ABSTRACT

The motivation for this thesis was growing demand in scaling down the size of devices and increasing the speed of information processing. The electronic devices offer small size but they are limited in speed due to fundamental limitations from RC-delay and power dissipation. In contrast, photonics offers bandwidth in the THz range but they require physical dimensions on the order of wavelength of light due to diffraction limitations. The difference in physical size between nanometer-scale electronics and micrometer-scale photonic elements yields an incompatibility between the two types of devices. To overcome this problems a lot of efforts is now turn to plasmonics which merges the high bandwidth offered by photonics and the nano-scale integration offered by nanoelectronics. However, the main problems in plasmonic technology are high losses related with metal-induced attenuation. This impact can be minimized by integration of short plasmonic waveguides with longer dielectric waveguides. In this way, the small size and low power switching capabilities of plasmonic can be blended with the low loss of dielectric waveguides and processing capacity of electronics, to provide miniaturized and power efficient photonic interconnect routers.

In this thesis, it was demonstrated efficient coupling of light to and from Dielectric-Loaded Surface Plasmon Polariton Waveguides (DLSPPWs) realized through the end-fire arrangement. The measured a coupling loss of 3 dB per photonic –DLSPP waveguide transition at 1550 nm corresponds to coupling efficiency of 50 %. However, this coupling efficiency can be highly improved by proper adjusting the photonic waveguide compared to plasmonic waveguide. In this case, the coupling losses can be decreased below 1 dB, what corresponds to the coupling efficiency of > 80 %. The far-field observations have also confirmed the expected polarization properties of the DLSPPW mode, i.e., the efficient coupling of photonic modes into DLSPPs has been found only with TM-polarized light.

Among many available switching technologies, the thermo-optic switches are very attractive due their small size, large scalability, and potentiality for integration with waveguide dense-wavelength division-multiplexing multiplexers. Their optical performances, in terms of cross talk and insertion losses, are acceptable for many applications. In addition, the speed of waveguide devices based on the thermo-optic effect is adequate for all routing applications. The measurements show that full switching performance is possible for the Mach-Zehnder interferometer (MZI) with Cyclomer ridge for very low power of 2.35 mW and switching time in the range of microseconds and an extinction ration of 15 dB. Furthermore, it was demonstrated that very efficient rerouting can be achieved with Directional Coupler Switch (DCS) for very low power consumption of 0.92 mW.

In this thesis, further DLSPPW-based portfolio of available functionalities was extended by demonstrating the DLSPPW mode power monitoring realized via measuring variations in the resistance of the metal stripes (supporting DLSPP ridges) caused due to the mode absorption. The DLSPPW power monitors were characterized at telecom wavelengths exhibiting the μW-sensitivity and responsivity of ~25.1 μV/μW·V for structure with Cyclomer ridge and Cytop as the underlying layer. Since the frequency response is determined by a time constant of the system this structure exhibits a frequency response of ~ 15 kHz.

As the main factor limiting the DSLPP structures for use into practical systems are propagation losses, the new configuration was introduced, so called long-range dielectric-loaded surface plasmon polariton (LR-DLSPP) which combines two well-know concepts of guiding of SPP: stripe LRSPP waveguides with mm-long propagation length but poor mode confinement and DLSPPWs with strong mode confinement but short propagation length. A LR-DLSPPW with a propagation length of 3.1 mm and a lateral mode with of 1.6 μm was demonstrated theoretically and confirmed experimentally showing an estimated propagation length of up to 0.5 mm and mode width ~ 1 μm. The new figure of merit was proposed which considers the spatial field distribution as well as the propagation length and the SPP wavelength. Compared to the DLSPPWs, and LRSPPWs the introduced figure of merit (*FoM*) was 103 and 102 times higher respectively revealing a great potential of LR-DLSPPWs for building plasmonic waveguides with a high integration density.