Heating of Metal Nanoparticles on Absorbing Substrates

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Abstract

It is well-known that metal nanoparticles (NPs) excited at the plasmon frequency not only exhibit peculiar optical properties (e.g., a peak in the extinction spectrum, an enhanced electromagnetic near-filed) but also heat up [1]. This phenomenon is highly investigated for medical applications, but it can be exploited also for the realization of optical devices.
So far many analytic and numeric (involving FDTD, BEM, ...) models have been proposed for describing the heating process of the nanoparticle under laser illumination. However, these models allow to handle only systems with isolated NPs or NPs on top of non-absorbing substrates.

In our study we use COMSOL Multiphysics software as a tool to simulate the temperature profile evolution in time of metal nanoparticles placed on top of an absorbing substrate when illuminated with picoseconds light. The simulation involves two physical steps and, thus, two physical interfaces. First, the system is impinged by a plane-wave at the plasmon resonance and both the NPs and the substrate start absorbing: we used the Wave-Optics interface with a frequency study in this case to obtain the amount of light absorbed in each point of the system. This steps involves the solution of the Maxwell equations in the frequency domain. Afterwards, supposing that the light is switched off, the absorbed points were used as heating sources: we exploited here the Heat-Transfer module with the initial conditions taken from results of the Wave-Optics interface. By solving the heat diffusion equations in the time-domain the evolution of the temperature in the system is eventually achieved.

The use of COMSOL Multiphysics enabled us to describe complex systems involving different physical processes otherwise difficult to combine in other numerical approaches. The final goal is to test this proceeding for different absorbing substrates with physical properties (e.g., thermal conductivity, electrical conductivity, ..) depending on the undergone temperature.

We think that COMSOL Multiphysics represents a key tool for the investigation of such complex structures and that our study can provide a precedent of broad interest among the

plasmonics/Condensed-Matter community.

Reference

[1] Baffou G. and Quidant R., Laser Photon. Rev., 7, 171 (2013)

Figures used in the abstract

Figure 1

Figure 2

Figure 3

Figure 4