Carrier Dynamics and Linewidth Enhancement Factor in Nanostructure-based Semiconductor Diode Lasers

by

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First part of this talk deals with the theoretical study of InAs/InP quantum dot (QD) lasers. Thanks to optimized growth techniques, a high density of uniformly sized InAs QD can be grown on InP(113)B substrates. This talk will review the recent progress toward the understanding of carrier dynamics and device modeling in this system, taking into account materials and nanostructures properties. A complete analysis of the carrier dynamics is first performed by combining time-resolved photoluminescence experiments and a dynamic three-level model, for the ground state (GS), the excited state (ES) and the wetting layer (WL). The observed double laser emission for a particular cavity length is explained by adding photon populations in the cavity with ES and GS resonant energies. Direct carrier injection from the WL to the GS related to the weak carrier confinement in the QD is evidenced. In the final step, this model is extended to GS and ES inhomogeneous broadening by adding multi-population rate equations (MPREM). The almost continuous transition from the GS to the ES as a function of cavity length is then attributed to the large QD GS inhomogeneous broadening comparable to the GS-ES lasing energy difference. Second part of the talk is on the linewidth enhancement factor (\(\alpha_H\)), which is known to influence several fundamental aspects of diode lasers, such as the linewidth, the chirp under current modulation, the mode stability and the occurrence of filamentation. The dramatic variation in the \(\alpha_H\)-factor that has been reported for QD lasers makes them an interesting subject for optical feedback and injection-locking studies. A low \(\alpha_H\)-factor combined with a high damping factor is especially interesting because it should increase the tolerance to optical feedback in these devices and may offer potential advantages for direct modulation. In the particular case of QD lasers, the lasing wavelength can switch from the GS to the ES as the current injection increases meaning that a carrier accumulation occurs in the ES even though lasing in the GS is still occurring. The filling of the ES inevitably enhances the GS \(\alpha_H\)-factor above the laser’s threshold. This strong variation of the GS \(\alpha_H\)-factor has found to produce significant changes in the laser’s dynamics as compared to their QW counterparts.

Frédéric Grillot was born in Versailles (France), on August 22, 1974. He received the M.Sc. from the University of Dijon (1999) and the Ph.D. degree from the University of Besançon (2003). His doctoral research activities were conducted within the optical component research department in Alcatel-Lucent. Along his PhD, Dr. Grillot studied the effects of the optical feedback in semiconductor lasers, and the impact this phenomenon has on optical communication systems for high bite rate transmissions. From 2003 to 2004, he was with the Institut d’Electronique Fondamentale (University of Paris-Sud) where he focused on integrated optics modelling and on Si-based passive devices for optical interconnects. On September 1st 2004, he has been appointed to the Institut National des Sciences Appliquées de Rennes where he is currently working as an Assistant Professor within the Materials and Nanotechnologies department. His main research activities are on advanced laser diodes using new materials like quantum dots for low-cost applications as well as on nonlinear dynamics in semiconductor lasers. From 2008 to 2009 he was also a Visiting Research Professor at the University of New-Mexico (USA) leading research in optoelectronics at the Center for High Technology Materials.

A light lunch will be served following the seminar.