Quantum dots as midinfrared emitters

23 February 2009, By Miranda Marquit

(PhysOrg.com) -- “People are interested in the mid-infrared,” Dan Wasserman tells *PhysOrg.com*. Infrared light has a wavelength longer than visible light, and many molecules have numerous very strong optical resonances in the midinfrared. “Because of this, the midinfrared is an important wavelength range for trace gas sensing applications.” In addition the midinfrared is also of interest for applications such as thermal imaging, countermeasures, and even free space communication.

Right now, much of the work that takes place with regard to emitting light in the mid-infrared range is done with what are known as quantum cascade lasers, complex structures consisting of hundreds of connected quantum wells. Wasserman, a scientist at the University of Massachusetts Lowell, believes that - for some applications at least - indium arsenide (InAs) quantum dots could be used as an alternative to the quantum wells in quantum cascade lasers.

Wasserman, along with his graduate student, Troy Riboudo at Lowell, Prof. Steve Lyon at Princeton University in New Jersey, and Drs. Ken Lyo and Eric Shaner at Sandia National Laboratory in Albuquerque, have developed a device that uses InAs quantum dots as midinfrared emitters. Their work is presented in Applied Physics Letters: “Room temperature midinfrared electroluminescence from InAs quantum dots.”

“One of the main problems with quantum cascade lasers,” Wasserman points out, “is that they emit in a frequency range close to thermal energies. These lasers sometimes make heat instead of light. If you could enhance optical transitions over thermal, then they would be more efficient emitters, since there would be less power going to the heat.”

Wasserman also says that with quantum cascade lasers, the geometry is two dimensional, and that means that emission, without complicated fabrication techniques, comes from the sample edges, rather than the surface. “Our design works similarly to the quantum cascade laser, but since we are growing quantum dots, we are using a 3-D geometry that emits from the surface. This 3-D geometry also makes thermal transitions in the dot less likely, an effect known as the ‘phonon bottleneck’.”

Could a midinfrared light emitter such as Wasserman describes actually replace quantum cascade lasers? “It would presumptuous to think so,” Wasserman insists. “However, there are some cases where this quantum dot device might be more efficient. But I don’t think that this would be an outright replacement. It would just be an alternative for some situations and device requirements.” He points out that nanoscale surface emitters of midinfrared light, such as these quantum dots, would be ideal for an array that could complete lab on a chip applications.

“We still have a ways to go before the quantum dot devices can even approach quantum cascade lasers, though,” Wasserman concedes. “We grew quantum dot samples that were not designed for lasing. As a result, we would need to design a waveguide in order to confine the dot emission and give us gain, and ultimately, lasing in these structures.” He also says that right now the quantum dots are only grown in a single layer. “In order to get the kind of power we would need for lasing applications, we’d need more layers. So we’re looking into that as well.”

“The important thing is that we showed that this is possible. We can design these special structures that work similarly to a quantum cascade laser, but that have the potential to improve on the efficiency in certain situations. We have some room in the design space to play around, and we’ll see where this can go.”

More Information: Wasserman, et. al. “Room temperature midinfrared electroluminescence from InAs quantum dots.” *Applied Physics Letters* (2009). Available online:

link.aip.org/link/?APPLAB/94/061101/1 .