Plasmonics and Metamaterials for Strong Light-Matter Interaction

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Plasmonics and metamaterials have opened new frontiers in controlling light–matter interactions, enabling a wide range of applications from photonic devices to sensing, imaging, and quantum technologies. In this talk, I will present our recent efforts to design and fabricate plasmonic and metamaterial structures that realize highly tunable optical properties through enhanced light–matter interactions.

A key focus will be on random plasmonic metamaterials, including the Nano-Hemisphere-on-Mirror (NHoM) structures[1], which allow broadband and flexible control of localized surface plasmon resonances (LSPR) by simple tuning of spacer thicknesses. These structures achieve full-color tunability, improved resonance quality, and have been applied to colorimetric biosensing[2], imaging[3-4], and emission enhancement for ultraviolet to infrared light[5-10].

Beyond optical control, we also explore emission engineering using plasmonic structures. Enhanced light–matter coupling, even within the weak coupling regime, enables accelerated spontaneous emission through mechanisms such as the plasmonic Purcell effect. Such advances contribute to the development of high-efficiency LEDs, nanolasers, and potential single-photon sources for next-generation photonic systems[11].

By combining advances in bottom-up nanofabrication with physical insights into plasmonic and metamaterial resonances, we aim to push the boundaries of ultrafast, energy-efficient, and multifunctional nanophotonics[12-15]. Our research demonstrates that the integration of plasmonics and metamaterials offers a versatile platform for future optical technologies.

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