interview

Levon Asryan

"Our work aids the understanding of the physical phenomena that control the output optical power of diode lasers with a low-dimensional active region."

Doctor Levon V. Asryan from Virginia Polytechnic Institute and State University, talks to *Electronics Letters* about the paper 'Evolution of light-current characteristic shape in high-power semiconductor quantum well lasers', page 550.

Tell us about your field of research

Diode lasers, which are also termed laser diodes, injection lasers, or semiconductor lasers, have numerous practical applications, among which are fiber-optic communication systems. In present-day diode lasers, the stimulated emission (the useful optical output) is generated in low-dimensional active regions. While reducing the dimensionality of the active region of injection lasers was proposed some time ago as an efficient tool to improve their operating characteristics, many challenges still exist for such lasers. Among them is the internal optical absorption loss, which consumes generated photons thus reducing the useful optical output of the laser. The effect of internal loss on the light output of semiconductor quantum well lasers is one of the focuses of this Letter.

Light-current characteristic (LCC) is one of the key characteristics of injection lasers. It presents the output optical power as a function of the input injection current. Ideally, this characteristic should be as steep as possible and remain linear with increasing pump current. In diode lasers with a low-dimensional active region, there are always considerable concentrations of electrons and holes in the optical confinement layer (the region wherein the emitted light is confined) in addition to those in the active region. These unwanted charge carriers outside the active region absorb the light generated in the active region. The concentrations of these carriers increase with increasing pump current. Hence more photons are absorbed with increasing pump current. As a result, the output optical power is degraded and the linearity of the LCC is adversely affected. The purpose of our study was to quantify the extent to which the LCC is impacted by the internal loss.

Can you describe the background to the work performed and the advance reported in your *Electronics Letters* paper?

We showed that, in addition to the expected decrease in linearity, roll over of the LCC occurs with increasing injection current in quantum well lasers. More surprisingly, depending on the parameters of the laser structures, the LCC can be two-valued, i.e., at high enough pump currents, there will be two possible values of the output optical power at a given current. We showed how a single-branched LCC evolves into a double-branched LCC with increasing velocity of capture of charge carriers from the optical confinement layer into the active region (quantum well).

Both the phenomena of rolling-over LCC and the existence of the second branch in the LCC present very interesting and important results. The roll-over should be inherent in any diode lasers with a quantum-confined active region. The point is that both factors contributing to rolling-over (the increase in the concentrations of charge carriers outside the quantum-confined active region that occurs with increasing injection current, and the internal absorption of generated light) are inherent in such lasers. As for the second branch in the LCC, with the parameters of a given laser structure, we can predict whether it will be present in that structure. In addition, by tuning the parameters of laser structures, we can transform a single-branched LCC into a double-branched LCC.

What is the significance of this and what challenges did you have to overcome?

Our work aids the understanding of the physical phenomena that control the output optical power of diode lasers with a low-dimensional active region, such as quantum well lasers and quantum dot lasers. In the short term, by controllably changing the parameters of laser structures, the findings of this work will help to improve the linearity of the LCC and hence to increase laser output optical power at a given pump current. In the longer term, provided that controllable transitions between the two branches of the LCC are experimentally feasible, a diode laser offering fast switching between two optical outputs will be possible.

How are you planning to develop this work and what else are you working on now?

We are planning to identify feasible approaches for experimental observation of the second branch in the LCC and for switching between the two branches. We are also currently working on other factors that control the operating characteristics of diode lasers with a low-dimensional active region, such as non-instantaneous capture into the active region and parasitic recombination outside it. Work is also planned on novel types of semiconductor lasers with a quantum-confined active region, such as double tunnelling-injection lasers and lasers with asymmetric barrier layers.

How do you think the field will develop over the next ten years?

Technological advances have allowed us to continuously improve the characteristics of the existing types of diode lasers as well as realise novel semiconductor lasers such as quantum dot lasers. Future research in the field of diode lasers, in our opinion, will be on the development of truly temperature-insensitive, high-speed, and energy-efficient laser diodes for a broad range of applications.

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