



EE 232 Lightwave Devices Lecture 1: Overview and Introduction

Instructor: Ming C. Wu

University of California, Berkeley
Electrical Engineering and Computer Sciences Dept.

EE232 Lecture 1-1

Prof. Ming Wu



Course Information (1)

- **Website:** 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)**
 - S.L. Chuang, *Physics of Photonic Devices*, 2nd Edition, John Wiley and Sons, 2009

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Course Information (2)

- **Reference Books** (on reserve at Engineering Library)
 - Yariv & Yeh, *Photonics: Optical Electronics in Modern Communications*, Oxford University Press, 2006
 - L A Coldren; S W Corzine; Milan Mashanovitch, *Diode Lasers and Photonic Integrated Circuits*, John Wiley & Sons, 2012
 - Saleh & Teich, *Fundamentals of Photonics*, 2nd Ed. Wiley, 2007
- **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.

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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.

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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 (?)

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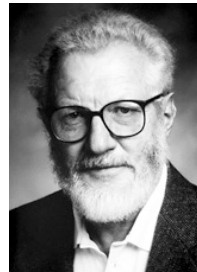
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The Nobel Prize in Physics 2000



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".

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The Nobel Prize in Physics 20



Isamu Akasaki



Hiroshi Amano



Shuji Nakamura

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"*.

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Common Optoelectronic Components



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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

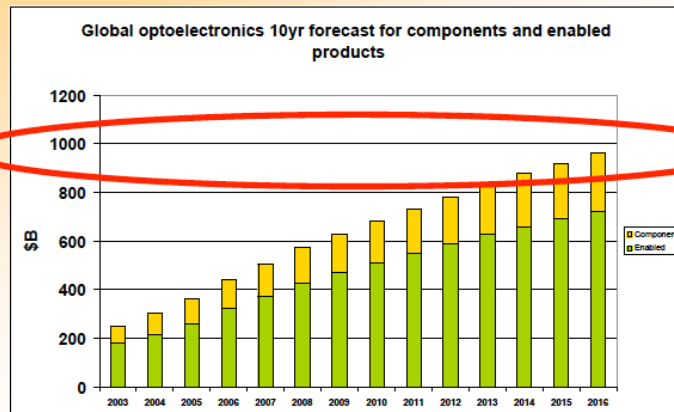
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Next decade in optoelectronics

n Combined OE components and enabled products

• 2004-16 CAGR 11%



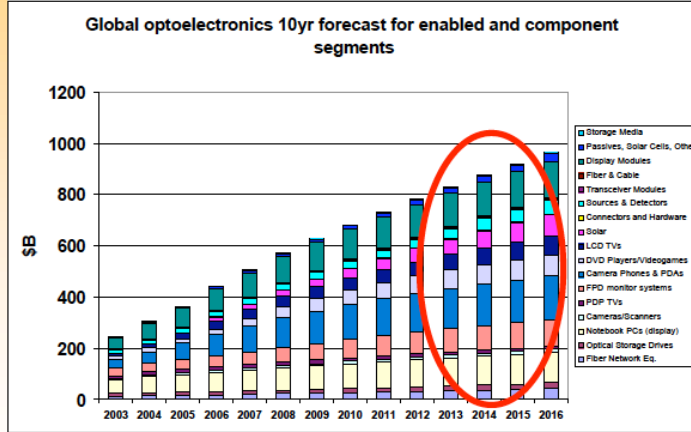
Michael Lebbby (lebbby@oida.org)



Is this a \$T industry?

Next decade optoelectronics segments

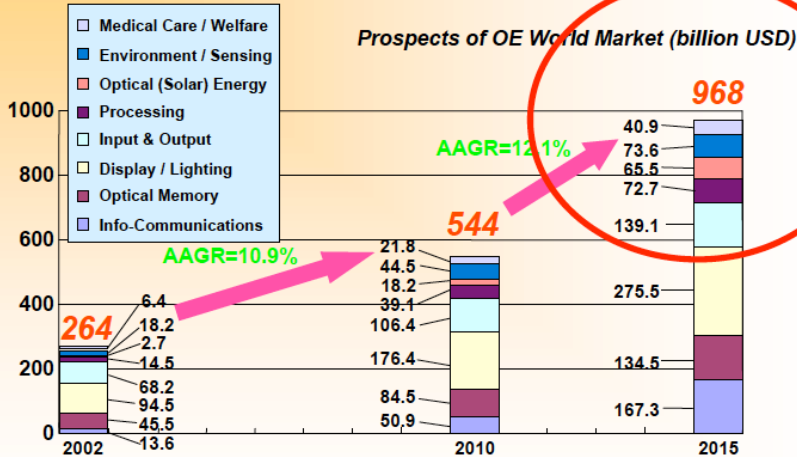
Strong consumer/entertainment drivers



Michael Lebbby (lebbby@oida.org)

