NOLOSS
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Optical design for manufacture at different length scales

Marie Curie Actions

Application of FDTD method for the Spatial Light Modulator (SLM)

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Project objective

1. Simulation : Investigation of influence of pixel geometry and fringe fields for SLM through robust electromagnetic wave model
2. Experiment : Investigation of polarization states of diffraction orders after propagation through SLM

Introduction

Spatial Light Modulator

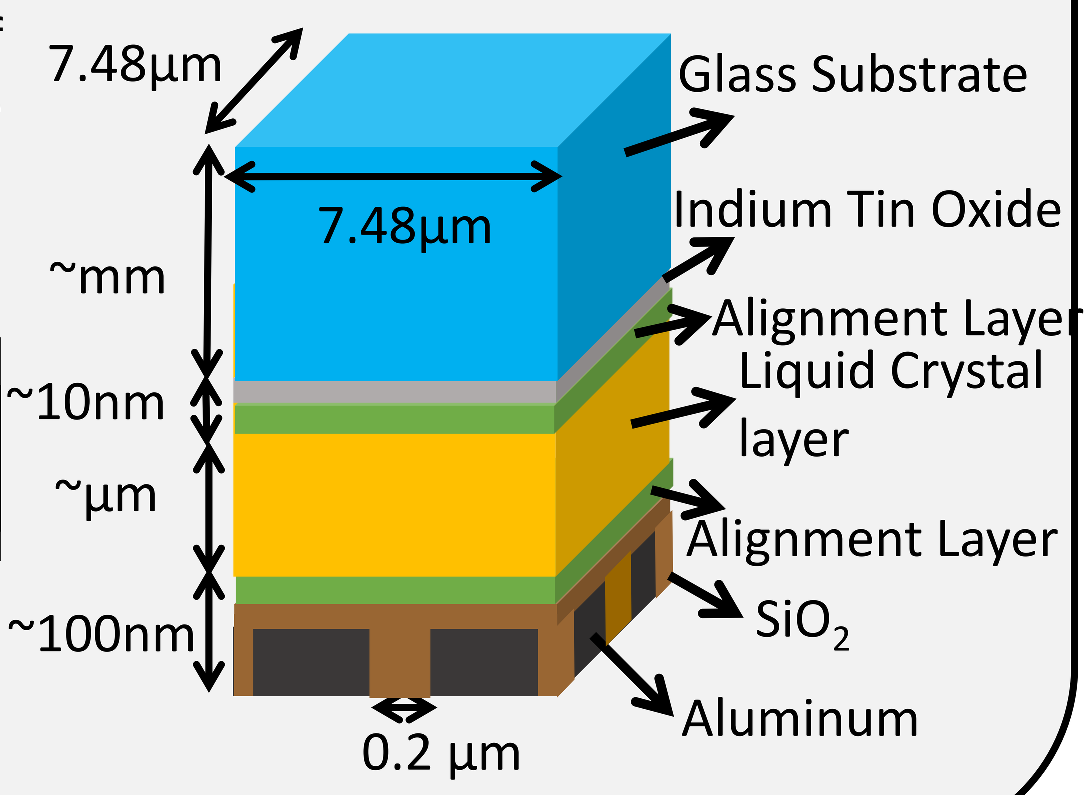
A device that can manipulate the phase of incident light via electrically adjusting the dielectric tensor of liquid crystal (LC).

Optical property of LC

$$\varepsilon = \varepsilon_0 \begin{bmatrix} n_x^2 & & \\ & n_y^2 & \\ & & n_z^2 \end{bmatrix} = \varepsilon_0 \begin{bmatrix} n_o^2(V) & & \\ & n_o^2(V) & \\ & & n_e^2(V) \end{bmatrix}$$

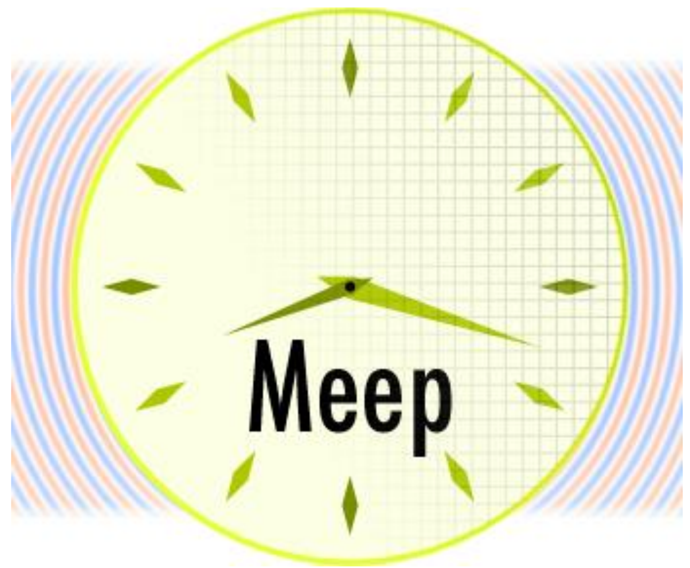
n_o : ordinary refractive index
n_e : extraordinary refractive index
V : applied voltage
ε_0 : permittivity in vacuum

