The Effect of Induced Electron Diffusion on the Optical Properties of Plasmonic Nanostructures

Changyin Ji[1], Qingfan Shi[1], Yongyou Zhang[1], Ning Zheng[1], Liangsheng Li[2]

[1]Beijing Institute of Technology,school of physics,Beijing,China
[2]Science and Technology on Electromagnetic Scattering Laboratory, Beijing，china

Abstract

Recently, the researchers usually use the hydrodynamic Drude model (HDM) to investigate the nonlocal optical response of metallic nanostructure. The advantage of the HDM is easy to implement numerical calculation for larger and more complex-shaped nanoplasmonic structures. For the HDM, it is predicted that the nonlocal response blueshifts the resonance peak, modifies the electric field enhancement, gives a series of subsidiary peaks above plasma frequency, and influence the nonlinear optical phenomena of the metallic nanostructure and so on. However, the HDM only considers the convective current due to the quantum pressure, losing sight of any currents due to the classical diffusion effect. In fact, the quantum and classical effects on the optical properties of metallic nanostructure are always coexistence and interaction with each other, and have profound implications for our understanding of light-matter interplay. Thus, it's meaningful and indispensable to study the diffusion under the nonlocal optical response.
In this work, we use COMSOL Multiphysics® software to investigate the effect of induced electron diffusion on the optical properties of metallic nanostructure based on the generalized nonlocal optical response(GNOR) model which takes into account both quantum pressure convection and induced electron diffusion. We compare the numerical results between the GNOR and the HDM, of isolate nanowires, and of nanowires on a semi-infinite dielectric substrate .The results show that the electron diffusion which is usually disregarded can lead to significant effect on the optical properties of metallic nanostructure.

Reference

Mortensen,N.A et.al, A generalized non-local optical response theory for plasmonic nanostructures, Nat.Commun,5,3809 (2014)
Christensen,T.et.al,Nonlocal response of metallic nanospheres probed by light, electrons, and atoms, ACS Nano 8, 1745–1758 (2014)
Ciracì,C.et.al,Probing the Ultimate Limits of Plasmonic Enhancement,Science ,337,1072-1074(2012)
Søren Raza.et.al,Multipole plasmons and their disappearance in few-nanometre silver nanoparticles,Nat.commun,6,8788(2015)
Jeffrey M. McMahon,et.al,Optical Properties of Nanowire Dimers with a Spatially Nonlocal Dielectric Function,Nano Lett,10, 3473–3481(2010)
Aeneas Wiener,et.al,Nonlocal Effects in the Nanofocusing Performance of Plasmonic Tips,Nano Lett,12,3308−3314(2012)
Jeffrey M. McMahon,et.al,Nonlocal Optical Response of Metal Nanostructures with Arbitrary Shape,Physical review letters,103, 097403 (2009)
Yu Luo,et.al,Surface Plasmons and Nonlocality: A Simple Model,Physical review letters,111, 093901 (2013)

Figures used in the abstract

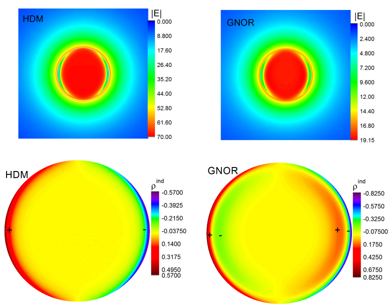

Figure 1: The electric field and induced charge density of an isolated Au nanowire with r=2nm calculated using HDM model, GNOR model, respectively.

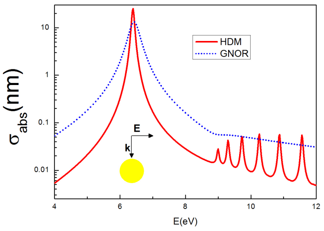

Figure 2: The absorption spectrum of an isolate Au cylindrical nanowire with radius r=2nm in vacuum, for a TM-polarized plane incident wave.

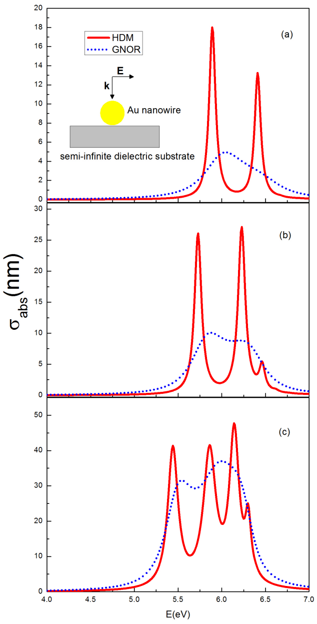

Figure 3: The absorption spectrum of a gold cylindrical nanowire positioned on a semi-infinite dielectric substrate of the refractive index 1.5, for a TM-polarized plane normally incident from the top. The radius of the nanowire is (a) 2nm, (b) 3nm, and (c) 7nm.