Inverse Design of Metasurfaces in 2D FDFD

Jiahuan Zheng | zhengjiahuan123@gmail.com
Hsu Lab
Diamond Bar High School, Class of 2022
USC Viterbi Department of Electrical Engineering, SHINE 2021

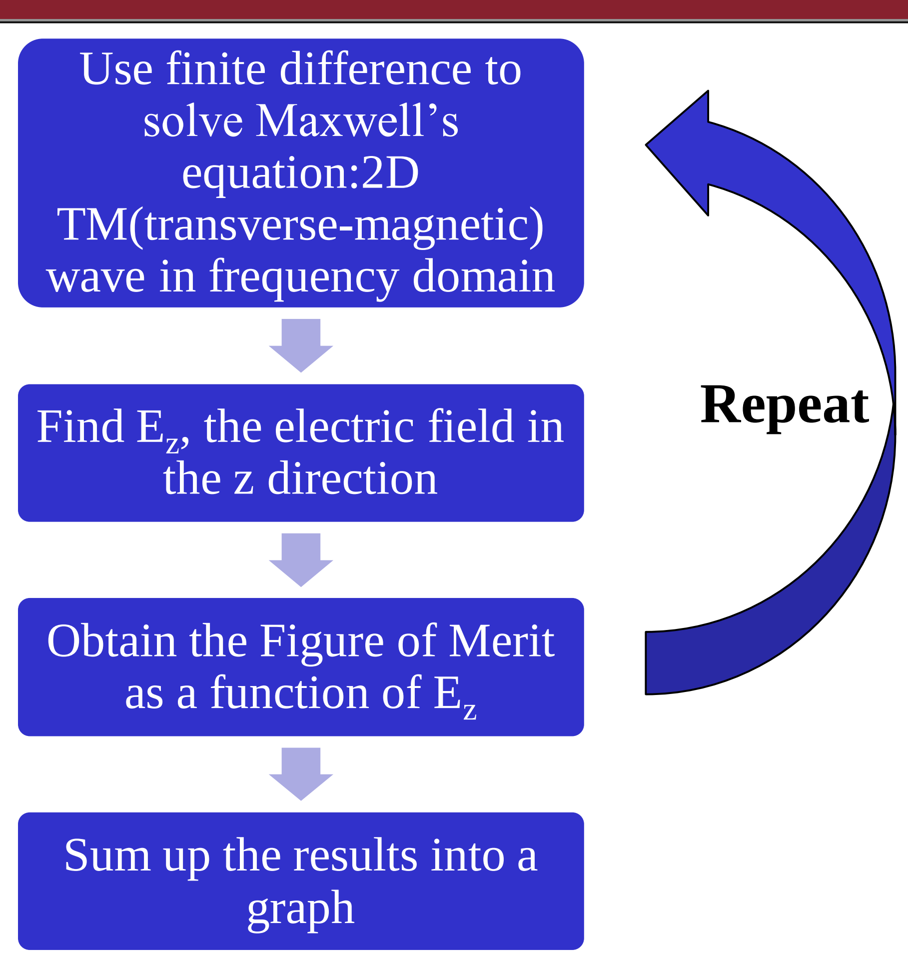
Introduction

In Professor Hsu's research lab, we focus on using modern technologies to control interactions between light and matter in complex systems. Examples include exploring new paradigms for controlling light, overcoming and harnessing light scattering, retrieving information from photons, and much more. One of the current interests is developing computational imaging methods that can reconstruct volumetric 3D images inside an opaque scattering medium that typically cannot be seen through.

