PhD Thesis Defense LIJUN MENG ' Thermal and optical-gain effects in nanophotonics with applications to sensing and perfect absorption'

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Nanophotonic Theory

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Surface plasmons, which are characteristic oscillations of induced charges at metal surfaces that can interact strongly with light, are a key topic in nanophotonics. It can tightly confine the optical electric energy in the vicinity of metallic nanostructures, resulting in a largely enhanced field intensity. Plasmons can be engineered to interact strongly with external light, which is oftentimes illustrated by a large absorption cross-section of the host structure compared with its projected physical area. When such nanostructures are arranged into a periodic array, it can even totally absorb the energy of an incident light wave, a phenomenon that is known as perfect absorption. Controlling the full width at half maximum (FWHM) of the spectrum, especially realizing perfect absorption with ultranarrow bandwidth, is desirable for sensitive photodetection among other appealing potential applications.

In the first part of this thesis, we present a grating-based absorber with FWHM

In the second part of this thesis, we investigate the use of localized plasmon resonances supported by a metal shell to enhance the emission intensity of an upconversion nanoparticle embedded in the center of the dielectric core. To this end, a theoretical model accounting for absorption and emission processes of the system is established. Based on this theory, optimized coreshell structures are found under different pump intensity regimes. In the same chapter, we extend the simple coreshell nanoparticle structure to more complex multilayers, which consist of alternate metal/dielectric shells. We reveal a cascade effect of the field enhancement in the structure. This can lead to huge intensity in the core under moderate light illumination. We further study its photothermal performance by computing the resulting temperature distribution. It is interesting to find that the temperature increase can be very spatially inhomogeneous with the highest temperature in the center. The reason lies in the high inhomogeneity of the field enhancement and considerable thermal boundary resistance provided by multiple metal/dielectric interfaces. Finally, the thermally induced internal pressure lift is also calculated. The interaction between light and particle arrays is a popular topic with great potential for practical applications. For example, a regular array of tiny nanoparticles is able to totally reflect the impinging light. Recently, it has been realized that a regular array of two-level atoms holds the same capability.

In the third part of this thesis, we take a step further to explore light scattering on three-level atom arrays. Unlike the two-level atom, which elastically interacts with light, the three-level atom can either dissipate, perfectly reflect, or amplify the probed light. Our investigations demonstrate these effects vividly.

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