Physics and modeling of semiconductor lasers

Abstract:

This short course will highlight the insight gained from theoretical studies on the physics governing semiconductor-laser behavior. The discussion will start with a systematic and consistent quantum mechanical description (with more pictures than equations) of a semiconductor laser medium. With different approximations, one produces a hierarchy of theories, ranging from a simple phenomenological theory based on a linear gain approximation to a sophisticated many-body theory that provides significant predictive capability. This course will discuss the connections between different approaches, identifies ranges of validity and indicate where physical effects such as bandstructure, quantum confinement and many-body interaction enter into an analysis.

A hope is that by describing semiconductor lasers from the combined viewpoint of condensed matter theory and laser physics, one achieves for physicists and engineers, common ground for discussing underlying physical mechanisms. In addition to concepts and theories, applications will be presented, using examples ranging from VCSELs to wide-bandgap and quantum-dot lasers. Finally, there will be an overview of ongoing work on quantum-dot laser theory.

A rough outline is as follows:

1) Gain from an electron-hole plasma
   - Free-carrier and many-body effects
   - Collisions and dephasing

2) Semiconductor-laser modeling
   - Coupled/composite cavity lasers
   - High-speed modulation and nonequilibrium carrier dynamics
   - Quantum-dot lasers

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) Terminologies to discuss e.g. many-body effects at the level of cocktail-party conversation.

(Teaching objective: Present semiconductor-laser physics without burdensome mathematical or numerical details.)

Intended Audience:

This short course is intended for engineers and scientist, students and researchers interested finding out what theory tells us about the underlying physical mechanisms affecting semiconductor laser behavior. It is also intended to give an overview of presently available analytical tools. Comfort with undergraduate-level quantum mechanics is 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 and was an IEEE JQE associate editor and LEOS distinguished lecturer. Also, he is OSA and IEEE fellow, and recipient of the Dept of Energy, Basic Energy Science and Alexander von Humboldt Senior Scientist Awards.