ECE 595, Section 10
Numerical Simulations
Lecture 17: Applications of the Beam Propagation Method II

Prof. Peter Bermel

February 18, 2013

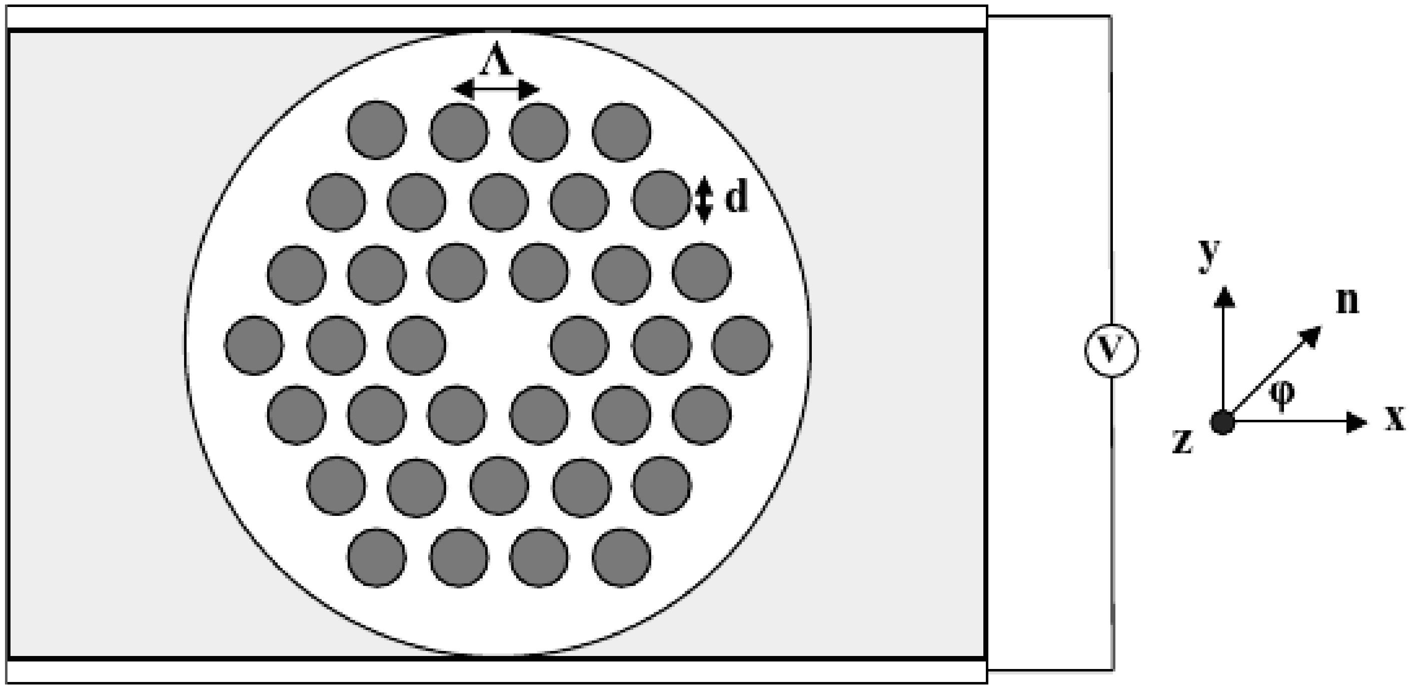
Outline

- Recap from Friday
- Applications of Beam Propagation Method
  - Tunable Photonic Crystal Fibers
  - Electro-Optic Modulator
  - Electro-Optic Switch

Recap from Friday

- BPM Mode Solver
- Vectorial BPM Applications:
  - Waveguide
  - Photonic Crystal Fiber

Tunable PhC Fiber



S. Obayya, "Computational Photonics" (Wiley, 2010)

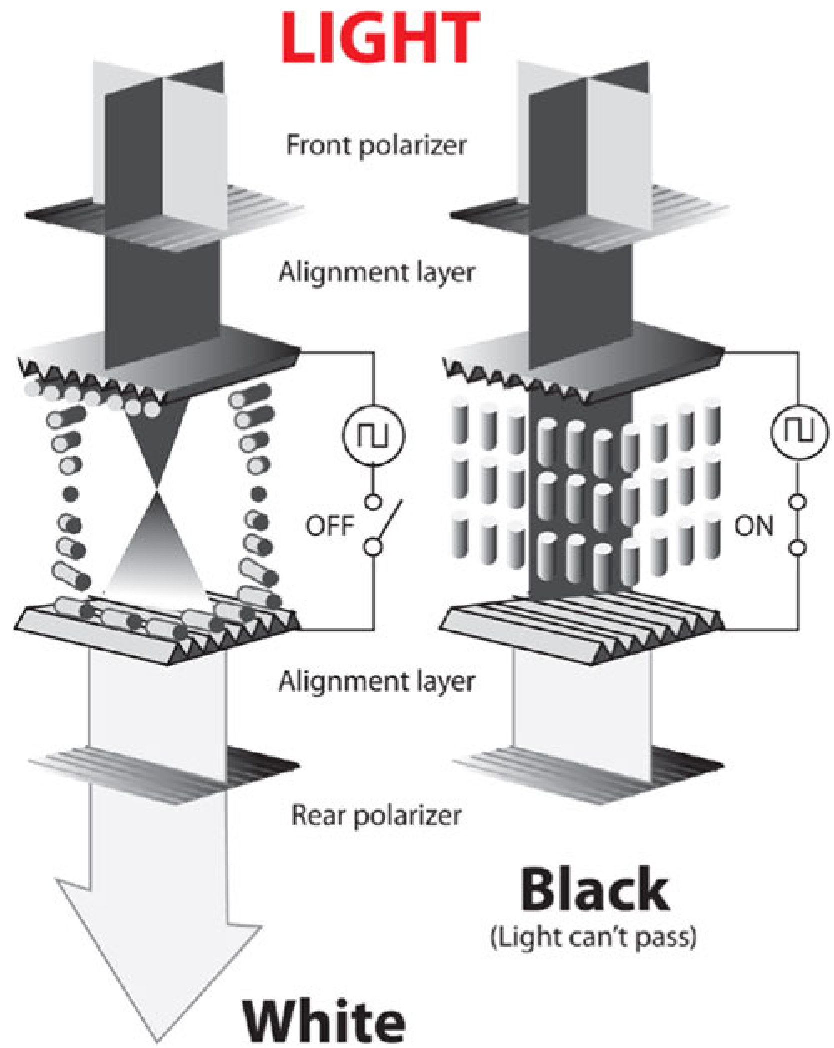
- Cross-section of a PhC fiber filled with electrostatically tunable liquid crystals

