QSTAR is the MPQ, LENS, IIT, UniFi joint center for Quantum Science and Technology in Arcetri

Monday 1st October 15:00 Aula Querzoli (LENS) I QSTAR/LENS Seminar

Paola Cappellaro: **Quantum Sensors at the Nano-Scale**

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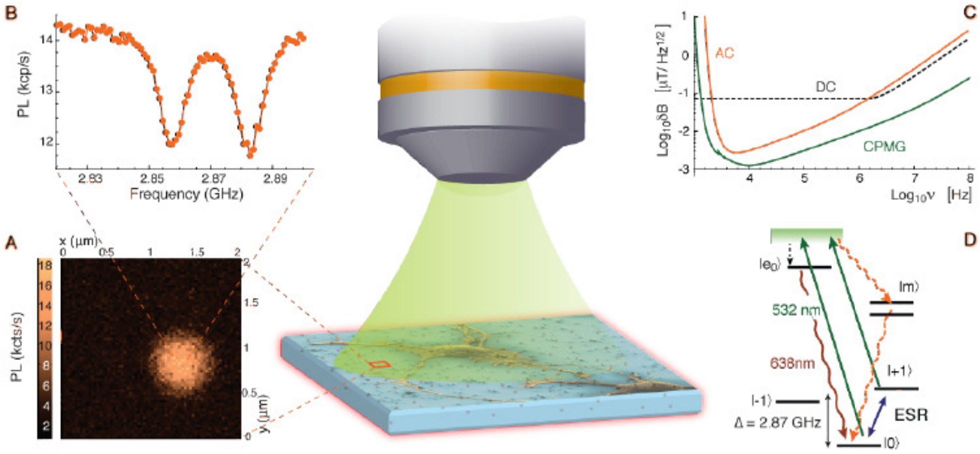
Quantum mechanics governs physical phenomena. Yet, classical laws describe objects and devices we use in everyday life. Where does the practical boundary between quantum and classical world lie? More importantly, what benefits would we obtain if we could push this boundary closer to the scales of human devices? Improving the control over quantum systems while understanding the mechanisms that destroy their quantumness holds the keys to answering these questions and would lead to the development of quantum devices, such as computers and simulators, that can outperform their classical counterparts.

A particularly promising application of quantum devices is in precision sensing. Solid-state quantum sensors may enable unprecedented combination of sensitivity and spatial resolution at the nano scale. A major breakthrough has been our proposal to use Nitrogen-Vacancy (NV) centers in diamond as magnetic field sensors [1]. The NV consists of a single electronic spin that can be polarized and read out optically and controlled by magnetic resonance techniques. NV centers can be used for magnetic field imaging in ensembles, as magnetic scanning tips or even as fluorescent bio-markers in-vivo, sensitive to local magnetic fields.

A NV-based magnetometer could sense individual electronic and nuclear spins in biological specimens and allow unraveling molecular structure and functionality at the single bio-molecule level. NV ensembles could detect magnetic fields generated by ionic activity in complex neuronal networks, which could lead to breakthroughs in understanding how microscopic connectivity affects macroscopic, whole brain functions.

In this talk I will describe strategies to address major challenges that hinder these quantum sensors from reaching their full potential: the fragility of entangled states [2], decoherence [3] and inefficient readout [4].



***Diamond-based magnetometer for in-vivo detection of neuronal activity**: Center image: schematic of the NV-magnetometer used to sense a neuronal network. A: confocal image of a single NV. B: optically detected magnetic resonance of a single NV, showing transitions to the ms=1 levels. The energy levels involved in the magnetometry scheme are shown in D, while panel C shows the sensitivity achievable by a single-NV magnetometer for constant (DC) or AC magnetic field. Quantum control techniques we proposed considerably improve the sensitivity (CPMG).*

References

[1] J. M. Taylor, P. Cappellaro, et al., Nature Physics 4, 810-816 (2008).
[2] P. Cappellaro, et al., Phys. Rev A 85, 032336 (2012); P. Cappellaro & M. Lukin, Phys. Rev. A. 80, 032311 (2009)
[3] N. Bar-Gill, et al., Nature Comm. 3, 858 (2012)
[4] P. Cappellaro, Phys. Rev. A 85, 030301(R) (2012)