Machine Learning in Photonics:

EMEPy

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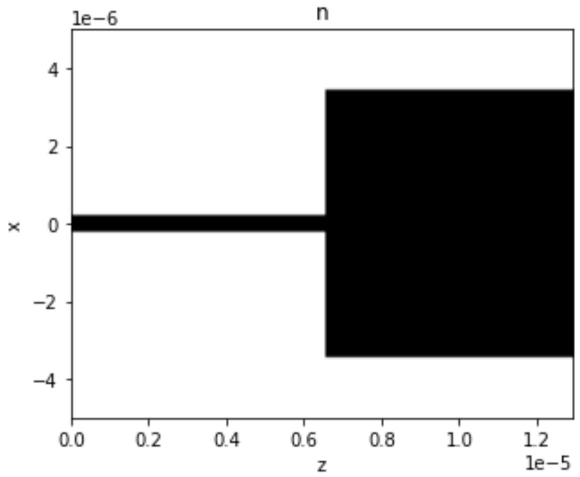
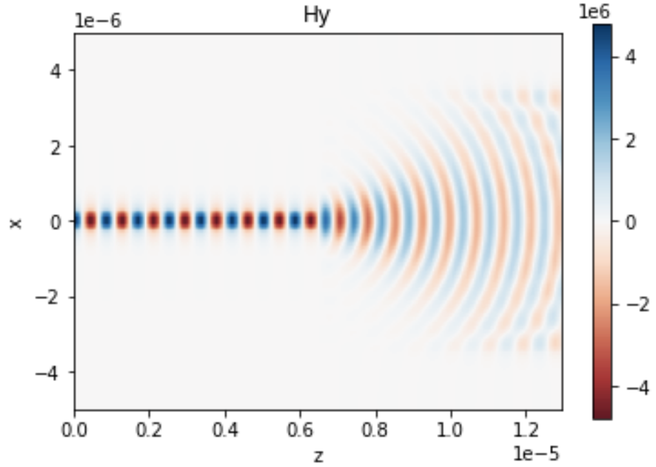
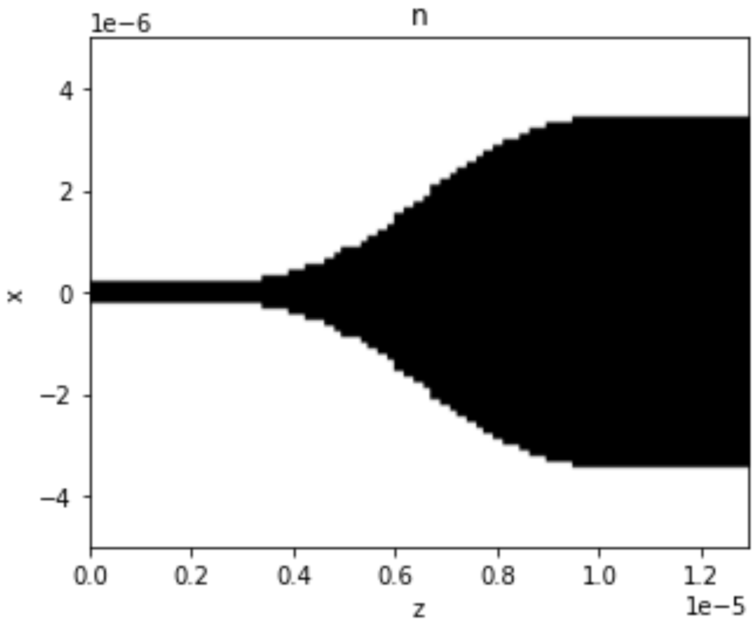
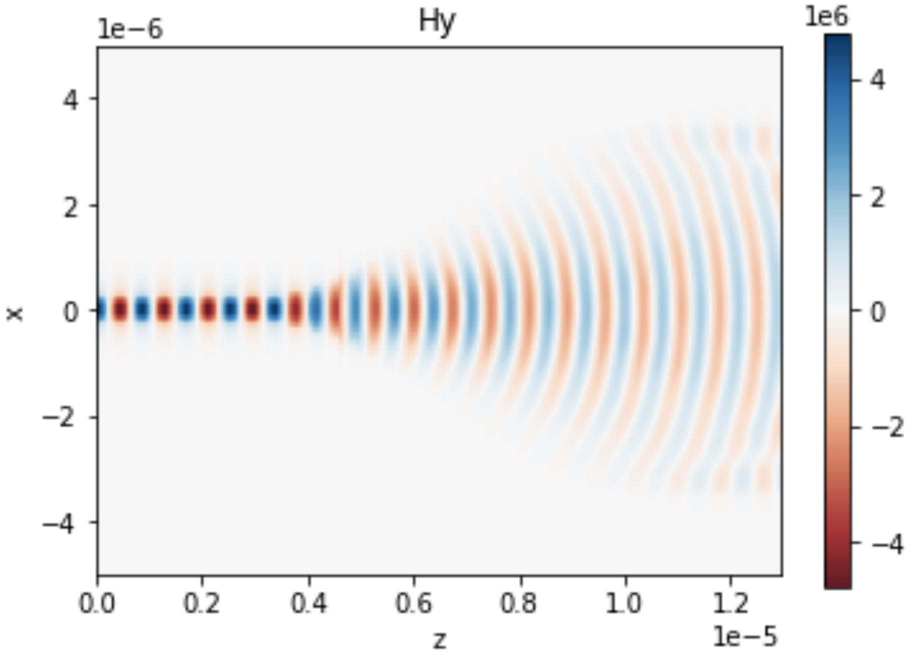
EME Overview







