EE 232 Lightwave Devices
Lecture 1: Overview and Introduction

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Course Information (1)

- **Website**: [www-inst.eecs.berkeley.edu/~ee232/sp16/](http://www-inst.eecs.berkeley.edu/~ee232/sp16/)
  - All lecture notes, homeworks will be posted there
  - HW and exam scores will be posted in bCourses
  - Discussion in Piazza

- **Instructor**:
  - Prof. Ming Wu (511 SDH, wu@eecs)
  - GSI: Seth Fortuna (fortuna@eecs)

- **Lectures**: Tu/TH, 3:30 to 5:00 pm @ 285 Cory
- **Discussion**: Monday 2-3 pm @ 293 Cory
- **OH**: Tue 2-3 @ 511 SDH (tentative)

- **Textbook (on reserve in Eng Lib)**
Course Information (2)

- **Reference Books** (on reserve at Engineering Library)
  - Yariv & Yeh, *Photonics: Optical Electronics in Modern Communications*, Oxford University Press, 2006

- **PREREQUISITES**
  - **EECS 130**: Simple p-n junction, semiconductor physics, concept of energy bands, Fermi levels.
  - **PHYS 137A**: recommended. Basic concept of quantum mechanics, perturbation theory
  - **EECS 117**: recommended. Concept of dielectric waveguide, electromagnetic waves.

Course Information (3)

- **EXAM & GRADES**
  - Homework 10%
  - 2 Midterms 20% + 20%
  - Final Exam 30%
  - Projects 20%

- **Final Exam**
  - Final Exam Group: 20
  - Friday, MAY 13, 2016 7-10P
    (may move to the week before RRR, pending on everybody’s availability)

- **HW/Project policy**
  - Discussion is permitted (and encouraged), but you must do your own HW, including literature search, derivation, or calculation.
Course Information (4)

- Simulation project (part of HW)
  - Lumerical simulation
    - Photonic integrated circuits, Si photonics
    - (New feature this semester, still evolving)
  - Passive optical components
  - Photonic integrated circuits
  - Active optoelectronics (?)

The Nobel Prize in Physics 2000

Zhores I. Alferov, Herbert Kroemer, Jack S. Kilby

The Nobel Prize in Physics 2000 was awarded “for basic work on information and communication technology” with one half jointly to Zhores I. Alferov and Herbert Kroemer “for developing semiconductor heterostructures used in high-speed- and opto-electronics” and the other half to Jack S. Kilby “for his part in the invention of the integrated circuit”.

The Nobel Prize in Physics 2014 was awarded jointly to Isamu Akasaki, Hiroshi Amano and Shuji Nakamura "for the invention of efficient blue light-emitting diodes which has enabled bright and energy-saving white light sources".

Common Optoelectronic Components
Optoelectronics Market Segment

- Flat panel displays
  - PC, Tablet, TV, mobile devices, head-mount displays
- High brightness LEDs
  - Solid state lighting, large display panels, automotive applications, LCD backlighting
- Imaging array sensors
  - Digital cameras
- Diode lasers
  - Data communications and telecommunications
  - Computer mice
  - High power laser pumping source
- Renewable energy
  - Solar cells

Next decade in optoelectronics

Combined OE components and enabled products

2004-16 CAGR 11%

Global optoelectronics 10yr forecast for components and enabled products

Is this a $T industry?
Next decade optoelectronics segments

Strong consumer/entertainment drivers

Displays grow more slowly

Japanese future vision

Prospects of OE World Market (billion USD)

AAGR: average annual growth rate

OITDA expects $1T OE business
Photonic Integrated Circuits (PIC) for Telecommunication Networks

Silicon Photonic Links

Courtesy of Intel Corp.
Who’s Driving the Growth of Photonic Devices?

Facebook example
- 1.45 billion monthly users @ 12.8% Y/Y
- 1.25 b mobile users
- 10b photo uploaded every month
- 2b photos shared daily across Facebook, Instagram, WhatsApp
- 3b video views daily on Facebook

Young people are driving the growth of internet → datacenters → photonics

Internet and Data Centers
Every 60 Seconds
- 204 MILLION Emails
- 5 MILLION Google Searches
- 1.8 MILLION “Likes”

Global Data Center IP Traffic Growth
3 X in 5 years

Data Center Traffic (2019)
Within Data Center 73.1%
**Generic Intra-Datcenter Network Model**

**Intra-DC Network Pain Points (Physical Layer):**
- Total Cost of Ownership (Switches+Optics)
- Scalability: oversubscription in upper network layers, workload fragmentation, resilience, ...
- Infrastructure, cabling, ...

**Data Centers come in all sizes. Just a few racks ... to largest ones in the world: ~ 1 million square feet, ~ 100,000 servers.**

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**InGaN (405nm) for Optical Storage**

**CD**
- Wavelength: \(\lambda = 780 \text{ nm}\)
- NA = 0.46
- 1.2-mm Substrate
- 0.78 for 1H digital Audio

**DVD**
- Wavelength: \(\lambda = 660 \text{ nm}\)
- NA = 0.6
- 0.6-mm Substrate
- 4.7GB for SD MPEG2 135 min.

**Blu-ray disc**
- Wavelength: \(\lambda = 405 \text{ nm}\)
- NA = 0.85
- 0.1-mm Conner Layer
- 23GB for HD MPEG2 2 hours

Evolution of LED Materials/Performances

Packaged LEDs

Figure 3.24: BB LED Cross Section

Figure 3.25: A High Power BB LED Cross Section—Note the Heat Sink Size
HB-LED Technology

AlGaN flip-chip (Lumiled)

AlGaInP/GaP truncated inverted pyramid (Lumiled)

AlInGaN flip-chip (Lumiled)

AlInGaN micro mirror (Osram), AlInGaN patterned substrate and mesh electrode (Nichia)

Source: Lumileds

Applications of HBLEDs

Traffic Signals (inc white)

Outdoor lighting scenarios

Furniture Lighting

Architectural lighting

Source: http://www.northamericanlighting.com

Source: Wustlich Design AG

Source: http://www.northamericanlighting.com
3D Imaging: Velodyne LiDAR

Google unveils self-driving car

Google has begun building a fleet of experimental electric-powered cars that will have a stop-go button but no controls, steering wheel or pedals. Google claims that the two-seater vehicle will revolutionise transport by making roads safer, and decrease congestion and pollution.

1. GPS receiver
   Matches position with customised version of Google’s road maps

2. Laser range finder
   Rotating sensor scans 180m distance through 360° to generate 3D map of surroundings

3. Video camera
   Identifies other road users, lane markers and traffic signals

4. Radars
   Located at front and rear, detect proximity of obstacles

Speed: Limited to 40km/h to help ensure safety

Engine: 160km-range electric motor – equivalent to one used by Fiat’s 500e

Windscreen: Flexible plastic designed to reduce injuries

Front: Foam-like material minimises impact in case of crash

Car would be summoned with smartphone application

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