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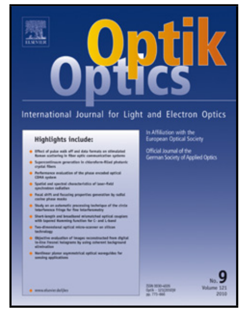

Title: High-bandwidth photonic-crystal-based ring resonator pin modulator

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High-bandwidth photonic-crystal-based ring resonator pin modulator

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Abstract: The present study described a photonic-crystal-based ring resonator pin modulator on an InP-substrate. The device geometry was based on a single ring resonator coupled to one straight waveguide by creating line defect holes through slab layer stack InP/InGaAsP/InP having a hexagonal lattice. The radius of the holes was calculated to be 187 nm with a lattice constant of 500 nm. The distribution of carriers and the electrical field in the guiding and cladding layers determined the effective refractive index of the ring resonator. Transient analysis of the pin modulator was carried out by applying a pulse to the electrodes that switched between 0 and -7 V. The frequency response of the ring resonator modulator shows over 300 GHz of bandwidth.

Keywords: Microring-based modulator, photonic-crystal-based ring resonator, frequency response; electro-optic modulation, transient analysis, InP material.

1 INTRODUCTION

InP-based materials can provide a platform for integration with lasers and photodetectors [1]. Optical intensity and phase modulators with structures based on InP materials have been reported [2-4]. Using narrow full width at half-maximum (FWHM) transmission spectra, the dimensions of ring resonator based modulators can be decreased, especially in comparison with Mach-Zehnder interferometer (MZI) modulators that have very long arms, to create an 180° phase difference [3].

For ultra-high modulation speeds of up to a terahertz (THz), electro-optic devices are required. Plasma and band-filling effects available in bulk InGaAsP materials are both linear and quadratic (Pockel's and Kerr) [2, 5]. Because these effects are relatively weak in InGaAsP materials, using them to achieve significant modulation normally requires long devices [6]. Transmittance near the resonance of a ring resonator cavity is very sensitive to small refractive index changes, making it suitable for intensity modulation. In a ring resonator, light at the resonant wavelength makes several round trips in the ring and interacts with the carriers and electric field many times [3,7].

Photonic crystal nanostructures take advantage of the significantly-reduced device size. Photonic crystal waveguides (photonic crystal line defects) slow down the speed of light, which significantly reduces the modulator electrode length by several orders of magnitude in MZI-based modulators [2, 8, 9]. Wang et al. [9] reported a lithium-niobate-based photonic crystal MZI modulator with an operational bandwidth of 100 GHz, a length of 42.6 µm, and a driving voltage of 1.25 V. A SOI-based photonic crystal MZI pin modulator was designed which functions at up to 1 Gb/s with an applied peak-to-peak amplitude voltage of 3 V [8]. A very compact MZI pin modulator on an InP-substrate made entirely of photonic crystal waveguides has been discussed [2] that has a dimension of $148 \mu m^2$ and a drive voltage of 7 V.

The present study proposes an ultra-compact InP-based ring resonator intensity modulator with over 1 THz of modulation bandwidth and a drive voltage of 7 V that is only $10.25 \times 10 \mu m^2$ in size. This