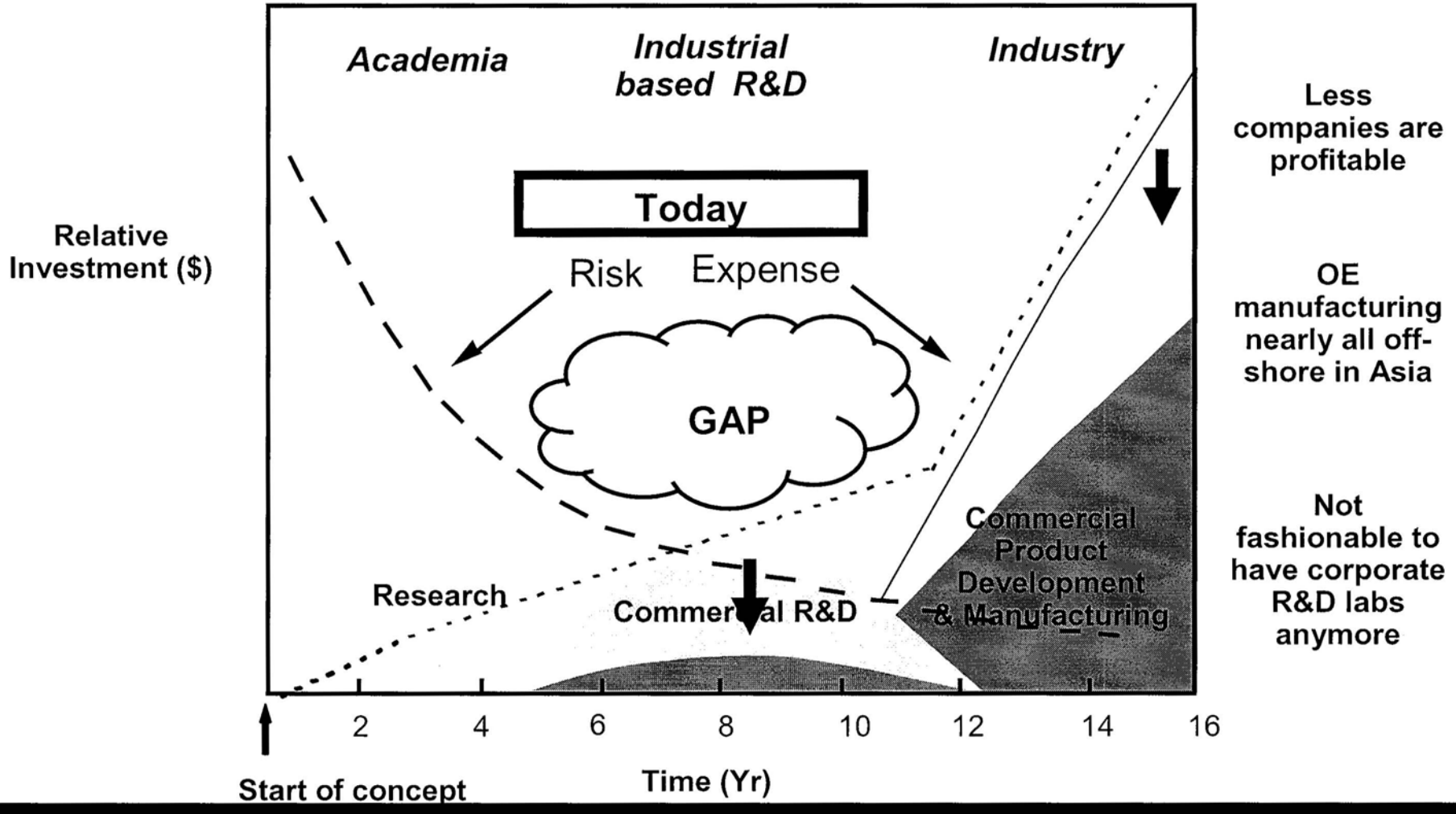
Capacity Issues & Challenges

- Long Term – US Needs More R&D to Retain Leading Role in Network Development & Innovation
  - Industry Structure has Changed Over Time
- Mid-Term – Escalating Consumer Bandwidth Demands
  - New Technologies to Scale Core, Edge & Datacenters
  - Broadband Ecosystem Highly Interwoven & Interdependent
- Short-Term – US Opportunity to Regain Leading Role
  - Continuing Investment is Critical

R&D gap

How do we bridge this gap in the optoelectronics industry?