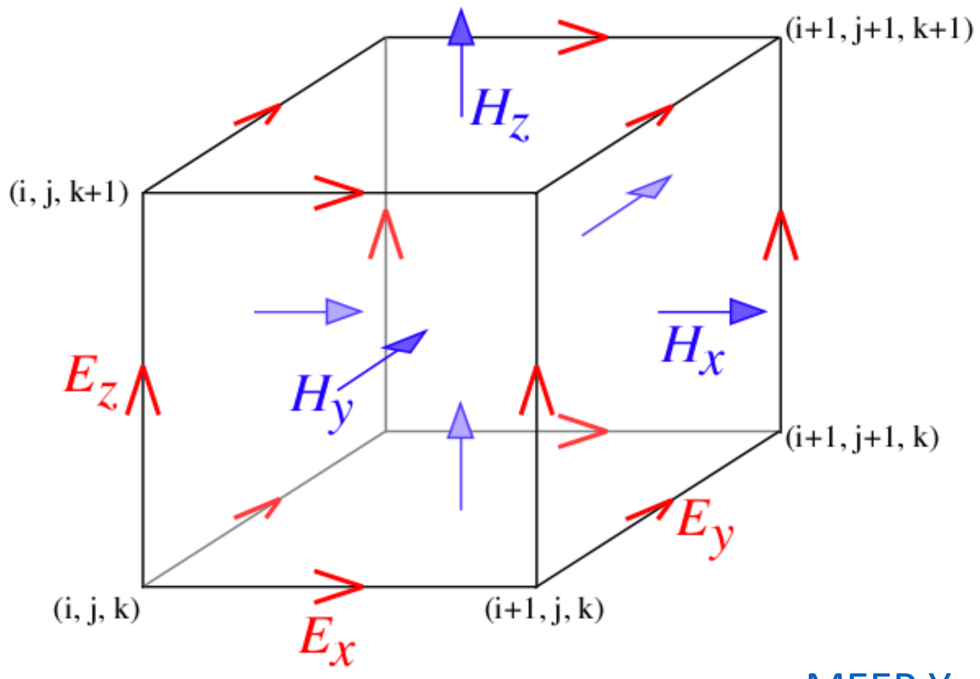


Photonic Crystal EME with PML

Dielectric Waveguide EME

EME Advanced Boundary Conditions

Finite Difference Overview



$$\nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_0}$$

$$\nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

