Calculating Electromagnetic Modes of Anisotropic Waveguides

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Introduction

- Anisotropic Waveguide
  - ***D*** and ***E*** in different directions
  - All optics have some anisotropy
- No conventional method accounts for it

$$\begin{bmatrix} D_x \\ D_y \\ D_z \end{bmatrix} = \begin{bmatrix} \varepsilon_{xx} & \varepsilon_{xy} & 0 \\ \varepsilon_{xy} & \varepsilon_{yy} & 0 \\ 0 & 0 & \varepsilon_{zz} \end{bmatrix} \begin{bmatrix} E_x \\ E_y \\ E_z \end{bmatrix}$$

The Eigensystem

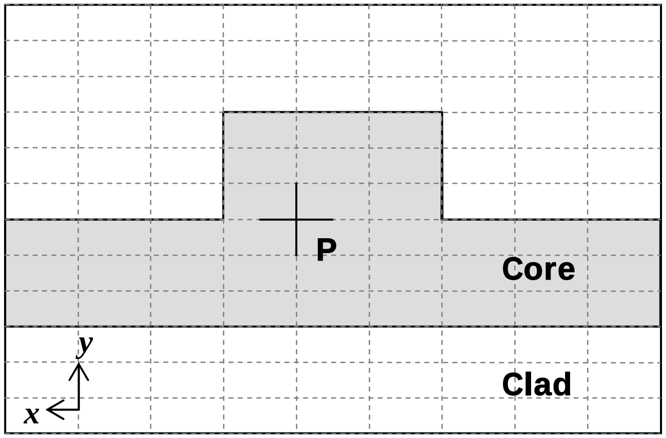
- Magnetic Field
  - Apply Maxwell's Equations
  - Boundary Conditions
  - Eigenequations

$$\frac{\partial^2 H_x}{\partial x^2} + \frac{\varepsilon_{yy}}{\varepsilon_{zz}}\frac{\partial^2 H_x}{\partial y^2} - \frac{\varepsilon_{xy}}{\varepsilon_{zz}}\frac{\partial^2 H_y}{\partial x^2} + \frac{\varepsilon_{xy}}{\varepsilon_{zz}}\frac{\partial^2 H_x}{\partial x \partial y} + (1 - \frac{\varepsilon_{yy}}{\varepsilon_{zz}})\frac{\partial^2 H_y}{\partial x \partial y} + k^2(\varepsilon_{yy} H_x - \varepsilon_{xy} H_y) = \beta^2 H_x$$

$$\frac{\partial^2 H_y}{\partial y^2} + \frac{\varepsilon_{xx}}{\varepsilon_{zz}}\frac{\partial^2 H_y}{\partial x^2} - \frac{\varepsilon_{xy}}{\varepsilon_{zz}}\frac{\partial^2 H_x}{\partial y^2} + \frac{\varepsilon_{xy}}{\varepsilon_{zz}}\frac{\partial^2 H_y}{\partial x \partial y} + (1 - \frac{\varepsilon_{xx}}{\varepsilon_{zz}})\frac{\partial^2 H_x}{\partial x \partial y} + k^2(\varepsilon_{xx} H_y - \varepsilon_{xy} H_x) = \beta^2 H_y$$

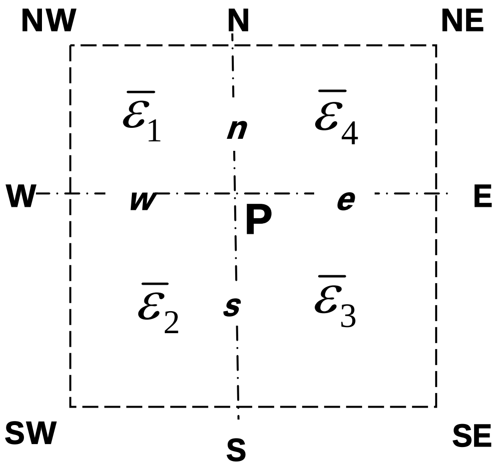
Finite Difference

- Approximate Differential Operators
  - Solve for Eigenmodes in MATLAB
  - Effective Index of Refraction



