ECE 162C
Mat 162C

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ECE 162C
"Optoelectronic Materials and Devices "
Spring, 2008

Mondays and Wednesdays

12:00 - 1:50, 1431 Phelps

Professor:		John Bowers
Teaching Assistant:		Ramya Yeluri
Discussion period:		Mondays, 1:20 to 1:50
Office hours:	Bowers:	Fridays, 1:00 to 2:00 pm, By appt.
	Ramya:	Tuesdays 1-3 and Fridays 12-1 pm

Text

Title: Optoelectronics and Photonics: Principles and Practices

Author: Kasap

ISBN 0-201-61087-6

Publisher: Prentice Hall (2001).

Supplemental Texts:

Solymar, Electrical Prop. of Materials, Oxford.

Yariv, Optical Electronics in Modern Communication, Oxford

P. Bhatarcharya, Semiconductor Optoelectronic Devices, 2nd Edition (1997).

C. Pollock, Fundamentals of Optoelectronics, Irwin (1995).

S. Tiwari, Compound Semiconductor Device Physics, Academic Press (1992).

Rules

- There will be a homework set assigned every Wednesday which will be due at the beginning of class the following Wednesday. You are encouraged to work together on solving the homework problems but the final write up must be your own.

- Homework which is one day late can earn a maximum of 75 % of the total score, two days late 50 %, three days late 0. Homework turned in after the Wednesday class is considered 1 day late. Your lowest score won't count towards your grade, so you can skip one homework completely if you are sick/travelling/busy, etc.

- You'll be allowed to bring in one single-sided page of notes (8.5 x 11) into the mid-term. For the final you can have notes on both sides.

Lectures posted at
http://www.ece.ucsb.edu/courses/ECE162/162C_S08Bowers

Grading

• Homework	25%
• Midterm	20%
• Final exam	30%
• Class Presentation	20%
• Class Participation	5%

Topics

1. Wave Nature of Light. Maxwell's equations. Electronic properties of semiconductor materials for optoelectronic devices.

2. Dielectric Waveguides and Optical Fibers. Optical properties of selected semiconductor materials.

3. Semiconductor Science and Light Emitting Diodes. Energy bands. P-N junction – the basic structure for optoelectronic device realization.

4. Stimulated Emission Devices: Lasers. Semiconductor Laser Diodes

5. Photodetectors.

6. Photovoltaic devices.

7. Polarization and Modulation of Light. Optoelectronic modulators. Electro-optic effect.

Where is the world going? What do you need to know? What do you need to get out of this class?