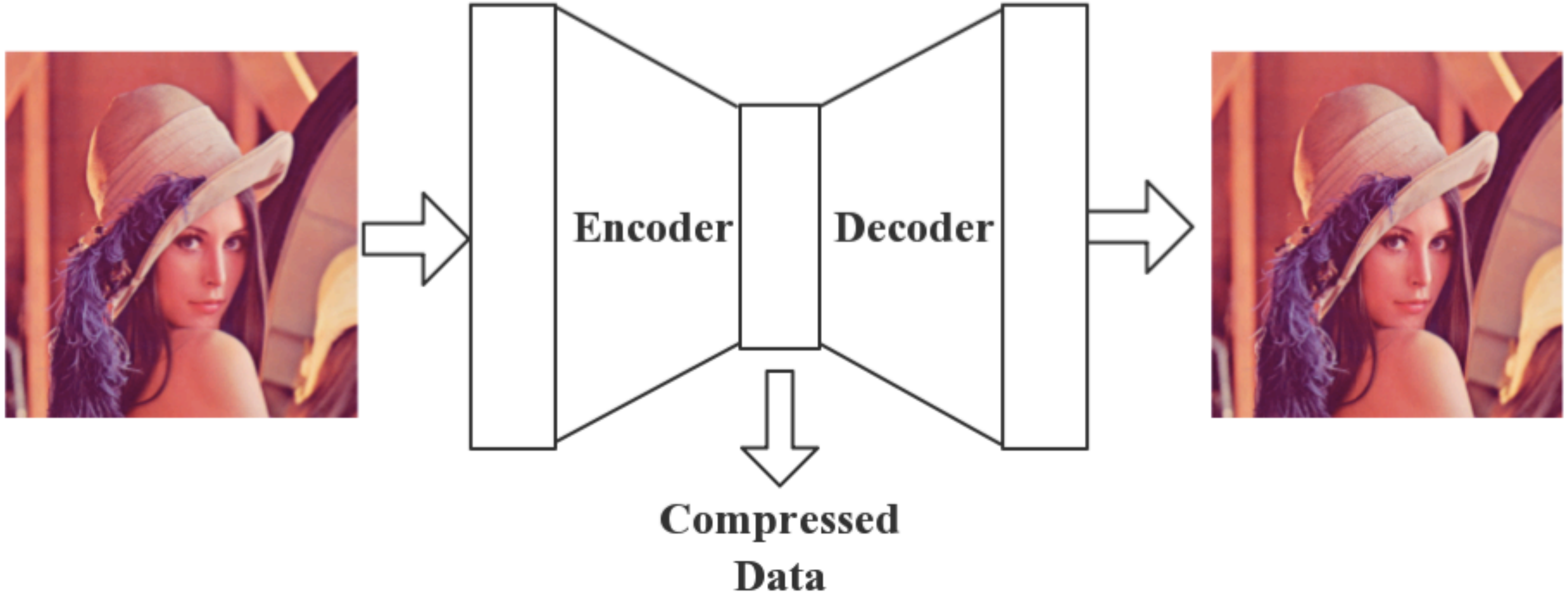
$$\nabla \times \mathbf{B} = \mu_0 \mathbf{j} + \frac{1}{c^2}\frac{\partial \mathbf{E}}{\partial t}$$

MEEP Yee Lattice

MEEP FDTD Paper

EMpy FD Modesolver Paper

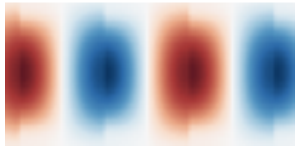
Neural Network (Convolutional Autoencoder)

