Investigations of plasmonic resonant and waveguiding nanostructures

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This Ph.D. thesis focuses on the resonant interaction between light and conduction electrons in metal thin films and metal nanostructures with the purpose of confining and guiding light at the nanometer-scale. This study is therefore related to plasmonics, a subfield of nano-optics, which has gained increasing interest during the last years due to the possibility of realizing exciting and new optical functionalities by proper design of metal nanostructures supporting plasmonic resonant excitations.

In optics, metals are mainly used as highly reflective mirrors and beam splitters, however, metal nanostructures supporting plasmonic resonances are strongly wavelength dependent on the metal nanostructure size, composition, surrounding environment, and its configuration w.r.t. other metal nanostructures or thin films. Furthermore, plasmonic resonances exhibit a unique property of confining light to the metal nanostructure, which often results in huge light intensities. Plasmonic resonances therefore offer a wide range of applications such as nano-scale bio-sensing, enhancement of weak spectroscopic processes such as Raman scattering, ultra-thin super absorbers for realization of black surfaces, and guidance of light along compact waveguides with subwavelength cross sections, which is otherwise impossible to realize with bulk metals.

The work in this Ph.D. project involves modeling, fabrication and optical characterization of various metal nanostructures and can be divided into three main subjects:

1. Tailoring of plasmonic nanoantennas and resonators with the purpose of facilitating significant scattering and absorption resonances which are useful for sensing of the environmental refractive index, realization of ultra-thin super absorbers with potential applications in photovoltaics, and enhancement of local field intensities.

2. A general concept based on two detuned plasmonic resonances which are exploited for inducing metamaterial optical transparency, sensing of the environmental refractive index, and manipulation of light polarization.

3. Optimization and demonstration of plasmonic waveguides with focus on minimization of insertion losses, increasing propagation length, and subwavelength field localization.

The investigated metal nanostructures are fabricated by electron-beam lithography and characterized optically by linear spectroscopy and microscopy as well as nonlinear two-photon luminescence microscopy. Furthermore, the experimentally obtained optical responses are supported by numerical models based on the Finite Element Method.