Optical properties of single quantum dots in nanopillars

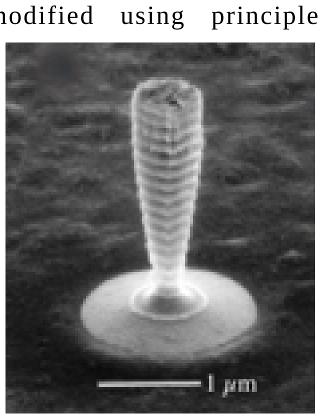
G. S. Solomon*

Department of Electrical Engineering
Stanford University
76 South Ginzton Laboratory
Stanford, CA 94305-4085
Solomon@stanford.edu

Through optical pumping of single quantum dots (QDs), aspects of the discrete electronic structure can be probed. And, while analogies to atomic systems can be made, they can be limited. In addition to investigating such fundamental issues, the optical pumping of single QDs is a useful structure for a variety of device applications including low power, high coupling efficiency light sources, quantum key distribution and perhaps quantum computing. In the context of these two topics, I will discuss our results using InAs QDs isolated in nanopillars of GaAs, and GaAs/AlAs. An inhomogeneously broadened ensemble of QDs is formed without lithography through lattice mismatch strain. Single QDs are then isolated using lithography to form nanopillars. The nanopillars contain a reduced number of QDs and may be individually probed.

Using the nanopillars, the emission spectrum from the QDs can be explored as a function of exciton filling near the ground state of the QD, where the exciton filling is controlled by pump power. Many particle interactions are immediately clear leading to state filling that is generally discrete, but different from the simple atomic-like picture. Because of these effects and finite exciton decay rates, the statistics of the spontaneous emission is significantly altered.

In conjunction with a planar semiconductor microcavity, the nanopillar can be made into a three-dimensional cavity. The nanopillar is now composed of AlAs/GaAs mirror pairs and a one-way length cavity region containing QDs. A SEM image of such a nanopillar cavity is shown below. Here the layered contrast is due to the AlAs and GaAs upper mirror pairs. The properties of the vacuum field in the cavity are modified using principles of cavity quantum electrodynamics (cavity QED). This is initially observed using a planar microcavity before the pillar is defined, where a continuous distribution of modes is present from the cutoff wavelength to the stopband edge. In the nanopillar cavity, the continuous mode distribution becomes discrete. Inhibited and enhanced spontaneous emission of individual QDs in the nanopillar can now observed within the discrete electromagnetic cavity mode. This structure is a promising candidate for a high efficiency, single photon-light source.



* In collaboration with M. Pelton, C. Santori, and Y. Yamamto. The work is supported by JST and ARO.