Topology optimization of optical surfaces

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Motivation and goals

For many applications the need for specifying and controlling the optical properties of surfaces is of high importance. Furthermore, the advances in nano-technology allow for fabrication of increasingly complex nano-structured surfaces. The problem of designing nano-structured surfaces with specific optical properties can be extremely challenging. A systematical design method is desireable to design surfaces of complex topology with tailored optical properties and to ensure design robustness considering practical dimensional tolerances.

Goals:
- Development of systematic method for designing optical surfaces
- Consider manufacturing tolerances and minimum length scale
- Verification of method by numerical examples

Example Applications:
- Advanced high performance gratings
- Structural color surfaces
- Optical filters

Modelling

The problem is modelled as a periodic cell

The electro-magnetic field is described by the 2D Helmholtz equation

\( \nabla \cdot (A(x) \nabla u(x)) + \omega^2 B(x) u(x) = 0 \)

with polarisation dependent parameters

\( A_{TM} = \frac{1}{\mu_r} \), \( B_{TM} = \frac{\epsilon_r}{c^2} \)

\( A_{TE} = \frac{1}{\epsilon_r} \), \( B_{TE} = \frac{\mu_r}{c^2} \)

Parameterization

Material properties are interpolated by elemental material parameters

\[ A_e = A_1 + \frac{\rho_e}{A_2 - A_1} \]

\[ B_e = B_1 + \frac{\rho_e}{B_2 - B_1} \]

Elemental density: \( 0 < \rho_e \leq 1 \), for \( e \in \Omega \)

Robust design

Simulates eroded, intermediate and dilated design realisations [5]

Topology optimisation

\[ \min \{ \max \{ h_i((\rho_e)^q) \} \} \quad 0 < \rho_e \leq 1, \quad q \in \{ T \text{ or } R \} \]

s.t. \( (K_\epsilon - \omega^2 M_\epsilon)u = f_\epsilon \)

\[ h_2 = \{ T \text{ or } R \} \]

\[ (K_\epsilon - \lambda_l N_l)x = 0, \quad \lambda > \delta, \quad q = \{ e, i, d \}, \quad i = 1, \ldots, N_{\omega,\theta}, \quad j = 1, \ldots, N_d \]

Numerical examples

Max transmittance - multigap

Maximise reflectance - multifrequency

Selective reflectance

References


Previou examples

Cloaking

Extreme materials

Micro Antennas

TopOpt App

TopOpt App