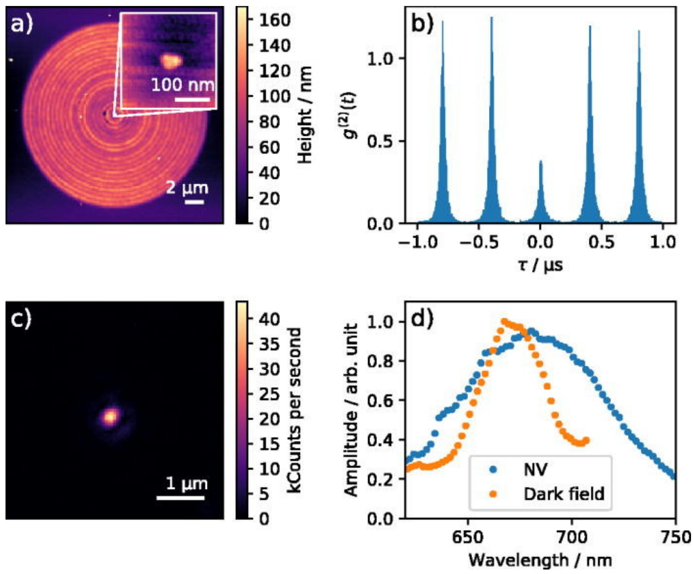
A "bullseye" antenna helps to read out a quantum sensor

An ideal platform to study the light-matter interaction at the fundamental level consists of single quantum emitters coupled to photonic and plasmonic elements.

Such elements are also needed to realize quantum interfaces between stationary and flying quantum bits in quantum networks. Reaching the required nanometer precision for optimum coupling is still a challenge. Approaches for different scenarios have been developed. A very precise approach uses nanomanipulation with the help of atomic force microscopy (AFM) tips, the so-called pick-and-place approach. Here, single nanoparticles containing quantum emitters are transferred from substrate to substrate. The method is highly accurate and deterministic, and it also allows for pre-characterization of the luminescent particles. Moreover, the placement is not final, and several iterations can be performed by nanomanipulation if required. Finally, very different materials for the emitters or substrates (these may contain complex photonic structures like optical waveguides or microresonators) can be employed in order to assemble hybrid systems. A joint team of the Department of Physics and IRIS Adlershof of Humboldt-Universität zu Berlin and the Hebrew University, Jerusalem, now successfully presented a versatile technique allowing for high accuracy placement of a single quantum emitter an a plasmonic nanoantenna. The antenna operates by collecting light in a two-dimensional dielectric waveguide, which is then scattered into a well-defined narrow solid angle by concentric metallic (Ag) rings.



AFM, confocal scan, and optical characterization of a placed nanodiamond containing a single nitrogen vacancy (NV) center. a) AFM scans of the placed nanodiamond in the center of the plasmonic bulleseye antenna. b) Measured normalized photon coincidences (g(2)-function) recorded under pulsed excitation with a repetition rate of 2.5MHz. The strongly reduced probability to find two photons after an excitation pulse (reduced peak height near zero time delay) proves emission of single photons. c) Confocal scan of the antenna with the nanodiamond in the middle. d) Spectrum of the fluorescence from the NV (blue) and a dark field scattering spectrum of the antenna (orange) show a good overlap.

Due to these rings such antennas are called bulleseye antennas. A key advantage of a plasmonic antenna is its broad bandwidth, i.e., even light from emitters with a rather wide fluorescence spectrum can be concentrated and directed with very high efficiency. Then, simple subsequent collection optics, even optical fibers, may collect more than 90% of all the emitted light.
The quantum emitter was a single nitrogen-vacancy (NV) defect center in a nanodiamond.

The NV center can be used a single photon source emitting at room temperature. On the other hand it hosts an electron spin state, which can be manipulated and read out optically. In this way nanomagnetometry on the level of single spins can be performed even at room temperature. Prof. Ronen Rapaport and Prof. Oliver Benson, who lead the research teams in Jerusalem and Berlin, respectively, point out: "The coupling of an NV center to a plasmonic antenna dramatically increases the efficiency of the device. This is crucial for its use as quantum light source, and even more for an application as magnetic field quantum sensor. Particularly for applications in biophysics or medicine room-temperature operation and fast non-invasive read out is crucial." As next steps the researchers want to combine the NV quantum sensor, plasmonic light collecting structures and a microfluidic platform to develop reliable sensors for applications in biophysics.

Accurate Placement of single nanoparticles on opaque conductive structures

N. Nikolay, N. Sadzak, A. Dohms, B. Lubotzky, H. Abudayyeh, R. Rapaport, and O. Benson
Appl. Phys. Lett. 113 (2018) 113107
DOI: 10.1063/1.5049082