Full-Wave Simulation of Light Propagation Through a Quarter-wave Plate

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Abstract

Advances in 3D display technology relies heavily on the birefringence of light as it propagates through various optical components such as the quarter-wavelength plate. While the Jones matrix formulation is commonly adopted as a convenient means to study optical systems involving such optical components [1], full-wave simulation provides an alternative theoretical approach which could offer more insight and intuitive understanding to the behavior of light through such components. In this research, we study the behavior of monochromatic visible light (wavelength 500 [nm]) as it propagates through a birefringent quarter-wave plate based on full-wave simulation using the Wave-Optics module. Simulation using the electromagnetic waves, frequency domain interface is carried out to model light propagating through a quarter-wave plate with ordinary refractive index of value 1.48, and extraordinary refractive index of value 1.65. In the model, incident light of different polarization configurations are directed towards the plate. Simulations are carried out with different linear and circular polarization configurations, and results show that right-hand circularly-polarized light becomes 45-degree linearly-polarized (please see figure) as it emerges from the quarter-wave plate [2]. Respectively, left-hand circularly-polarized light becomes negative 45-degree linearly-polarized [3]; 45-degee linearly-polarized light becomes left-hand circularly-polarized [4]; negative 45-degree linearly-polarized light becomes right-hand circularly polarized [5]. In addition, results reveal the interference effect of the incident light with those reflected from the plate. In particular, for linearly polarized incident light sources (animations [3] and [4]), the oscillatory deviation in the polarization direction of light (from incident polarization angles of 45 and -45 degrees, respectively) in the incident light region is attributed to the interference of incident light and reflected light from the plate. On the other hand, emerging waves in all cases exhibit properties of plane waves. Overall, the numerical approach by full-wave simulation produces the correct birefringent behavior of light, it also captures the phenomena of interference, giving a comprehensive understanding of the behavior of light as it propagates through the quarter-wave plate.

1. Youngmin Kim et al., A frontal projection-type three-dimensional display, Opt. Express 20, 20130-20138 (2012)
2. Animation:
http://www.pitotech.com.tw/[1]%20RH_circularly_polarized_to_45deg_linear.gif
3. Animation:
http://www.pitotech.com.tw/[2]%20LH_circularly_polarized_to_nagative45deg_linear.gif

4. Animation:
http://www.pitotech.com.tw/[3]%2045deg_linear_to_LH_circularly_polarized.gif
5. Animation:
http://www.pitotech.com.tw/[4]%20neagativ45deg_linear_to_RH_circularly_polarized.gif

Figures used in the abstract

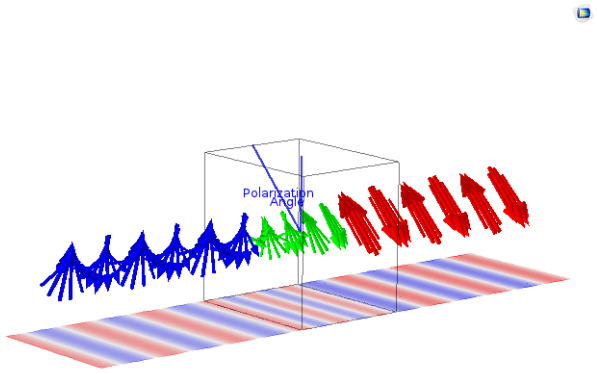

Figure 1: Changing of light polarization as it passes through a quarter-wave plate