We can't afford to do R&D or manf in USA

What has changed over the last decade?

- Market share
  - 1993 – Losing manufacturing to Japan
  - 2009 – Movement off-shore broadening and accelerating
    - Competition from Korea, Japan, Taiwan, China . . .
    - US companies moving operations off-shore
    - R&D following manufacturing
- Corporate infrastructure
  - 1993 – Vertically integrated
  - 2009 – Fragmented, down-sized, divested, more focused start-ups
- Technology platform
  - 1993 – Primarily III-V based
  - 2009 – Si has expanded into optoelectronics areas; higher precision growth, dimensional tolerances and structures
- Technology drivers
  - 1993 – Corporate central labs
  - 2009 – Central labs no longer exist in industry
    - University research
    - National laboratories

Optoelectronics is in deep trouble in USA

The challenge of network scaling in the core

Scaling the core of the network…

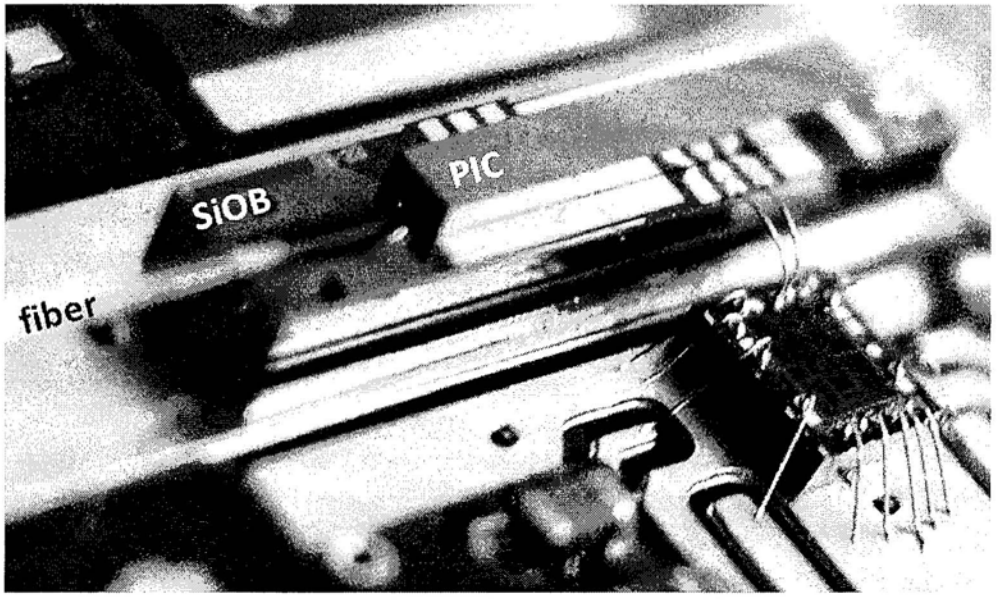
- We know (or severely suspect)
  - Traffic growth will outstrip capacity growth
  - System capacity will be important in the next decade
  - Volumes will be large and growing (internet utility users)
  - New photonics and electronics technologies are critically needed

- We are worried that extreme choking (congestion, traffic-jams) will bring the network down when we most need it…
  - If we assume 1Mbps at the edge today → 40Gbps core today
  - Then simple math suggests 10Mbps edge → 400Gbps
  - And with fiber 1Gbps edge → 40Tbps ! Let's hope we are wrong!