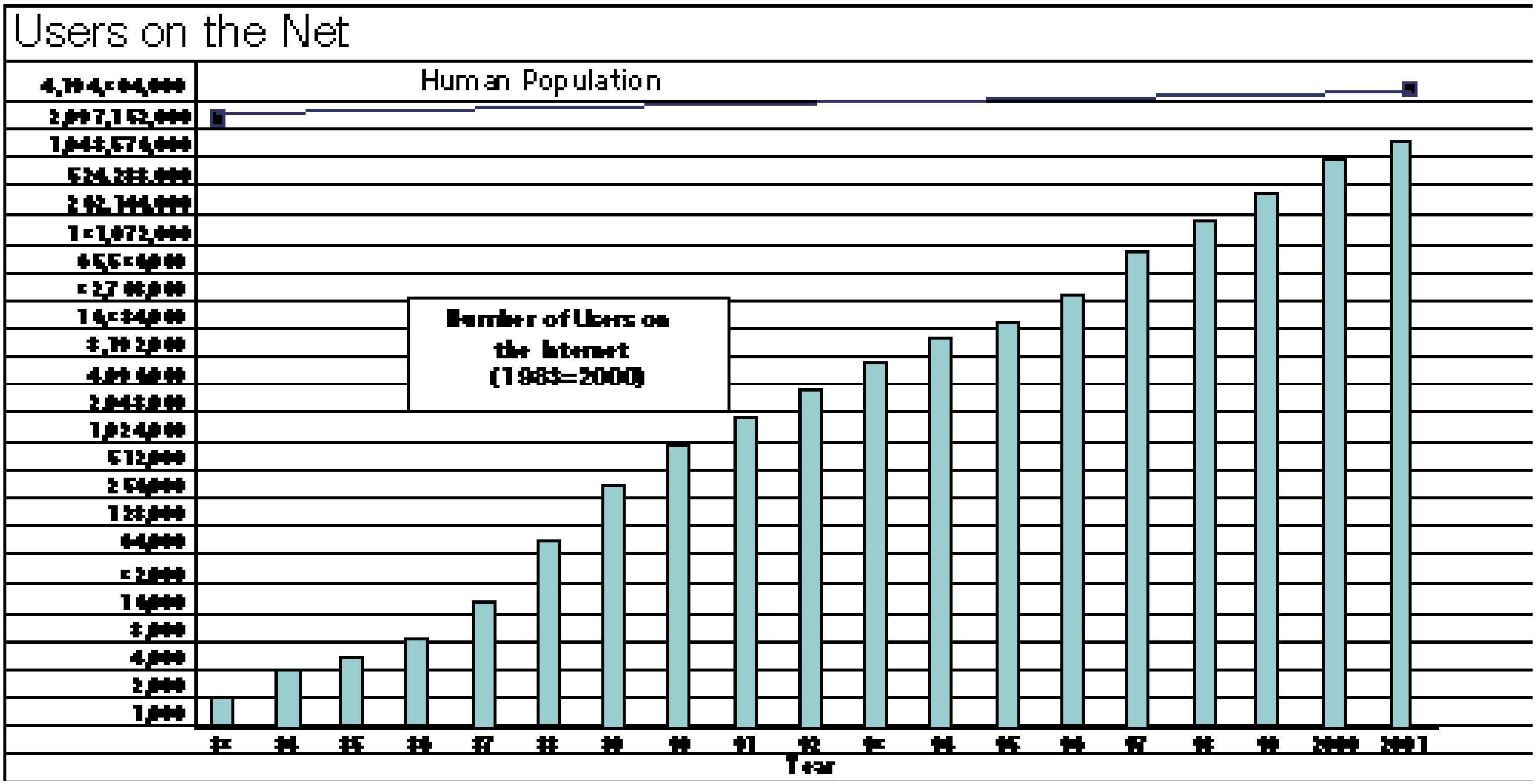
ECE 162C

Lecture #1

Prof. John Bowers

- Why did the optical fiber revolution happen?
- (What is next?)