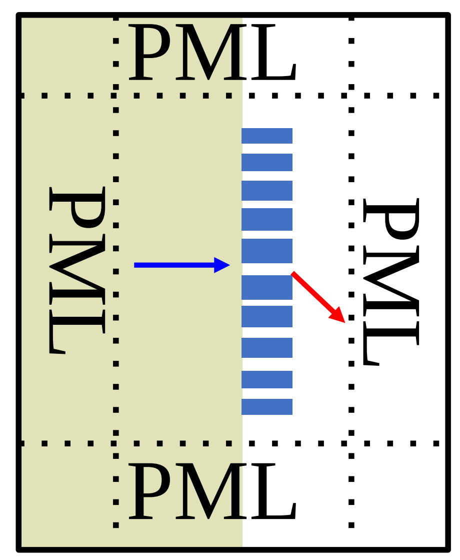
Impact of Research

- Utilizing cutting edge fabrication and high-performance simulations to manipulate light, to have deeper and finer resolution in imaging system. It can be widely used in medical and biomedical purpose, such as detecting the tumor behind human skin.

Flow chart of optimization



Methods and Results



By radiating a light beam(blue arrow) from the silicon oxide substrate(beige color) into the silicon nitride grating(blue squares), the light beam is scattered into multiple directions. Our goal is to alter the pillar width to end up with a light beam with the strongest transmittance at a specified angle(in this simulation, -10 degrees).

Figure 1. Diffractive optical elements surrounded by perfectly matched layer

FoM = $|t_{10°}|^2$ - $|t_{0°}|^2$, t = transmission coefficient

$\vec{w} = \vec{w}_{old} + \eta \frac{\nabla FoM}{|\nabla FoM|}$, η = learning rate

- Our goal is to find the position with maximized FoM.
- We measured the figure of merit for each of the first 300 iterations to produce this graph.
- As the graph suggests, we can see an increasing trend for the Figure of Merit.

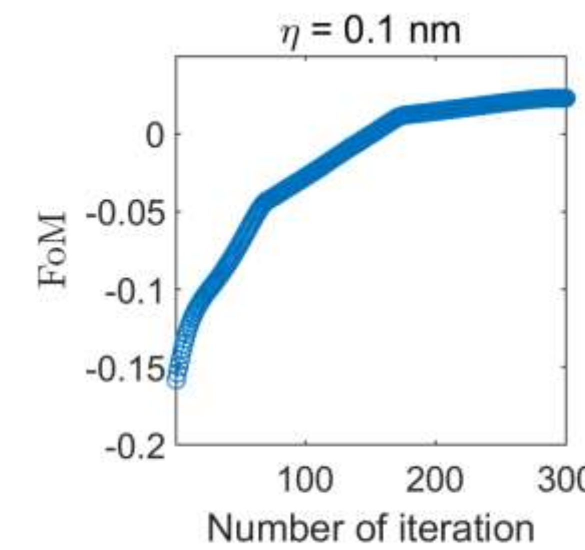
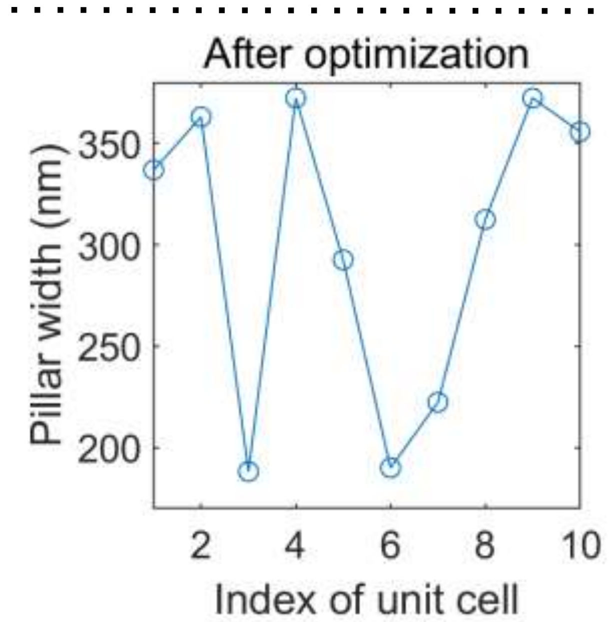


Figure 2. Figure of merit of the first 300 iterations



Conditions:

1. Light wavelength is 532 nm
2. Pillar height is 692 nm
3. Pillar width vary from 173 to 372 nm

- After 300 iterations, we have the width of each individual pillar.