The technical community is worried…

New Optical Technologies for the Edge

- Consumer Bandwidth Demands are the Driving Force
  - Applications, Architectures, Services, Content Distribution
- Photonic Integrated Circuits
  - Lower costs
  - Use less space
  - Consume less power
  - Better performance
- FTTH Delivers
  - Very high bandwidth
  - Network efficiencies
  - Future proof technology



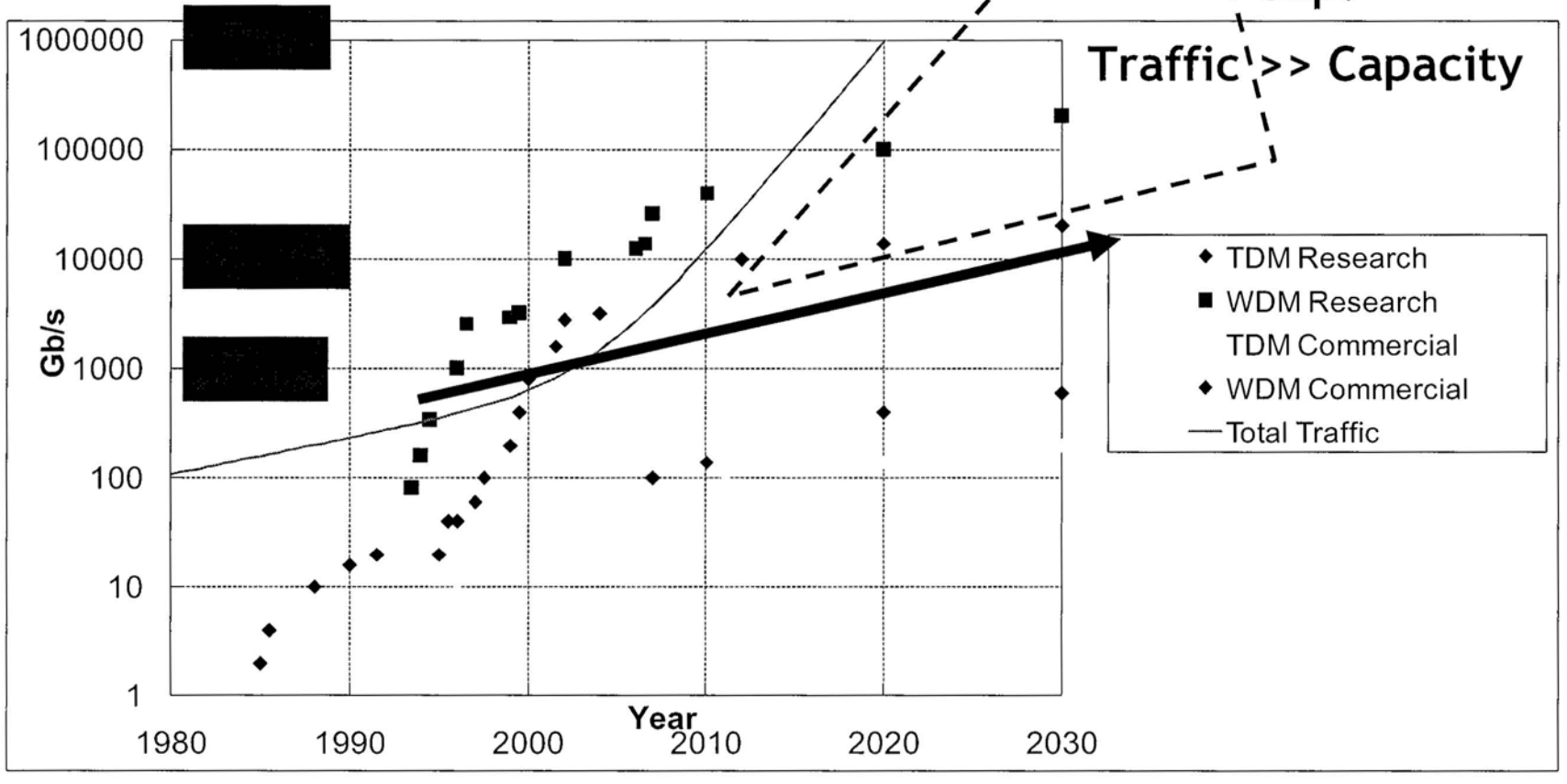
Source: OneChip Photonics

Capacity Demands Headed in 1 Direction

System capacity and network traffic

(Including voice)