Displays grow more slowly

Japanese future vision



Source: <http://www.oida.or.jp/main/syouri04-.html>

[1 USD=110 JPY]

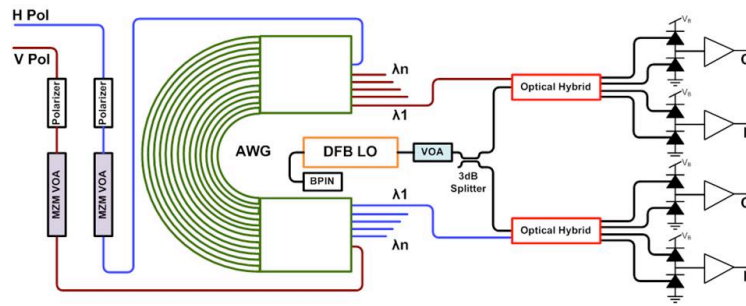
AAGR: average annual growth rate

Michael Lebbby (lebbby@oida.org)

OITDA expects \$1T OE business



Photonic Integrated Circuits (PIC) for Telecommunication Networks



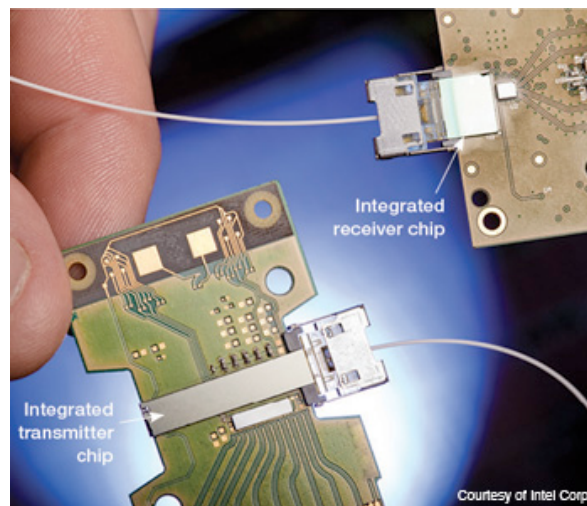
Infinera

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Silicon Photonic Links



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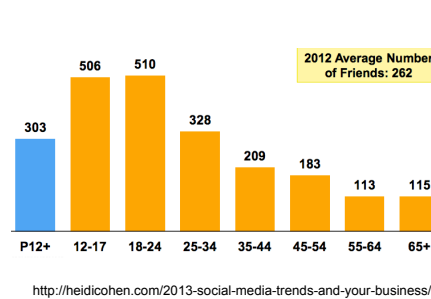
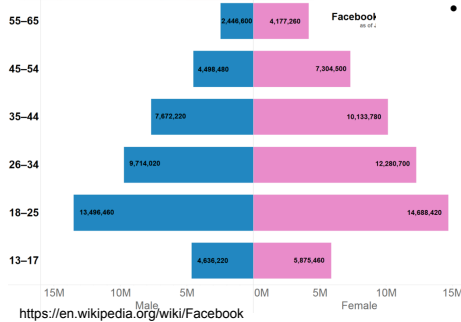


Who's Driving the Growth of Photonic Devices?



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
- 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

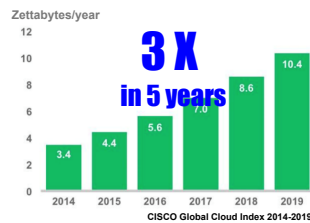
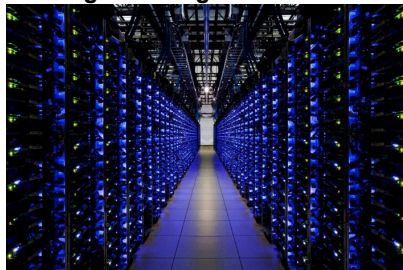
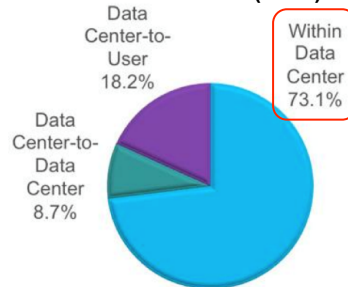


Image of Google Data Center



<http://www.google.com/about/datacenters/gallery>

Data Center Traffic (2019)