Number of Internet Accounts

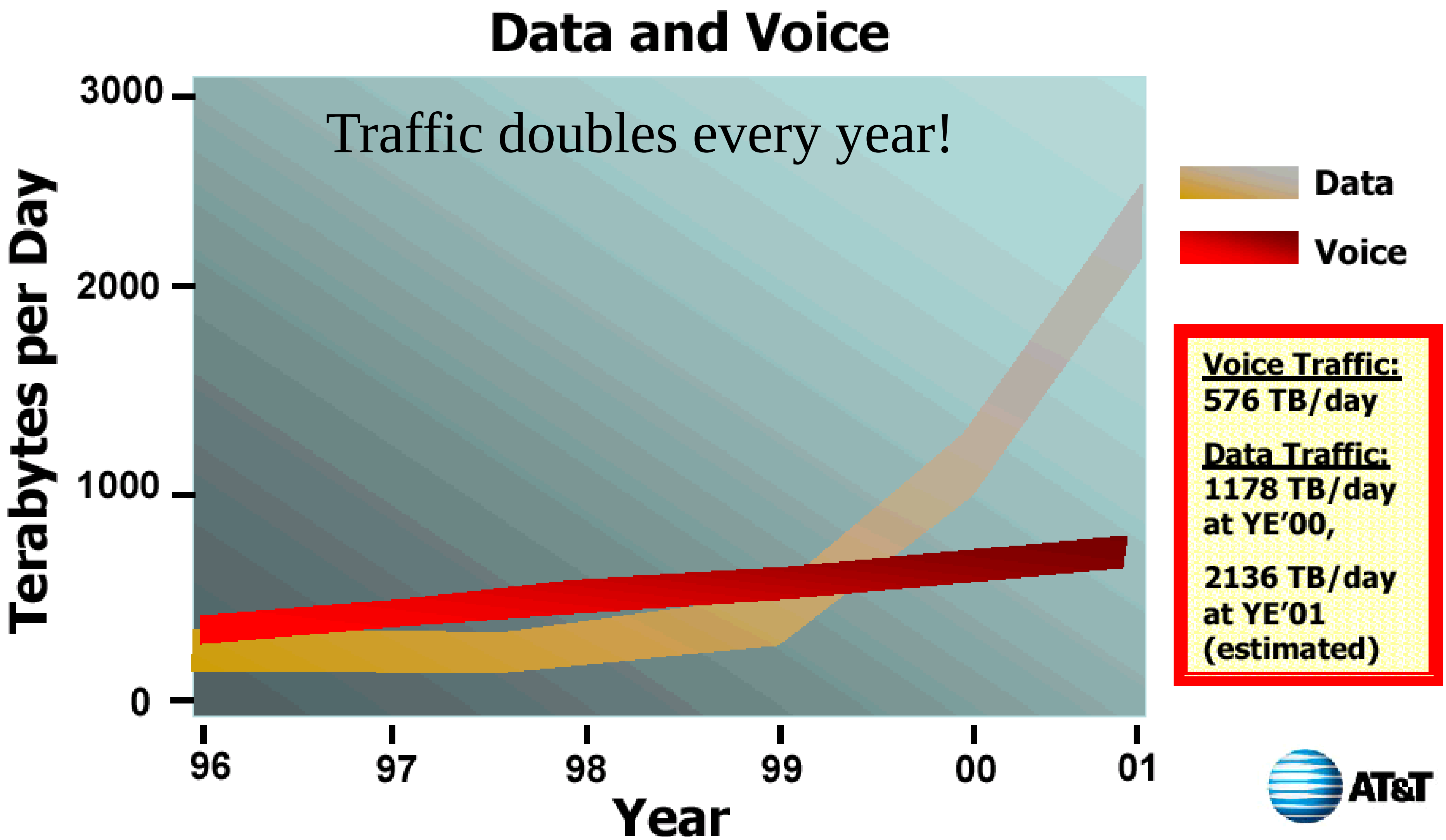


Explosion in Bandwidth Requirements

- E-mail: 10 bit/s
- World Wide Web: 1 Mbit/s
- Internet videoconferencing: 10 Mbit/s
- Video on demand, HDTV: 100 Mbit/s

- More users x Higher bandwidths = More transmission capacity.
- Today: 100 million users x 50 kbit/s = 5 Tbit/s worldwide
- 2015: 5 billion users x 50 Mbit/s = 250 Pbit/s (P stands for peta $=10^{15}$)

