation (TEA)]

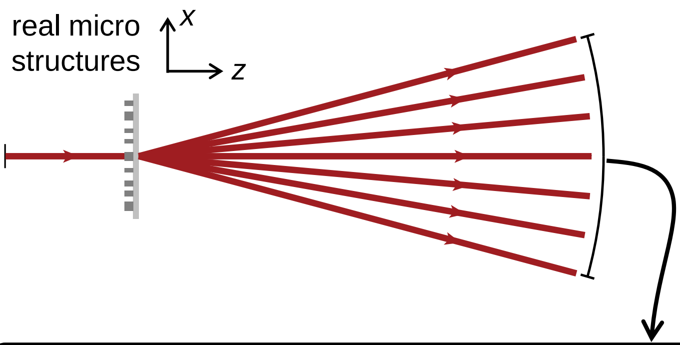



Automatic conversion from phase-only transmission to structure height profile, according to given wavelength and material.

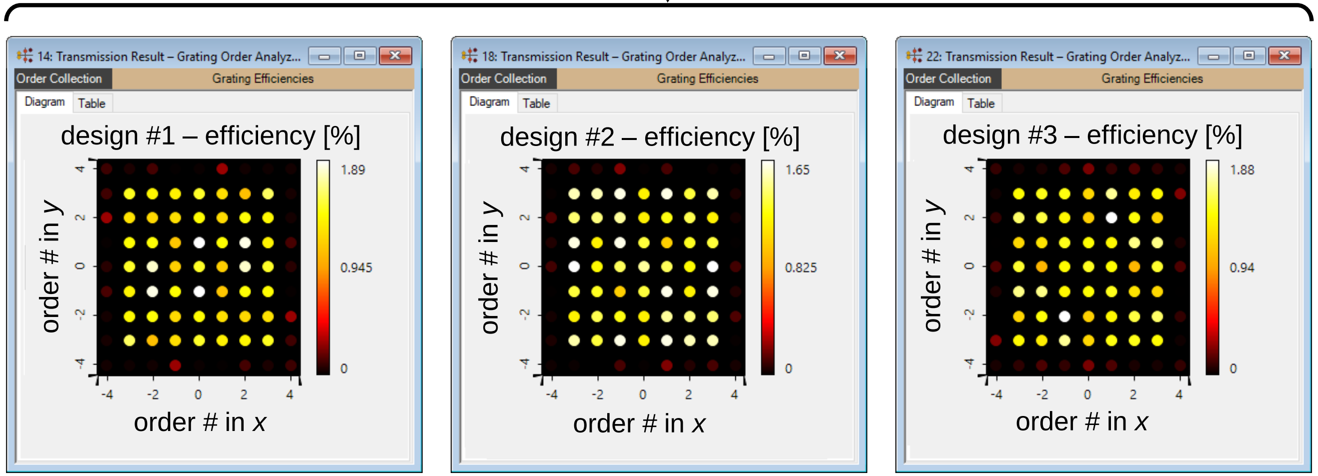


# Results

- Performance evaluation with TEA



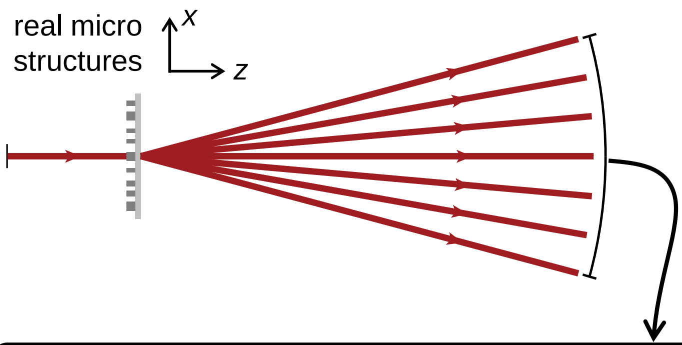

| Merit functions | Design #1 | Design #2 | Design #3 |
|---|---|---|---|
| total efficiency | 69.057% | 68.068% | 69.613% |
| average efficiency | 1.4093% | 1.3892% | 1.4207% |
| zeroth efficiency (zeroth order error) | 1.4888% (5.6374%) | 1.4888% (7.1723%) | 1.4704% (3.5%) |
| uniformity error | 14.422% | **12.266%** | 12.989% |