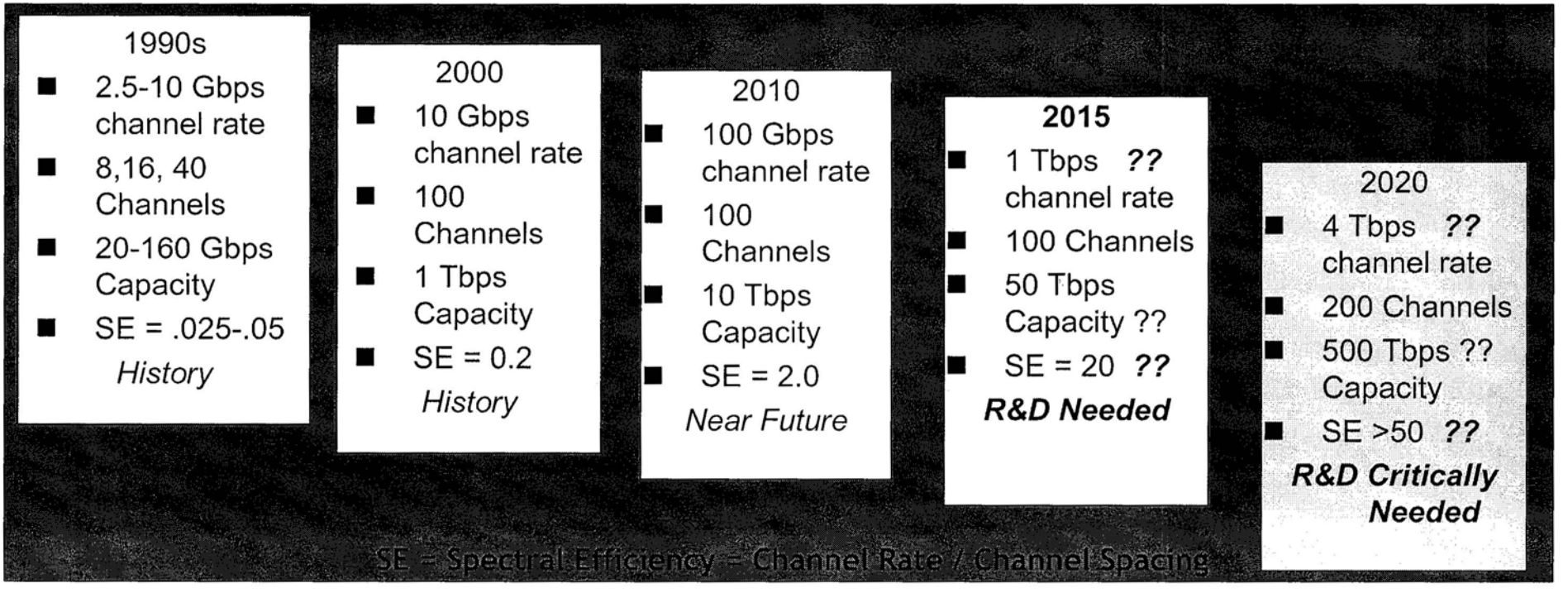
■ 2010-2030 forecast trends



Source: R. Tkach Alcatel-Lucent

Traffic will exceed capacity....grind2halt!

System evolution to choking…



- Even with 2015 target, traffic growth will exceed capacity growth by a factor of 10…

Source: R. Tkach Alcatel-Lucent

What technology will we use for 10Tbps?