Liquid Crystals

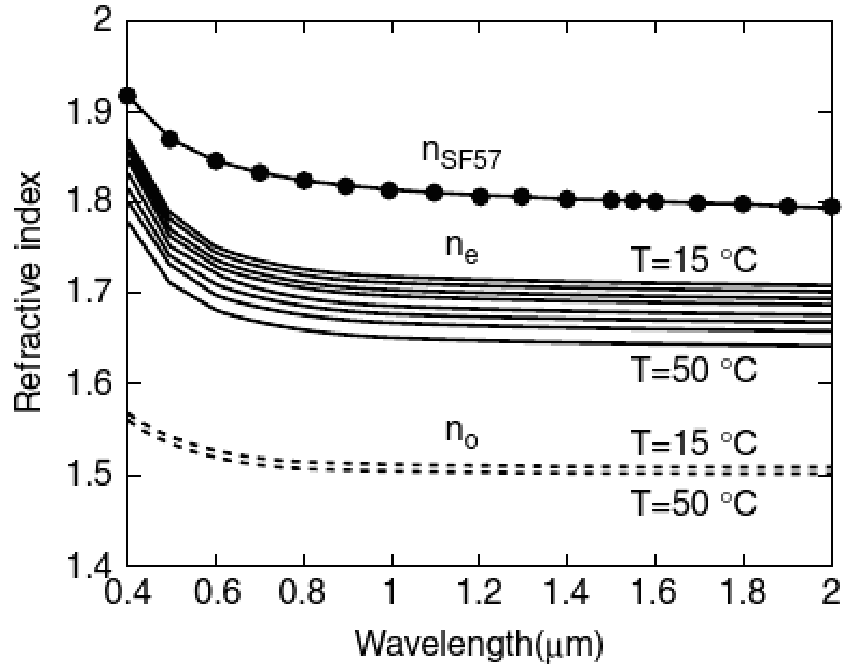
- Liquid crystals consist of many stiff molecules
- LC order in between that of liquids and crystals
- LCs have a uniaxial dielectric function:

$$\epsilon_{ij} = \epsilon_o + \delta\epsilon\, \hat{n}_i \hat{n}_j$$

- The director is oriented along applied electrostatic fields



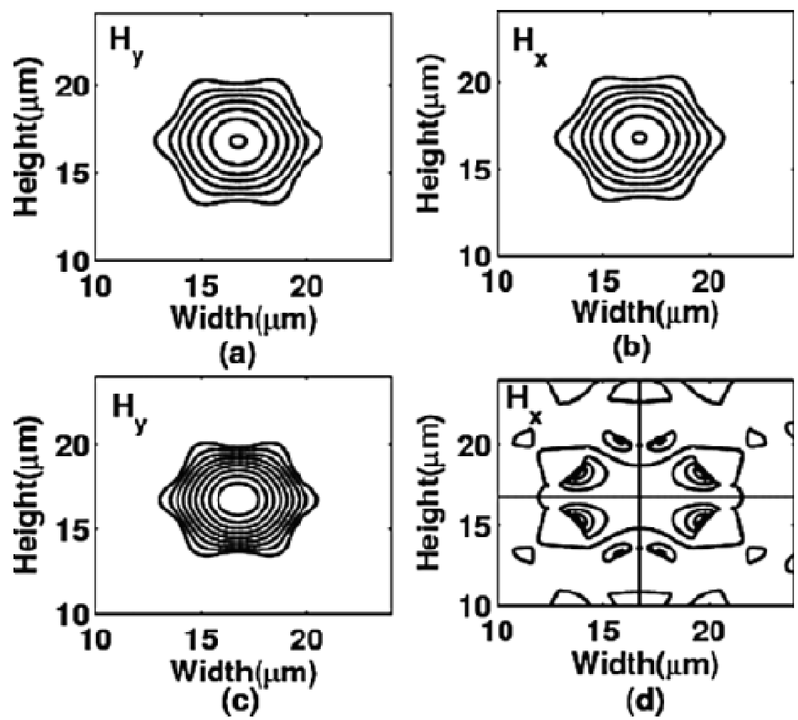
Tunable PhC Fiber



S. Obayya, "Computational Photonics" (Wiley, 2010)

- Variation of LC refractive indices both on and off-axis, consistent with normal dispersion

