Parametric Optimization and Tolerance Analysis of Slanted Gratings
Abstract

Coupling of light into guiding structures with high efficiency is an important issue for many applications, like backlight, optical interconnector, and near-to-eye displays. For such applications, slanted gratings are well-known for being capable to couple monochromatic light with high efficiency. In this example, the optimization of a slanted grating with the rigorous Fourier modal method (FMM, also known as RCWA) is presented. The optimized grating shows a diffraction efficiency of over 90% for a predefined direction order. In addition, the influence from the slope deviation and the rounded edges of the grating are investigated.
Modeling Task

How to optimize the diffraction efficiency of the $T_{+1}$ order, by adjusting the slant angle $\varphi$, grating depth $h$, and filling factor $c/d$?

In addition, how to evaluate the grating performance with the slope deviation and the rounded edges due to fabrication processes taken into account?
In order to find an optimized set of parameters for the slanted grating, the *Optimization* document enables the definition of parameter constraints and weights for the target values. Find more information under:

[Introduction to the Parametric Optimization Document]
Parametric Optimization for 1\textsuperscript{st} Order

<table>
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<th>Order</th>
<th>Efficiency</th>
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<tbody>
<tr>
<td>-1</td>
<td>11.551%</td>
</tr>
<tr>
<td>0</td>
<td>72.795%</td>
</tr>
<tr>
<td>+1</td>
<td>11.551%</td>
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</table>

Initial structure:
- $d = 405\text{ nm}$
- $c/d = 50\%$
- $h = 500\text{ nm}$

Optimized structure:
- $d = 405\text{ nm}$
- $c/d = 57\%$
- $h = 324\text{ nm}$

Optimization setup:
- $\varphi = 34^\circ$

Parametric optimization – downhill simplex method – with rigorous Fourier modal method (FMM) used for grating efficiency calculation.

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<th>Order</th>
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<tr>
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<td>3.257%</td>
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<tr>
<td>0</td>
<td>0.365%</td>
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<td>+1</td>
<td>93.659%</td>
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The fabricated slanted gratings often show a deviation from the perfect parallel grating lines. Such deviations of the angles of the sidewalls should be taken into account for the tolerance analysis.

- fixed average slant angle \( \varphi = (\varphi_1 + \varphi_2)/2 = 34^\circ \)
- fixed filling factor (average) \( c/d = 57\% \)
- varying \( \varphi_1 \) from 34 to 44°

Rigorous simulation with Fourier modal method (FMM).

Slightly higher efficiency is due to additional parameters introduced in the tolerance analysis.

\[ d=405\text{nm} \]
\[ h=324\text{nm} \]
Results – Tolerance Analysis

The fabricated slanted gratings often show a deviation from the perfect parallel grating lines. The rounded edges should be taken into account for the tolerance analysis.

- fixed average slant angle \( \varphi = 34^\circ \)
- fixed filling factor \( c/d = 57\% \)
- varying \( r \) from 15nm to 70nm

Rigorous simulation with Fourier modal method (FMM).
VirtualLab Fusion Technologies

Field Solver

- 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
- waveguides & fibers
- nonlinear components
- free space
- crystals & anisotropic components

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| further reading | • Analysis of Slanted Gratings for Lightguide Coupling  
• Optimization of Lightguide Coupling Grating for Single Incidence Direction  
• Introduction to the Parametric Optimization Document  
• Advanced Configuration of Slanted Gratings  
• Configuration of Grating Structures by Using Interfaces  
• Grating Order Analyzer |