Physics of semiconductor lasers: theory and modeling

Abstract:

At present, there is a wide variety of semiconductor-laser theories and models providing analytical support to a broad range of experiments being performed. The theories and models vary from a simple phenomenological laser theory based on a linear gain approximation to the more sophisticated many-body laser theory that help resolved the longstanding laser lineshape problem.

This short course will survey some of the commonly used analytical tools. An approach will be taken where the starting point is a systematic and consistent quantum mechanical description (done without equations!) of the semiconductor laser medium. With increasingly limiting approximations, one recovers the hierarchy of simpler theories, such as the free-carrier theory and the rate equation model. The process shows the connections between different approaches, clearly identifies ranges of validity and precisely indicates where physical effects such as bandstructure, quantum confinement and many-body interaction enter into the analyses.

Another hope is that by describing semiconductor lasers from the viewpoint of combining input from condensed matter theory and quantum optics, one achieves for physicists and engineers, common ground for discussing underlying physics. In addition to the concepts and theories, there will be presentations of calculations and results involving a variety of optoelectronic systems, e.g., VCSELs, wide-gap group-III nitride compounds, high-speed lasers and slow light optical buffers. Finally, there will be an overview of current theoretical activities, such as the ongoing work on a microscopic quantum-dot laser theory, where the mechanisms and treatment of dephasing effects due to carrier-carrier and carrier-phonon scattering remain under much discussion.

Learning Objectives:

1) Semiconductor laser behaviors at the level of electrons and holes.
2) Bird's eye view of available analytical tools, capabilities and limitations.
3) State-of-the-art microscopic theory and applications.
4) Terminologies to discuss e.g. many-body effects at the level of cocktail-party conversation.

Intended Audience:

This short course is intended for engineers and scientist, students and researchers interested in familiarizing themselves with presently available analytical tools for investigating semiconductor lasers. Comfort with basic quantum mechanics may be helpful. No prior knowledge of many-body physics is necessary. A lack of inhibition to ask questions or provide real time feedback is encouraged for an enjoyable learning experience.

Instructor biography:

Weng Chow works at Sandia National Laboratories, where his primary research interest is in the application of microscopic theory to semiconductor laser development. Some of this work is described in two texts, *Semiconductor-Laser Physics* and *Semiconductor-Laser Fundamentals: Physics of the Gain Materials*. He served on the CLEO semiconductor laser program committee, is an IEEE JQE associate editor, OSA fellow, LEOS distinguished lecturer and recipient of the Dept of Energy, Basic Energy Science and Alexander von Humboldt Senior Scientist Awards.