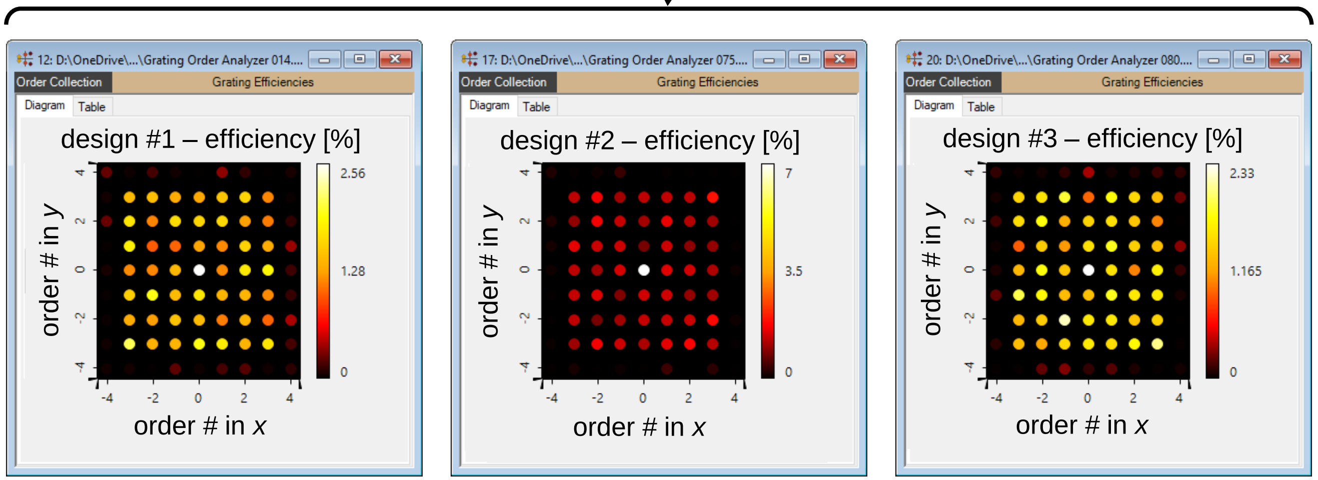

Design #2 seems to give the best uniformity, based on the evaluation results from thin-element approximation. But, is it still true for the non-paraxial situation?

# Results

- Performance evaluation with Fourier modal method



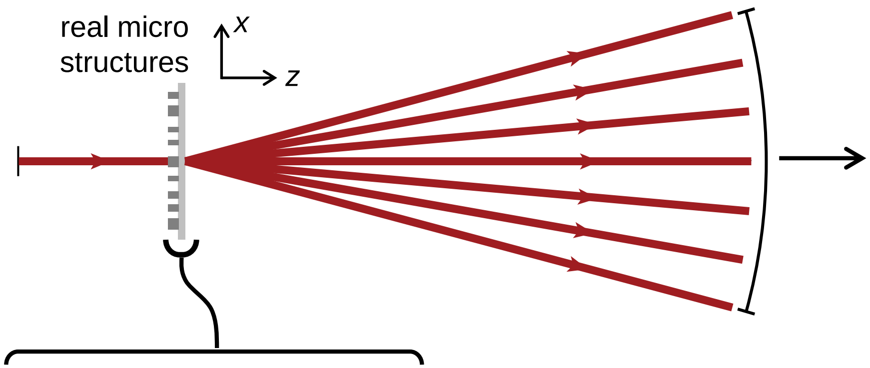

| Merit functions | Design #1 | Design #2 | Design #3 |
|---|---|---|---|
| total efficiency | 72.122% | 70.619% | 74.311% |
| average efficiency | 1.4719% | 1.4412% | 1.5165% |
| zeroth efficiency (zeroth order error) | 2.5574% (73.753%) | 7.011% (386.47%) | 2.3324% (53.799%) |
| uniformity error | 21.064% | **58.431%** | 18.946% |

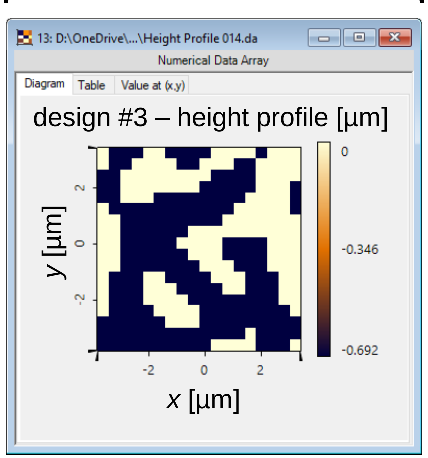



With the rigorous Fourier modal method (FMM), it turns out that design #2 produces strong zeroth diffraction order, resulting in very poor uniformity in fact.