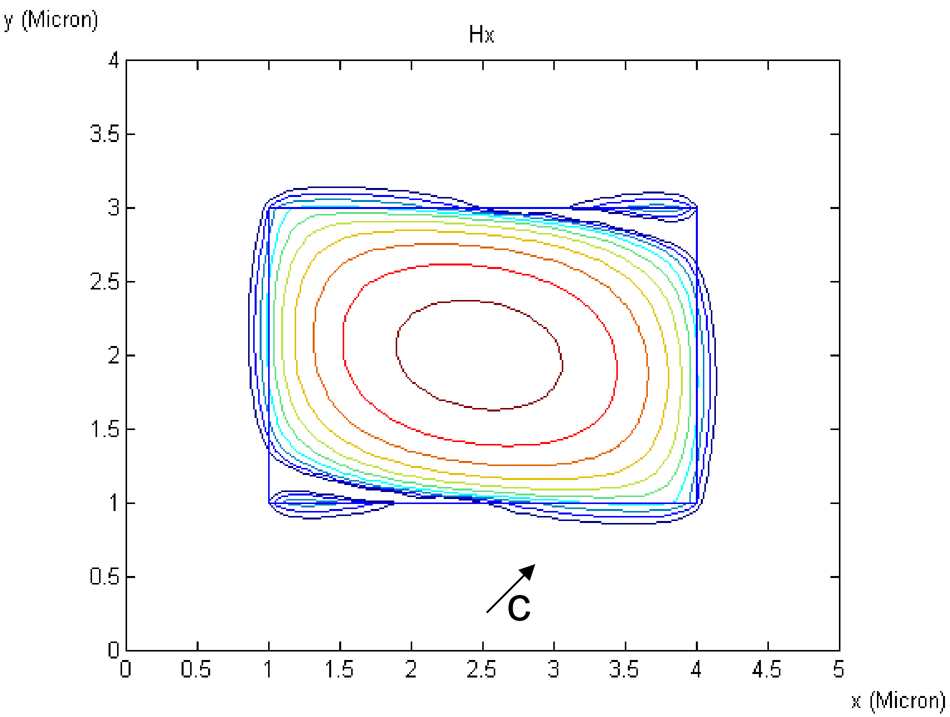
$$\begin{bmatrix} A_{xx} & A_{xy} \\ A_{yx} & A_{yy} \end{bmatrix} \begin{bmatrix} H_x \\ H_y \end{bmatrix} = \beta^2 \begin{bmatrix} H_x \\ H_y \end{bmatrix}$$

