



THESIS DEFENSE: Deterministic control of nanoantenna and single-photon emitter interaction at the nanoscale

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March 24, 2021

15:00 to 17:30

Online (Teams) and ICFO Auditorium

The study of light-matter interaction at the nanoscale is a very promising field of research, providing the possibility to manipulate the interaction with single quantum systems like single atoms, molecules, atomic defects or quantum dots, systems that can emit one photon at a time, so-called single-photon emitters (SPEs). From the fundamental point of view, light-matter interaction at the nanoscale allows the exploration of the ultrascale, providing superresolution and decomposition of the ensemble. From the applied point of view, it offers the possibility to manipulate SPEs and control their optical properties for important applications in the field of ultrasensitive detectors development and quantum

communications.

Yet, the ultrasmall SPEs have a relatively small absorption cross-section, making their interaction with light quite weak. In fact, even in a tight excitation focus at room temperature they only absorb one photon over ten million. Additionally, in many cases such emitters have a low quantum efficiency, making them hard to detect. Furthermore, in many cases, they are optically quite fragile and tend to blink and bleach, thus no high illumination powers can be used in order to increase their emission of light.

Fortunately, nanoantennas allow to confine light well below the diffraction limit, and through efficient coupling can increase the effective absorption cross-section of SPEs, allowing effective excitation and high-resolution imaging. Moreover, nanoantennas coupled to SPEs modify the local mode density, shortening the emitters excited state lifetime, increasing the internal quantum efficiency, resulting in bright SPEs.

In this thesis, we study the interaction of light and matter at the nanoscale through deterministic coupling between a SPE and a nanoantenna, using nanometer scale control. We use scanning probe technology to scan a single nanoantenna in close proximity to a single emitter. First, we show a novel near-field probe based on a dipolar nanoantenna design that provides a higher optical and topographical resolution compared to the state-of-the-art.

Next, we apply such novel antenna probes to the study of recently discovered single atomic defects in hBN, ultrastable SPEs in an atomically thin layer, ideal for nanoscale control.

Despite the hBN high refractive index, and the low absorption cross-section of the defect, we provide high-resolution imaging of single hBN emission centers, enhanced by the hot-spot of our antenna probe. The controlled interaction is demonstrated by lifetime mapping, showing a shorter lifetime for the coupled emitter-antenna case. Finally, we develop a novel light confinement mechanism based on local subwavelength field suppression by near field interference: generating $i\frac{1}{2}$ cold $i\frac{1}{2}$ spots. We obtain such dark spots by antenna phase engineering through length control. We image optically for the first time and with high resolution the cold spots, and measure fluorescence lifetime reduction, inhibition of emission for the coupled system, despite the losses of the metallic nanoantenna. Such low-intensity sub-wavelength dark spots provide novel tools for high-resolution imaging of SPEs with ultralow intensity and a nanoscaling of advanced super-resolution techniques like MINFLUX.

Members of the Committee:

PRESIDENT Costanza Toninelli, LENS Institute - Universita degli Studi di Firenze

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MEMBER Martin Frimmer, ETH Zürich

Due to recommendations in place to contribute containing the spreading of COVID-19, th

defence will be carried out semi presencial with a maximum of 66 Icfonians in the Auditorium, and partly remotely via MS Teams. This is the link to follow the Thesis Defence online [Click here to join the meeting](#)

If you are interested in attending in person, please address your request to mery.gil@icfo.eu by Monday March 22nd .

Hosted by: Prof Dr Niek van Hulst