NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

SPMS19016 – Light in Magneto-optic Media

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The Polarization of Light

Circular polarization (CP) occurs when the electric field vector in a plane rotates about the axis of light propagation at a constant magnitude, in a helical spiral. While linearly polarized light has been studied extensively, the unique properties of CP light recently remain of interest, with wide-ranging applicability.

Simulating Light

Light is made up of time-varying electric and magnetic fields (E and B respectively), of which the relationship $E \times B$ gives the direction of wave propagation. Maxwell's Equations describe the mutual time-varying relationship between E and B.

MEEP is a software that simulates the behavior of light in various media, based on Maxwell's Equations.

Magneto-optic (or Gyrotropic) Media

Magneto-optic media affect the light passing through them when a magnetic field is passed through in the same direction as the light propagation. In linearly polarized light, magneto-optic media are responsible for rotation of light polarization – known as the Faraday Effect.

For circularly polarized light, left-circularly polarized light tends to rotate at a different speed compared to right-circularly polarized light when moving across a gyrotropic medium subject to a magnetic bias in the propagation direction.

From Maxwell's Equations, and inputting the proper electrical permittivity tensor for gyrotropic media,

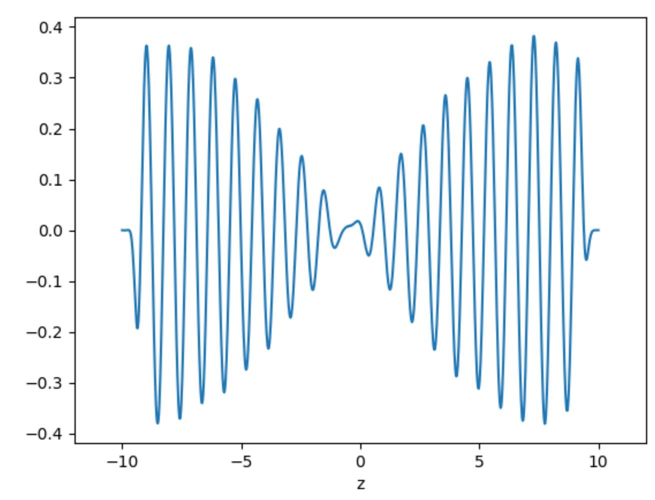
$$\text{i.e. } \epsilon = \begin{pmatrix} \epsilon_\perp & -i\eta & 0 \\ i\eta & \epsilon_\perp & 0 \\ 0 & 0 & \epsilon_{zz} \end{pmatrix},$$

the following result was derived:

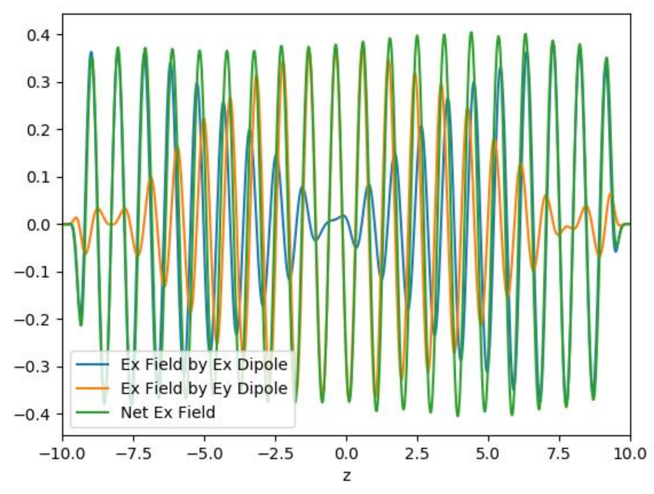
$$\omega = \frac{|k|}{\sqrt{\epsilon_\perp \pm \eta}}.$$

Behavior of CP Light in Magneto-optic Media

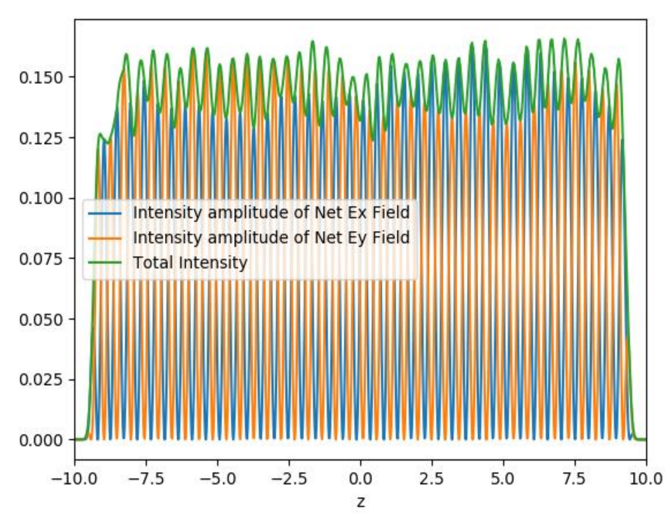
Using MEEP, experiments were simulated to study light propagating in a cuboidal gyrotropic material.



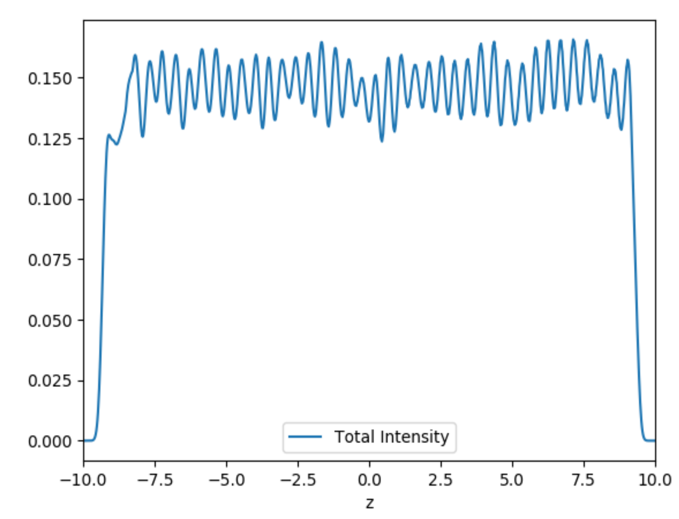
(a)



(b)



(c)



(d)

(a): In a medium with tensorial electric susceptibility and scalar magnetic permeability ($\mu = 1$), circularly polarized light was passed along the z-axis. For a single dipole source with an Ex component, the following Ex field along the z-axis was obtained. A sinusoidal envelope constrains the wave along each polarization axis (x and y) due to the helical rotation of the light wave about the propagation axis in gyrotropic media.

(b)-(d): 2 dipole sources were overlaid together on the z-axis inside a gyrotropic media. The conditions were identical to those in (a); however, the additional dipole point source emitted an Ey component, at a phase difference of roughly $\pi/2$ in relation to the first dipole source used in (a).

(c), (d): For two sources emitting out of phase along perpendicular axes in the polarization plane (one along x, the other in y), we expect the total intensity at any point along z to be consistent along the entire axis. From the results, as expected, the net light intensity along z is roughly constant.