Abstract

The study of localization of electromagnetic waves in disordered photonic systems [1-5] has attracted great interest in the recent years due to the rich physics in disordered media [6] and various potential applications [7]. However, there are only a few studies of localization of electromagnetic waves in dissipative systems [8-11] where propagation is limited resulting in highly localized modes of plasmonic nature. In this study, we use finite element method simulations to study localization of light in a two-dimensional system consisting of disordered arrays of hybrid plasmonic waveguides. Combining the advantages of dielectric waveguides and surface plasmon polaritons on a metal dielectric interface, these waveguides have been previously shown to possess both superior propagation properties and deep-subwavelength confinement along the lateral directions [12,13], and offer an interesting platform for studying localization of electromagnetic waves.

Modes of Waveguide Arrays

Effective Mode Area $A_{\text{eff}}$

$$A_{\text{eff}} = \frac{\left( \iint |\mathbf{E}|^2 \, dx \, dy \right)^2}{\iint |\mathbf{E}|^4 \, dx \, dy}$$

Integration is performed over the entire lateral cross section. Introducing the effective mode area allows us to compare the localization of modes supported by arrays of different disorder strengths.

Traditional Coupled Mode Theory

$$\left( \psi_{2d}^*, \mathbf{H}_{2d} \psi_{2d} \right) - \left( \mathbf{H}_{2d}^\dagger \psi_{2d}, \varphi_{2d} \right) = 0$$

$$\varphi_{2d} = [e^+, h^+], \quad \psi_{2d} = [e^-, h^-]$$

$$\mathbf{H}_{2d} = \begin{bmatrix} \nabla \times -i\beta_2 \times & i k_0 \mu_r \\
- i k_0 \epsilon_r & \nabla \times -i\beta_2 \times \end{bmatrix}$$

$$\sum_{j=0} a_j (\beta - \beta_{0,j}) p_{ij} = \sum_{j=0} a_j k_{ij}$$

Current finding

A. Results from the CMT are in qualitative agreement with numerical results from COMSOL, but the discrepancy becomes appreciable when the gap size is below 150 nm.

B. Generalized CMT is needed to calculate mode indices in lossy waveguides especially when the coupling between neighboring waveguides is strong.

Future Plan

➢ In our next step, we will apply the Generalized Coupled Mode Theory framework, and implement it into our original MATLAB code.
➢ Once we have a new MATLAB code, we will calculate the mode indices and compare whether they are closer to COMSOL results.
➢ We will vary the disorder strength by changing geometric distance (gap sizes) between nearby waveguides, and measure what type of Anderson localization we could have.

References