Tunable quantum cascade laser

July 7 2010, By Miranda Marquit

(PhysOrg.com) -- One of the issues associated with lasers is their tunability. In many cases, if you want to produce a particular wavelength, you have to build a laser to accomplish this. In order to get another wavelength, you may have to build a different laser. A tunable laser would provide an opportunity to adjust the wavelength, without the use of another laser. One novel quantum cascade laser design that could achieve this is based on a dual upper state design.

A team at the Central Research Laboratory at Hamamatsu Photonics K.K. in Japan has come up with, and tested, a tunable quantum cascade laser design that demonstrates broad optical gain. Their work is published in *Applied Physics Letters*: "High-performance, homogenous broad-gain quantum cascade lasers based on dual-upper-state design."

"Usually, quantum cascade laser designs have only one upper state, except for superlattice active region," Kazuue Fujita, the lead author on the paper, tells *PhysOrg.com* in an email interview. In this case, though, there is an additional upper state added to the design of the laser. "The additional upper state is created by a first quantum well adjacent to the injection barrier. This state corresponds to a lowest energy state in the first quantum well."

Fujita goes on to explain that the regular upper state, seen in most conventional quantum cascade lasers, is designed to be nearly the same energy at operating condition as the state in the first quantum well. "Electrons are injected into the higher upper state via resonant tunneling from the previous injector. And then, electrons populated in the both

upper states transit from both upper states to a lower state." Both of these transitions contribute to optical gain.

This new laser design would have a number of advantages over current quantum cascade laser designs insists Fujita. This laser design allows for broadband tuning. On top of that, there is weak dependence on voltage by these lasers, and they are not sensitive to temperature change. "Slow efficiency at threshold is observed to be nearly constant over the wide range. Also I-L characteristics show super-linear behavior. These distinctive features have never been observed in a quantum cascade laser so far," Fujita explains. "I think this design concept holds large potentialities."

Fujita says that the design has actually been tested. "We have already fabricated and measured many lasers with the design. The lasers demonstrate very good performances. In addition, high temperature, continuous wave operation of the laser has also been achieved."

In terms of application, Fujita sees a great deal of usefulness, especially in terms of spectroscopy. Trace gas sensing is considered one of the more likely applications, since wide tunability is desired. "The external cavity quantum cascade laser with this design may operate very stable due to its low dependences on voltage and temperature," he says. Due to its tunability, this quantum cascade laser design could also increase the cost efficiency of some applications. "This design can lead to high-performance broadband tuning. Therefore, the laser allows a reduction in the number of lasers in a spectroscopic analysis system."

More information: Kazuue Fujita, Tadataka Edamura, Shinichi Furuta, and Masamichi Yamanishi, "High-performance, homogenous broad-gain quantum cascade lasers based on dual-upper-state design," *Applied Physics Letters* (2010). Available online: link.aip.org/link/APPLAB/v96/i24/p241107/s1