Nanoscale mapping of the local density of optical states in the near-field of a plasmonic antenna

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We report on the experimental and theoretical study of the local density of states (LDOS) and intensity fluctuations of the electro-magnetic field at the surface of a plasmonic nanoantenna. The experimental data are acquired by scanning a fluorescent nanoemitter, grafted at the apex of the tip of an atomic force microscope (AFM), in the near-field of the sample. By combining our AFM with a confocal microscope, we can simultaneously measure the topography of the sample, the intensity of the fluorescent emission and the fluorescence decay rate. The last quantity is directly proportional to the LDOS.

Some recent results [1] obtained with the experimental setup described above are shown in figure 1. In this case a 100 nm fluorescent bead was scanned on the top of three gold nanodiscs of diameter 150 nm, separated by 50 nm. As one can see, two dimensional maps of the intensity (fig.1b) and the decay rate (fig.1c) of the fluorescent bead show subwavelength details.

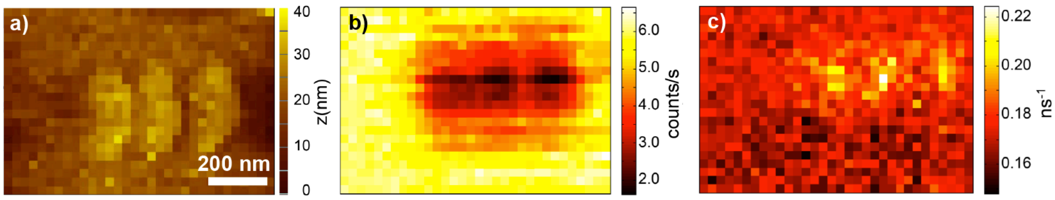

Figure 1. Topography (a), fluorescence intensity (b) and fluorescence decay rate (c) maps measured on the top of three gold nanodiscs of diameter 150 nm, separated by 50 nm.

A good understanding of these maps is achieved by comparison with exact numerical simulations, which also allows one to analyze the optical response of the fluorescent near-field probe used to perform the experiments. Theory and experiments are in good agreement. Since the near-field images of fluorescence intensity and LDOS provide complementary information, the simultaneous acquisition of the two maps is crucial to achieve a full characterization of the optical properties of the studied sample.

While the study presented here is devoted to the analysis of the optical response of a plasmonic nanoantenna, the developed active AFM can be used for the investigation of the electromagnetic modes on any type of photonic nanostructure. The manipulation of a fluorescent nano-object with nanometer accuracy at the surface of a photonic nanostructure opens interesting new perspectives for the realization of quantum optics experiments, such as the investigation of the coupling of quantum emitters with plasmonic (or dielectric) devices, the characterization of electromagnetic modes on photonic nanostructures, or the search for Anderson localized modes in disordered systems [2-4].

References

[1] V. Krachmalnicoff, D. Cao, A. Cazé, E. Castanié, R. Pierrat, N. Bardou, S. Collin, R. Carminati, and Y. De Wilde, “Towards a full characterization of a plasmonic nanostructure with a fluorescent near-field probe", submitted (2013).

[2] V. Krachmalnicoff, E. Castanié, Y. De Wilde and R. Carminati, “Fluctuations of the Local Density of States Probe Localized Surface Plasmons on Disordered Metal Films", Phys. Rev. Lett. **105** (2010) 183901.

[3] E. Castanié, V. Krachmalnicoff, A. Cazé, R. Pierrat, Y. De Wilde, and R. Carminati, “Distance dependence of the local density of states in the near field of a disordered plasmonic film", Opt. Lett. **37** (2012) 3006.

[4] A. Cazé, R. Pierrat and R. Carminati, “Radiative and non-radiative local density of states on disordered plasmonic films", Phot. Nano. Fund. Appl. **10** (2012) 339.