'Squeezing' light into quantum dots

April 1 2009, By Miranda Marquit

(PhysOrg.com) -- "Quantum wells have been instrumental in telecommunications, enabling light amplification," Patanjali Kambhampati tells *PhysOrg.com*, "but theory has suggested that a very small - colloidal - quantum dot could amplify light even better than a quantum well. There have been problems, however, in getting lasers to work properly with colloidal quantum dots, so focus has shifted to other types of structures."

Now, though, that view has changed. Kambhampati says that he and his colleagues at McGill University in Montreal, Quebec, Canada have figured out how to train lasers to properly drive a quantum dot so that light amplification is in line with theories developed years ago. Ryan Cooney, Samuel Sewall, D.M. Sagar and Kambhampati present the results of their experiment in Physical Review Letters: "Gain Control in Semiconductor Quantum Dots via State-Resolved Optical Pumping."

"We figured that if you took the quantum dot that most had given up on," continues Kambhampati, "that we could figure out why it wasn't working as predicted, and try to determine what went wrong. We found out that it was all in the way that experiments were done. By virtue of the available driving lasers, previous experiments were coincidentally done under conditions that were actually best for blocking the useful amplification process. Quantum dots may actually be more useful for light amplification than previously imagined. They have the potential to be very powerful."

Kambhampati and his peers discovered that the clue to getting the quantum dots to properly amplify light was in the color of the laser light used to power the dot. “Each quantum dot is different,” Kambhampati explains. “Everything absorbs different colors of light, and that is true of quantum dots. We found that you have to know which colors works for which dots. Certain colors will produce amplification as theoretically predicted. The color of the laser being used to pump the dot is one of the most important factors.”

Once you know that information, it is possible to use the laser to drive the quantum dot appropriately. The Montreal group “trained” their lasers to find the correct color in order to pump the quantum dot in such a manner as to amplify the light. In this manner, they were able to stimulate emission in quantum dots using specific interactions. The way that these quantum dots are pumped, “squeezing” light into the box-like structure, makes a big difference in the output seen.

Even though Kambhampati can see uses for such light amplifiers down the road - especially in terms of fiber optics and long-distance telecommunications, he acknowledges that there are some fairly significant hurdles to overcome. The first problem is that right now the lasers used to drive the dots are prohibitively expensive for commercial use. “Telecom companies don’t have the same scientific lasers that we have to produce different colors. The eventual goal is to be able to make small, cheap practical lasers that can be used commercially.” He says that there are already efforts underway to figure out how to fine tune lasers to work in this manner, but “sometimes there is a long path from science to engineering to manufacturing.”

Kambhampati remains hopeful, however. And he also points out that there are some other interesting things to learn on a fundamental from this experiment. “We saw some things that no one has seen before - things not seen in a quantum well.” In addition to long-term commercial uses, it is possible that this experiment could help other investigations dealing with extremely short pulses, or that require an efficient white light source.

"Really, this is just the beginning. A number of interesting ideas, fundamentally and practically, may come out of this ability to control the output of a quantum dot."

More information: Ryan R. Cooney, Samuel L. Sewall, D.M. Sagar, and Patanjali Kambhampati, "Gain Control in Semiconductor Quantum Dots via State-Resolved Optical Pumping." *Physical Review Letters* (2009). Available online: link.aps.org/doi/10.1103/PhysRevLett.102.127404 .