Growth in Network Traffic



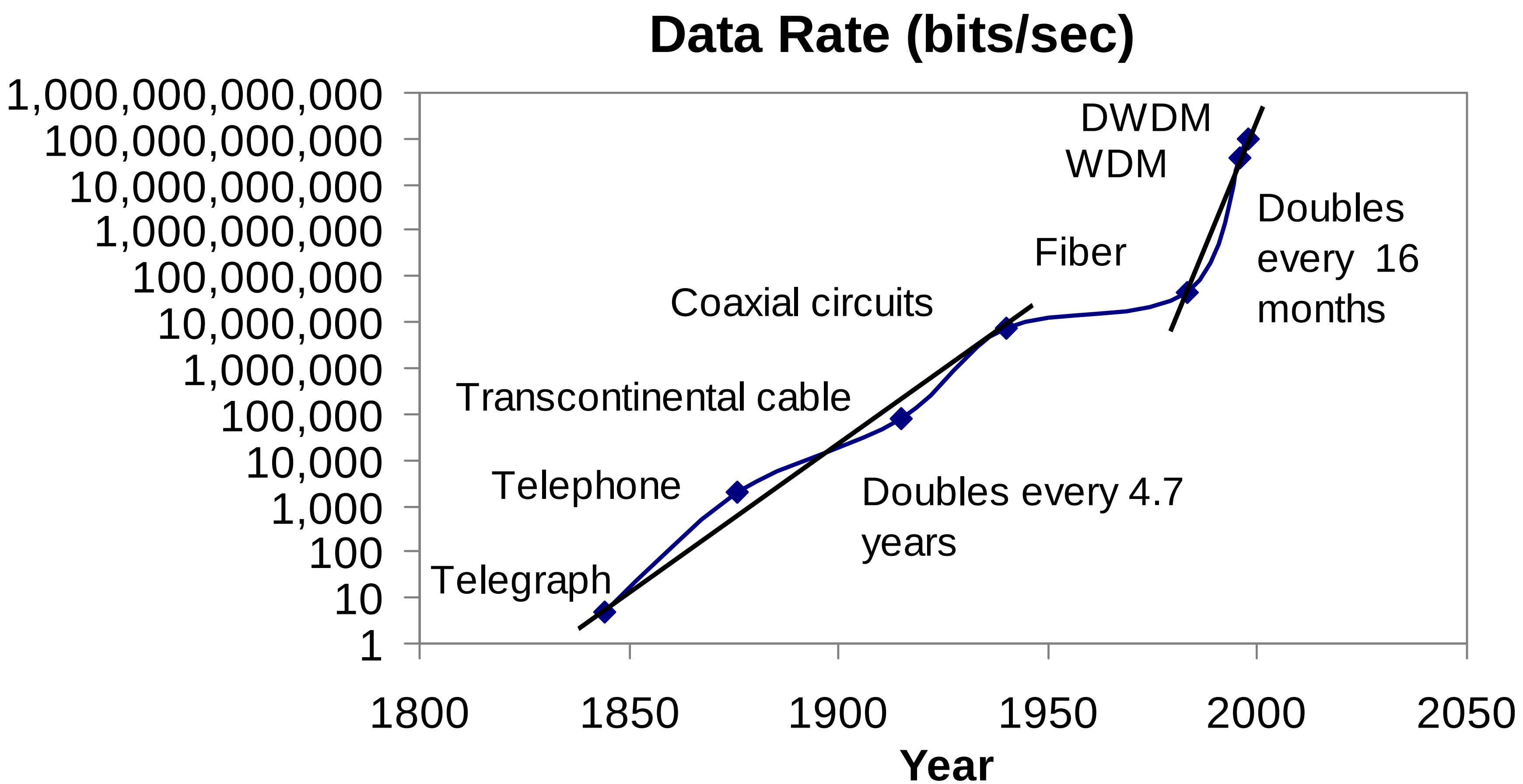
AT&T

Data Transmission

• -2000	0.1 Bit/s	Smoke Signals
• -300	1 Bit/s	Alphabetic signaling (Greeks)
• 1840	10 Bit/s	Telegraph (Morse)
• 1870	100 Bit/s	Time Division Multiplexing (Baudot)
• 1930	1 kBit/s	Teletype
• 1970	50 Mbit/s	Microwave transmission
• 1979	100 Mbit/s	LEDs/Fiber optic transmission
• 1985	1 Gbit/s	Lasers/Single mode fiber
• 1996	10 Gbit/s	WDM: Wavelength division multiplexing

Law of the Photon

Data rate doubles every 16 months



Propagation Limits: Attenuation and Dispersion

Medium	Max Bit Rate	Loss at 10 Gbit/s
Twisted pair:	100 kbit/s	
Coaxial cable:	1 Gbit/s	1 dB/m
Microwave waveguide:	1 Gbit/s	0.1 dB/m
Optical fiber (0.82 μm)	1 Gbit/s	0.001 dB/m
Optical fiber (1.55 μm)	100 Gbit/s	0.0002 dB/m

The low loss window in optical fiber is from 1.3 to 1.6 μm is 50,000 GHz wide.

