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Plasmon-enhanced Absorption, Modulation and Spontaneous Emission in Semiconductor Quantum Dots and Films

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Recent advances in plasmon dispersion and localization in quantum dot layers and semiconductor thin films have enabled study of several phenomena in coupled metal/semiconductor nanophotonic structures, including i) enhanced spontaneous emission in quantum dots, ii) all-optical modulation of plasmon propagation in quantum dot active media, and iii) enhanced absorption in plasmonic solar cells. Metal-dielectric plasmon waveguides with quantum dot active layers can serve as switching elements when the complex refractive index is actively modulated. We demonstrate all-plasmonic modulation in which the complex refractive index seen by a surface plasmon polariton at an infrared free-space wavelength of 1420 nm is modulated via interband excitation of the quantum dots at a visible wavelength of 514 nm. Metallic nanostructures can excite surface plasmons which can dramatically increase the optical path length in thin active photovoltaic layers to enhance overall photoabsorption, with potential for increased photovoltaic conversion efficiency, and new solar cell device designs. The strong mode localization of surface plasmon polaritons at metal-dielectric interfaces leads to strong absorption in very thin semiconductor films, enabling a dramatic (10-100X) reduction in the semiconductor absorber physical thickness needed to achieve optical thickness. Modal analysis in full wave simulation allows us to determine the fraction of power absorbed for both dielectric waveguide and plasmonic modes in a thin solar cell.