PhD THESIS DEFENSE: Extreme nanophotonics architectures for the control of light at deep-subwavelength scales

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11:00

Elements Room

Technological progress in the twenty first century increasingly relies on the ability to control light and electromagnetic fields across multiple spatial and spectral scales. As device dimensions shrink, strong confinement becomes essential, and plasmons, the collective oscillations of conduction electrons in metals, provide an efficient route to concentrate optical fields far below the diffraction limit and enhance light matter interactions. In this thesis, we engineer and study strongly confined optical fields in nanoengineered metallic systems, where plasmonic resonances play a central role in shaping both linear response and nonlinear emission.

In the first part, we study scatterer assisted coupling of free space radiation into surface supported plasmonic modes, which cannot be efficiently excited by direct illumination due to strong momentum mismatch. We show that metallic nanodisks placed near a plasmon supporting interface can launch surface plasmons, with coupling governed by disk position and distance from the surface. By tuning the nanodisk size, we control its resonance wavelength and access a wide near infrared to infrared spectral region. We further investigate periodic nanodisk arrays, where lattice resonances reshape the scattering response and shift the optimal scatterer to substrate distance. By tuning the array geometry, we identify configurations that maximize coupling and determine optimal launching conditions. Results are supported by analytical modelling and numerical simulations.

The second part focuses on ultrathin epitaxial crystalline silver films with thicknesses of only a few tens of monolayers, approaching the monolayer limit. These films provide strong intrinsic confinement and support high quality resonances over a broad spectral range spanning the visible and near infrared. We investigate patterned geometries including ribbons, nanotriangles, bow tie antennas, and rods, and demonstrate robust tunability with quality factors approaching, and for optimal configurations reaching, values on the order of 11. We compare pre patterned and post patterned fabrication approaches and show that suitable capping layers suppress dewetting and ensure long term stability. Despite their reduced thickness, we show that their optical response can be described using a modified Drude model with increased damping to account for confinement and fabrication related losses.

Finally, we investigate the nonlinear optical response of these ultrathin metal systems with emphasis on second harmonic generation. In ultrathin crystalline films, strong interfacial symmetry breaking and vertical confinement enable a measurable nonlinear response. We show that decreasing film thickness enhances the second harmonic signal, and that resonant nanopatterning, particularly using stable capped silver nanoribbon arrays, yields broad tunability and strong plasmon enhanced near fields, producing conversion efficiencies a few orders of magnitude higher than planar films under resonant excitation.

Overall, this work highlights plasmon enabled nanoengineering as a powerful route to control and concentrate light beyond the diffraction limit, enabling compact nonlinear photonic architectures, silicon compatible frequency conversion, and emerging quantum photonic technologies.

Thursday March 19, 11:00 h. Elements Room

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