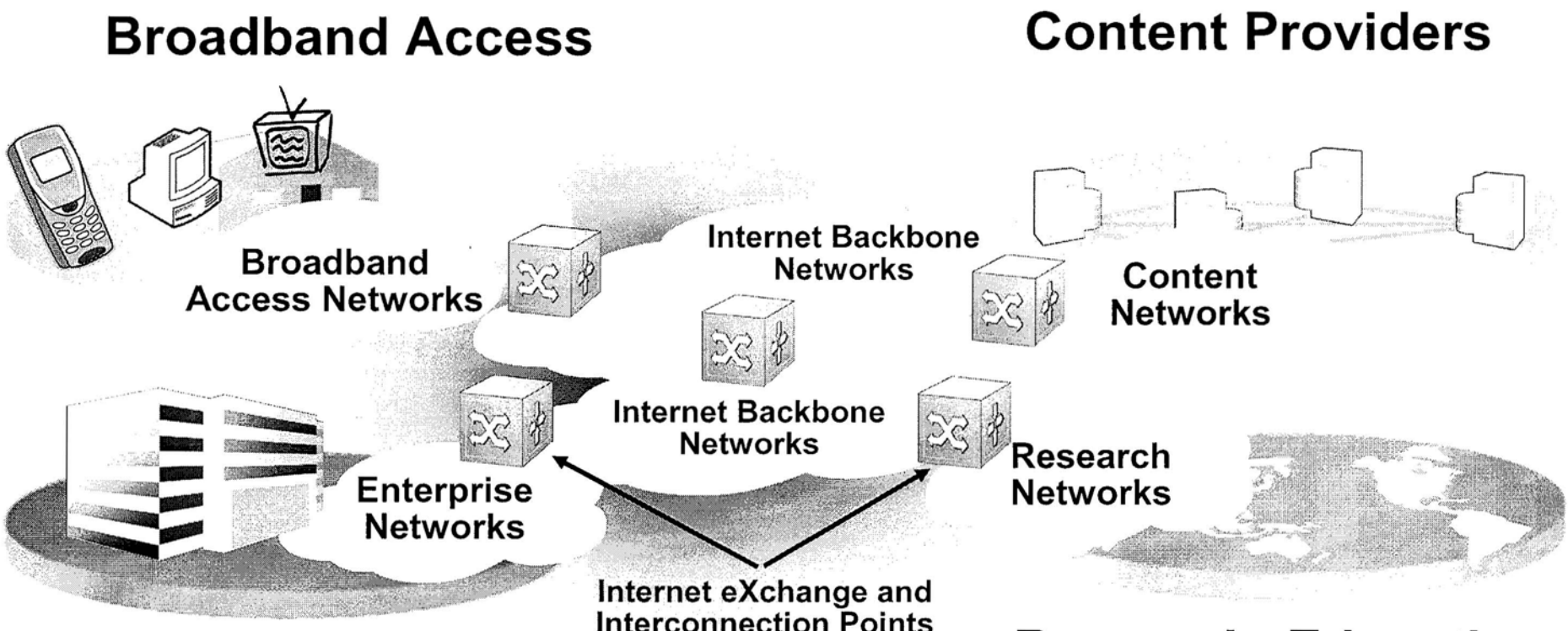
What do we need to do technically?

- Even more sophisticated modulation formats
  - Current systems at 40 Gb/s use DPSK
  - Coming systems will be Polarization Multiplexed QPSK with coherent detection
  - Next: 16QAM? Multi-ring constellations?
- More optical bandwidth
  - Beyond C+L band
- Higher power fibers
- Photonic integrated circuits
  - Game-changer for the edge (FTTH)
- New laser diode/modulator schemes → maybe non semiconductor ????

USA is lacking in commercial R&D...

Data-centers need to scale also...

The Ethernet ecosystem evolves



Source: J. D/Ambrosia, Force10 Networks

Datacenters → high speed intersections

Why higher speed Ethernet?

Fundamental bottlenecks are happening everywhere

Increased # of users + **Increased access rates and methods** + **Increased services** = **Bandwidth explosion everywhere**

As demonstrated by the number of ISPs: Comcast, AOL, YahooBB, NTT, Cox, EasyNet, Rogers, BT, ...

