Parametric Optimization and Tolerance Analysis of Slanted Gratings
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 $T_{+1}$ order diffraction efficiency, 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 the fabrication technique taken into account?
Parametric Optimization for 1st Order

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<tr>
<th>Order</th>
<th>Efficiency</th>
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<tbody>
<tr>
<td>-1</td>
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<tr>
<td>0</td>
<td>72.795%</td>
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<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:
- $\varphi = 34^\circ$
- $d = 405\,\text{nm}$
- $c/d = 57\%$
- $h = 324\,\text{nm}$

Optimization setup: parametric optimization – downhill simplex method – with rigorous Fourier modal method (FMM) used for grating efficiency calculation.

Efficiency [%]

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<td>0.365%</td>
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<td>+1</td>
<td>93.659%</td>
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The fabricated slanted gratings often shows a deviation from the perfect parallel grating lines. Such slope deviations should be taken into account for the tolerance analysis.

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

Rigorous simulation with Fourier modal method (FMM), for tolerance analysis over 50 steps, takes 30 seconds.
Results – Tolerance Analysis

The fabricated slanted gratings often shows 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 70nm

Rigorous simulation with Integral Method (IM), for tolerance analysis over 30 steps, takes 9 seconds.
Peek into VirtualLab Fusion

- Flexible and easy settings of slanted gratings
- Parametric optimization of grating parameters
Workflow in VirtualLab Fusion

- Construct grating structure
  - Configuration of Grating Structures by Using Special Media [Use Case]
  - Advanced Configuration of Slanted Gratings [Use Case]
- Analyze grating diffraction efficiency
  - Grating Order Analyzer [Use Case]
- Optimize grating parameters with Parametric Optimization
- Tolerance analysis with Parameter Run
  - Usage of the Parameter Run Document [Use Case]
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| further reading | - [Parametric Optimization and Tolerance Analysis of Slanted Gratings](#)  
| | - [Optimization of Lightguide Coupling Grating for Single Incidence Direction](#) |