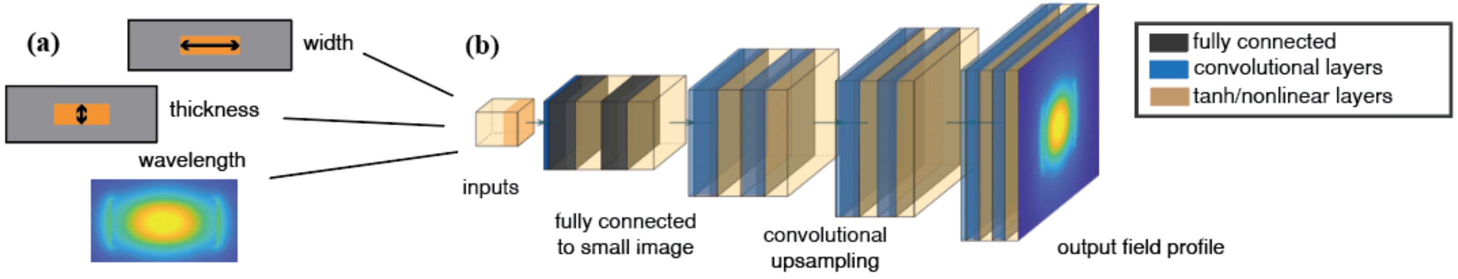


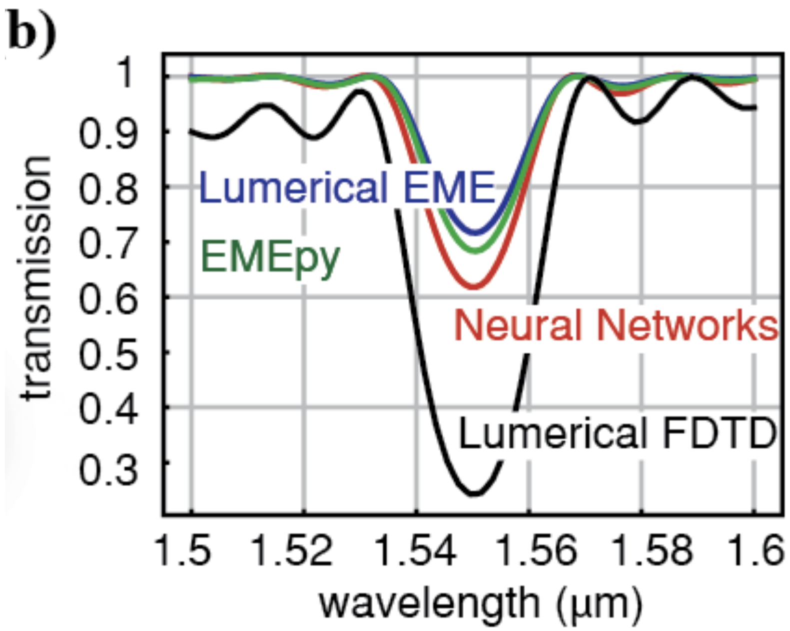
[Convolutional Autoencoder]
[MIT OpenCourseWare Neural Networks]