# Results

- Further optimization – zeroth order tuning



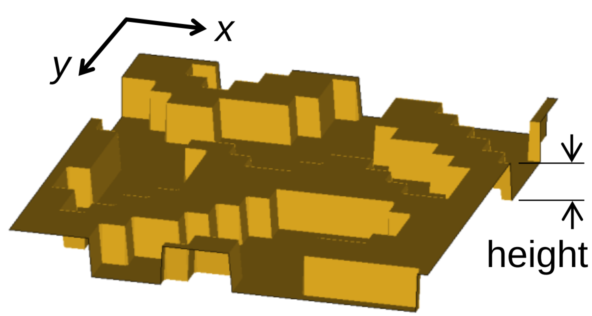




FMM evaluation results

| Merit functions | Design #3 |
|---|---|
| total efficiency | 74.311% |
| average efficiency | 1.5165% |
| zeroth efficiency<br>(zeroth order error*) | **2.3324%**<br>**(53.799%)** |
| uniformity error | 18.946% |

Design #3 gives good overall performance but still produces undesired zeroth order error.

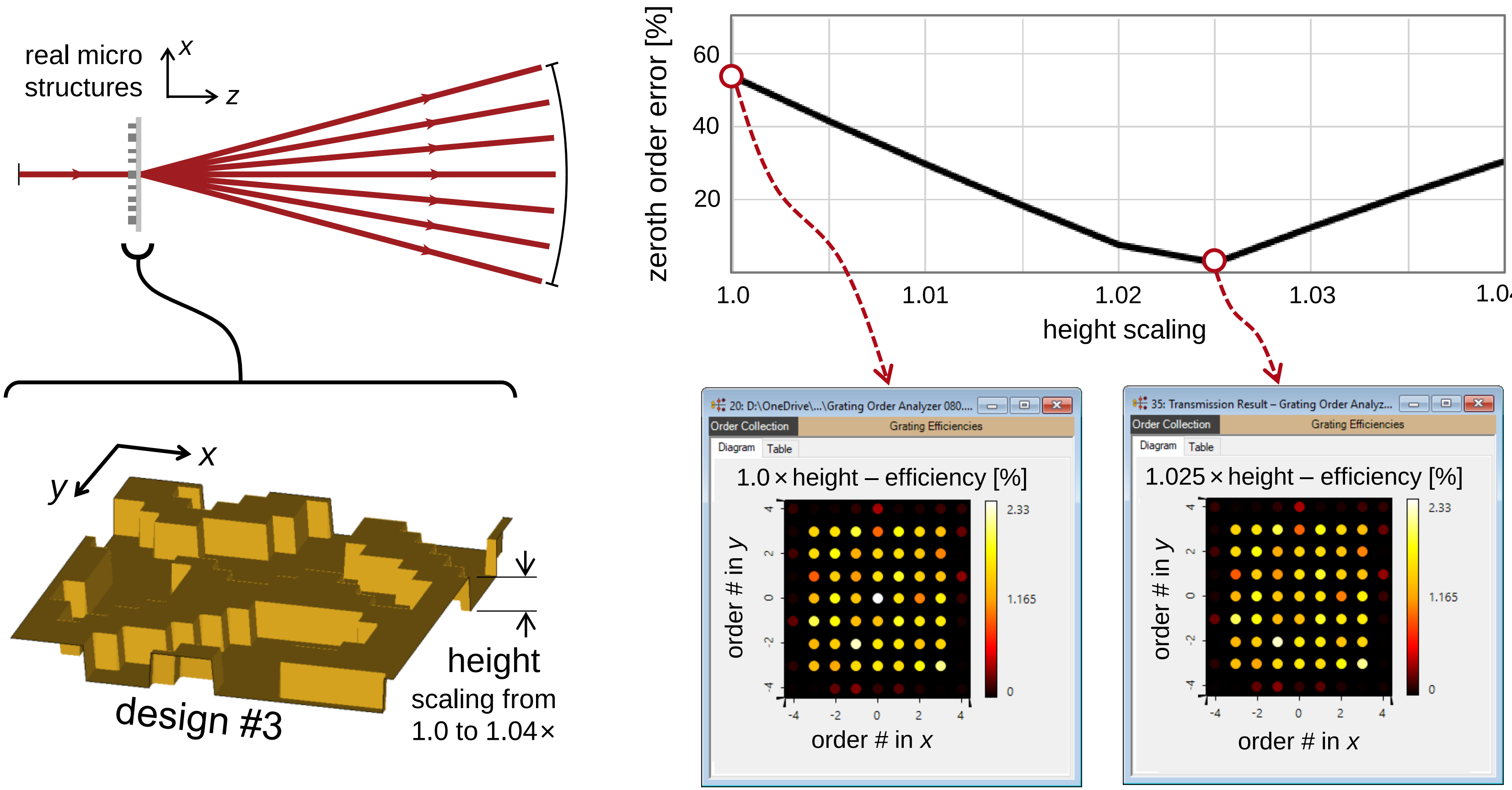
$$\text{*zeroth order error} = \frac{\text{zeroth efficiency} - \text{average efficiency}}{\text{average efficiency}}$$




Sometimes, the zeroth order error can be reduced by tuning the height of the binary structure.

# Results

- Further optimization – zeroth order tuning



# Document Information

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|---|---|
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