Tailoring the flow of light at the nanoscale with hyperbolic metasurfaces

Abstract: Metamaterials, artificial optical media composed of sub-wavelength metallic and dielectric building blocks, can significantly enhance our ability to tailor the flow of light at nanoscale dimensions. However, three-dimensional (3D) metamaterials suffer from extreme propagation losses, limiting their practical utility. Two-dimensional (2D) metasurfaces and, in particular, hyperbolic metasurfaces (HMSs) for propagating surface plasmon polaritons (SPPs), have the potential to alleviate this problem. Because SPPs are guided at a metal-dielectric interface (rather than passing through metallic components), these HMSs have been predicted to feature much lower loss while still exhibiting optical phenomena akin to those in 3D metamaterials. In this seminar, I will present our experimental realization of a visible-frequency HMS using single-crystalline silver nanostructures defined by lithographic and etching techniques. The resulting devices display the hallmark properties of metamaterials, such as negative refraction and diffraction-free propagation. Moreover, HMSs exhibit strong, dispersion-dependent spin-orbit coupling, enabling polarization- and wavelength-dependent routing of SPPs. Crucially, the low-loss, 2D nature of our devices results in a substantial, orders of magnitude improvement over 3D metamaterials in terms of optical loss. In an outlook, I will discuss how HMSs can be used for enhancing interactions of SPPs with quantum emitters — a new pathway for realizing solid-state single-photon nonlinear optical circuits. Furthermore, I will show how HMSs hold significant promise for experimental studies of non-reciprocal, chiral quantum optics. I will also discuss efforts to control the flow of excitons – which carry light – in semiconductor heterostructures.

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