Ultrafast Thermo-Optical Dynamics of Metal Nano-Objects in a Transparent Environment

Marco Gandolfi [C, S]
Department of Physics and Astronomy, KU Leuven, Heverlee, Leuven, Belgium
Dipartimento di Matematica e Fisica and Interdisciplinary Laboratories for Advanced Materials Physics (I-LAMP), Università Cattolica del Sacro Cuore, Brescia, Italy

marco.gandolfi@kuleuven.be

Fabio Medeghini, Aurélien Crut and Tatjana Stoll
Institut Lumière Matière, Université Lyon1, CNRS, Univ Lyon, Villeurbanne, France

Francesco Rossella
Piazza S. Silvestro 12, NEST, Scuola Normale Superiore and Istituto Nanoscienze-CNR, Pisa, Italy

Sylvain Hermelin, Paolo Maioli, Fabrice Vallée and Natalia Del Fatti
Institut Lumière Matière, Université Lyon1, CNRS, Univ Lyon, Villeurbanne, France

Gabriele Ferrini, Claudio Giannetti and Francesco Banfi
Dipartimento di Matematica e Fisica and Interdisciplinary Laboratories for Advanced Materials Physics (I-LAMP), Università Cattolica del Sacro Cuore, Brescia, Italy

With ever-decreasing device downscaling, understanding thermal transport in nanoscale systems is a key technological issue [1]. In this context, we theoretically address the ultrafast cooling of metal nano-objects embedded in a transparent environment as measured in time-resolved optical spectroscopy [2]. In the experiment, a “pump” laser pulse impulsively heats a metal nano-object. The thermal relaxation is then accessed exploiting a time-delayed “probe” pulse, monitoring the temperature-dependent relative transmittivity variation. The modeling, based on the Finite-Element Method, couples the two physics involved in the experiment, namely the thermal and optical problem. The system thermal dynamics is first computed in the frame of Fourier's law and Kapitza-like thermal resistance [3]. The system electromagnetic extinction spectrum is then calculated at various delay times, thus accounting for the temperature-dependent variations of the system dielectric functions. Within this frame, we numerically simulate the experiments performed on metal nano-spheres embedded in a liquid environment and metallic nano-disks patterned on a dielectric substrate. By tuning the Kapitza resistance we obtain good agreement between the experimental and theoretical optical traces, allowing estimation of the Kapitza resistance at the metal nano-object-environment interface. We speculate also on the importance of considering the environment heating in the model.

References:

[1] Hartland, Chem.Rev. 111,3858 (2011)
[2] Stoll et al., J.Phys.Chem.C 119,12757 (2015)
[3] Banfi et al., Appl.Phys.Lett. 100,011902 (2012)