Controlling the interaction of light with the very small

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Abstract

Extensive research in plasmonics over the last decade has demonstrated the ability of noble metal nanostructures to control optical fields on the nanometer scale. Such concentration of light, well beyond the limit of diffraction, potentially opens new opportunities for enhanced interaction with tiny amounts of matter down to the single molecule/atom level. In practice though, fully exploiting the capability of plasmonics requires nanoscale positioning of the molecule/atoms within the hot spot, where the light is concentrated.

In this talk, we first present different experimental strategies to accurately control the interaction of top-down metallic nanostructures with few to single molecules or artificial atoms. We then discuss some applications to different areas including nanochemistry and biosensing.

The first approach we discuss is based on immobilizing a nano-object of interest (either a molecule, a nanoparticle or a qdot) at a predefined location of the plasmonic nanostructure, and more especially in the hot spot where the plasmonic field is concentrated. A first technique consists in combining e-beam lithography with surface chemistry to define a functionalized nanowell in which the nano-object can bind [1]. Along the same line, we report on another technique in which the immobilization within the hot spot is triggered by a photochemical process that creates a chemical bond that acts as a scaffold for the subsequent immobilization of a nano-object of interest [2]. As an illustration of the potential of these techniques, we demonstrate reproducible immobilization of single qdots in the gap of gold dimers. The delivered qdot is used as a nanoprobe of the plasmonic hot spot. By monitoring the change in the X/BX ratio via lifetime measurement, we are able to retrieve the actual local field enhancement within the gap [3].

Beyond permanent immobilization, the second approach we discuss here consists in raster scanning the nano-object of interest above the plasmonic structure. In particular we report on the use of optical tweezers to trap and manipulate an individual diamond nanocrystal hosting a single Nitrogen Vacancy (NV). Remarkably, we find the NV axis is nearly fixed inside the trap and can be controlled in-situ, by adjusting the polarization of the trapping light. By combining this unique spatial and angular control with coherent manipulation of the NV spin and fluorescent lifetime measurements near an integrated photonic and plasmonic systems, we prove optically trapped NV center as a novel route for both 3D vectorial magnetometry and sensing of the local density of optical states [4].

References

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