Optical antennas: nanoscience meets quantum optics

The ultimate control of light-matter interaction is achieved when a single emitter strongly interacts with single photons. A manipulation at the level of single quanta is not only of fundamental interest but is of special importance for emerging quantum technologies, such as quantum information processing. In this talk I will first briefly review our experimental progress on the interaction of strongly focused photons with a single molecule [1]. Then I will discuss how optical antennas can be used to enhance light-emitter interaction and how the emission properties of a single emitter can be dramatically altered. Two types of antennas are presented. With a metallic nanoantenna consisting of a single gold nanoparticle attached to the end of a dielectric tip, we experimentally achieved enhancements up to 30 times for the fluorescence of a single molecule. Such a nanoantenna can be used as a scanning near-field probe to image single molecules with a resolution better than 20nm. In another experiment we embedded a single organic molecule in a planar dielectric antenna which directs the emission towards the collection optics. We realized a single-photon source with near-unity collection efficiency and a record count rate of 50×10^6 photons per second [3]. With our current design we collect 96% of the photons emitted by a single molecule.

[1] J. Huang *et al*., Nature **460**, 76 (2009).

[2] H. Eghlidi *et al*., Nano Letters **9**, 4007 (2009).

[3] K.-G. Lee *et al*., Nature Photonics, accepted.

In the second part of the talk, we will examine a new planar dielectric antenna for the strong modification of the molecular radiation pattern. This has allowed us to collect 96% of the photons emitted by a molecule with a commercial microscope objective.

In one experiment a single gold nanoparticle is used to enhance the excitation and to change the spontaneous emission rate of a single molecule. In another experiment we realized a single-photon source with near-unity collection efficiency and a record count rate of 50×10^6 photons per second [3]. The device consists of a single organic molecule embedded in a planar dielectric antenna which directs the emission towards the collection optics. With our current design we collect 96% of the photons emitted by a single molecule.

Controlling the properties of a single quantum emitter and its interaction with photons are both at the heart of quantum optics.