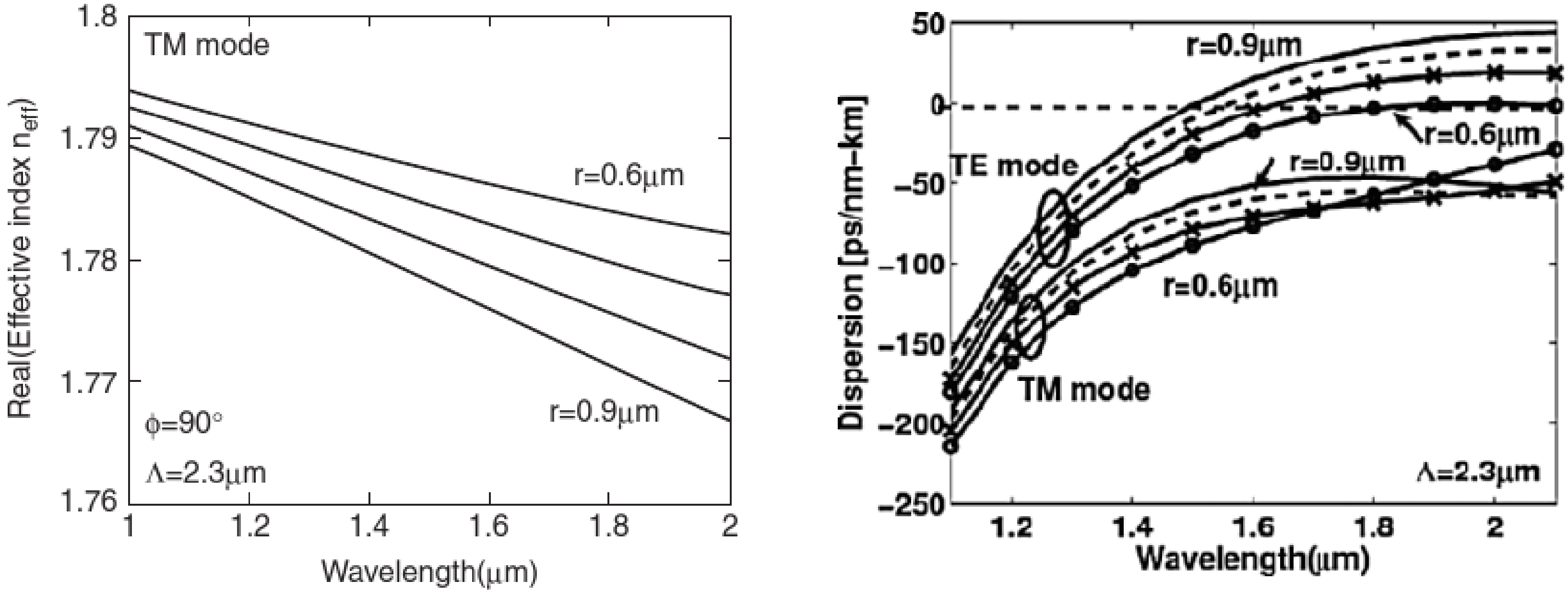
Tunable PhC Fiber



S. Obayya, “Computational Photonics” (Wiley, 2010)

- Dominant and non-dominant HE (quasi-TE) modes for tunable PhC fiber

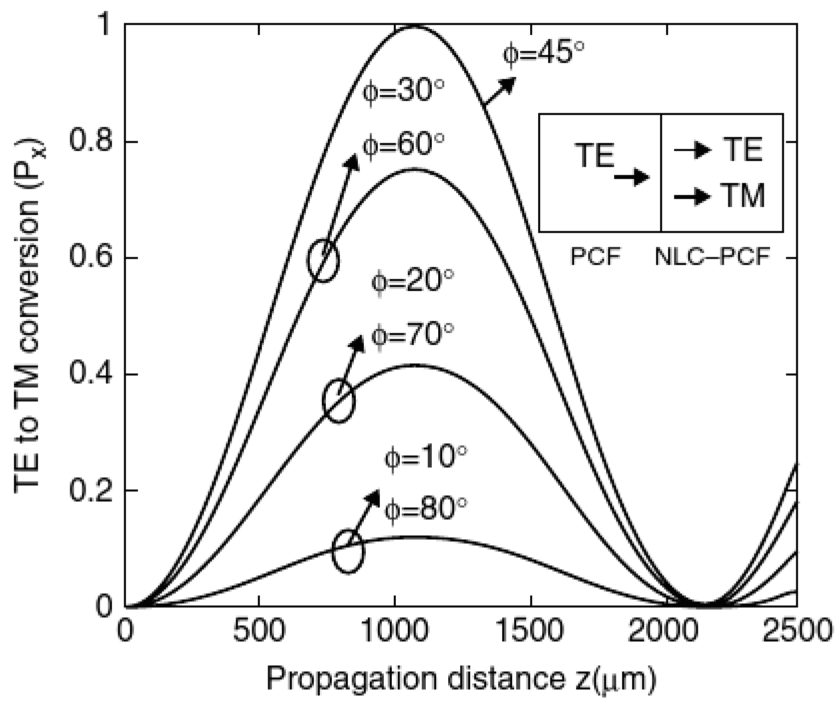
Tunable PhC Fiber



S. Obayya, "Computational Photonics" (Wiley, 2010)

- Wavelength dependence of the effective index (left) and dispersion (right)

Tunable PhC Fiber



S. Obayya, "Computational Photonics" (Wiley, 2010)

- Polarization conversion versus propagation distance Z

Electro-Optic Modulation

- The refractive index matrix for a Pockels medium subject to an external electric field in the xy-plane can be written as follows:

