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ScienceDirect
Pacific Science Review 16 (2014) 49–54
www.elsevier.com/locate/pscr

A novel mode converter based on a 2D dielectrically chiral photonic structure

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Available online 16 September 2014

Abstract

We designed a novel two-dimensional periodic chiral waveguide structure, which can achieve complete TE-TM mode conversion. We study the effect of the relevant parameters of structure on the conversion efficiency and confirm that in a certain range, the mode conversion has a rather high efficiency.
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Keywords: Chirality; Planar waveguide; Periodic structure; Mode conversion

Introduction

Optical polarized mode control, such as polarization rotation and mode conversion, has long been a popular direction of research [1,2], in which the miniaturisation of devices is a main development trend. A planar waveguide with a chiral core, known as a type of chirowaveguide [3], is an important approach to convert the optical polarization [4]. However, the use of such planar waveguides has limits. A planar waveguide with high contrast in refractive index has propagation constants that are quite different for the two orthogonal polarization modes, such as TM/TE modes, which leads to the mode mismatch. Therefore, the conversion of the two polarization modes is not complete.

In fact, the light propagation in a planar chirowaveguide is quite different from that in ordinary achiral waveguide. In a 2D achiral waveguide, the TM and TE mode are fundamental, while in bulk chiral medium, the eigenmodes are circular polarized with opposite handedness (namely RCP or LCP mode). In a planar chirowaveguide, however, these two types of polarized modes would both disappear and the hybrid modes become eigenmodes, which implies that the polarization plane is no longer freely and continuously rotated or remains unchanged in a certain direction. When an initially polarized mode, such as the TE mode, is launched into a simple chirowaveguide, the resultant output is no longer a mode with the desired polarization. Here, we analyse the variation law of the mode in the chirowaveguide and utilise the special design of periodic structure to realise a complete mode conversion.

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Peer review under responsibility of Far Eastern Federal University, Kangnam University, Dalian University of Technology, Kokushikan University.

http://dx.doi.org/10.1016/j.pscr.2014.08.010
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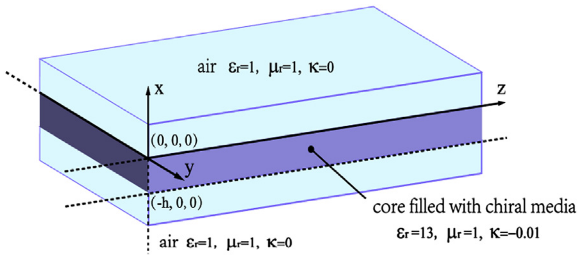

Fig. 1. The structure of the chirowaveguide.

The principle of mode conversion

The mode variation in the chirowaveguide

Fig. 1 shows a schematic structure for chirowaveguide used in the work, in which we assume that the waveguide core is filled with chiral medium; this structure is described by Tellegen's constitutive relation with $\mathbf{D} = \varepsilon\mathbf{E} + i\kappa(\varepsilon_0\mu_0)^{1/2}\mathbf{H}$, $\mathbf{B} = \mu\mathbf{H} - i\kappa(\varepsilon_0\mu_0)^{1/2}\mathbf{E}$, where κ denotes the chiral parameter to represent a bi-isotropic chiral media. For simplicity, the waveguide is assumed to be surrounded by air.

To simulate the given photonic structure, the 2-D non-dispersive Double-Grid-FDTD (DG-FDTD) method [5] is adopted. The method was developed from ordinary FDTD (with a single Yee grid). The main idea is based on the fact that the electric field and the magnetic field are always coupled together in the chiral media. It is convenient to introduce two sets of superposed grids bound together to realise the coupling in the chiral media.

Based on the DG-FDTD method, the light propagation is first simulated in the planar chirowaveguide. The core layer is set with $\varepsilon_r = 13$ and $\kappa = -0.1$, and its width is fixed to $\lambda/2$ to guarantee single mode transmission. In the input end, the point current source is set to stimulate the generation of a linearly polarized wave − TM mode component (at wavelength λ in the core). The intensity variation inside the waveguide is plotted in Fig. 2(a). A snapshot of the transmission in the waveguide is shown in Fig. 2(b). In the meantime, in Fig. 2(c), the corresponding conversion process of newly generated field component (H_z denotes the TE component) with the position of the waveguide is demonstrated.

When the TM polarized component propagates through the chirowaveguide, it partially changes into the TE polarized component, which in fact is not dominant and fluctuates along the propagation direction because the phases of TE/TM components do not match. We define a distance L as the period where H_z recovers to zero. In one period, the process of conversion may be roughly divided into two parts, as shown in Fig. 2(c). In part one, the phase differences among the newly generated TE field from the original TM in the path remains within π. The TE component tends to grow in phase generally. In part two, the generation of TE field from the original TM proceeds, but their phase difference becomes larger as they

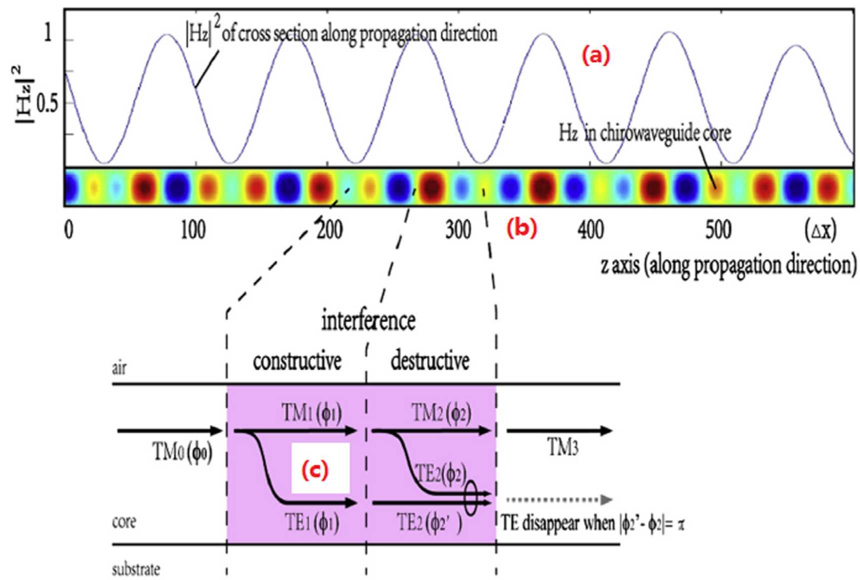

Fig. 2. Period change of the TE component in the chirowaveguide. (a) Field intensity of the TE component. (b) Snapshot of the field. (c) Corresponding schematic of the conversion of TM/TE.

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