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Effects of Strain on the Optical Properties of Quantum Dot Molecules

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ABSTRACT

The application of quantum mechanics provides the most precise measurements of physical phenomena ever devised. As an example, the atomic clock only loses one second of time per one hundred billion years. This is made possible by the extraordinarily long coherence times of the super cold atoms involved in the measurement. It is this very precision that makes quantum mechanical techniques highly coveted in the field of metrology. The drawbacks to atomic clocks are their large size, expense, and lack of scalability. A more readily scalable architecture is required to mass produce sensors of this type; epitaxial semiconductor quantum dots (QDs) provide such a scalable architecture. QDs are nanoscale semiconducting crystals that behave more like a single atom than like bulk material. Due to their atom-like nature, it becomes possible to controllably study quantum effects in a solid-state architecture, which allows for straightforward incorporation into conventional electronic devices. QDs are a promising candidate for solid-state sensors due to their long charge and spin state coherence times. A recent study has shown that single particle charge and even spin states in QDs embedded in mechanical resonators couple to the mechanical motion of their local environment through the deformation potential. This realization allows for the measurement of classical motion via a quantum mechanical system. Until now, only spectral shifts have been quantified, leaving unknown the amplitudes of the mechanical motion inducing such shifts. In the Quantum Matter Group at UC Merced, we have developed a technique to quantify the strain-induced spectral shifts of the charge and spin states in QDs using nanoindentation atomic force microscopy in concert with photoluminescence (PL) spectroscopy. Our initial strain-shifted PL measurements indicate a spectral shift of 3 meV, readily resolved by standard spectroscopic techniques. Further experiments aim to quantify the displacement, force, and strain imposed on the QDs to obtain a better understanding of the system's sensitivity to such effects. In addition to the overall spectral shifts, other optical properties such as linewidth or fine structure can be monitored under the application of strain. The ability to spectrally shift charge and spin states in QDs via strain opens the door to novel techniques of sensing classical motion with quantum mechanical precision.

BIO:

Joshua Casara is a doctoral candidate in the physics department at University of California Merced. He is one of the recipients of the 2017-2018 President's Dissertation Year Fellowship. His research interests lie in the area of semiconductor optics, with a focus on epitaxial quantum dots. More specifically his work examines the effects of strain on the optical properties of quantum dots.