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Optimization of adiabatic optical coupling between Silicon nitride and Germanium-based nanostructures for energy-efficient photonic integrated circuits

Combining photonics with electronics is identified as one of the viable solutions to accommodate data traffic increase in an energy-efficient manner for various applications such as optical interconnect, quantum computing, sensing, and environment with favorable price-volume curve. Therefore, photonic-electronic integration on Silicon (Si) has shown strong potential to become the new technology platform for modern society with good economic and environmental sustainability [1-4]. The current Si photonics based on high refractive index contrast between Si and SiO2 can have adverse effects in terms of power durability, temperature stability, and technological robustness [4, 5]. In this regard, silicon nitride (Si3N4) has been viewed as a promising Si-compatible platform as it has a significantly-lower thermo-optics coefficient while remaining monolithically integrable with Si substrate. Nevertheless, efficient integration of Si3N4 with other Ge-based optical components, such as Germanium (Ge) or Ge/SiGe quantum wells, remains critically challenging due to large refractive index difference between Si3N4 (n ˜ 2) and Ge (n˜ 4.3).

This paper aims to propose an integration scheme between these materials that would allow efficient optical propagation based only on these Si-compatible materials, which would potentially allow both photonic and electronic components to be integrated on bulk Si for low-energy consumption. It will theoretically investigate the integration scheme between the Si3N4 optical circuitry and active Ge-based photonic components. On bulk Si, we envision to integrate Si3N4 platform side by side with Ge components. The integration between Ge-based optoelectronic devices and Si3N4 passive optical circuitry on bulk silicon wafer requires development of efficient couplers. Therefore, for optical coupling between the active Ge and Si3N4 materials, the paper will report a double tapered structure incorporating optical mode transformers in both sections. The objective is to match the optical mode from the active optoelectronic part to the passive circuit and vice versa. The project will focus on 3D FDTD simulation to obtain a good coupling design.

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