ABSTRACT

In recent decades, plasmonic nanoparticles have attracted considerable attention due to their ability to localize electromagnetic energy at a scale much smaller than the wavelength of optical radiation. The study of optical plasmon waveguides in the form of chains of nanoparticles is important for modern photonics. However, the widespread use of OPWs is limited due to the suppression of the resonance properties of classical plasmon materials under laser irradiation. The study of the influence of nanoparticle heating on the optical properties of waveguides and the search for new materials capable of stable functioning at high temperatures is an important task.

In this thesis, the processes occurring during heating of plasmon nanoparticles and OPWs are studied. For this purpose, a model was developed that takes into account the heat transfer between the particles of an OPW and the environment. The calculations used temperature-dependent optical constants. As a one of possible way to avoid thermal destabilization of plasmon resonanses, new materials for OPWs formed by nanoparticles were proposed. I show that titanium nitride is a promising thermally stable material, that might be useful for manufacturing of OPWs and that works in high intensity laser radiation.

Another hot topic at present is the study of periodic structures of resonant nanoparticles. Periodic arrays of nanoparticles have a unique feature: the manifestation of collective modes, which are formed due to the hybridization of a localized surface plasmon resonance or a Mie resonance and the Rayleigh lattice anomaly. Such a pronounced hybridization leads to the appearance of narrow surface lattice resonances, the quality factor of which is hundreds of times higher than the quality factor of the localized surface plasmon resonance alone. Structures that can support not only electric, but also magnetic dipole resonances becomes extremely important for modern photonics on chip systems. An example of the material of such particles is silicon. Using the method of generalized coupled dipoles, I studied the optical response of arrays of silicon nanoparticles. It is shown that under certain

conditions, selective hybridization of only one of the dipole moments with the Rayleigh anomaly occurs.

To analyze optical properties of intermediate sized particles with $N = 10^2 – 10^5$ atoms and diameter of particle d<10 nm an atomistic approach, where the polarizabilities can be obtained from the atoms of the particle, could fill an important gap in the description of nanoparticle plasmons between the quantum and classical extremes. For this purpose I introduced an extended discrete interaction model where every atom makes a difference in the formation optical properties of nanoparticles within this size range. In this range are first principal approaches not applicable due to the high number of atoms and classical models based on bulk material dielectric constants are not available due to high influence from quantum size effects and corrections to the dielectric constant. To parametrize this semi-empirical model I proposed a method based on the concept of plasmon length. To evaluate the accuracy of the model, I performed calculations of optical properties of nanoparticles with different shapes: regular nanospheres, nanocubes and nanorods. The model was subsequently also used to calculate hollow nanoparticles (nano-bubbles).