EMEPy Overview

- Convolutional Neural Networks (CNN) replace Finite Difference (FD) solver



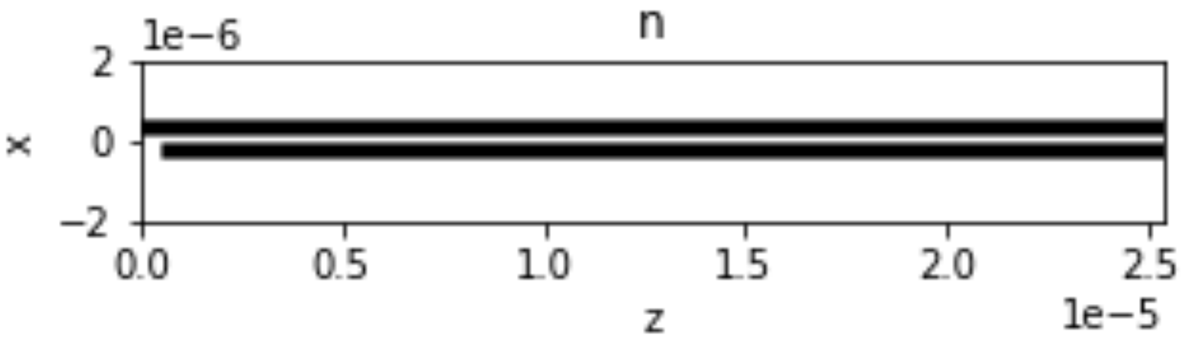


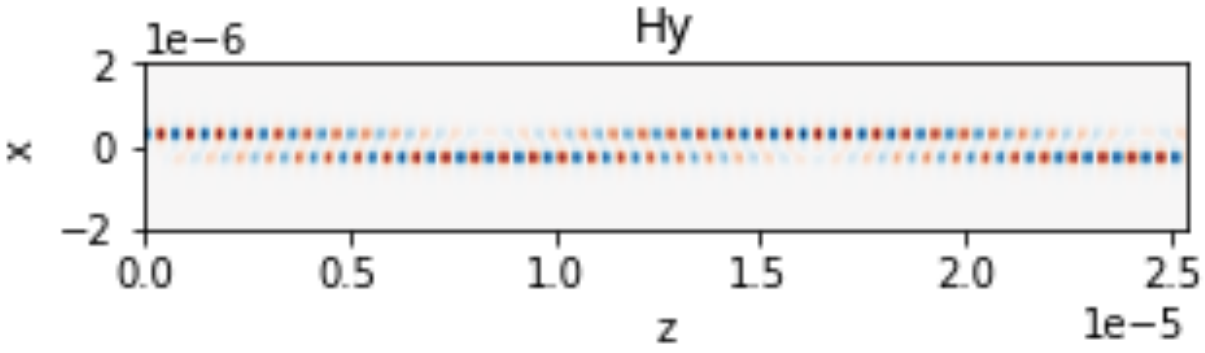


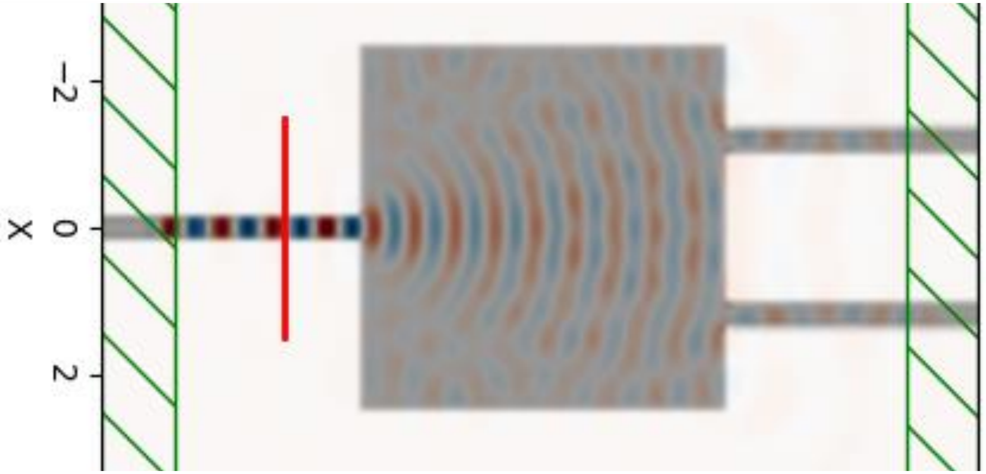
[EMEPy Docs]
[CLEO EMEPy Paper]
Optics Letters EMEPy Paper