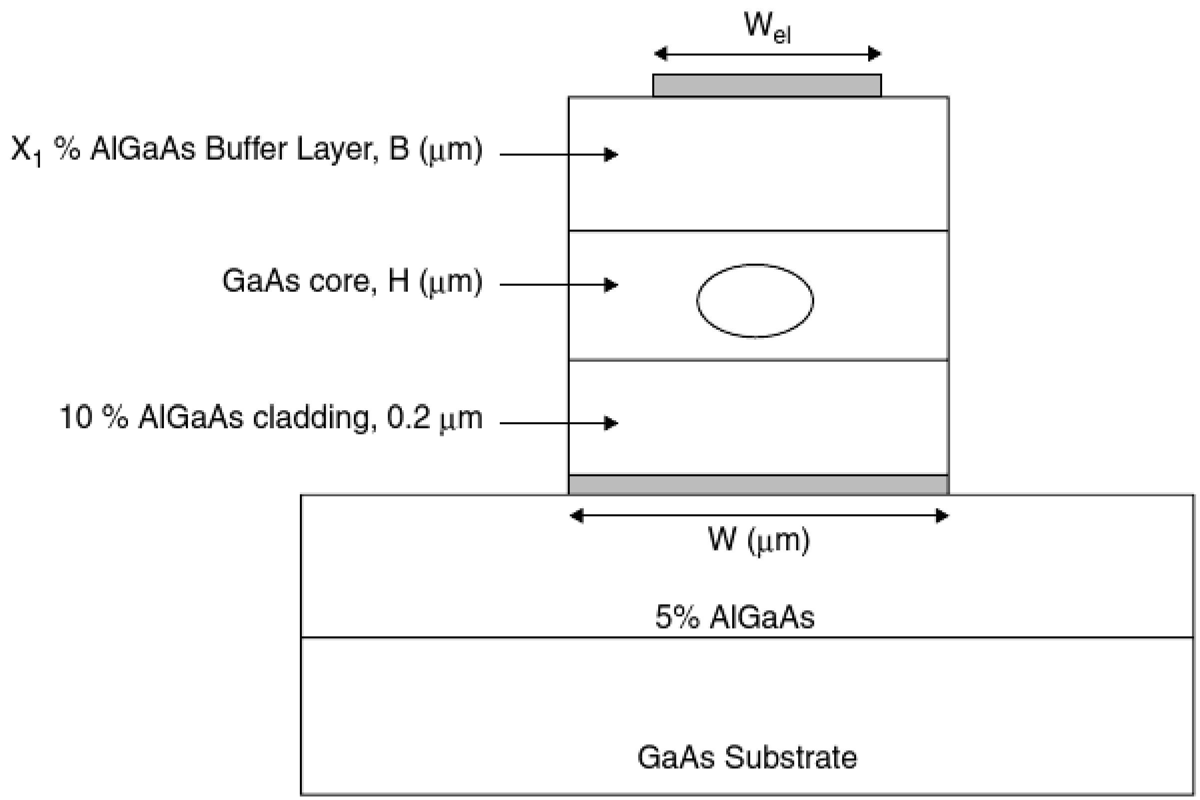
$$n = \begin{pmatrix} n_o + \delta n_{xx} & \delta n_{xy} & 0 \\ \delta n_{yx} & n_o & 0 \\ 0 & 0 & n_o - \delta n_{zz} \end{pmatrix}$$

- Where:

$$\delta n_{xx} = \delta n_{zz} = \frac{1}{2} n_o^3 \, r_{41} E_y$$

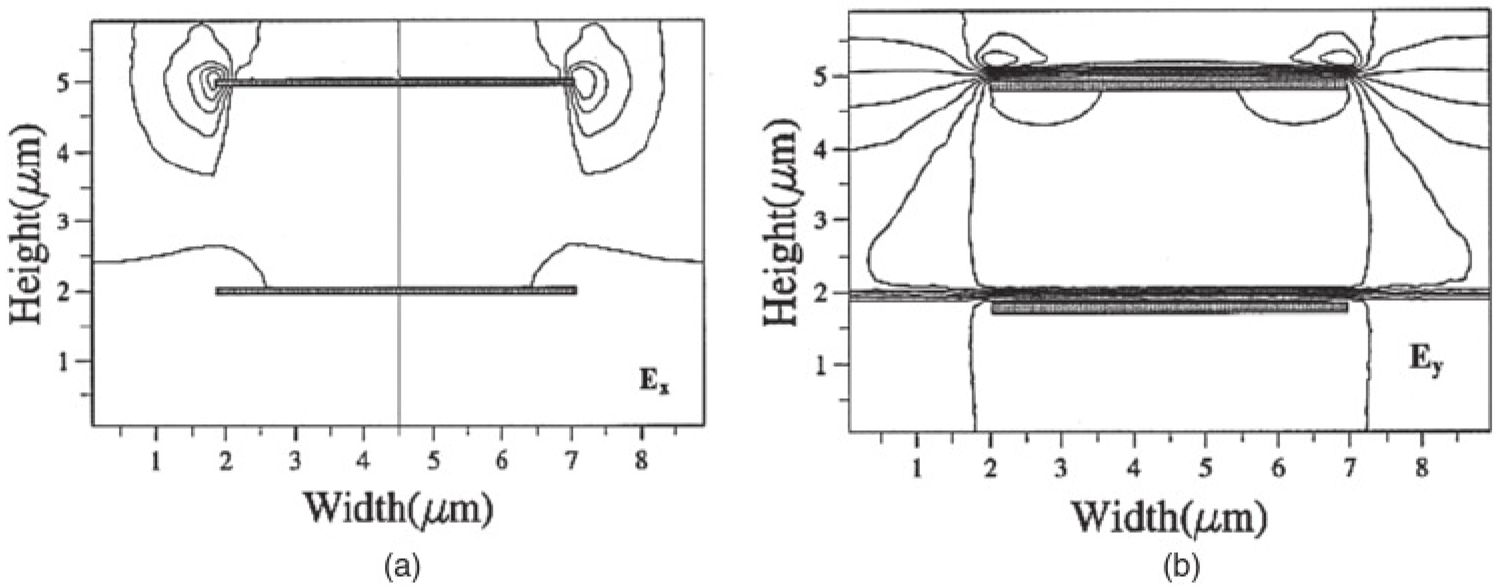
$$\delta n_{xy} = \delta n_{yx} = \frac{1}{2} n_o^3 \, r_{41} E_x$$