Geometry of 2x2 structure



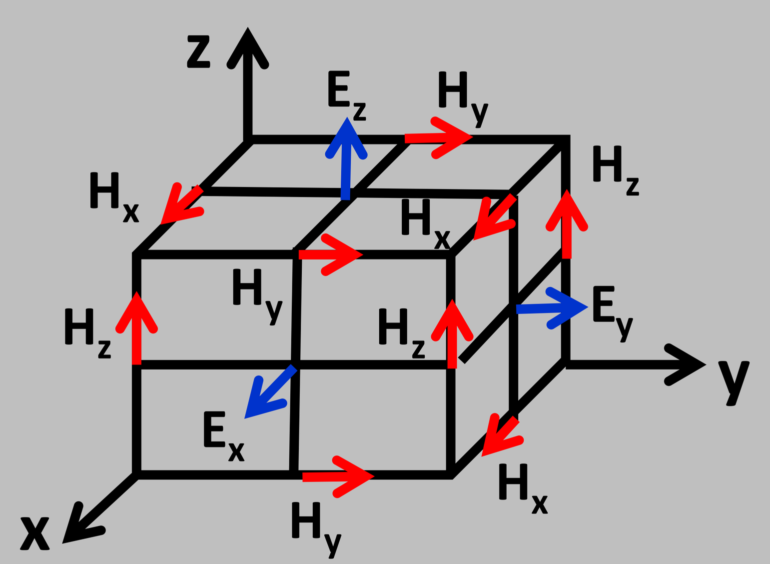
Simulation

1. Method: Finite-difference time-domain (FDTD) method
2. Open Source Software : Meep, version 1.3



Main Theory behind FDTD method

1. Yee lattice



To maintain 2nd-order accuracy, E field are discretized and stored differently in space than H field, which also lead to divergence-free nature.

2. Unsplit perfectly matched layer

To handle the wave reflection from the anisotropic dispersive media at boundary, the following equations are used.

$$\vec{C}_k^{n+1} = (1+\sigma_D \Delta t/2)^{-1}[(1-\sigma_D \Delta t/2)\vec{C}_k^{n} + \nabla \times \vec{H}_k^{n+0.5}]$$
$$\vec{U}_k^{n+1} = (1+\sigma_{k+1} \Delta t/2)^{-1}[(1-\sigma_k \Delta t/2)\vec{U}_k^{n} + \vec{C}_k^{n} - \vec{C}_k^{n-1}]$$
$$\vec{D}_k^{n+1} = (1+\sigma_{k-1} \Delta t/2)^{-1}[(1-\sigma_{k-1} \Delta t/2)\vec{D}_k^{n} + \vec{U}_k^{n} - \vec{U}_k^{n-1}]$$
$$\vec{W}_k^{n+1} = \varepsilon_\infty^{-1}(\vec{D}_k^{n+1} - \vec{P}_k^{n+1})$$
$$\vec{E}_k^{n+1} = \vec{E}_k^{n} + (1+\sigma_k \Delta t/2)\vec{W}_k^{n+1} - (1-\sigma_k \Delta t/2)\vec{W}_k^{n}$$
$$\vec{P}_k^{n+2} = \chi_E(\omega)\vec{W}_k^{n+1}$$

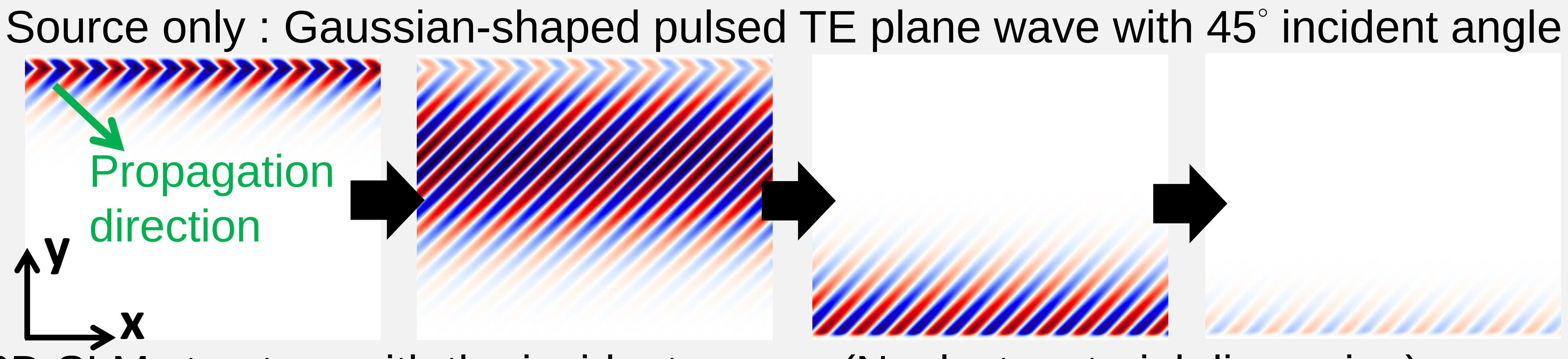
$k = x, y, z$ (direction, k+1 means shift of direction)
n = 1,2,3,... (time steps)