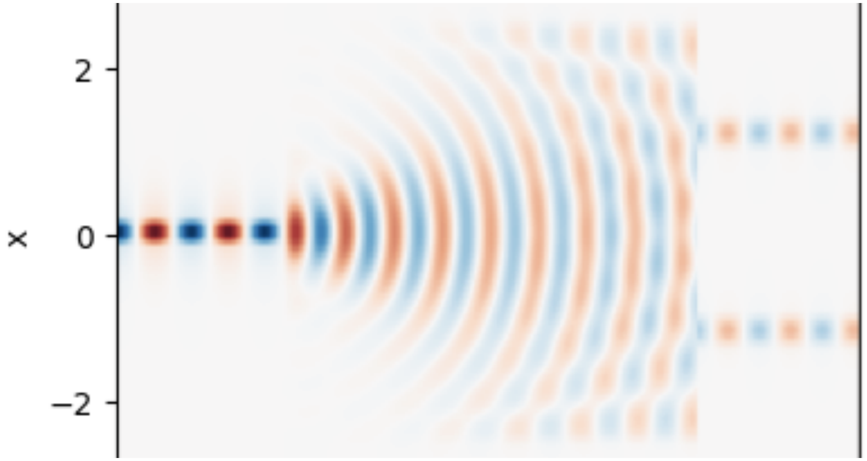
EMEPy Recent Updates

- MultiMode Field Propagation
- Recently discovered critical error!*









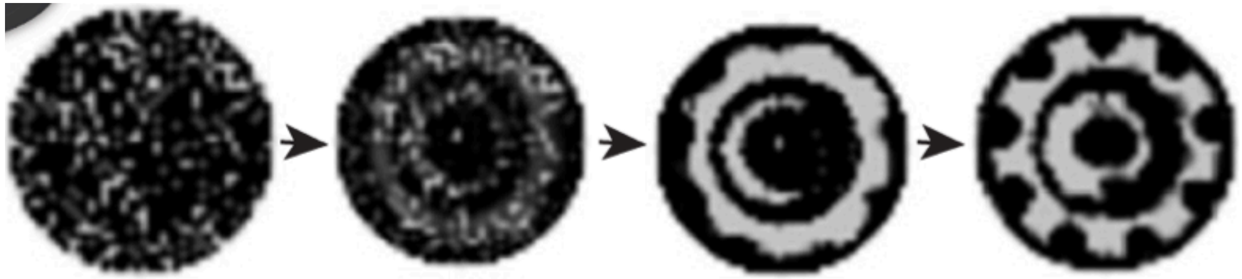
EMEPy Inverse Design

1) Overlap Integrals

2) Phase Propagation

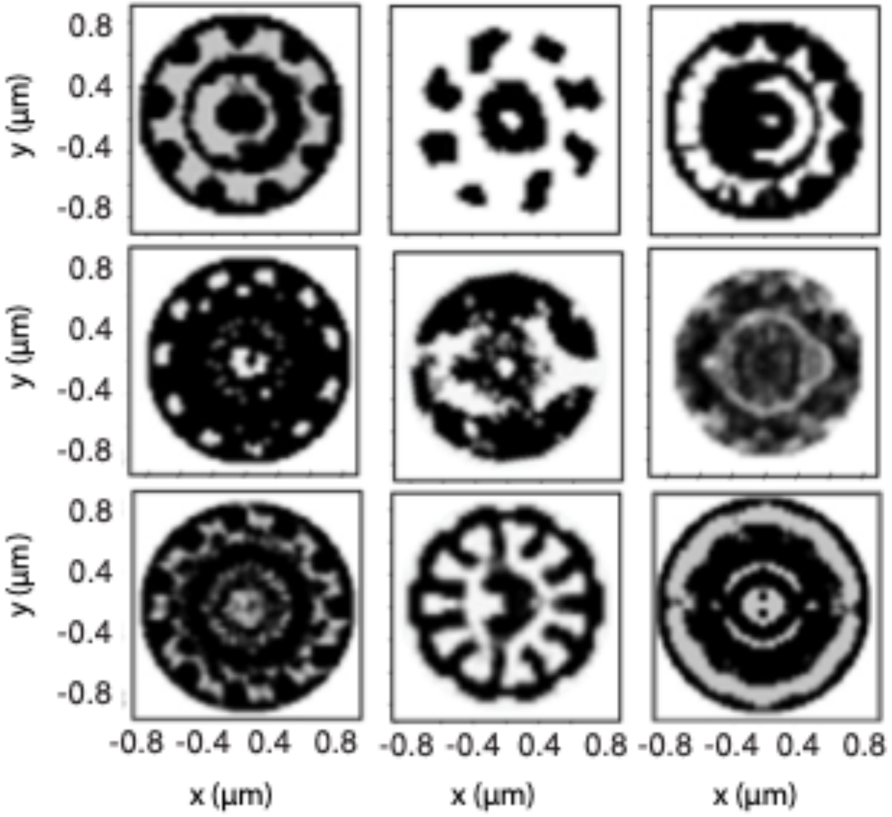
Density Based Inverse Design

- Pixel Based
- Binary material at each pixel

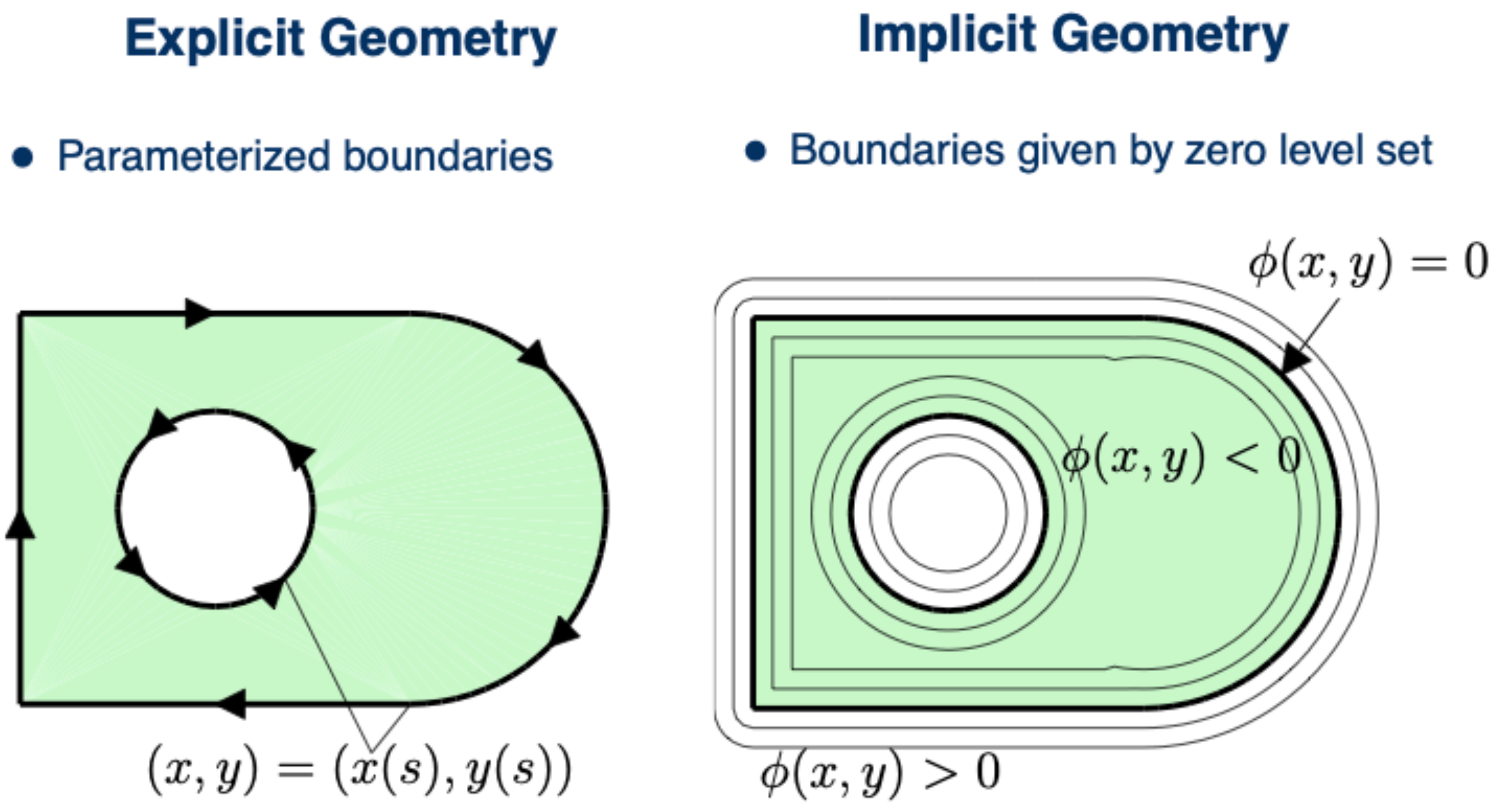


MEEP Topology Optimization

[Quantum Emitter Topology Optimization (FiO)]
[Photonic TopOpt for Foundry Design]