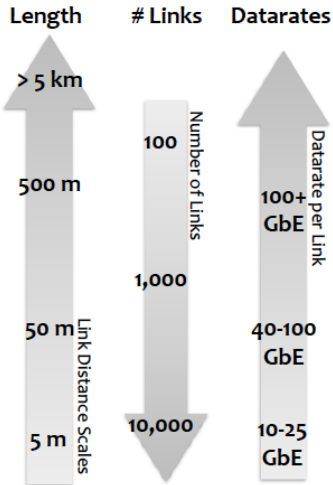


Generic Intra-Datacenter Network Model



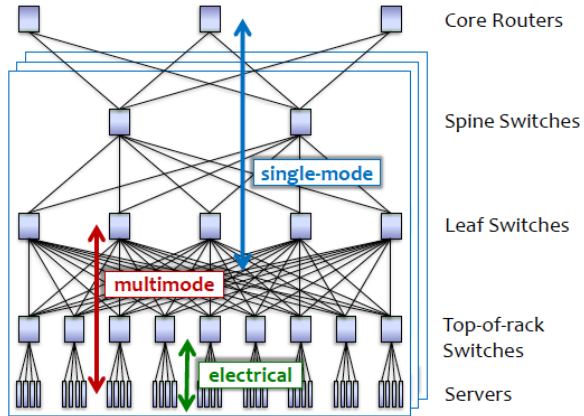
VG by Laurent Schares (IBM)

Link Parameters:



Intra-DC Network Pain Points (Physical Layer):

- Total Cost of Ownership (Switches+Optics)
- Scalability: oversubscription in upper network layers, workload fragmentation, resilience, ...
- Infrastructure, cabling, ...



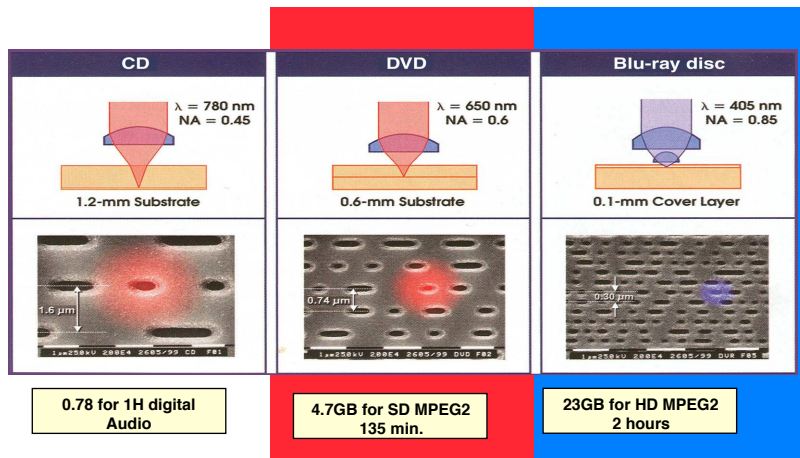
Generalized picture based on public information from a variety of datacenter operators

