Experimental investigation of QCSE-based Stokes vector modulator on InP

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Stokes vector modulation (SVM) is gaining increasing interest for data center networks and short-reach communication links. This is mainly driven by demand in improving the power and spectral efficiencies of current low-cost direct-detection (DD) formats without introducing expensive coherent optical technologies. Lately, various types of transmitters in photonic integrated circuits for SVM have been demonstrated [1-2]. Here, we experimentally investigate a SV modulator on InP using quantum-confined Stark effect (QCSE).

Fig.1 shows the schematic of the device, which consists of a pair of passive polarization converter (PC) and an active multiple-quantum-well (MQW) based polarization-dependent phase modulator (PD-PM) sections, concatenated in series. The PC sections is designed to operate as a quarter wave plate with its principal axes tilted by 45° with respect to the substrate, while the PD-PM is electrically driven to convert input TE or TM polarization state to arbitrary state on the Poincare sphere [1]. Unlike our previous devices [1,3], QCSE in a 0.4% compressively strained InGaAsP/InGaAsP MQW is used to enhance the polarization dependence of the refractive index change under a reverse bias, thus allowing potentially high-speed and efficient polarization modulation.

The device was fabricated by offset quantum-well scheme using single metal-organic chemical vapor deposition (MOCVD) regrowth step. After selective removal of MQW layers from the passive part, p-InP cladding and p-InGaAs layers were grown. Then, self-aligned process is employed to define the PC, PD-PM and the passive waveguides [3].

Fig. 2 depicts the polarization-dependence of optical absorption spectra, measured for a single 750 µm long PD-PM waveguide. Excitonic peak at 1540 nm wavelength for TE mode proves the presence of large polarization-dependent absorption in the strained MQW layer. From Fig. 2, we set the operating wavelength to be 1610 nm, where the material is nearly transparent but light experiences large polarization-dependent refractive-index change upon external bias. At this wavelength, we obtain VLL of 2.1 V·cm and PDL of 3.5 dB at Vn. Fig. 3 shows the state of polarization (SOP) modulation when we vary both V1 and V2 for TM incident light. We can confirm that the SV rotates in nearly orthogonal directions for respective PD-PMs, in agreement with theory. We expect further improvement in modulation efficiency and reduction of PDL by optimizing MQW design and waveguide structure at PD-PM.

Fig. 1. Schematic of integrated Stokes vector modulator.

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Reference