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Spins in InAs Quantum Dots: Qubits, Sensors, and Photon Sources

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ABSTRACT

Over the past few decades a number of exciting applications of quantum coherence and entanglement have been developed that promise fundamental improvements in a variety of areas, including computing, secure communications, metrology, and sensing. A team of scientists at the Naval Research Laboratory have been working for many years to develop a physical implementation for these quantum information applications using semiconductor indium arsenide quantum dots. This system has the advantages of a robust solid state host, strong optical transitions, mature device fabrication, engineerable properties, and a scalable, monolithic architecture. A single electron or hole spin within a quantum dot acts as a stationary quantum bit that can be optically controlled on a picosecond timescale. In this presentation, I will discuss how a spin in a quantum dot or in a pair of coupled quantum dots can also be used for sensing mechanical motion and for generating tunable single photons. To sense motion, quantum dots have been incorporated into mechanical resonators, which couple to the dots through strain. When mechanical resonators are driven, the optical transitions of QDs shift significantly, and the spin states shift as well, particularly the hole spins. To generate photons, we make use of Raman spin-flip processes (1,2) which have the advantage of generating photons with properties determined by the drive laser and the spin properties. In this way, we are able to demonstrate spectral and temporal control over single photon wave packets.

1. Sweeney, T. M. et al. Cavity-stimulated Raman emission from a single quantum dot spin. Nat. Photonics 8, 442–447 (2014).
2. Vora, P. M. et al. Spin–cavity interactions between a quantum dot molecule and a photonic crystal cavity. Nat. Commun. 6, 1–9(2015).

BIO:

Dr. Samuel G. Carter is an experimentalist in the area of condensed matter physics with interests in semiconductor quantum dots, defect spins in solids, ultrafast coherent control, and quantum information science. He received his Ph.D. in Physics in 2004 at the University of California, Santa Barbara, working with Professor Mark Sherwin on terahertz-driven quantum wells. After postdoctoral studies at NIST and the University of Colorado, Boulder with Professor Steve Cundiff on ultrafast spectroscopy, he joined the Naval Research Laboratory in Washington, DC in 2007. There, he works on developing solid state implementations for quantum information science and technology.