Δt = time step
σ_D = conductivity
ε_∞ = non-dispersive permittivity
$\chi_E(\omega)$ = dispersive permittivity

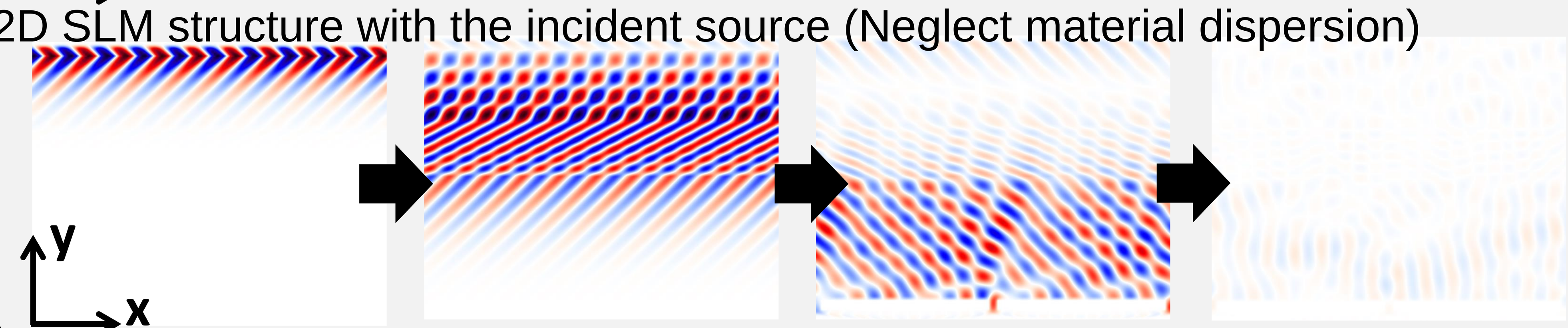
Preliminary results

We have always started from 2D structure for simplicity.

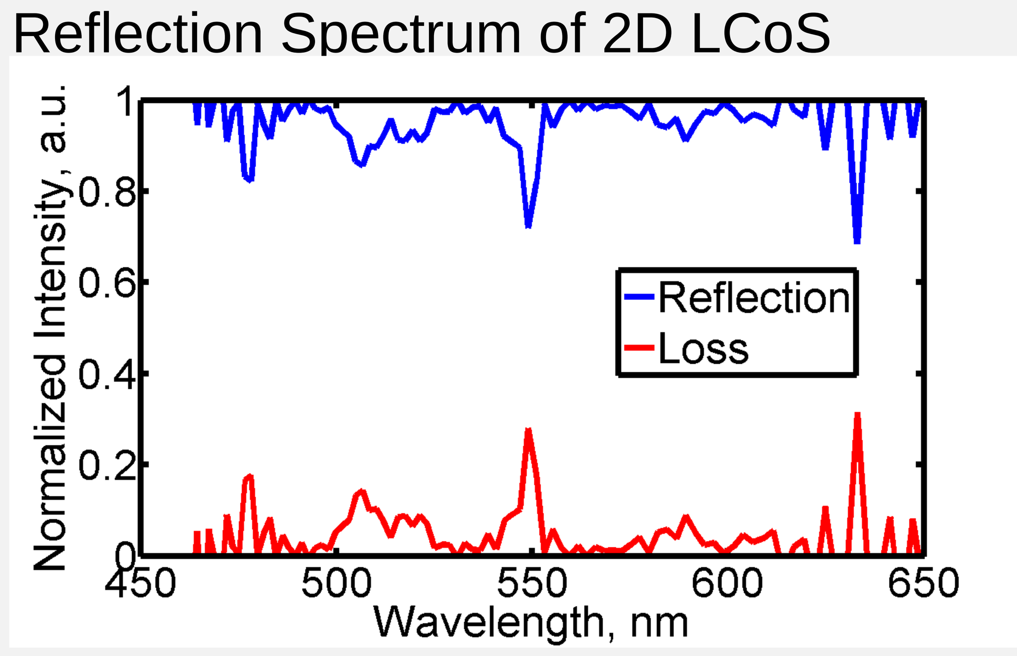
Source only : Gaussian-shaped pulsed TE plane wave with 45° incident angle



2D SLM structure with the incident source (Neglect material dispersion)



Reflection Spectrum of 2D LCoS



Key issues to deal with
1. Real 3D geometry
2. High requirement for the resolution (~nm) to get robust result

References
1. A. Taflove and S.C. Hagness, Computational Electrodynamics: The Finite-Difference Time-Domain Method (Artech House, third ed., 2005)
2. A. Oskooi and S.G. Johnson, Distinguishing correct from incorrect PML proposals and a corrected unsplit PML for anisotropic, dispersive media. J. Comput. Phys. 230 (7), 2369–2377 (2011)
3. MEEP, https://meep.readthedocs.io/en/latest/

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