[Hybrid Time/Frequency-Domain TopOpt]



Level Set Based Inverse Design



[Implicit vs Explicit Level Set]

Adjoint Formulation

$$\nabla f(x, y) = \lambda \nabla g(x, y)$$

Lagrange Multiplier

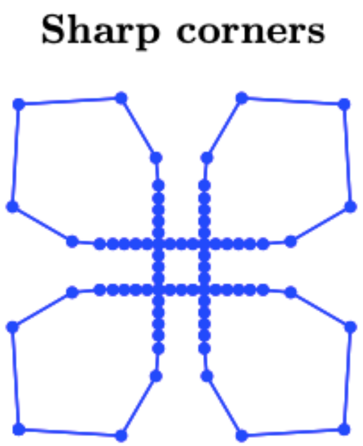
$$\frac{\partial f_n}{\partial \rho} = -\widehat{\mathbf{E}}_a^T(\boldsymbol{\rho}, \widehat{\omega}) \frac{\partial \varepsilon_r(\boldsymbol{\rho}, \widehat{\omega})}{\partial \boldsymbol{\rho}} \widehat{\mathbf{E}}_f(\boldsymbol{\rho}, \widehat{\omega})$$

FDTD/FDFD Adjoint

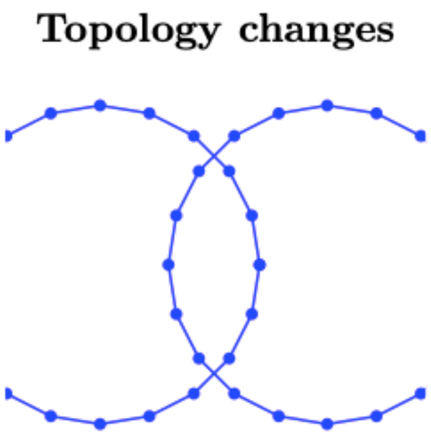
[Adjoint Defined for MEEP]
[Stephen Johnson MIT Adjoint Notes]

Proposed Algorithm

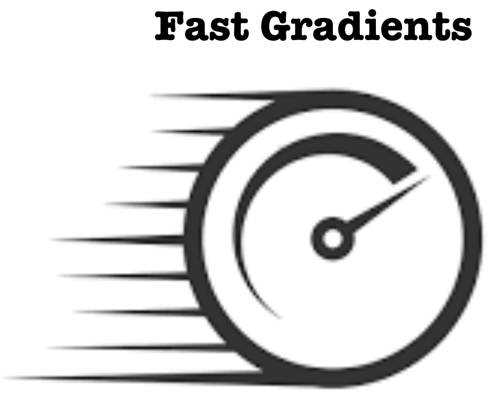
1. Use **explicit** level set (discretization then differentiation)
2. Utilize **implicit** level set method of sub pixel smoothing
3. Forward simulation -> Store steady state fields (E)
4. Adjoint simulation -> Store steady state fields (λ)
5. $\nabla_{\phi} f = -\lambda A_{\phi} E$ A = Maxwell Operator



Subpixel Smoothing Eliminates



Explicit Level Set Allows



Adjoint Routine