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Characterization and Interactions of Ultrafast Surface Plasmon Pulses

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Abstract
Surface Plasmon Polaritons (SPPs) are considered to be attractive components for plasmonics and nanophotonic devices due to their sensitivity to interface changes, and their ability to guide and confine light beyond the diffraction limit. They have been utilized in SPP resonance sensors and near field imaging techniques and, more recently, SPP experiments to monitor and control ultrafast charge carrier and energy relaxation dynamics in thin films. In this thesis, we discuss excitation and propagation properties of ultrafast SPPs on thin extended metal films and SPP waveguide structures. In addition, localized and propagating surface plasmon interactions in functional plasmonic nanostructures will also be addressed. For the excitation studies of ultrafast SPPs, we have done detailed analysis of femtosecond surface plasmon pulse generation under resonant excitation condition using prism coupling technique. Our results show that photon-SPP coupling is a resonant process with a finite spectral

bandwidth that causes spectral phase shift and narrowing of the SPP pulse spectrum. Both effects result in temporal pulse broadening and, therefore, set a lower limit on the duration of ultrafast SPP pulses. These findings are necessary for the successful integration of plasmonic components into high-speed SPP circuits and time-resolved SPP sensors. To demonstrate interactions between localized and propagating surface plasmons, we used block-copolymer based self assembly techniques to deposit long range ordered gold nanoparticle arrays onto silver thin films to fabricate composite nanoparticle thin film structures. We demonstrate that these gold nanoparticle arrays interact with SPPs that propagate at the film/nanoparticle interface and therefore, modify the dispersion relation of SPPs and lead to strong field localizations. These results are important and advantageous for plasmonic device applications. For the propagation studies of ultrafast SPPs, we have designed and constructed a home-built femtosecond photon scanning tunneling microscope (fsPSTM) to visualize ultrafast SPPs in photonic devices based on metal nanostructures. Temporal and phase information have been obtained by incorporating the fsPSTM into one arm of a Mach-Zehnder interferometer, allowing heterodyne detection. Understanding plasmon propagation in metal nanostructures is a requirement for implementing such structures into opto-electronic and telecommunication technologies.