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

© 2015 IBM Corporation



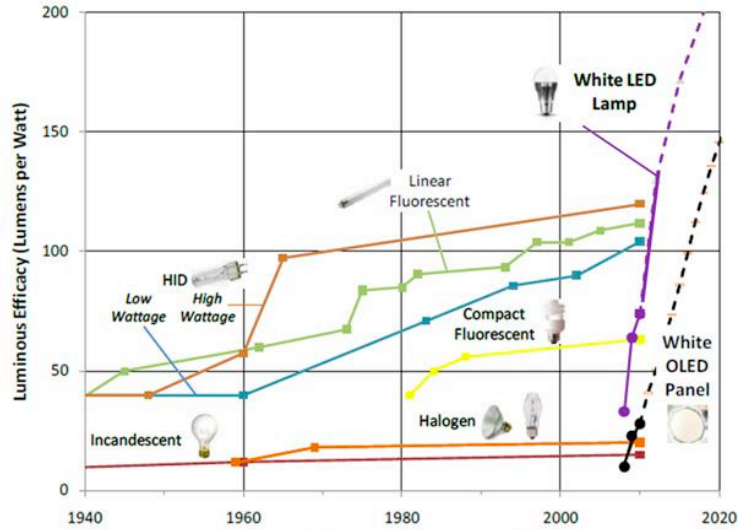
InGaN (405nm) for Optical Storage



Source: Photonics Spectra, Jan. 2004. LaserFocusWorld Marketplace Seminar



Evolution of LED Materials/Performances



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Packaged LEDs

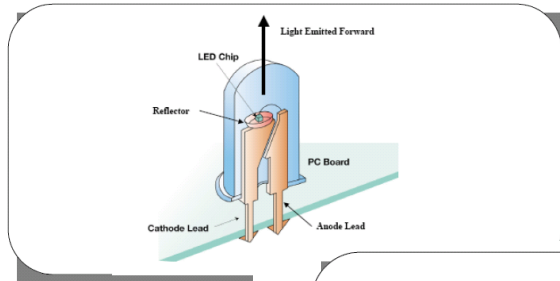


Figure 3.24: HB LED Cross Section

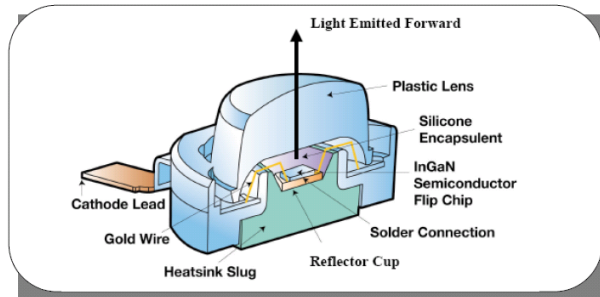


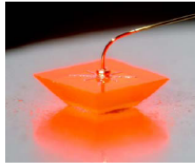
Figure 3.25: A High-Power HB LED Cross Section--Note the Heat Sink Size

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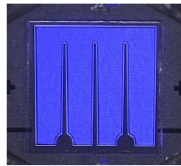
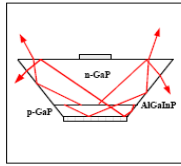
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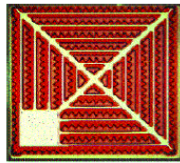
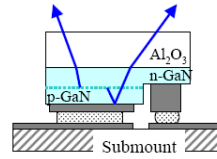
HB-LED Technology



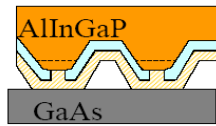
AllInGaN flip-chip (Lumiled)



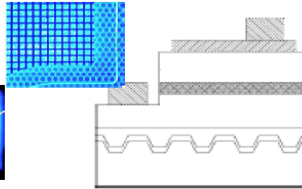
AlGaInP/GaP truncated inverted pyramid (Lumiled)



AlInGaP micro mirror (Osram),



AlInGaN patterned substrate and mesh electrode (Nichia)



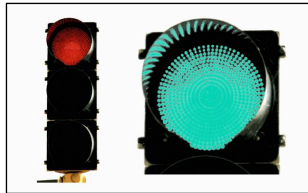
Source: LumiLeds

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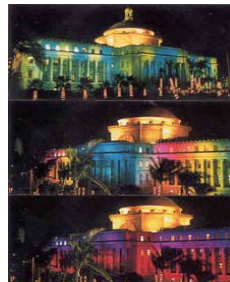
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Applications of HBLEDs



Traffic Signals (inc white)



Source: <http://www.northamericanlighting.com>



Architectural lighting



Source: Toshiba (Technoscreen)

Outdoor lighting scenarios



Source: Wustlich Design AG

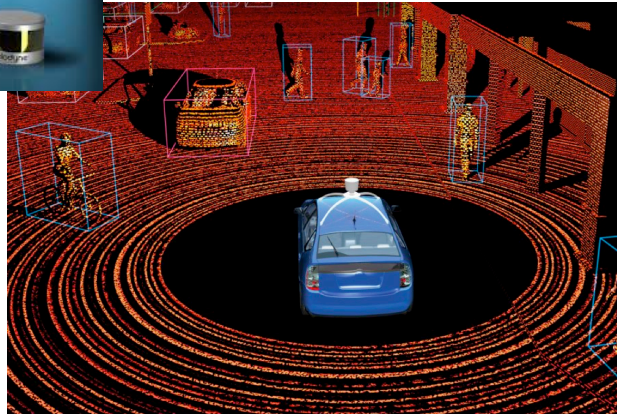
Furniture Lighting

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3D Imaging: Velodyne LIDAR



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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

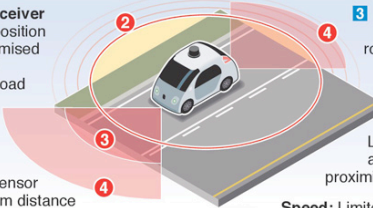
Windscreen: Flexible plastic designed to reduce injuries

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

Car would be summoned with smartphone application



Radar



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

Inertial motion sensors determine velocity and direction



Source and Picture: Google

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