# NANOANTENNAS - CONTROLLING SINGLE MOLECULE EXCITATION AND EMISSION

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Antennas have been used for over a century to control the emission and reception of radio and microwave radiation. An optical equivalent is of great interest as it will enable unique nano-scale control of both the absorption and emission of single molecules[1]. Here we will discuss results obtained by reversible coupling single molecules to an optical monopole antenna (shown in figure 1), precisely tuned to resonance [2]. It is shown that under illumination a locally enhanced field is created leading to increased excitation. The field is confined within 25 nm. The antenna effectively focuses optical energy far below the diffraction limit and is used as a high-resolution optical microscope with single molecule sensitivity (figure 1).

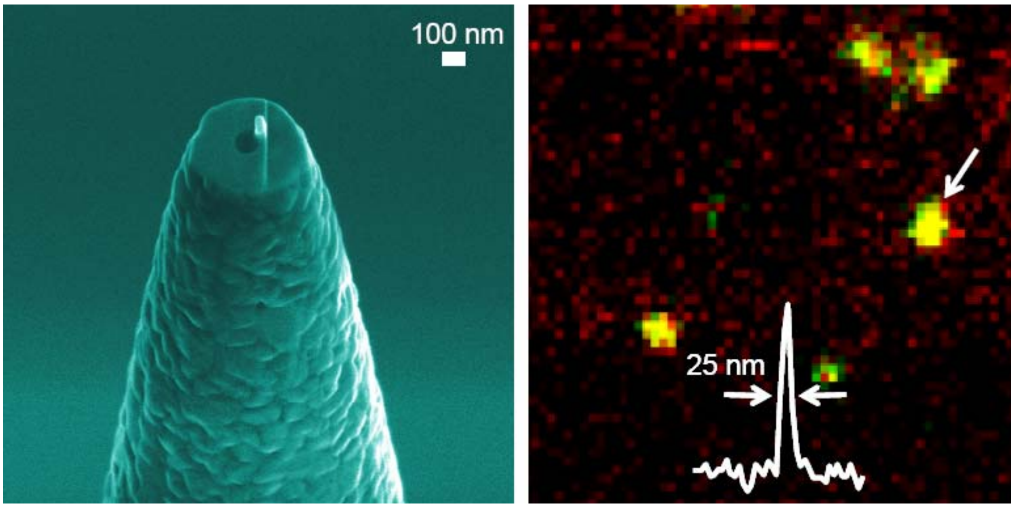


*Figure 1.* *Left: Optical monopole antenna.*
*Right: Single molecule fluorescence at 25 nm resolution.*

In emission, the radiative properties of a molecule, e.g. the excited state lifetime [3] and emission spectrum [4], can be manipulated. We experimentally demonstrate control of polarization [5] and emission direction of a single molecule by an optical antenna [6]. It is shown how the emission is determined by the antenna design regardless of the orientation of the molecule. This directly reveals the role of the plasmon resonance in the emission process and provides a clear guideline to arbitrarily direct single-molecule emission with optical antennas, an interesting prospect for efficient nano-sized sensors and light sources.

Inspired by these initial results we now explore the limits of the nanoantenna probes. Several aspects are under study to enhance and localize the optical field: metal, shape, antenna configuration, fabrication method, etc.

*Metal*: Aluminum is a relatively good electrical conductor in the optical regime, with very short skin depth and suitable for sharp tip definition. However, other less perfect conductors, such as silver and gold, display stronger plasmon resonances with potentially stronger field enhancement for nanoantennas.

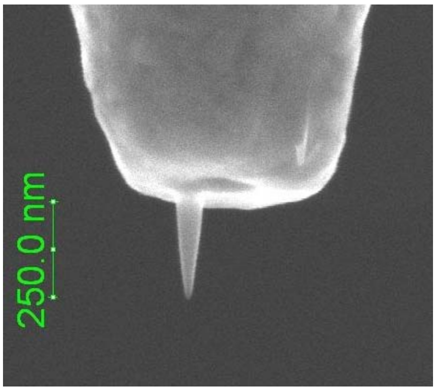


*Figure 2:*
*E-beam deposited nano-antenna.*
*Material: Platinum*

*Shape*: The field enhancement of a resonant antenna and its decay length are roughly inversely related to the radius of curvature of the antenna apex, making small radii of curvature a must. Beyond sharp tip also gap antennas are an interesting alternative to increase the local field further.

*Fabrication*: Our monopole nanoantennas have been fabricated using FIB milling. Shape, sharpness and size of the antennas are limited to 10-20 nm by the finite resolution of the ion beam. Moreover, the optical properties of the antennas are affected by gallium ions that are implanted during the FIB milling, and the evaporation process that leaves the metal in small crystalline clusters on the scale of the antenna dimensions instead of a smooth layer. A good alternative is given by metal deposition assisted by a focused electron beam. We show how e-beam fabrication shows much narrower, sharper and smoother antennas.

In this presentation we will show recently fabricated nanoantenna probes, calculations for different materials and configurations and experimental data on antenna performance.

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