Frozen Modes in All-Dielectric 3-Way-Coupled Ridge Waveguides

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Slowing-down electromagnetic waves through dispersion engineering has been instrumental for many applications in optical and microwave regimes. Control of wave speed can be utilized to design phase shifters, improve light-matter interaction for linear and nonlinear optics and lasing, and, provide true time delay signals. Optically, slowing down light or even completely vanishing group-velocity dispersion can be realized through two approaches, namely, strongly-dispersive media, and periodically inhomogeneous media. In this work, we develop 3-way coupled periodic silicon ridge waveguides that are fine-tuned to create the stationary inflection behavior, previously only realized in magnetic photonic crystals (MPCs) (see e.g. G. Mumcu, K. Sertel, J. L. Volakis, I. Vitebskiy and A. Figotin, "RF propagation in finite thickness unidirectional magnetic photonic crystals," *IEEE Transactions on Antennas and Propagation*, vol. 53, no. 12, pp. 4026-4034, Dec. 2005). Unlike MPCs that are based on the simultaneous breaking of time-reversal and space-inversion symmetries using bulk magnetized ferrite layers, all-dielectric 3-way-coupled ridge waveguides can be realized to exhibit symmetric stationary inflection points (SIPs) in their dispersion diagram, as first proposed first in (G. Mumcu, K. Sertel and J. L. Volakis, "Partially coupled microstrip lines for printed antenna miniaturization," *IEEE International Workshop on Antenna Technology*, Santa Monica, CA, 2009). As such, these simple implementations exhibit many of the proprieties that can only be otherwise realized in multi-dimensional structures, but with reduced footprint and fabrication complexity. In particular for photonics applications, periodic arrangements of coupled ridge waveguide structures can be fine-tuned to exhibit the "frozen mode" associated with the SIP in the dispersion diagram, where the group velocity vanishes. In this work, we show representative designs of conventional ridge waveguides that exhibit zero group-velocity "frozen" modes, enabling integrated photonic delay lines with controllable time delays. We incorporate liquid crystal tuning into the design for real-time controls of the light velocity in the proposed structure. We will present detailed simulation results at the conference.