Modeling of GaSb-Based Monolithically Integrated Passive Photonic Devices at λ > 2 μm

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Photonic integrated circuits for the extended short and mid-wave infrared (eS-MWIR) wavelength regime are crucial for potential applications including on-chip chemical and biological sensing and non-invasive medical diagnosis. The lack of high-performance lasers on an SOI wafer and material limitations in InP necessitate an alternative material system. A monolithic platform based on GaSb addresses these concerns through the tight integration of both passive and active components since it is an optimal material system for realizing long-wavelength lasers and photodetectors. In this work, we modeled and optimized various fabrication-compatible passive components including 1×2 power splitters/combiners based on directional coupler (DC), multimode interferometer (MMI), and Y-branch as well as a grating coupler on GaSb substrates at 2.56 μm.

Surface ridge waveguides designed on GaSb-based epitaxial layers are schematically shown in Figure 1(a). Figure 1(b) shows the effective refractive indices n_{eff}, of a few lowest-order guided modes as a function of the ridge width W, and the inset shows the mode profile of TE_0 at W = 4 μm. Figure 1(c) shows the transmission through the two output ports of DC-, MMI-, and Y-branch- splitters with 1-dB bandwidth, Δλ ~ 1 μm at a center wavelength of 2.56 μm. For all the splitters, we achieve 50:50 power splitting with an excess loss lower than 0.12 dB. For the grating coupler, a coupling efficiency of -5.4 dB and a 3-dB bandwidth of 80 nm are achieved at 2.56 μm. Details of the design and simulation results of all these passive photonic devices will be presented at the conference.

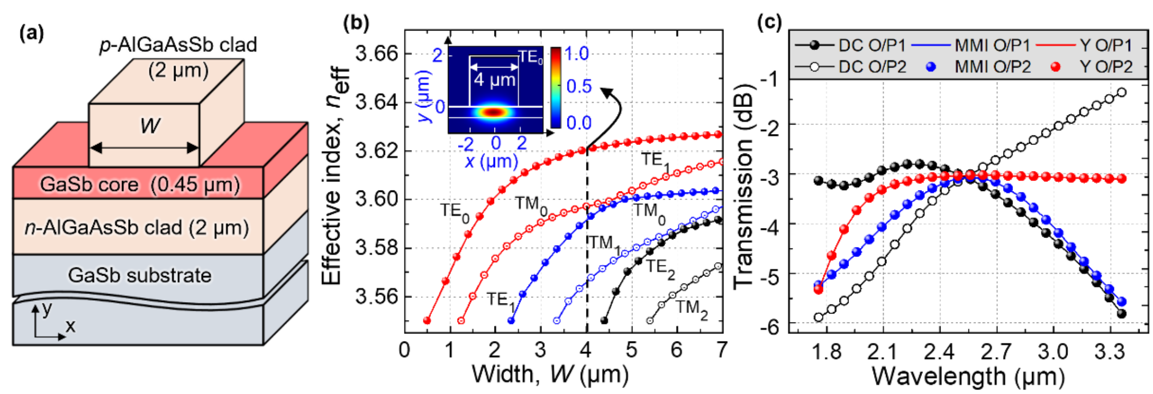

Figure 1. (a) Schematic cross-section of the GaSb-based single-mode surface ridge waveguide, (b) mode effective index as a function of waveguide width, W. Inset: fundamental TE_0 mode at 2.56 μm, and (c) transmission through the two output ports of DC (black), MMI (blue), and Y-branch (red) at a center wavelength of 2.56 μm.

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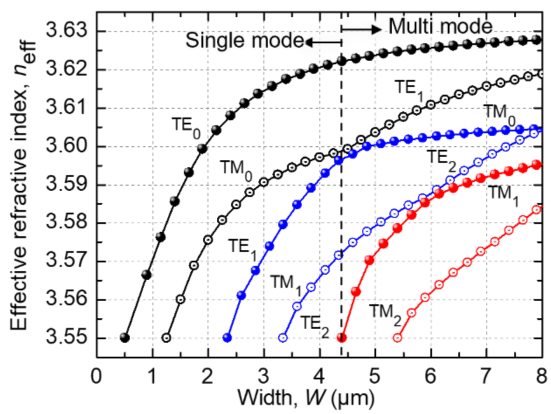
Supplementary Pages

Figure 1(b): Up to a width of 2.4 µm, the waveguide supports only single TE modes. However, in experiments, devices with wider widths are found to emit a single fundamental mode. The first higher-order odd mode TE_1 in a laser cavity receives very little gain due to a null at the waveguide center and is not usually considered while defining the single-mode waveguide cut-off condition [1]. TM modes were also not considered since the III-V laser structure employs compressively strained quantum wells which favor only TE-polarized light. Thus, the calculated ridge width supporting single mode is 4.4 µm, as represented by the vertical dashed line.



[1] Arafin, Shamsul, Alexander Bachmann, and Markus-Christian Amann. “Transverse-mode characteristics of GaSb-based VCSELs with buried-tunnel junctions.” IEEE Journal of Selected Topics in Quantum Electronics 17.6 (2011): 1576-1583.

Acknowledgments

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