**EECS 529**
**Semiconductor Lasers and LEDs**

*Fall 2009; Instructor: P.C. Ku*
*Updated 9/7/09*

**Instructor:** P.C. Ku, 2245 EECS, (734) 764-7134, peicheng@umich.edu
**Lectures:** TTh: 10:30 am – 12 pm at 3433 EECS
**Office Hours:** M 9:30 – 10:30; Tu 12 – 1; W 9:30 – 10:30 at 2245 EECS
**Grading (3 credit hours):**
Regular and mini-project based homework (60%), final exam (30%), class participation (10%)
**Mini Project:**
Part of the homework problems will be assigned as design projects. Teaming may be required. Some projects will require oral presentations (around 10 minutes) in the class.
**Prerequisites:** EECS 429 or Graduate Standing or instructor's approval
**Course website:** CTools / EECS 529 001 F06
**Lecture style:** Primarily using the chalkboard and being supplemented by slides
**Make-up class:** tentatively Fridays 3:30 – 5 if necessary (e.g. for classes originally scheduled for October 6, 8, and 22)

**Required textbook:**
*Physics of Photonic Devices* by Shun-Lien Chuang, 2nd edition, Wiley (2009).

**References:** Readings on research papers and other materials will be assigned in class. Reference books will be placed on reserve in AAEL. A partial list is given at the end of this syllabus.

**Overview:**

In this course, we will give an in-depth overview of modern optoelectronic devices including semiconductor lasers, light-emitting diodes (LEDs), photodetectors, solar cells, and optical modulators. After completing this course, students are expected to gain basic knowledge for R&D careers involving photonic devices.

In this semester, we plan to take a new approach to this course. Over the past ten years, we have witnessed many changes in optoelectronic research and industry. New applications in energy, display and electronic interconnect have emerged. Advances have been seen in the development of new physics, materials and fabrication technologies in the nanoscale. To this end, I plan to teach this course using a different approach. Rather than treating novel topics such as surface plasmonics, photonic crystals, stimulated Raman scattering, and meta-materials as supplementary materials, we will incorporate them in the first place within a unified framework. In this way, new ideas can be stimulated over the course of the semester rather than as afterthoughts. Building upon a previous success, mini-projects will again be provided to strengthen students' understanding and <u>practical</u> design capabilities.

Modern optoelectronic devices leverage the interaction of electrons and photons over a vast range of length and time scales. Hence physical concepts and "languages" describing the electron-photon interaction are indispensible to the understanding and applications of optoelectronic devices. In this course, I will attempt to introduce these topics with the ultimate desire to explain the "concepts" while at the same time keeping the mathematical rigorousness at the graduate level. However, it is <u>not</u> the purpose of this course to substitute formal courses in electromagnetic waves (e.g. EECS 530) and quantum mechanics (e.g. EECS 540), nor is this course intended to require such a formal background from students. Nevertheless, *familiarity with Maxwell's equations and semiconductor pn junctions at the undergraduate level is strongly recommended*.

The following topics will be covered (not necessarily in the following order) in this course:

- Overview of modern optoelectronic devices and their underlying electron-photon interactions
- Basic physical principles governing electron-photon interactions
  - Introductory (non-rigorous) electromagnetic, quantum and statistical mechanics
  - Electrons in free and confined states
  - Photons in free and confined states
  - Electron-photon interaction in semiconductors, dielectrics, metals and meta-materials
  - Phonons – the culprit or not?
- Basic photonic structures
  - Optical waveguides
  - Optical cavities
  - Sub-wavelength structures and meta-materials
- Optical absorption
- Optical amplification
- Design and properties of optoelectronic devices
  - Heterostructures
  - Light-emitting diodes
  - Semiconductor lasers
  - Photodetectors and solar cells
  - Optical modulators
- Fabrication and characterization of optoelectronic devices
  - Overview of technology
  - Thermal management and failure mechanism

**List of References:**


- Physical principles governing electron-photon interactions:
  - C. Klingshirn, *Semiconductor Optics*, 2nd edition, Springer (2005).
  - R. W. Boyd, *Nonlinear Optics*, Academic Press (1992).
- Basic photonic structures:
  - J. D. Joannopoulos et al., *Photonic Crystals*, 2nd edition, Princeton University Press (2008).
- Design and properties of optoelectronic devices:
  - J. Piprek, *Semiconductor Optoelectronic Devices*, Academic Press (2003).
  - E. Fred Schubert, *Light Emitting Diodes*, 2nd edition, Cambridge Press (2006).
  - M. A. Green, *Third Generation Photovoltaics*, Springer (2003).
  - E. Kapon, *Semiconductor Lasers II Materials and Structures*, Academic Press (1999).
  - L. A. Coldren and S. W. Corzine, *Diode Lasers and Photonic Integrated Circuits*, Wiley (1995).
  - P. Bhattacharya, *Semiconductor Optoelectronic Devices*, 2nd edition, Prentice Hall (1997).
- Fabrication and characterization of optoelectronic devices:
  - R. Mickelson et al., *Optoelectronic Packaging*, Wiley (1997).
  - M. Fukuda, *Optical Semiconductor Devices*, Wiley (1999).