Nonlocal Response of Metallic Nanospheres Probed by Light, Electrons, and Atoms

Inspired by recent measurements on individual metallic nanospheres that cannot be explained with traditional classical electrodynamics, we theoretically investigate the effects of nonlocal response by metallic nanospheres in three distinct settings: atomic spontaneous emission, electron energy loss spectroscopy, and light scattering. These constitute two near-field and one far-field measurements, with zero-, one-, and two-dimensional excitation sources, respectively. We search for the clearest signatures of hydrodynamic pressure waves in nanospheres. We employ a linearized hydrodynamic model, and Mie–Lorenz theory is applied for each case. Nonlocal response shows its mark in all three configurations, but for the two near-field measurements, we predict especially pronounced nonlocal effects that are not exhibited in far-field measurements. Associated with every multipole order is not only a single blueshifted surface plasmon but also an infinite series of bulk plasmons that have no counterpart in a local-response approximation. We show that these increasingly blueshifted multipole plasmons become spectrally more prominent at shorter probe-to-surface separations and for decreasing nanosphere radii. For selected metals, we predict hydrodynamic multipolar plasmons to be measurable on single nanospheres.