Electro-Optic Modulator



- Schematic diagram of the electro-optic modulator, made from epitaxial GaAs/AlGaAs layers

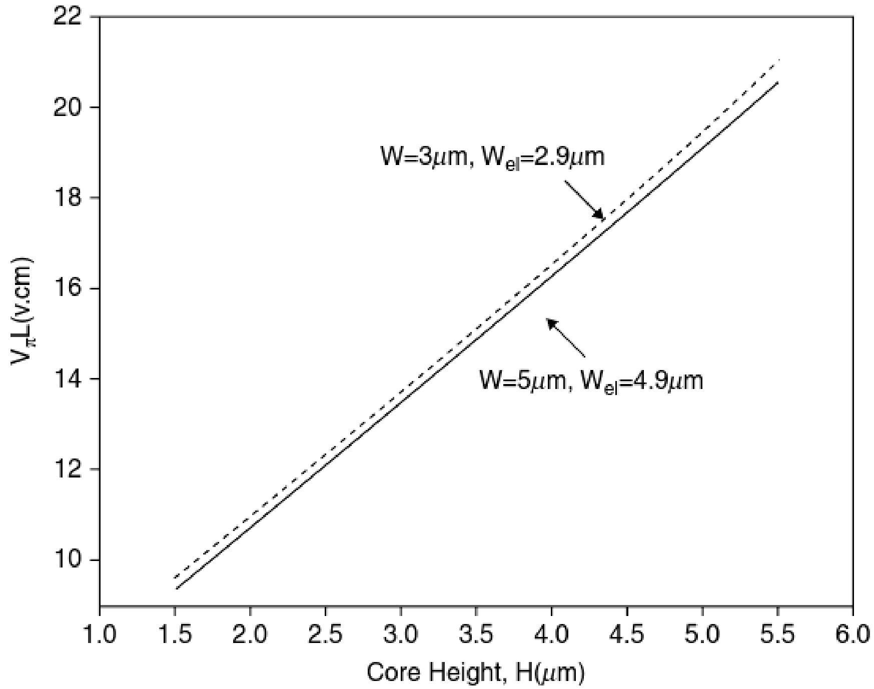
Electro-Optic Modulator

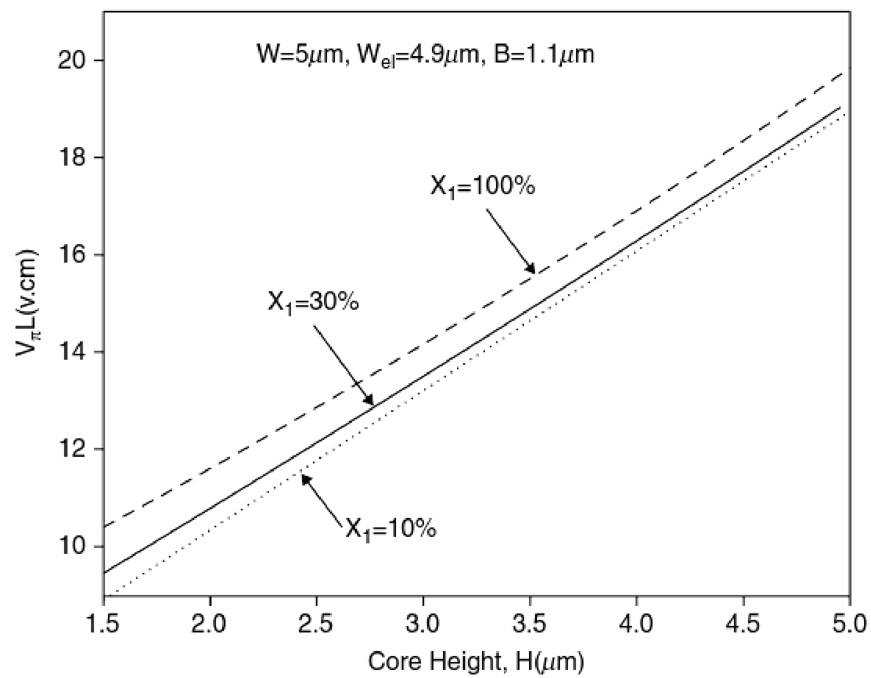


S. Obayya, “Computational Photonics” (Wiley, 2010)

- Electric modulation field distributions for Ex (left-hand side) and Ey (right-hand side)

Electro-Optic Modulator

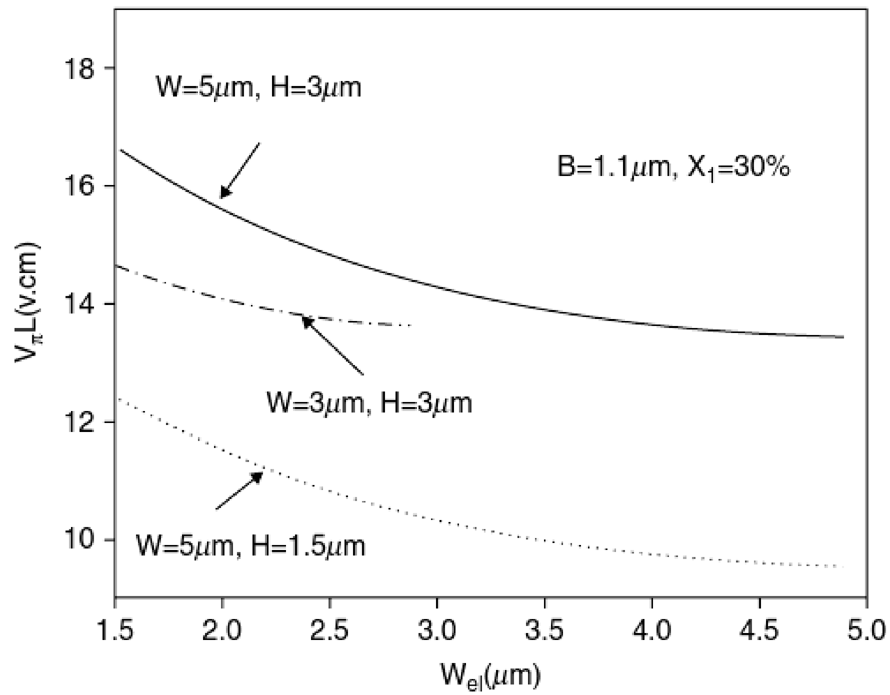




S. Obayya, "Computational Photonics" (Wiley, 2010)

- Key quantity $V_\pi L$, product of voltage and electrode separation necessary to create a π phase shift, is measured as a function of core height for a few designs

