Arbitrary on-chip polarization manipulation with twisted waveguides

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Introduction

Integrated photonics is a rapidly developing technology with applications in telecommunication, sensing, and quantum information processing. Making use of light polarization is advantageous as it serves as an additional degree of freedom for information encoding. That is why it is important to have robust integrated polarization manipulating building blocks.

Background

Traditionally, polarization manipulation on chip is performed with asymmetric waveguides having the structural linear birefringence with tilted optical axis thus acting as waveplates. This architecture, however, has several drawbacks: wavelength sensitivity, intolerance to fabrication imperfections, and coupling losses due to cross-section mismatch with normal symmetric waveguides. Moreover, such a waveplate can perform only a restricted class of polarization transformations. Direct writing integrated photonics fabrication technology allows to create waveguides with variable cross-sections particularly those with a twisted core able to rotate linear light polarization without suffering from neither of the mentioned problems due to utilization of a different physical principle of adiabatic mode evolution.

Objectives

We have theoretically investigated the ability of twisted waveguides to perform arbitrary polarization transformations beyond the rotations of linear polarization.

Methods

To analyze polarization dynamics in twisted waveguides we utilized an eigenmode solver in helical reference frame and applied the coupled mode theory. This allowed to obtain analytical expressions of the polarization transformation matrix (Jones matrix) of a twisted waveguide. To visualize polarization state, we use the Stokes parameters and Poincare (Bloch) sphere formalism.

Results

By analyzing obtained twisted waveguide's Jones matrix expression, we have found that twisted waveguides can perform arbitrary transformations of light polarization.

Conclusions

Twisted waveguide is a viable candidate as a new on-chip polarization manipulating building block which may facilitate exploitation of light polarization in integrated photonic applications. A particularly interesting application is as a quantum gate in polarization-encoded quantum information processing.

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