Rigorous Analysis and Design of Anti-Reflective Moth-Eye Structures
Abstract

The suppression of reflection at surfaces is of interest for numerous optical applications. One very interesting approach of controlling the reflection at surfaces is the usage of anti-reflective nano- and micro-structures, which are motivated by nature (moth-eye). These structures with feature sizes in the sub-wavelength domain exhibit unique properties concerning wavelength and angular dependency. In this document, the analysis and design of deterministic anti-reflective structures in VirtualLab Fusion is presented.
Design Task

input plane wave
- wavelength 532 nm
- normal incidence

How to optimize the anti-reflection moth-eye structural parameters, so to minimize the reflection from the air-PMMA interface?
Scanning over Parameter Space for Initial Solutions

- top diameter varying from 10 to 120 nm
- base diameter fixed at 125 nm
- height varying from 50 to 500 nm

reflection = ?

initial solution #1
relatively smaller aspect ratio and therefore preferable for fabrication

initial solution #2
relatively higher aspect ratio and maybe not the first choice for fabrication

Reflection Efficiency [%] (calculated by FMM / RCWA)
Parametric Optimization for Initial Solution #1

parametric optimization by downhill simplex method (each iteration calculated by FMM / RCWA)

final design #1

(logarithmic scale)
Performance Analysis of Final Design #1

Design #1 does not suppress reflection effectively for incidence over 50°.
Parametric Optimization for Initial Solution #2

Parametric optimization by downhill simplex method
(each iteration calculated by FMM / RCWA)

(logarithmic scale)
Performance Analysis of Final Design #2

Despite of the higher aspect ratio, design #2 suppresses reflection better for higher incidence angles.
Peek into VirtualLab Fusion

grating structure editor with preview

parametric optimization tools
with flexible variable and merit function definition
Workflow in VirtualLab Fusion

- Construct grating structure
  - Configuration of Grating Structures by Using Interfaces [Use Case]
  - Configuration of Grating Structures by Using Special Media [Use Case]
- Analyze grating diffraction efficiency
  - Grating Order Analyzer [Use Case]
- Search for initial solutions with Parameter Run
  - Usage of the Parameter Run Document [Use Case]
- Find final design with Parametric Optimization
  - Introduction to the Parametric Optimization Document [Use Case]
**VirtualLab Fusion Technologies**

- **Incidence**
- **Transmission**
- **Anti-reflection moth-eye structure**
- Reflection (to be minimized)
- **PMMA**, **air**

**Field Solver**
- Crystals & anisotropic components
- Nonlinear components
- Free space
- Prisms, plates, cubes, ...
- Lenses & freeforms
- Apertures & boundaries
- Gratings
- Diffractive, Fresnel, meta lenses
- HOE, CGH, DOE
- Diffusive beam splitters
- Diffusers
- Scatterer
- Waveguides & fibers
- SLM & adaptive components
- Micro lens & freeform arrays

**VirtualLab Fusion Technologies**

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| **further reading** | - [Parametric Optimization and Tolerance Analysis of Slanted Gratings](#)  
- [Optimization of Lightguide Coupling Grating for Single Incidence Direction](#) |