INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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The research presented in this thesis deals with enhancing the performance of an optical modulator in Si photonics platform using device-level engineering techniques. The thesis starts with an introduction to the field of Si photonics, followed by a comprehensive theory of modulation techniques and metrics used to characterize the modulation efficiency. A chapter on optical waveguides is presented elaborating on determining the waveguide characteristics, viz., mode, loss, and dispersion, using a Ge-doped Si strip waveguide for multimodal application over the whole optical telecom band. A PN phase shifter, which is an integral part of an MZM, is modeled, taking into account the 2D nature of carrier distribution and mode field. The proposed model can be used to design and optimize a PN phase shifter with multiple design parameters viz., wavelength, waveguide dimension, core and cladding material, doping concentration, and junction offset. The model is validated with numerical TCAD simulation. The performance of a Si MZM with quasi-TM mode propagation is evaluated and shown to achieve >100 Gbps transmission over a single channel. Material engineering to improve the performance is studied by designing a multi-layer SiGe phase shifter. The equivalent electrical circuit of the proposed multi-layer PN phase shifter is presented. A process simulation study to create the multi-layer structure by a single Ge implantation in Si is done and, both lateral and vertical PN phase shifter performance is evaluated. The high-speed characteristics of Ge-doped Si MZM are compared with a Si MZM and shown to achieve better performance in terms of higher modulation bandwidth, receiver tolerance, and fiber transmission. The designed Ge-doped Si MZM can be used for 400G datacom applications with >100 Gbps per channel.