A hybrid Approach to Build up Photonic Device

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Application Note

Introduction

For future nanophotonic devices, basic constituents are single photon emitters coupled to optical micro- or nano-structures to tailor the emission as desired. We recently developed methods to use scanning probes like SNOM and AFM tips to manipulate on these scales and build up complex photonic structures [1,2,3]. We call this a hybrid approach as we first characterize the single emitter and the optical structure before bringing them together.

One example of this approach is the controlled coupling of single nitrogen vacancy (NV) centers in nanodiamonds to high-Q whispering gallery modes of a spherical microresonator. Among the single photon sources, NV centers in diamond have attracted interest because of their unique feature of single photon emission at room temperature without the need of a complicated setup but an optical microscope. Microspheres on the other side provide so called whispering gallery modes (WGM) both with high-Q and small mode volumes. By using a SNOM-tip, we are able to couple individual NV-centers one-by-one to a microsphere, getting the typical resonances of the WGMs in the fluorescence spectra, without losing the single-photon characteristics of the emission.

Setup

Our setup (see Figure 1) consists of a home-made confocal setup with a SNOM or AFM on-top where we excite single NV-centers with a cw 532 nm laser. For the detection of the fluorescence we use an Andor iXon EMCCD camera DV885 LC-VP, an Acton spectrometer with an Andor iDus CCD detector DU401A-UVB to record the emission spectra, and a Hanbury-Brown and Twiss autocorrelator (HBT) (PerkinElmer APDs together with a PicoQuant time-correlated single photon counting card) to measure the $g^{(2)}(t)$-function.

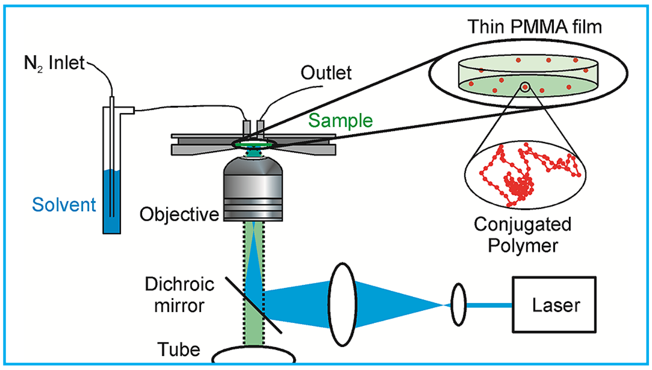

Figure 1: Setup for coupling single NV-centers to WGMs of a polystyrene microsphere. The SNOM can be exchanged by an AFM.

Coupling a single NV center to a polystyrene sphere

The typical spectrum of a NV center is presented in Fig. 2 a taken with the Acton spectrograph in combination with the Andor iDus. The inset shows the corresponding measured $g^{(2)}(t)$-function of the NV center. The pronounced dip at $t = 0$ below 0.5 proves the single-photon characteristic of the NV center and is called anti-bunching.

Then, with the help of the SNOM tip, a microsphere can be lifted and be brought in the vicinity of the NV center. This is done by shining white light from above and exciting the NV center. Both the white light shadow pattern of the polystytrene sphere and the single photon emission can be imaged simultaneously on the

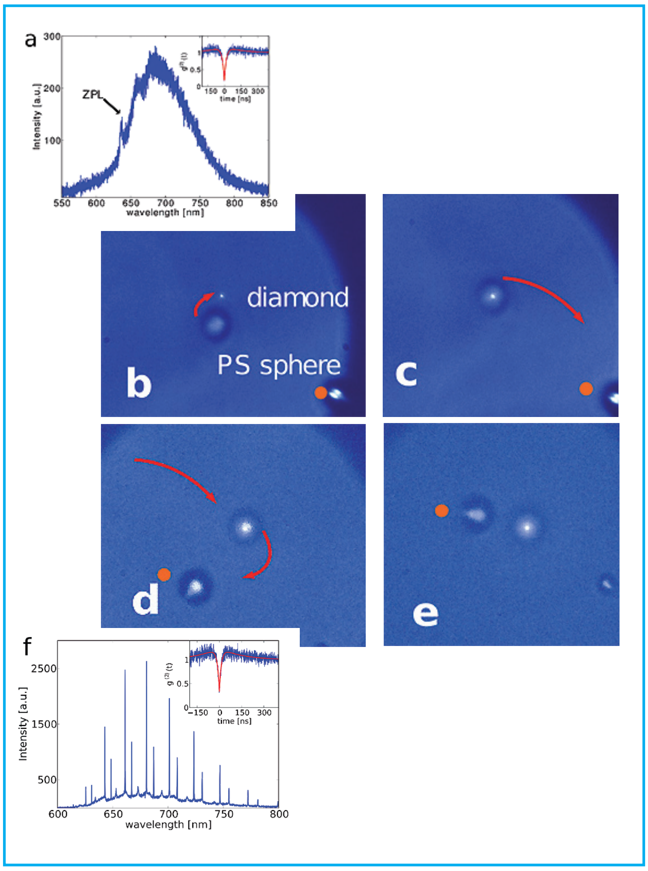

Figure 2:
a) Spectrum of a single NV center in a nanodiamond on the coverslip. The inset shows the pronounced anti-bunching.
b) to e) With the iXon EMCCD we can see both the NV center fluorescence emission and the microsphere. The sphere is placed directly above the NV center (b) and brought into full contact with the coverslip. The nanodiamond is attached and the coupled NV center – microsphere system can be moved around. The red dot indicates the same position on the sample in all pictures.
f) The fluorescence spectrum of the same emitter as in a).
The resonances due to the WGMs are clearly visible.

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iXon (see Fig. 2 b), a main requirement to position the sphere directly above the nanodiamond (see Fig. 2 c). Then the sphere is brought in full contact with the sample to attach the nanodiamond. This changes dramatically the spectrum of its emission as shown in Fig. 2 f. The resonances of the WGMs are clearly visible, while the anti-bunching dip remains well below 0.5.

It is worth mentioning that a pre-characterization of the spheres in respect to the spectral position of their resonances is possible and the method itself can be extended to more emitters and spheres which allows to build up more complex systems in the future.

Conclusion
The controlled assembly of nanophotonic devices will gain more and more relevance in the future. For this purposes, a camera like the Andor EMCCD camera iXon with its single-emitter sensitivity and wide dynamic is a necessity to have direct optical control during the assembly.

Literature

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