Forces and Heating in Plasmonic Particles

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Abstract

Introduction: Plasmonic particles can enhance near-fields due to surface plasmon resonances. A direct effect of the near-field enhancement are strong electromagnetic gradients surrounding the particle. These gradients lead to attractive optical forces on particles surrounding the plasmonic structures. Depending on the shape of the plasmonic particles, on their optical resonances and on the optical state of the excitation fields different forces can be generated. On the other hand, the optical absorption due to intrinsic absorption of the metal and due to plasmonic resonances leads to a rise of temperature on the particles. We investigate these effects using COMSOL Multiphysics® and compare the results with other from literature on the field obtained using other computational methods.

Use of COMSOL Multiphysics®: We have used COMSOL Multiphysics® to obtain the optical resonances, near-fields and optical forces on small particles in the neighbourhood of plasmonic structures. The optical forces were calculated using the Maxwell's Stress Tensor (MST). Based on the electric field distribution on particles and thermal properties of plasmonic particles and medium,the maximum temperatures can be obtained.

Results: In figure 1 are presented the near-field distribution (left) for incident wavelength of 1200 nm and optical forces (right) on two gold spheres of 60 nm diameter, close to a gold nanorod. The gold nanorod has an optical resonance at approximately 1200 nm. The optical forces were calculated using the MST. At the nanorod resonance the attracting forces acting on the spheres rise the maximum and reach values typical of conventional optical tweezers for a incident field strength of 10^6 V/m.

Conclusions: Optical forces between plasmonic particles at resonance, comparable to those of conventional optical tweezers, can be obtained using incident plane waves. The calculation of the distribution of the fields inside and near the particles permits to obtain temperature distribution and maximum temperature in the metal. The increase of temperature in plasmonic nanoparticles mediated by surface plasmons has been applied in the investigation of cancer therapy, and in the production of steam by solar light.

Figures used in the abstract

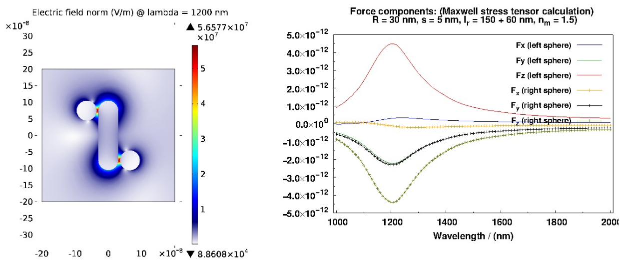

Figure 1: Electric field distribution (at left in linear-scale) of a plasmonic system composed by two gold spheres of 60 nm diameter and a gold rod of 210 nm length. The separation between the spheres and the rod is 5 nm. The medium has refractive index n = 1.5. The three components of the optical forces acting on the spheres are presented at right. The electric field strength of the incident plane wave is 10^6 V/m.