Sec. 1. Introduction
About Instructor

- Dr. Wei Jiang
- Room: EE 215
- Phone: (732) 445-2164
- Email: wjiangnj@rci.rutgers.edu
About this Course

- Class Time: T,Th 6:40 pm – 8:00 pm (change to Thur 6:40 – 9:20 pm??)
- Location: ECE 240
- Office hours: T.Th 4:00-5:00pm or by appointment

**Prerequisites:**
- Undergrad: 332:382 EM Fields and 332:361 Electronic Devices
- Graduate: (332:580 *EM waves*) **and** (332:581 Introduction to SOLID STATE ELECTRONICS or 583 SEMICONDUCTOR DEVICES I)

- Homework: 5 assignments
- Two exams and Final exam
Textbooks

- Amnon Yariv, Quantum Electronics, ISBN 0471609978, (advanced)
- All material will be covered in lecture notes.
Course Outline

- **Goal:** Overview optoelectronic device technology
- **Emphasis:** device physics/operating principles (mainly concepts, less on maths), along with some structural engineering, fabrication
- Introduction
- Dielectric Waveguides and Optical Fibers
- Review Quantum Mechanics & Semiconductor Physics
- LEDs, Lasers, and Optical Amplifiers
- Modulators, switches
- Photo-Detectors
- Other Optoelectronic Devices (solar cell, WDM?)
- Hot research topics (brief intro): Photonic Crystals, Plasmonics (if time allows)
Difference between undergraduate and graduate sections

- Different homework and exam questions
  - Undergraduate: more focus on conceptual questions
  - Graduate: more quantitative questions
- Advanced materials for graduate students only
  - Undergraduates are encouraged to learn, but not required
Optoelectronic Technology in Your Life Everyday

Electrical wires

Optical fiber (>~1000km)

Voice

Data

Electrical wires

332:591 Optoelectronics I (W. Jiang)
Year 1998 Projection:
- Voice growth assumed 10%
- Data growth assumed 100%
- Data overtakes voice in 2001

Year 2006 Traffic Data:
- Traffic crossing the network growing at ~80% annually
- AT&T traffic load is 5.1 PB/day (~1 Tb/s, assuming a 12-hr day)

Source: Coffman and Odlyzko (AT&T Labs, 1997); Cambron (AT&T Labs, 2006)

Tingye Li, AT&T Labs-Research (Retired), ICOCN 2006.
CAPACITY OF COMMERCIAL LIGHTWAVE SYSTEMS
Doubled Annually

Source: H. Kogelnik (Lucent)

Data rate per channel (Gb/s)

Number of channels

Total Capacity
100Tb/s
10Tb/s
1Tb/s
10Gb/s
100Gb/s

Optics
Electronics

ICOCN 2006

Tingye Li, AT&T Labs-Research (Retired), ICOCN 2006.
DILEMMAS AND CHALLENGES OF SERVICE AND NETWORK PROVIDERS

- Data traffic (doubling annually) >> voice traffic
- Data revenue << voice revenue (~1:3 for US)
- Traditional revenue stream disrupted by new technologies and competition
- Expenses increasing faster than revenue and profits
- Continuous network evolution essential
- Problems of innovative accounting practices
- New sources of business revenue compelling

Resulting in Industry Consolidation: Bankruptcies, Mergers and Acquisitions, And Creation of New Business Opportunities

Tingye Li, AT&T Labs-Research (Retired), ICOCN 2006.
THE TRANSFORMATION OF AT&T

1984: AT&T divested its Regional Bell Operating Companies (RBOCs)

1996: AT&T divested its manufacturing units (Lucent and Avaya)

2005: AT&T acquired by SBC (an RBOC) and re-emerged as the new AT&T

2006: The reborn AT&T will acquire Bell South, another RBOC, and (once again) become the biggest telecom company in the US (and in the world)

<table>
<thead>
<tr>
<th>Market Cap. (8/4/06)</th>
<th>AT&amp;T</th>
<th>Bell South</th>
<th>Verizon/(MCI)</th>
<th>China Mobile</th>
<th>Vodafone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Rev. (1H06)</td>
<td>$120B</td>
<td>$73B</td>
<td>$99B</td>
<td>$126B</td>
<td>$116B</td>
</tr>
<tr>
<td>No. of Employees</td>
<td>186K</td>
<td>63K</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Tingye Li, AT&T Labs-Research (Retired), ICOCN 2006.
CONSOLIDATION OF TELECOM SUPPLIERS