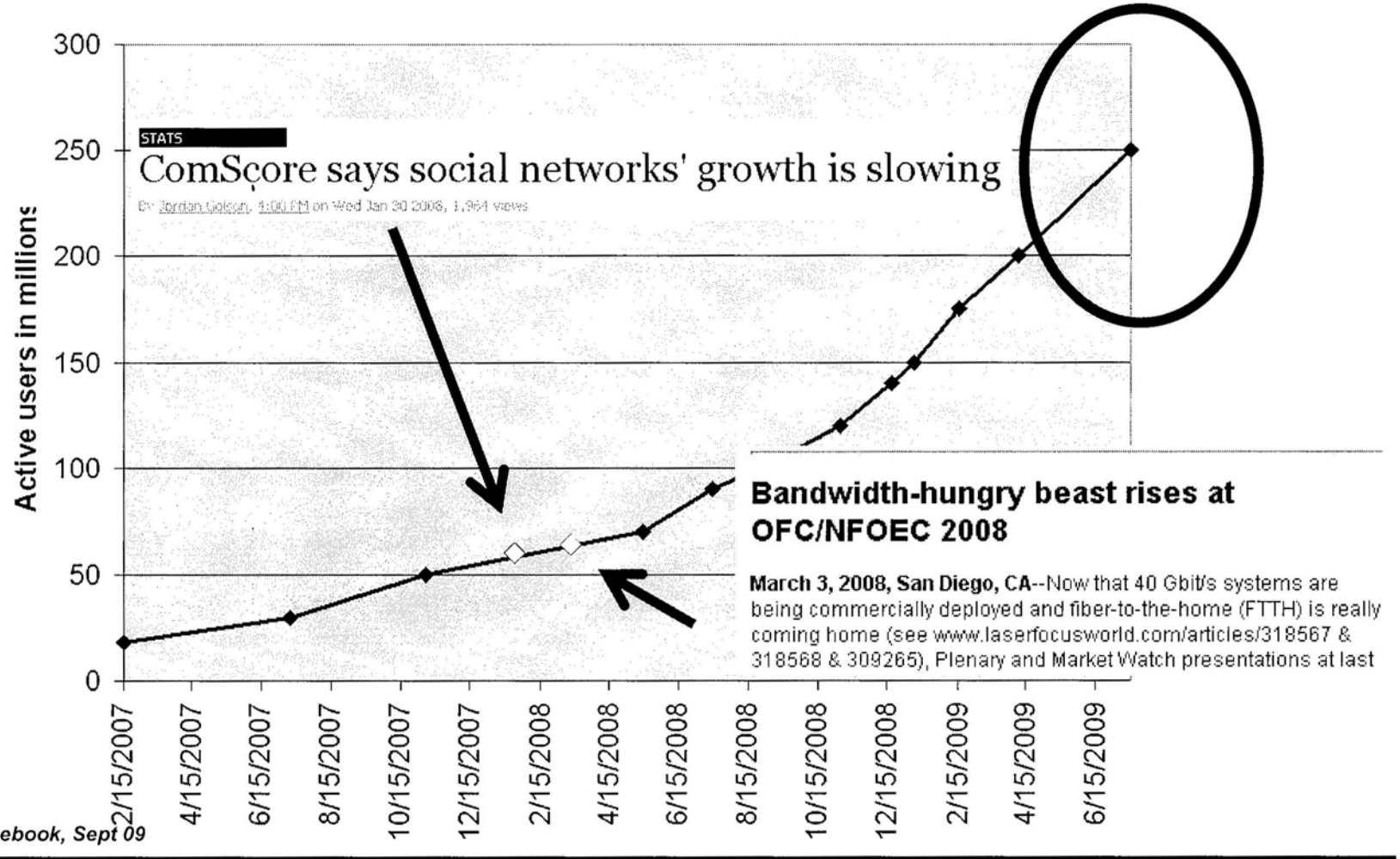
EFM, xDSL, WiMax, xPON, Cable, WiFi, 3G/4G...

YouTube, BitTorrent, VOD, Facebook, Kazaa, Netflix, iTunes, 2nd life, Gaming...

Source: IEEE 802.3 HSSG Tutorial, Nov 2007.