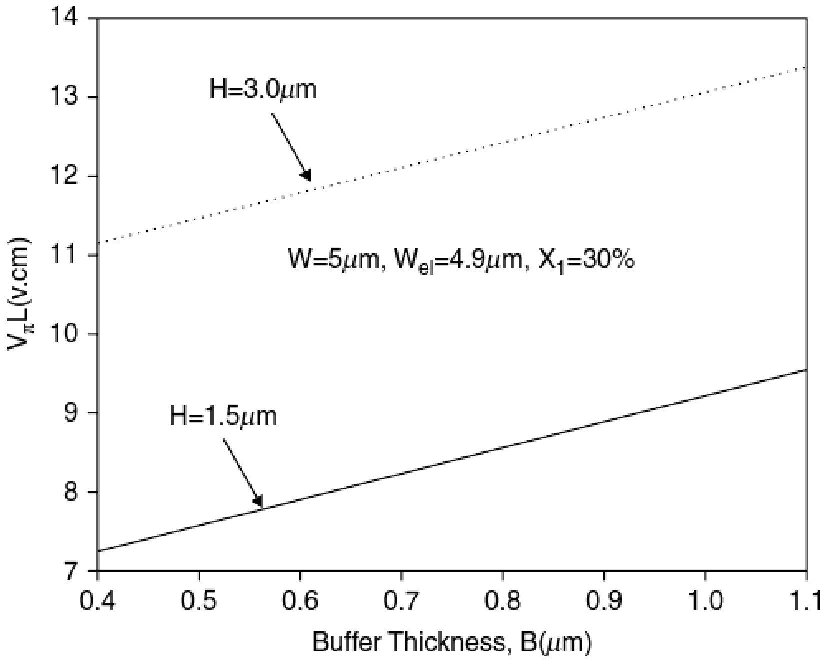
Electro-Optic Modulator

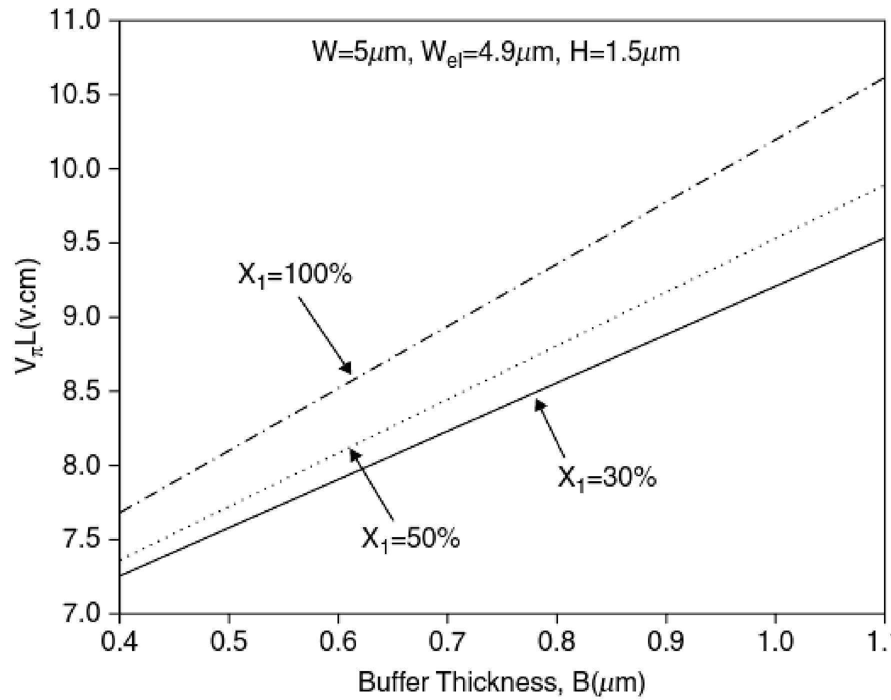


S. Obayya, "Computational Photonics" (Wiley, 2010)

- Here, $V_\pi L$ is measured as a function of core width for several designs – greater widths are more sensitive to voltage