Figure 3. Optimized width of the 10 pillars of the gradient

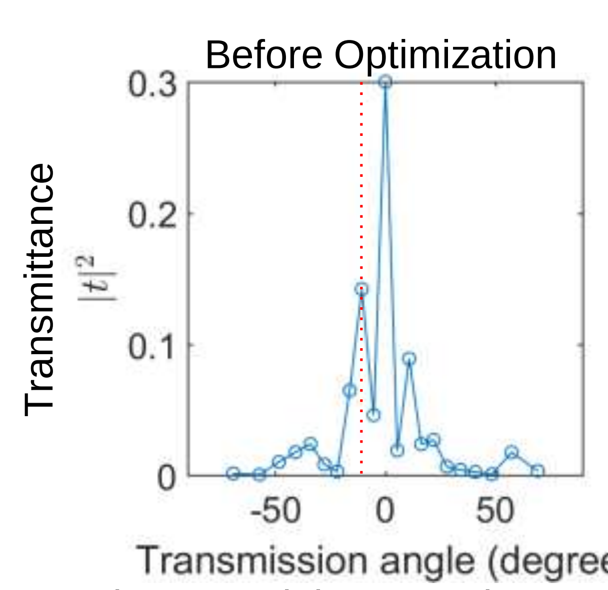


Figure 4. Light transmittance v.s. transmission angle before optimization

- The light beam initially has largest flux at normal (0 degrees) transmittance.
- As a result of altering the pillar width, the light beam of strongest transmittance projects at an angle of -10 degrees.

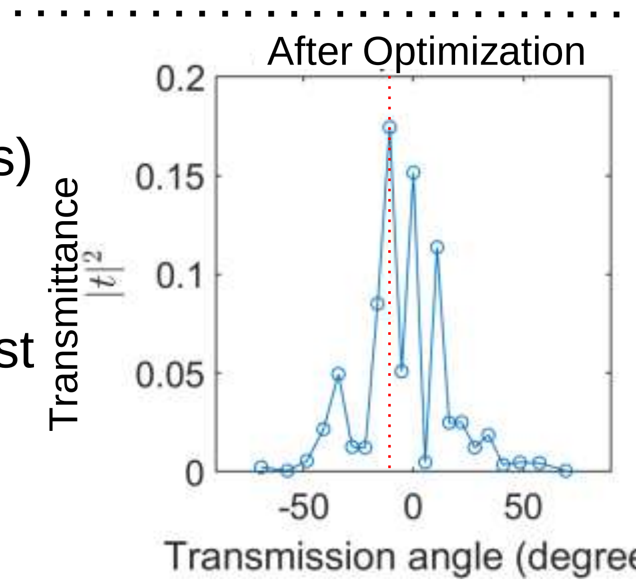


Figure 5. Light transmittance v.s. transmission angle after optimization

Skills Learned

- Utilization of MATLAB
- Multivariable calculus
- Finite difference method
- Maxwell's equations and wave equations
- Adjoint method
- Optimization methods, such as gradient descent(ascent) method and Monte Carlo method

Advice for Future SHINE Students

My advice for future SHINE students would be don't be afraid to ask for guidance. When SHINE first starts, everyone will feel new to the environment and not sure what to do. As SHINE progresses, everything will connect like puzzle pieces. Asking for help not only clarifies the questions you have, but also helps you connect with your professor and mentor as well.

Reference

[1] R. Lipsman and J. Rosenberg, "Multivariable Calculus With MATLAB", Springer International Publishing (2017)
[2] Zhi-Bin Fan *et. al.* "Silicon Nitride Metalenses for Close-to-One Numerical Aperture and Wide-Angle Visible Imaging", Phys. Rev. Applied, 10, 014005 (2018)

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