



ICFO Colloquium NATHALIE DE LEON 'Engineering Coherent Defects in Diamond'

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February 11, 2020

Tuesday, February 11, 2020, 12:00. ICFO Auditorium

NATHALIE DE LEON

Assistant Professor of Electrical Engineering

Princeton University \$\$Nathalie de Leon is assistant professor of Electrical Engineering at Princeton University. She earned her Ph.D. from Harvard University in 2011 and B.S. from Stanford University in 2004. Her awards and recognition include: DOE Early Career Award (2018), DARPA Young Faculty Award (2018), NSF CAREER Award (2018), Sloan Research Fellow in Physics (2017), and Air Force Office of Scientific Research Young Investigator (2017).

The de Leon group is focused on building quantum hardware with color centers in wide bandgap materials, such as NV centers in diamond. These color centers act as artificial atoms

in the solid state, and can have remarkable optical and spin properties. We aim to explore fundamental device physics, materials engineering, and nanophotonics to gain full control over color centers to build them into scalable quantum devices, with the large-scale technological goals of realizing quantum networks and nanoscale sensors. Complementarily, we will search for new color centers for applications in quantum information processing and quantum sensing. In the near term, this toolkit will enable the exploration of fundamental quantum optics, magnetic interactions, and many body physics. Our lab is highly interdisciplinary, spanning optics and photonics, surface science and materials engineering, atomic and molecular spectroscopy, nanofabrication, and cryogenics.

Engineering coherent systems is a central goal of quantum science and quantum information processing. Point defects in diamond known as color centers are a promising physical platform. As atom-like systems, they can exhibit excellent spin coherence and can be manipulated with light. As solid-state defects, they can be produced at high densities and incorporated into scalable devices. Diamond is a uniquely excellent host: it has a large band gap, can be synthesized with sub-ppb impurity concentrations, and can be isotopically purified to eliminate magnetic noise from nuclear spins. Specifically, the nitrogen vacancy (NV) center has been used to demonstrate basic building blocks of quantum networks and quantum computers, and has been demonstrated to be a highly sensitive, non-invasive magnetic probe capable of resolving the magnetic field of a single electron spin with nanometer spatial resolution. However, realizing the full potential of these systems requires the ability to both understand and manipulate diamond as a material. I will present two recent results that demonstrate how carefully tailoring the diamond host can open new opportunities in quantum science.

First, currently-known color centers either exhibit long spin coherence times or efficient, coherent optical transitions, but not both. We have developed new methods to control the diamond Fermi level in order to stabilize a new color center, the neutral charge state of the silicon vacancy (SiV) center. This center exhibits both the excellent optical properties of the negatively charged SiV center and the long spin coherence times of the NV center, making it a promising candidate for applications as a single atom quantum memory for long distance quantum communication. Our approach for systematically engineering new color centers in diamond is generalizable to a broader search for quantum defects in many material systems. I will also describe our recent efforts to develop a materials discovery pipeline for rapid screening of new host materials and new defects, including nuclear-spin-free host materials for Er³⁺, a promising system for quantum networks.

Second, color centers placed close to the diamond surface can have strong interactions with molecules and materials external to the diamond, which makes them promising for nanoscale sensing and imaging. However, uncontrolled surface termination and contamination can degrade the color center properties and give rise to noise that obscures the signal of interest. I will describe our recent efforts to stabilize shallow NV centers within 5 nm of the surface using new surface processing and termination techniques. Specifically, we are able to demonstrate reversible and reproducible control over the top layer of atoms. These highly coherent, shallow NV centers will provide a platform for sensing and imaging down to the scale of single atoms.

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