Electro-Optic Modulator

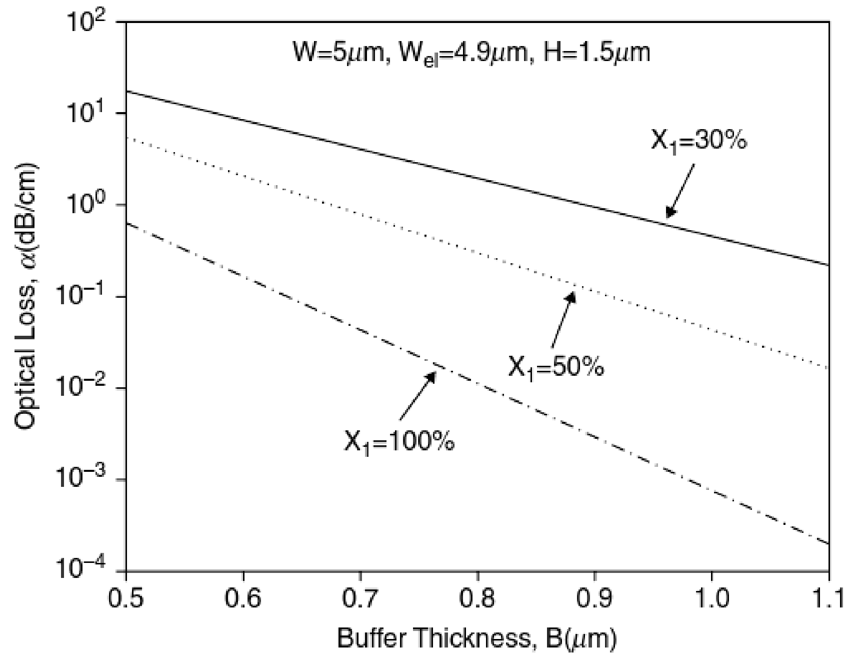




S. Obayya, "Computational Photonics" (Wiley, 2010)

- Here, $V_\pi L$ increases with buffer thickness, caused by diminishing field strength in the core region

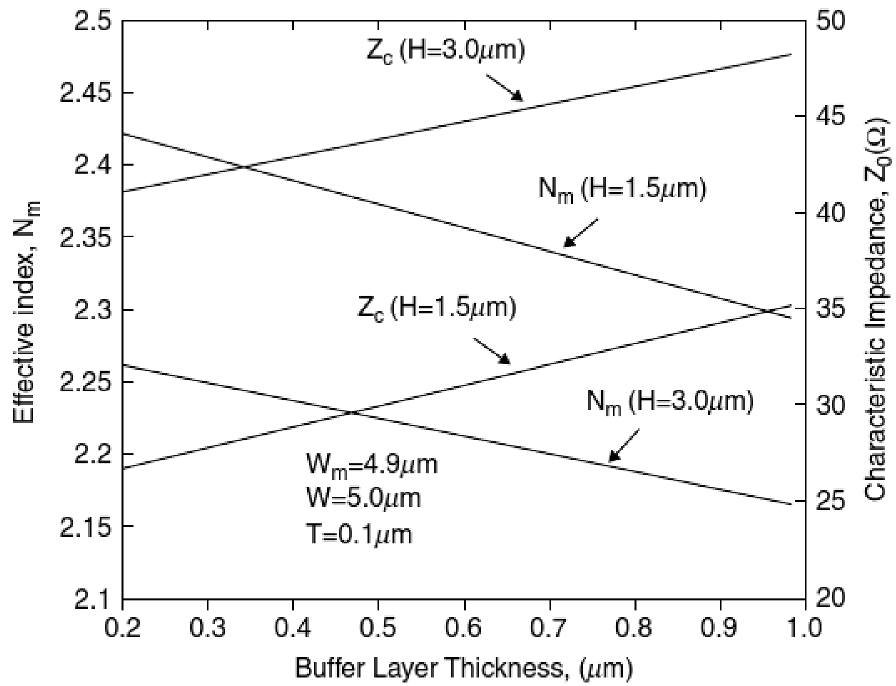
Electro-Optic Modulator



S. Obayya, "Computational Photonics" (Wiley, 2010)

- On the other hand, optical loss decreases with buffer thickness increases for similar reasons

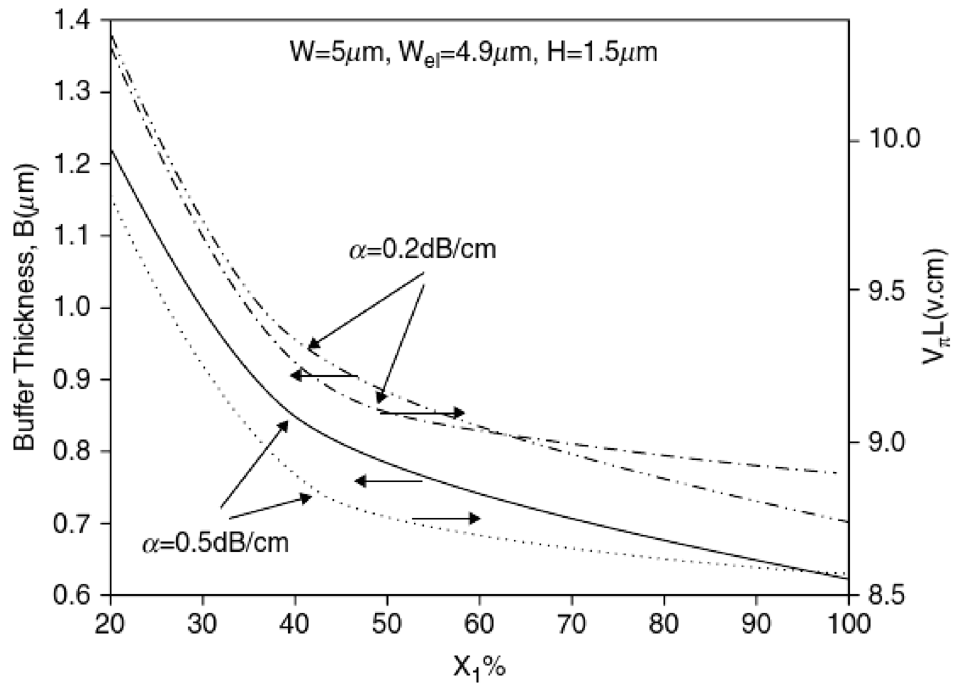
Electro-Optic Modulator



S. Obayya, "Computational Photonics" (Wiley, 2010)

- Effective impedance of microwaves and refractive index of IR signals cross over only at selected buffer thicknesses that vary greatly with core height

