Evaluation of a Method for Simultaneous Optimization of Multilayer Photonic Nanostructures

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What is a photonic nanostructure?

- Layered materials, with varying thicknesses (nanoscale) and optical properties
- Overall structure has unique optical properties: absorption, reflection, transmission
- Applications: fiber optics, anti-reflection coatings, mirrors

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Modeling photonic nanostructures: transfer matrix method

- Derived from Maxwell’s equations
- Can find the overall optical properties of a structure by finding the optical properties of each layer
- Depends on only wavelength of incident light, thickness of layer, and index of refraction of materials

\[
\begin{bmatrix}
  E_z(x = a) \\
  Z_0 H_y(x = a)
\end{bmatrix}
= \begin{bmatrix}
  \cos(k_1 a_1) & -i \sin(k_1 a_1) \frac{\omega}{ck_1} \\
  -i \sin(k_1 a_1) \frac{ck_1}{\omega} & \cos(k_1 a_1)
\end{bmatrix}
\begin{bmatrix}
  E_z(x = 0) \\
  Z_0 H_y(x = 0)
\end{bmatrix}
\]
Prior Work: Hybrid Optimization Algorithm

Three steps

- Monte Carlo Simulation: random structure generation with given materials
- Genetic Algorithm: optimizes thickness of each layer given viable material composition
- Pattern Search: locally minimizes results
Five Layer Absorber

Materials: MgF₂, TiO₂, Si, Ge, Cr, Ag, HfO₂, SiC, W, Mo
Monte Carlo Simulation

- Probability for 1 million structures converges at 69%
- Overall probability distribution: deviation from expected linear trend
Conclusion and Future Work

Conclusion

- Although the Monte Carlo simulation is random, the optimal structure material composition is repeatable.
- Overall probability distribution isn’t linear: underlying pattern to material composition?
- Indicative of material composition being more important than thickness in designing a structure.

Future Work

- Investigate other methods for choosing material composition.
- Explore other general purpose optimization algorithms for optimizing thicknesses.
- Look into material properties and their impact on structure design.
Questions?

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