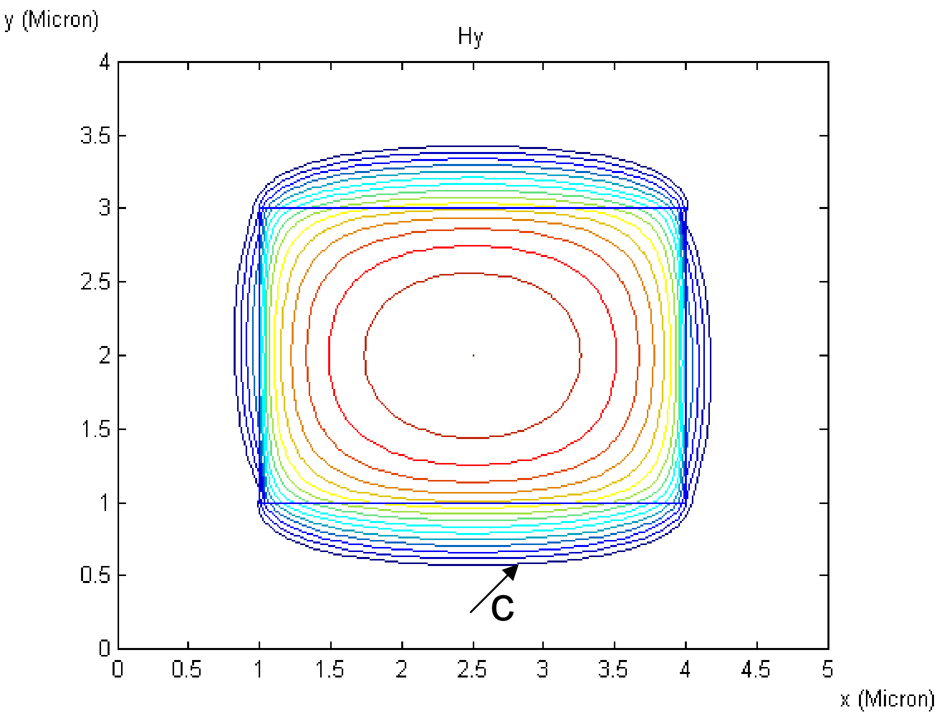
$$n_{eff} = \beta\lambda/2\pi$$



Results

- Lithium Niobate





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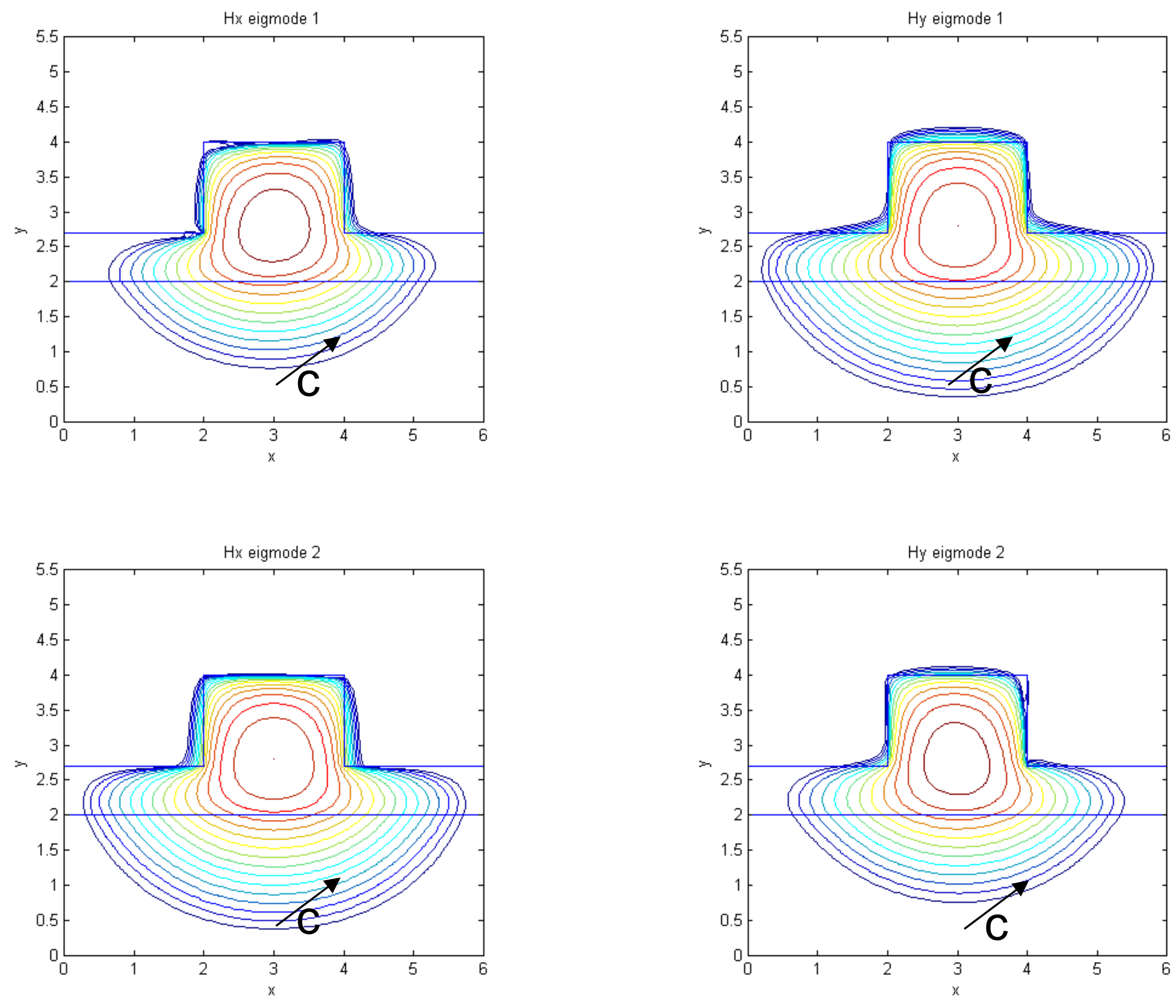
Results

- Ridge



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Conclusion

- New method that accurately simulates anisotropic waveguides
- Enable a wider range of possibilities for design

Please refer to our poster if you had any questions

Thank you!