Numerical explorations of subwavelength scale light interactions in metallic nanosystems

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Material processing techniques can now engineer materials with nanoscale features. When light interacts with such nanosystems, complex electromagnetic wave phenomena can emerge through strong near field interactions. For example, surface plasmons (SP's), collective resonances of free electrons in a metal, can be excited in metallic nanosystems. SP's yield intriguing near field phenomena such as highly localized fields and strong intensities. With strong, yet complex, near field interactions, such systems provide ways of controlling light at the subwavelength scale. First-principles computational modeling tools provide invaluable insights about the complex wave phenomena inherent in light interactions in metallic nanosystems. They also can be used to conduct inexpensive feasibility studies of novel device ideas. In this presentation, three new types of photonic systems are discussed through numerical simulations. The discussion is based on accurate numerical solutions of Maxwell's equations. The first system consists of a thin gold film with periodic hole arrays. Transmittance of light passing through the gold film structures is calculated numerically. We demonstrate and investigate how this system can be used for sensing applications. Comparison of simulation and experiment results are also presented to show the validity of simulations in terms of realistic representation of experimentally fabricated systems. The second system involves a cone shaped silver nanoparticle interacting with chirped optical pulses. Rigorous numerical simulations reveal how spatio-temporal control of an SP local hot spot can be achieved. The simulations also demonstrate counterintuitive negative group velocity in some situations. Next, we explore light propagating and bending in a metallic slit waveguide. The simulations of the system, using a realistic model for silver at optical wavelengths, show that good right-angle bending transmission can be achieved for wavelengths greater than 600 nm. The bending efficiency is shown to correlate with a focusing effect at the inner bend corner. Re-directing light propagation with a sharp angle turn is a decades long problem in photonic integrated circuit research. This result suggests a potential solution to achieve on-chip level optical interconnects with tight angle turning of light propagations.