Abstract

The nanoscale guiding and confinement of light are essential to developing the next generation of integrated on-chip optical technologies. Significant advancements in photonic interconnect and plasmonic nanostructures have resulted in unprecedented growth in nanophotonics for various applications, including data transmission, processing, computing, and sensing, due to new material explorations, fabrication technology improvements, and more active research.

Conventional dielectric waveguides in photonic circuits have numerous advantages in the integrated photonic circuit, but the dimension (diffraction limit) is a big concern. Exploring plasmonic-based waveguides, which can direct light beyond the diffraction limit, is a viable way to solve this issue. This thesis develops a deeper knowledge of plasmonic-based waveguides as well as photonic waveguides as a foundation for designing innovative nanophotonic and plasmonic devices required for effective light-matter interactions. Descriptions of the extensive theoretical investigations of various unique nanophotonic and plasmonic devices are presented in this thesis. These devices are proposed for the applications such as optical switching, logic operations, tunable power splitter, digital to analog converter, mode converter switch, reflector switch, plasmonic interconnects, and SERS based sensing.

In the first segment of the thesis, we present a novel optical power splitter having an arbitrary split-ratio that can be tuned over a wide range by employing relatively low voltage levels. An electro-optic polymer-filled slot is created throughout the circumference of a ring resonator. Then, we present rigorous numerical studies of long-range hybrid plasmonic waveguides consisting of a combination of plasmonic metal thin films and nanoscale structures of a high refractive index material, with a low refractive index material surrounding the nanoscale structures and the plasmonic metal thin film.

In the second section of this thesis, phase change materials are used to implement non-volatile switches and integrated photonic circuits. Beyond the von Neumann architecture, integrated photonic devices or circuits that can perform both optical computation and optical data storage are considered the building blocks for photonic computations. We combine photonics, plasmonics, and electronics on the

same platform to design an effective architecture for logic operations. Hybrid electro-optic plasmonic switches and non-volatile combinational and sequential logic circuits are presented using PCM as an active material. We propose novel architectures for non-volatile directed logic circuits that demonstrate low insertion losses, high extinction ratios, as well as multi-bit and broadband operations using a different phase change material. Then we investigate the hybrid device architectures utilizing the non-volatile properties of the PCM for integrated programmable photonics in Si_3N_4 platform. FDTD modelling is carried out to design two configurations of non-volatile reconfigurable switches: (1) The non-volatile reconfigurable reflector switch and (2) the non-volatile broadband mode converter switch.

Finally, we demonstrate that the optical electromagnetic fields in the vicinity of plasmonic nanoantennas are substantially enhanced on combining the plasmonic nanoantennas with bull's eye structures (BESs) as compared to those of isolated plasmonic nanoantennas or of isolated bull's eye structures. These structures can be used as a surface-enhanced Raman scattering (SERS) substrate for ultra-sensitive chemical and biological sensing.