• The Bubble
  – *Irrational fervor; religious vision*; over-supply

• The Long, Harsh Winter
  – Bankruptcies of start-ups; down-sizing of incumbents

• Recovery and Growth
  – Telecom capex growing: ($205B in 2005; $236 in 2009)*
  – Carriers’ needs: *cost savings and new revenue (new services)*

• Consolidation
  – Fewer customers and broader technology scope
  – Mergers to match customers’ scope and size

  e.g.  Alcatel/Lucent  ($21.5B)*
       Ericsson/Marconi  ($20.3B)*
       Nokia/Siemens  ($19.8B)*

*2005 Revenue attributable to service providers

**Source: www.infonetics.com

ICOCN 2006

Tingye Li, AT&T Labs-Research (Retired), ICOCN 2006.
NEW APPLICATIONS AND COMPETITION
(VoIP and IPTV)

- **VoIP** (Voice-over-IP)
  - Requires broadband access (>200 kb/s)
  - Competition among ILEC, CLEC, MSO, ISP & NNP
  - ILECs projected to lose ~$96B by 2010 *

- **IPTV** (Video-on-Demand, …)
  - Perceived as “The Next Big New Application”
  - Competition among ILEC, CLEC, MSO, ISP & NNP
  - Upgrade of core and metro networks (IP-based NGN)
  - Deployment of FTTH, FTTP,…
Service Provider Adapting to New IP Applications

IPTV
Long Haul – Metro – Access Fiber Designs

Source: K. Cambron (AT&T): OFC 2006

Tingye Li, AT&T Labs-Research (Retired), ICOCN 2006.
Global Optical Communications Revenue and Projection

Ray Chen, Univ. of Texas at Austin, 2006.
History of Optical Communication

Ancient ideas:
Smoke, flag, traffic lights
Problems: slow, limited distance, prone to error

~1800,
French Semaphore
1000km, 20minutes, 1000 relays, 0.1 bit/s

1880,
Bell Photophone
first wireless telephone
msg of the world

1837
Morse Telegraph
Few bits/sec

1878
Bell Telephone
4kHz

1888,
H. R. Hertz
Radio wave Tx

1895,
Marconi
Radio Commun

1940s
Radar
Radio detection And Range

1960
Ruby Laser
History of Fiber Optical Communication

1963:
Semiconductor laser
high threshold (~Amps)
Low temp (77K)

1966:
Charles Kao predicted
Fiber attenuation low limit 20dB/km
(in 1966, ~1000dB/km), Nobel Prize ‘09

1969:
Alferov (USSR) and Pannish & Hayashi
(Bell Labs) Rm Temp, CW, semiconductor lasers

1970:
Kapron, Keck, & Maurer (Corning)
Low loss Silica fiber (20dB/km)

1974:
MacChesney (AT&T)
1dB/km

1989:
Payne et al (U. Southampton, UK)
Er-doped fiber amplifier (EDFA)
Fiber Loss & Laser Lifetime
- Advances Year by Year

Source: Joe C. Campbell (Univ of Virginia)
Typical Fiber Optical Communication System

Source (laser) → Modulator → Fiber links → Repeater

Fiber links → splice → Fiber connectors

WDM → Fiber amplifier (Er-doped, or EDFA) → Receiver

Electrical Signal in → Electrical Signal out

Pump laser
Other applications

Commercial Electronics

Solar cells
Optical data storage (CD, DVD, Blu ray…)
LEDs
Optical interconnects
CCD image sensor
display
lighting
Other Applications of Optoelectronics

• Commercial Electronics
  – Before 2000, Optoelectronic technology was mainly driven by Optical Communications (for ~30 years)*
  – Optical Storage: CD, DVD, Blu-ray, etc.
  – Display: LCD, LEDs etc
  – Solid State Lighting
  – Optical interconnects.
  – Imaging Sensors
  – Solar cells

• Defense applications
  – laser communications (free-space)
  – laser radars
  – weapons

• Biomedical: laser surgery, spectroscopy, sensors, imaging

* Communication devices are probably the most sophisticated among all optoelectronic devices in many aspects, and are regarded as the cornerstone of optoelectronics.