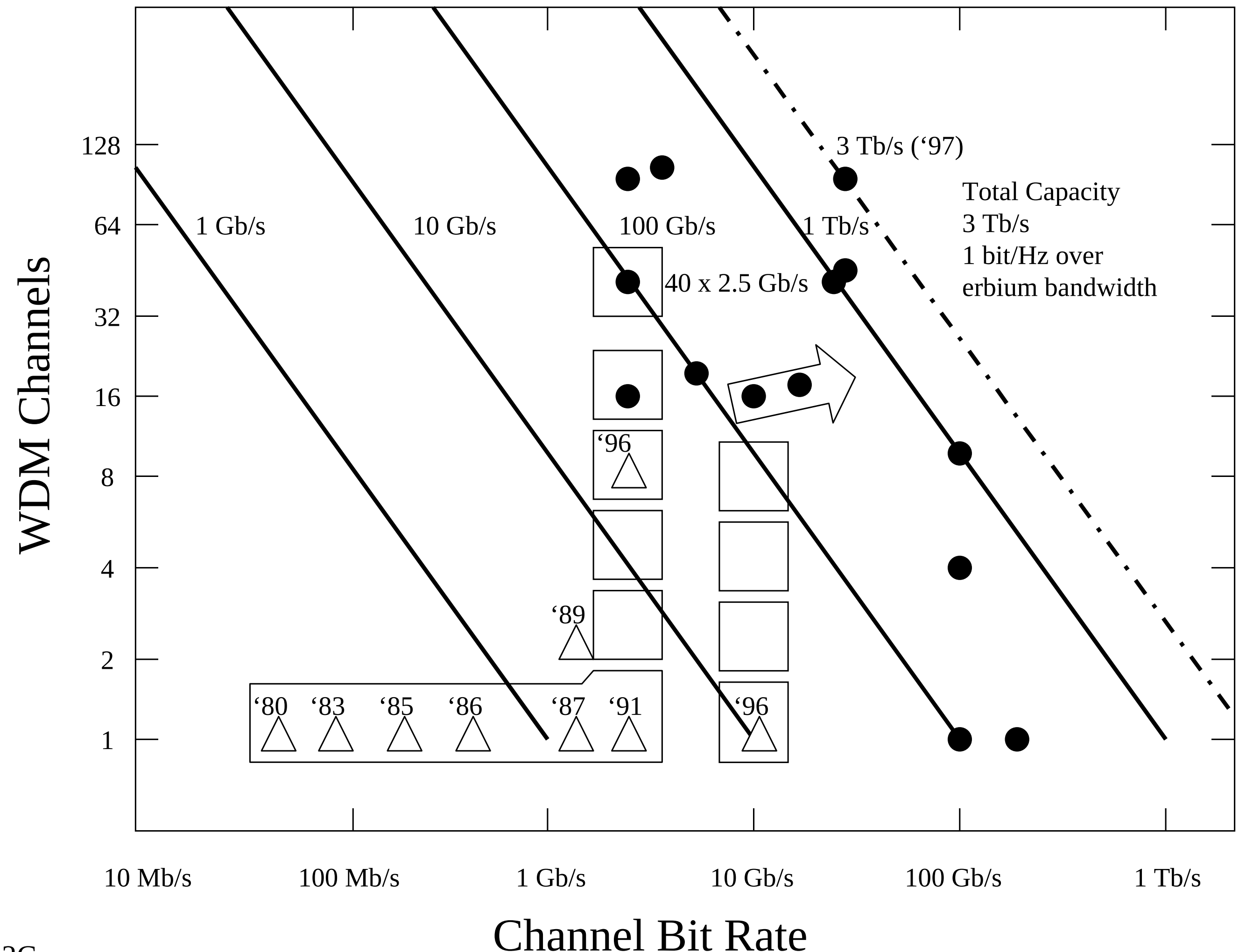
Communication

- Access will be Wireless (microwaves)
  - Cell phones
  - WiFi computer access
- Transmission will be optical
  - Optical fibers
  - Semiconductor lasers
  - Optical modulators
  - Photodetectors

