Design of 2D Non-Paraxial Beam-Splitting Metagrating
Metagratings are shown to have advantages when comparing with traditional gratings, especially in non-paraxial cases. In this example, we design a two-dimensional (2D) metagrating that splits the input into 3x3 beams. The metagrating is constructed with circular nano pillars, and in VirtualLab Fusion, we use FMM/RCWA to evaluate the diffraction efficiency of the metagrating. And, we show how to use the parametric optimization tool to improve the uniformity of the diffraction efficiencies.
Design Task

How to design a metagrating that splits the input into $3 \times 3$ beams, with
- uniform power distribution into the $3 \times 3$ beams, and
- high overall transmission power of the $3 \times 3$ beams?

- input field
  - wavelength $\lambda = 940\,\text{nm}$
  - $x$-polarization

- metagrating (top-view)
  - period $2 \times 2\,\mu\text{m}$
  - unit cell $400 \times 400\,\text{nm}$
  - substrate glass $n = 1.5$
  - circular pillar $n = 3.8$
Phase-Only Transmission Design (IFTA)

With differently random phase distributions as starting points, IFTA (iterative Fourier transform algorithm) calculates different possible design results.
With differently random phase distributions as starting points, IFTA (iterative Fourier transform algorithm) calculates different possible design results.

Select one of the results for further design.
Metasurface Unit Cell Analysis

- Unit cell dimension: $U = 400\,\text{nm}$
- $n = 1.5$
- $n = 3.8$
- $H = 465\,\text{nm}$
- Nanopillar diameter: $d$

Single nanopillar as the building block of the metasurface

Selected pillar diameter range

![Graph showing transmission efficiency and phase vs. pillar diameter](image)
Unit Cell Parameter Range Selection

- selected pillar diameter range

phase vs pillar diameter within the selected parameter range
Phase vs Pillar Diameter and Its Inverse

phase value vs pillar diameter
(result from last step)

pillar diameter vs phase value

The relation is inversed to have phase value as the variable, preparing for the construction of metagrating according to given phase transmission design.

In this example, function inversion can be done with the VirtualLab C# Module: Appx_01_Calculate Inverse of 1D Function.cs
Metagrating Construction

In this example, pillar distribution can be done with the VirtualLab C# Module: Appx_02_Calculate Pillar Diameters from Phase Profile.cs
Evaluation of Initial Metasurface Design

initial metagrating (top-view)

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
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<tbody>
<tr>
<td>Overall efficiency</td>
<td>79.6%</td>
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<tr>
<td>Uniformity error (PV)</td>
<td>25.3%</td>
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<td>Uniformity error (RMS)</td>
<td>16.9%</td>
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Parametric Optimization

- keep pillar positions
- vary pillar diameters (25 variables)

downhill simplex optimization with FMM/RCWA for grating analysis
Evaluation of Optimized Metagrating Design

optimized metagrating (top-view)

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<tr>
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<tr>
<td>Overall efficiency</td>
<td>79.5%</td>
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<td>3.1%</td>
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<td>Uniformity error (RMS)</td>
<td>1.8%</td>
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Peek into VirtualLab Fusion

- Flexible definition of 2D metagrating surface
- Parametric optimization of metagrating structure
Workflow in VirtualLab Fusion

- Analyze metasurface unit cell
  - Rigorous Analysis of Nanopillar Metasurface Building Block [Use Case]
- Construct metagratings
  - Metagrating Construction - Discussion at Examples [Use Case]
- Analyze grating diffraction efficiency
  - Grating Order Analyzer [Use Case]
- Parametric optimization of grating structure
  - Parametric Optimization [Tutorial Video]
VirtualLab Fusion Technologies

prisms, plates, cubes, ...
lenses & freeforms
apertures & boundaries
gratings
diffractive, Fresnel, meta lenses
HOE, CGH, DOE
micro lens & freeform arrays
SLM & adaptive components
diffractive beam splitters
scatterer
diffusers
waveguides & fibers
nonlinear components
free space
prisms, plates, cubes, ...
crystals & anisotropic components
## Design of 2D Non-Paraxial Beam-Splitting Metagrating

### Document Information

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| further reading              | - [Rigorous Analysis of Nanopillar Metasurface Building Block](#)  
|                              | - [Modeling and Design of Blazed Metagratings](#)      |