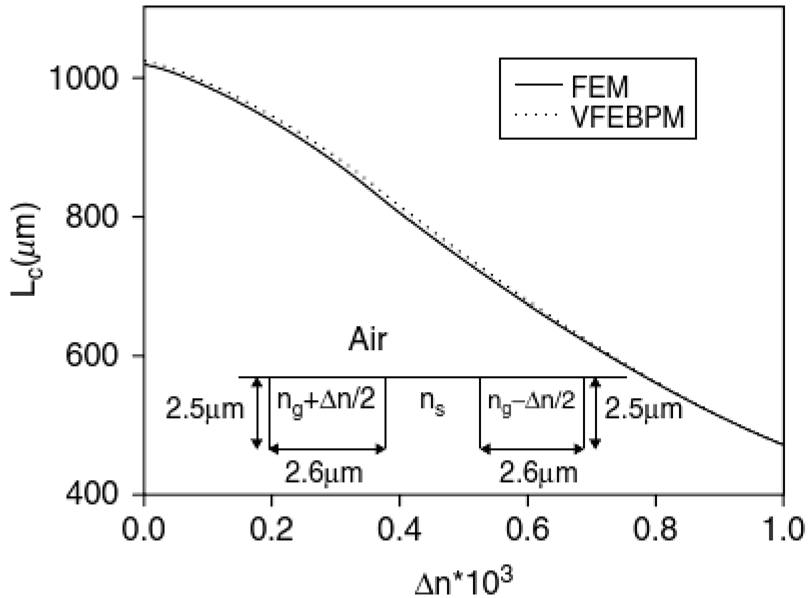
Electro-Optic Modulator



S. Obayya, "Computational Photonics" (Wiley, 2010)

- Here, the buffer thickness needed to achieve a given level of loss is calculated as a function of Al doping concentration X_f

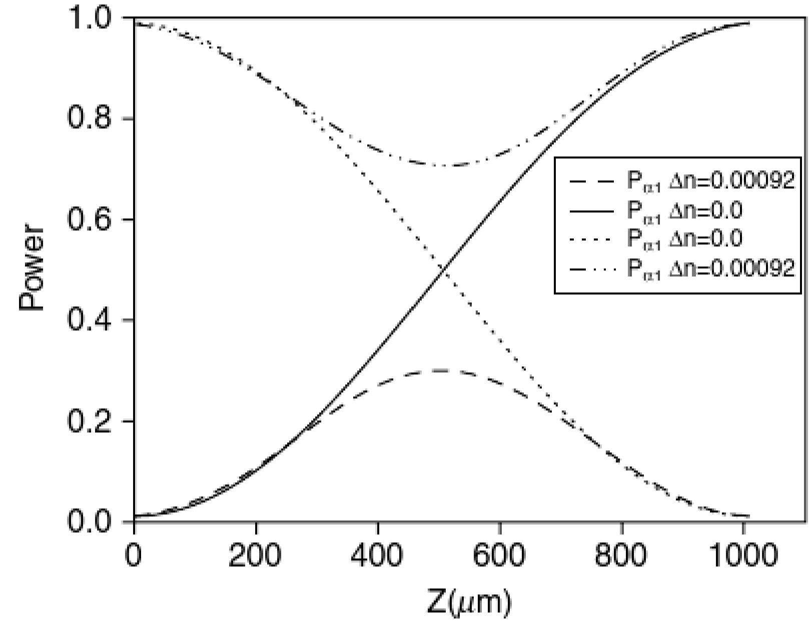
Electro-Optic Switch



S. Obayya, "Computational Photonics" (Wiley, 2010)

- Coupling length required for power transfer decreases as a function of EO index tuning

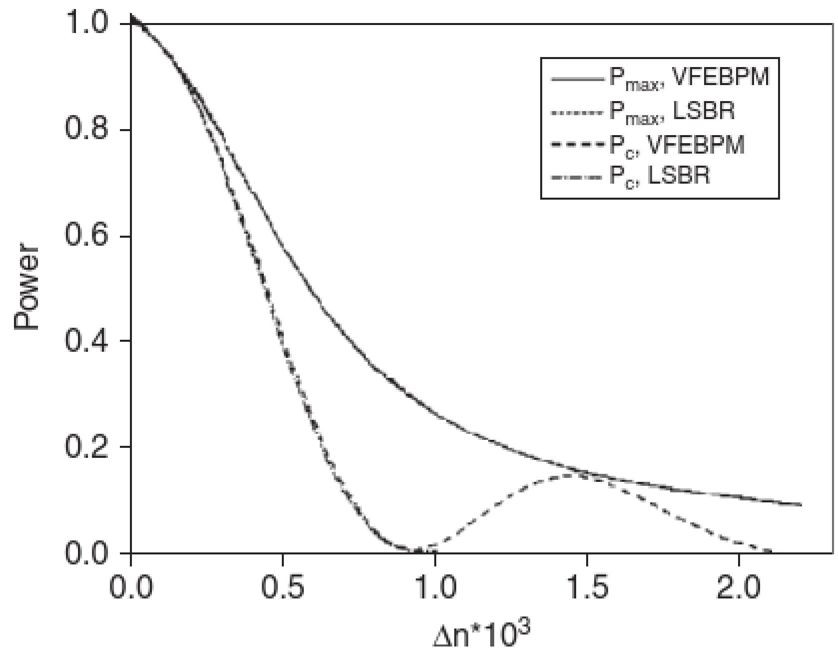
Electro-Optic Switch



S. Obayya, "Computational Photonics" (Wiley, 2010)

- Power transferred as a function of position for waveguides both with and without EO tuning

Electro-Optic Switch



S. Obayya, "Computational Photonics" (Wiley, 2010)

- Variation of output and maximum power transfer as a function of EO index tuning

Next Class

- Is on Wednesday, Feb. 20
- Next time, we will cover other FEM applications in heat transfer and electronic transport