ECE 304 - Photonic Devices

Instructors:

This course is taught and directed by Prof. Kent D Choquette. Professor Choquette is an incredibly engaging lecturer. He is constantly relating the course content to topics that students care about such as achieving faster internet speeds and longer smart phone battery life. Professor Choquette leads the Photonic Device Research Group (PDRG) and the focus of his research is vertical cavity service emitting lasers (VCSELs). As of fall 2013, the TA for this course was Tom Fryslie, a PhD candidate in the PDRG.

Prerequisites:

PHYS 214 (University Physics, Quantum Physics) is listed as a prerequisite for this course. The relationship between wavelength, frequency and energy of light comes up repeatedly in this course, so the knowledge gained in PHYS 214 really does come in handy for ECE 304. Although PHYS 213 Thermal Physics is not an official prerequisite, the introduction to semiconductors at the end of PHYS 213 is also useful in ECE 304.

When to Take It:

Taking this course as soon as prerequisites are met will be beneficial if you are interested in lasers, LEDs and communications. Just like ECE 340 (Solid State Electronic Devices), this course builds on the basic understanding of semiconductors from PHYS 213 (University Physics, Thermal Physics). Some knowledge about diffusion of electrons and holes (from PHYS 213), quantum wells and energy (from PHYS 214) will be used in ECE 304. So it will make life easier to have PHYS 213 and PHYS 214 beforehand. However, these concepts will be reviewed at the beginning of the semester before the class goes into semiconductor and photonic devices. This course has up to 50% overlapping content with ECE 340 (Solid State Electronic Devices), and will be easier when the two courses are taken together. Also be aware that as of 2014, this course is only taught in the fall.

Class Content:

This course is mainly about applications of semiconductors in photonic devices. In order to understand how photonic devices work, basic knowledge of semiconductor physics is required. In the beginning, the course content is motivated by discussing numerous applications of photonic devices such as optical fiber, cell phones, cameras, solar cells, etc. After a couple lectures focused on introduction/motivation, the course covers the following topics in detail:

- Interaction between matter and light
  - Formation of energy bands in solids
  - Dielectric materials
  - Semiconductors
- P/N Junctions
  - Charge transport: drift & diffusion
  - Built-in potential
  - Depletion region
  - Energy bands under forward & reverse bias
- Interaction between light and semiconductor
  - Light absorption in semiconductor
  - Light emission by semiconductor
  - Quantum well confinement of charge carriers
- Diode photonic devices
  - Photodetectors - light absorption
  - Solar cells - light absorption
  - Light Emitting Diodes - light emission
- Optical display
  - Emission arrays
  - Spatial light modulators
- Semiconductor lasers
  - Edge emitting lasers
  - VCSELs
- Optical waveguides
  - Cylindrical waveguides
  - Optical fiber properties
- Optical communication
  - Optical links
  - Multiplexing & modulation
The topics are taught with an emphasis on qualitative understanding, which is complemented by quantitative analysis. Topics are taught cumulatively, with later topics building upon previous ones. In particular, the P/N Junction and Band Gap are two topics that virtually all later topics will link back to.

The course is taught primarily via PowerPoint slides. There is no official textbook for the course, but supplementary readings from various sources are posted on the course wiki for each topic.

Work:

Homework: There are 9 homework assignments, each due one week after it is assigned. Most homework assignments require 2-5 hours of work. The homework problems are approximately half quantitative-half qualitative. Even the quantitative questions are designed to stimulate critical thinking about the material (e.g. what assumptions can we reasonably make to simplify this calculation? What conclusions can we draw from this result?). Most of the questions can be answered by referencing the content delivered in lectures (combined with the aforementioned critical thinking), while a few questions are based more on the supplemental readings posted on the course wiki. Seeking guidance from the TA during office hours may occasionally be necessary to complete an assignment and it is certainly always helpful. Sometimes simulations in nano Hub are required for the homework, which makes these assignments more time-consuming. Homework is worth 20% of the course grade.

Class participation / "pop quizzes": Class participation is worth 15% of the final grade. Most (or perhaps all) of this is based on "pop quizzes" that are given on random days throughout the semester. These quizzes only count for attendance—they are not graded for correctness. The quiz questions serve as a check-on-learning for recently covered topics, and students are encouraged to discuss their answers with the people seated around them. The quiz questions along with the homework problems give a good indication of the types of questions to expect on the exams.

Exams: There are three in-class hour exams. Each is worth 15% of the course grade. The final exam is worth 20% of the course grade. All the exams are a mixture of quantitative and qualitative questions. The exams are challenging, but they are written so that time is not an issue.

Life After:

If you have not already taken ECE 340 (Solid State Electronic Devices), that course will build on some of the topics covered in ECE 304. If you are interested in further study of photonic devices, you may want to plan to take ECE 455 (Optical Electronics) and/or ECE 495 (Photonic Device Laboratory) in the future. Also, taking ECE 444 (Theory and Fabrication of Integrated Circuits) after this course will provide a good perspective on fabrication of semiconductor devices.