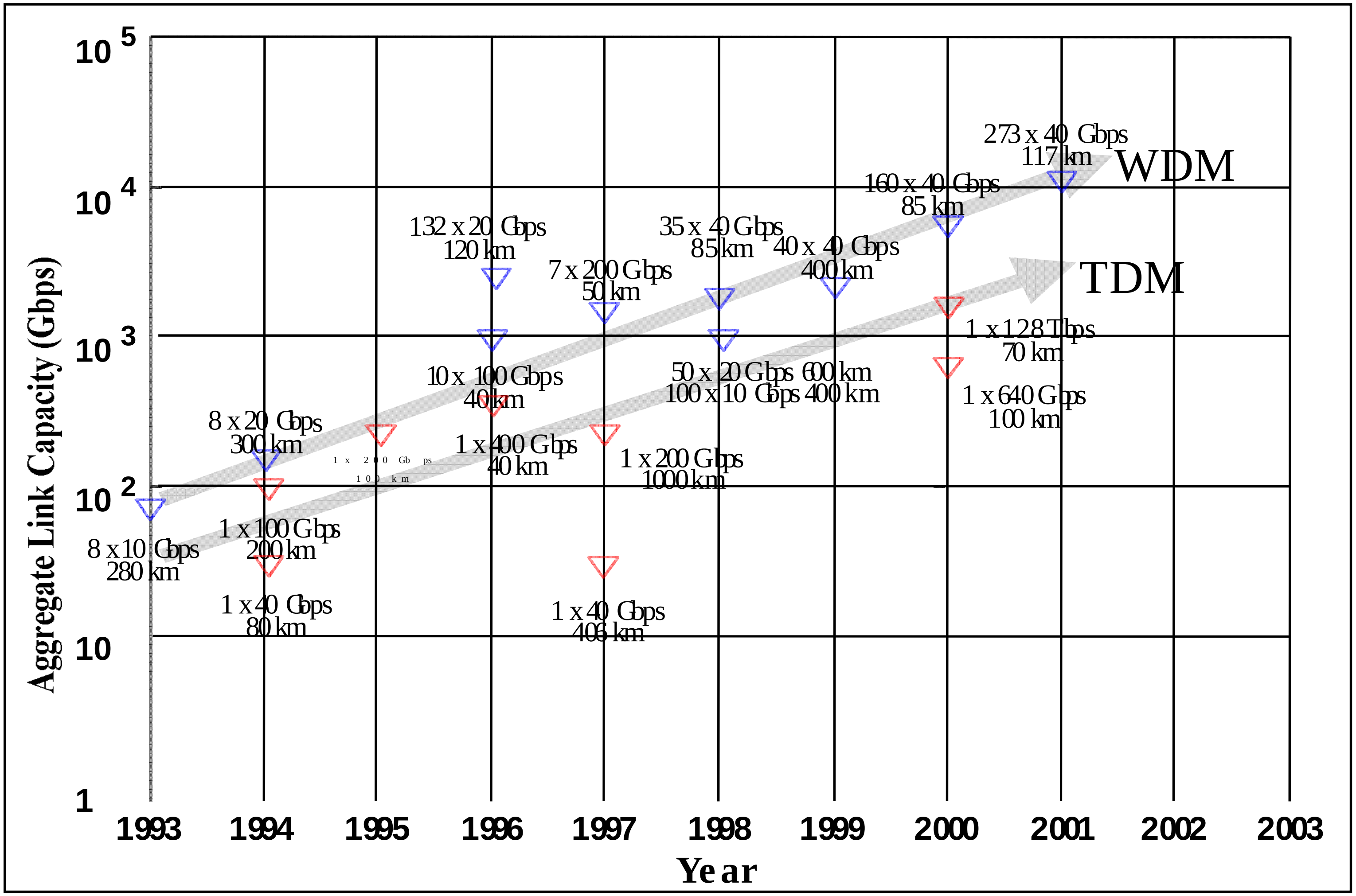
How to Achieve Higher Capacity?

- More cables
- More fibers/cables (600 fibers/cable common)
- Higher bit rates (10 Gbit/s now standard)
- Multiple wavelengths (WDM) (32 common)

