ABSTRACT

Novel Nanophotonic Devices for Optical Switching and Modulation

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Nanophotonics is an emerging area of research that deals with the interaction between light and matter, particularly nanostructures. This thesis is a summary of detailed theoretical studies of several nanophotonic devices having applications in optical switching and optical modulation. We firstly present a numerical study (using 3 D FDTD and MODE solver) of a broadband optical modulator based on a phase change material embedded in photonic crystal (PhC) slab waveguidewhich operates at telecom wavelength 1550 nm, showing a broadband switching capability and ON/OFF extinction ratio of >37 dB. This device is based on the shifting of the mode-gap in photonic bandgap of the PhC slab waveguide when the refractive index of the Phase Change Material layer i.e. Germanium Selenide (GeSe) changes on application of electric field. Further, we investigated an electro-optic switch based on microdisk resonator having Phase Change Material (GeSe) embedded in microdisc resonator, which is based on resonant frequency shift with change in refractive index on applying voltage. We employed Numerical FDTD for optical modeling and Numerical DEVICE for electrical modeling of the same. The third device proposed in this thesis a high-speed novel electro-optic tunable power splitter that is based on depletion-mode interleaved p-n junction in silicon-based microring resonator. The interleaved p-n junction configuration provides higher interaction between propagating mode and depletion region with moderate optical loss compared to other p-n junction configurations. The ring resonator operates between on-resonance and off-resonance states for a specific resonance wavelength on applying externally applied voltage, which enables it as an optical power splitter. and we have obtained a split ratio tuning range of 0.15 to 7.82, which is a very wide range of tunability with very low power consumption (35 mW) and low external voltage (0-3.5 V). In addition, we have proposed an optical switch based on 1D and 2D plasmonic nanogratings. This plasmonic switch is based on vanadium dioxide (VO_2) which is a smart material that changes its phase upon exposure to IR radiation or on application of voltage or temperature. VO_2 changes its phase from semiconductor to metallic which in turn changes its optical properties. Thus, the optical behavior of the proposed nanogratings changes upon the change of phase of VO_2, leading

to optical switching. The design of the 1D and 2D gratings can be varied to tunably vary the switching wavelength. Hence, we have designed efficient optical switches that can be employed for ultrafast switching.