Photo-Induced Heat Generation in Non-Plasmonic Nanoantennas

Stefano Danesi
INSTM and Chemistry for Technologies Laboratory, Mechanical and Industrial Engineering Department, Università di Brescia, Brescia, Italy

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
Marco.Gandolfi@unicatt.it

Nicolò Bontempi and Luca Carletti
INSTM and Chemistry for Technologies Laboratory, Mechanical and Industrial Engineering Department, Università di Brescia, Brescia, Italy

Costantino De Angelis
DII, Dipartimento di Ingegneria dell'Informazione, Università di Brescia, Brescia, Italy

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

Ivano Alessandri
INSTM and Chemistry for Technologies Laboratory, Mechanical and Industrial Engineering Department, Università di Brescia, Brescia, Italy

Nanoscale light management is crucial in fields ranging from chemistry and physics to materials science and medicine [1]. Light management at the nanoscale is in general pursued by means of plasmonic nanostructures, the work-horse materials being silver and gold [2]. The major drawback with metals though stands in their significant ohmic losses, potentially generating uncontrolled, high local heating in nanostructured devices [3]. For these reasons, non-plasmonic antennas – characterized by reduced dissipative losses – are emerging as a valid alternative in the field of nano-optics and related applications, such as Raman sensing [4]. Silicon nano-particles and silicon-based nanostructures are excellent candidates as new generation Raman enhancers, both because of their high-refractive index and compatibility with the most widespread nanofabrication techniques [5]. In this context, we investigate the thermo-optical behaviour of a paradigmatic nano-structure, made of a silicon-coated silica sphere deposited on a Silicon substrate, under continuous wave visible laser radiation. We discuss how the Si film thickness and its crystallinity degree affect heat generation, the temperature increase within the nano-structure and the threshold optical power for melting. In view of Raman sensing applications, we theoretically predict the optimal nano-structure's parameters yielding the best performances in terms of electric field enhancement, sensitivity, and thermal stability.

References:

[1] Novotny et al., Principles of Nano-Optics, Cambridge University Press, Cambridge 2012
[2] Novotny et al., Antennas for Light. *Nature Photon.* **5**, 83 (2011)
[3] Alessandri et al., Plasmonic Heating-Assisted Transformation of SiO2/Au Core/Shell Nanospheres (Au Nanoshells): Caveats and Opportunities for SERS and Direct Laser Writing. Plasmonics 2013, 8, 129-132.
[4] Alessandri et al., Enhanced Raman Scattering with Dielectrics. Chem. Rev., 2016, 116, 14921–14981.

[5] Cao et al., Enhanced Raman Scattering from Individual Semiconductor Nanocones and Nanowires. Phys. Rev. Lett. 2006, 986, 157402.