Higher demands on the network

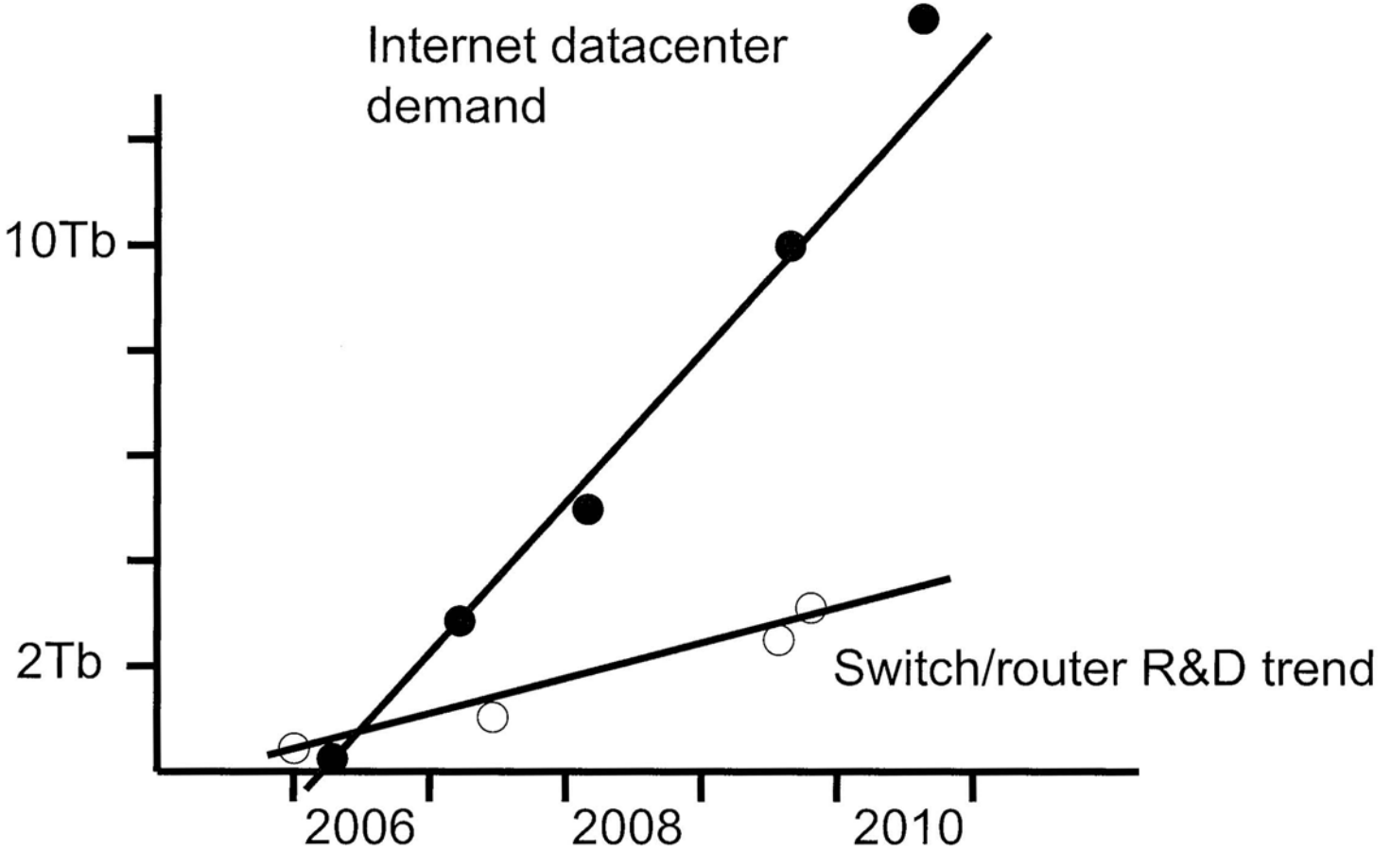
Social networking user growth is driving bandwidth, datacenters



