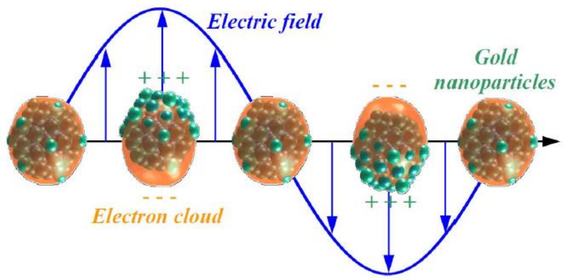

Quantum technologies

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Metal Nanoparticles: Theoretical Models of Surface Plasmons for Quantum Information

The control and manipulation of quantum phenomena can lead to a new paradigm for secure communication and advanced computing. This intense area of research rests on principles of quantum mechanics, which requires matter to have a “wave” nature and light to have “particle” properties. At macroscopic scales of matter and large intensities of light, it is difficult to observe either of these wave-particle dualities. Progress in nanofabrication and characterization allow us to probe light-matter interactions and study unique quantum properties in the solid state [1-3].

By coupling light to the free electrons of metals, which are readily available in modern circuits, subdiffraction light confinement and propagation is possible with dense networks of plasmonic nanowaveguides [1]. Surface plasmon resonance (SPR) is the manifestation of a resonance effect due to the interaction of conduction electrons of metal nanoparticles with incident photons. The interaction relies on the size and shape of the metal nanoparticles and on the nature and composition of the dispersion medium. Surface plasmon polaritons can lead to non-classical light sources as well as assist in quantum information transfer. It was recently shown that these propagating plasmon polaritons also emerge as a natural choice to carry non-classical information for future quantum networks. Plasmon polaritons address many challenges in quantum information technology [1, 3].

In this work we will quantify plasmon resonances and field enhancements for applications such as sensing using nanoplasmonic particles and for quantum network applications. We will study nanoparticles of sizes below 10 nm, where a simple classical model of the optical properties of metals breaks down. We will consider the transfer of quantum states, including single qubits as plasmonic wave packets, and highlight the quantum-mechanical description by comparing the predictions of quantum theory with those of classical electromagnetic theory. Namely, we will correlate the structure and size of nanoparticles with the surface plasmon state (i.e. quantum dimensional effect). In order to define excitation energies of the structures under study we will perform TD-DFT calculations. Also, long-distance entanglement of two metal nanoparticles by using plasmons instead of photons from the decoherence perspective will be studied.

[1] Anatoly V. Zayats et al, Nano-optics of surface plasmon polaritons, Physics Reports 408 (2005) 131–314

[2] Scholl, Jonathan A. et al, Observation of Quantum Tunneling between Two Plasmonic Nanoparticles, Nano Letters, vol. 13, (2013) 564-569

[3] Wenqi Zhu et al, Quantum mechanical effects in plasmonic structures with subnanometre gaps, Nature Commun. 7 (2016) 11495.