Lightwave Trends



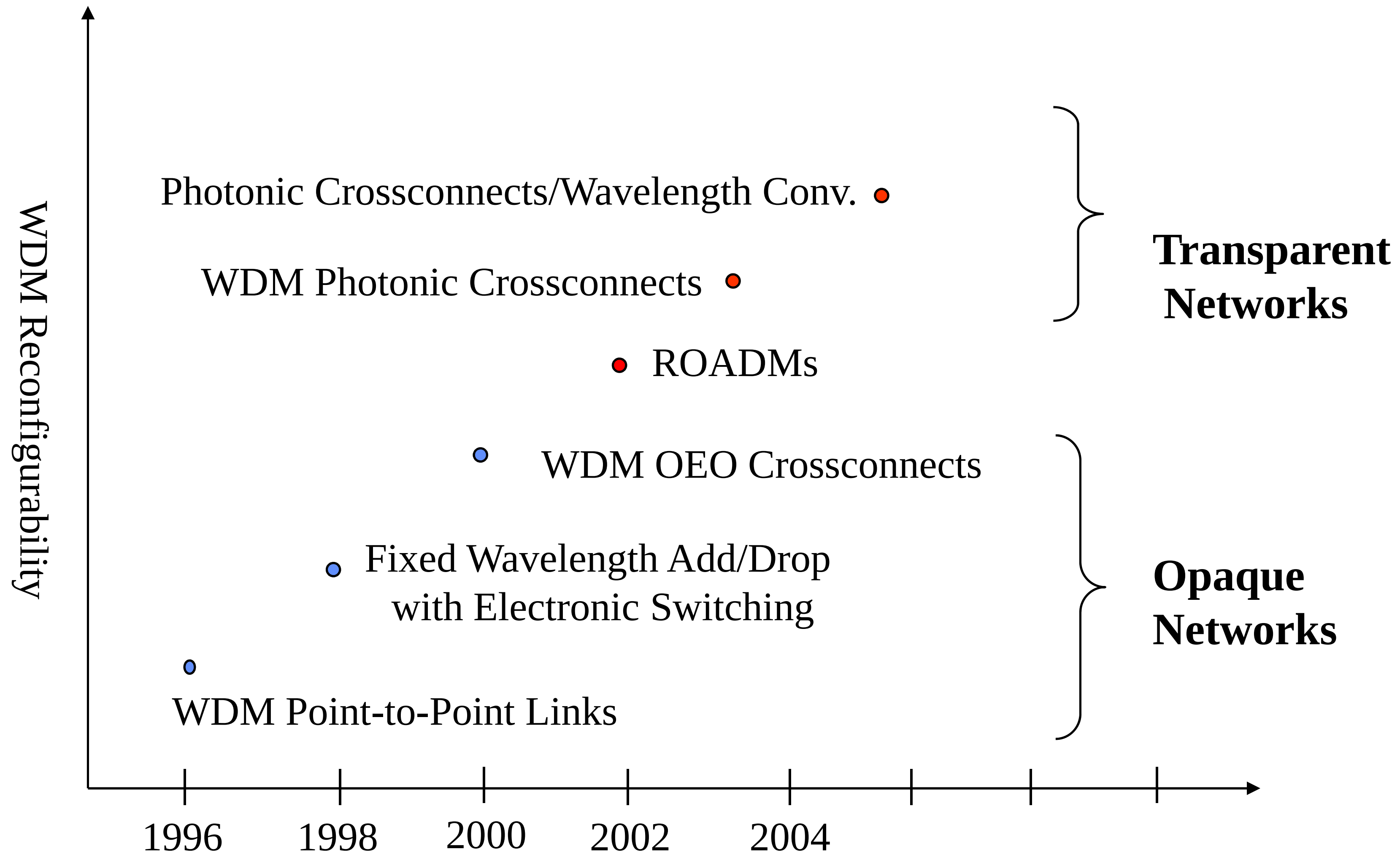
Fiber Capacity Improvements



Fiber Optic Revolutions

Date	Fiber	Wavelength	Source	Detector
1976	Multimode	0.88 μm	LEDs	Si APDs
1980	Singlemode	1.3 μm	Laser	InGaAs PIN
1985	Singlemode	1.55 μm	DFB Laser	InGaAs/InP APD
1990	Single mode	1.55 μm	Erbium doped fiber amplifiers	
1995	Single mode	1.55 μm	Wavelength division multiplexing (WDM)	
2005	Single mode	1.55 μm	Transparent WDM networks	

WDM Optical Network Evolution



Ultimate Modem: Fiber to the Home (FTTH)

	FTTH	FTTC
Bandwidth	Huge	Large
Cost	$1000	$600
Labor	23%	26%
Materials	19%	23%
Fiber	8%	7%
Electronics	58%	51%
Optoelectronics	14%	2%

FTTH Initiatives announced by Verizon, ATT for 2004-2010

The Big Players

- RBOCS (Regional Bell Operating Companies
  - Verizon
  - ATT
  - Quest
- IXCs (Interexchange carriers)
  - Sprint
- Cable Companies
  - Comcast
  - Cox,…

The Triple Play

- Who will deliver the Triple Play (Voice, data, video)?
- RBOCS, IXCs or Cable companies (Cox, Comcast,…)

Transmission will be Optical

What do you need to know?

- Modes in optical fibers (wave equation …)
- Modes in optical waveguides (lasers, modulators, …wave equation, birefringence)
- Lasers (gain, absorption, lasing,…)
- Modulators, Photodetectors, Amplifiers

Homework #1

- Read Kasap, Chapter 1
- Problems 1.2, 1.3, 1.7,1.8 due Wednesday, April 9