Mechanically induced sidebands on the fluorescence of single InAs quantum dots

Mechanical oscillators with dimensions below a micrometer are attractive candidates for observing and controlling quantum phenomena within fabricated systems. Sensing such systems optically, however, is a challenge, as they are smaller than the wavelength of light. A proposed solution to this difficulty is to embed a self-assembled quantum dot, acting as an "artificial atom," inside the oscillator. Theoretical studies predict that these quantum dots can be fast, sensitive probes of the motion of nanomechanical systems. In addition to monitoring nanomechanical motion, an embedded quantum dot should in principle enable a nanomechanical oscillator to be laser-cooled to its quantum ground state.

For laser cooling and quantum control, it is desirable to work in the "resolved sideband" regime, in which high frequency mechanical motion induces sidebands on the fluorescence spectrum of a quantum dot. These sidebands correspond to the absorption or emission of mechanical quanta. We have resolved the motional sidebands in quantum dot fluorescence for the first time. For these studies, in order to simulate the motion of a nanomechanical oscillator, we have fabricated thin film metallic interdigitated transducer (IDT) electrodes on chip, using the NIST nanofabrication facility. These electrodes are used to generate surface acoustic waves (SAWs), which "shake" our sample of quantum dots.

The accompanying figure is a simplified illustration of our experiment. Laser light is coupled via a fiber into a homemade cryostat at 4 Kelvin, where it excites quantum dots grown by molecular-beam epitaxy on a gallium arsenide substrate. The SAW, generated by means of the IDT electrodes, "shakes" the quantum dots at a frequency of 1 GHz. Fluorescence from the quantum dot is collected with the same optics used to excite it, and analyzed spectrally with a high-resolution homemade Fabry-Perot interferometer in conjunction with a grating spectrometer (not shown). The blue curve shows the fluorescence spectrum of a single quantum dot in the absence of mechanical excitation. The red curve shows the spectrum when a SAW is applied; motional sidebands appear, and the strength of the original fluorescence peak is greatly reduced. By raising the SAW amplitude still further, we can nearly extinguish the original peak, as well as excite sidebands of higher order.

The next phase of this work is to fabricate actual nanomechanical resonators with embedded quantum dots, observe their thermal motion, and attempt laser cooling. Another application of this work that we will pursue is to use the SAW to generate entangled photon pairs from the biexciton fluorescence of individual quantum dots.

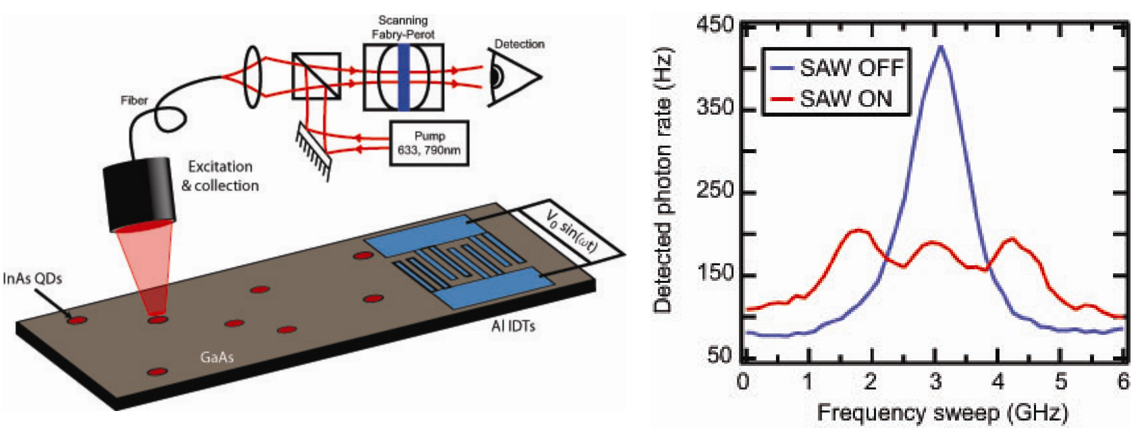

Figure 3.2**: Left**: Schematic diagram of apparatus used to "shake" a self-assembled quantum dot and resolve the fluorescence. **Right**: Fluorescence spectrum of quantum dot (blue curve) acquires resolved sidebands (red curve) when "shaken" by surface acoustic wave.

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