Source: Donn Lee, Facebook, Sept 09

Trend is not slowing, but accelerating

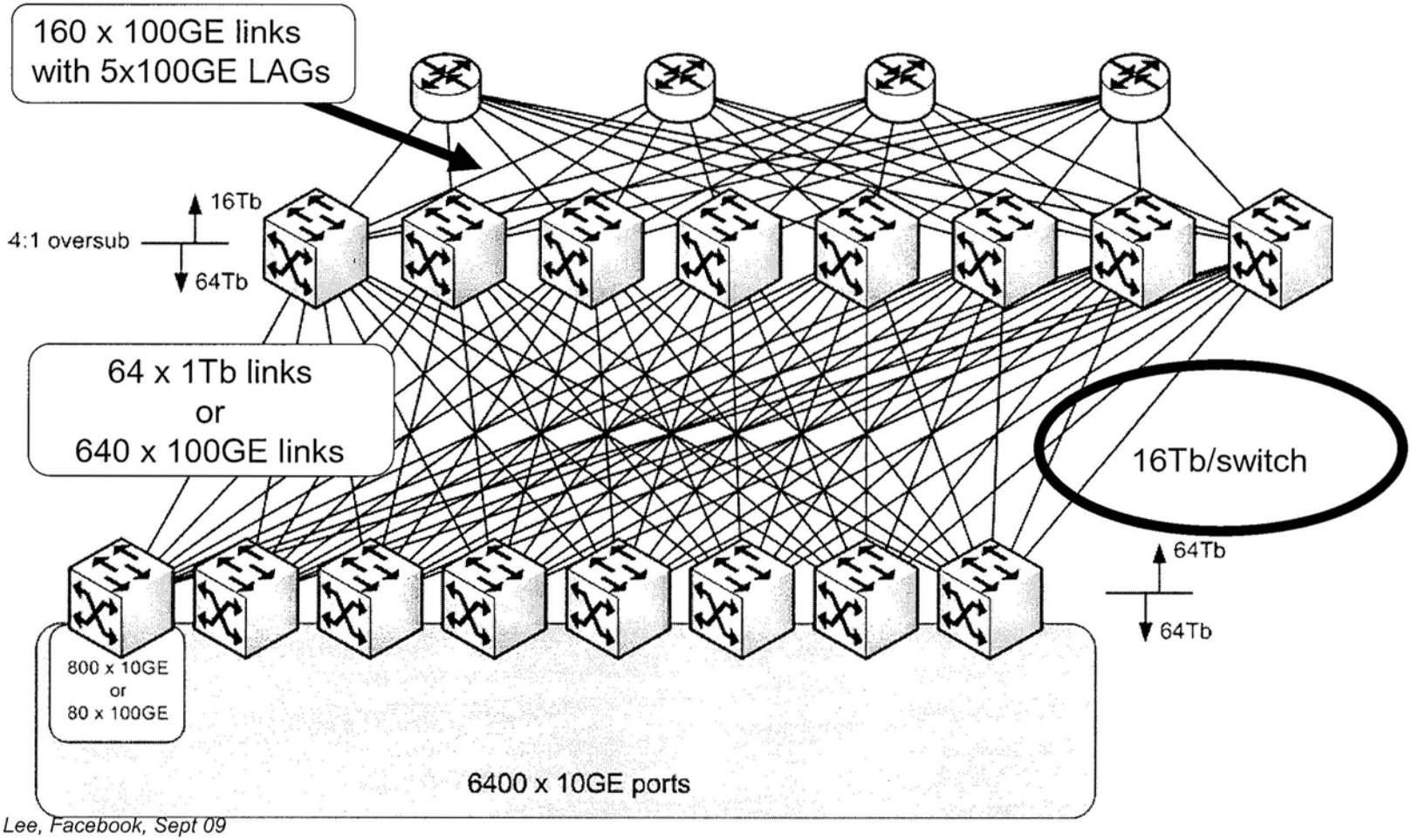
Demand outpacing equipment development



Source: Donn Lee, Facebook, Sept 09

Data-centers are 'under pressure'

Future data-center evolution…

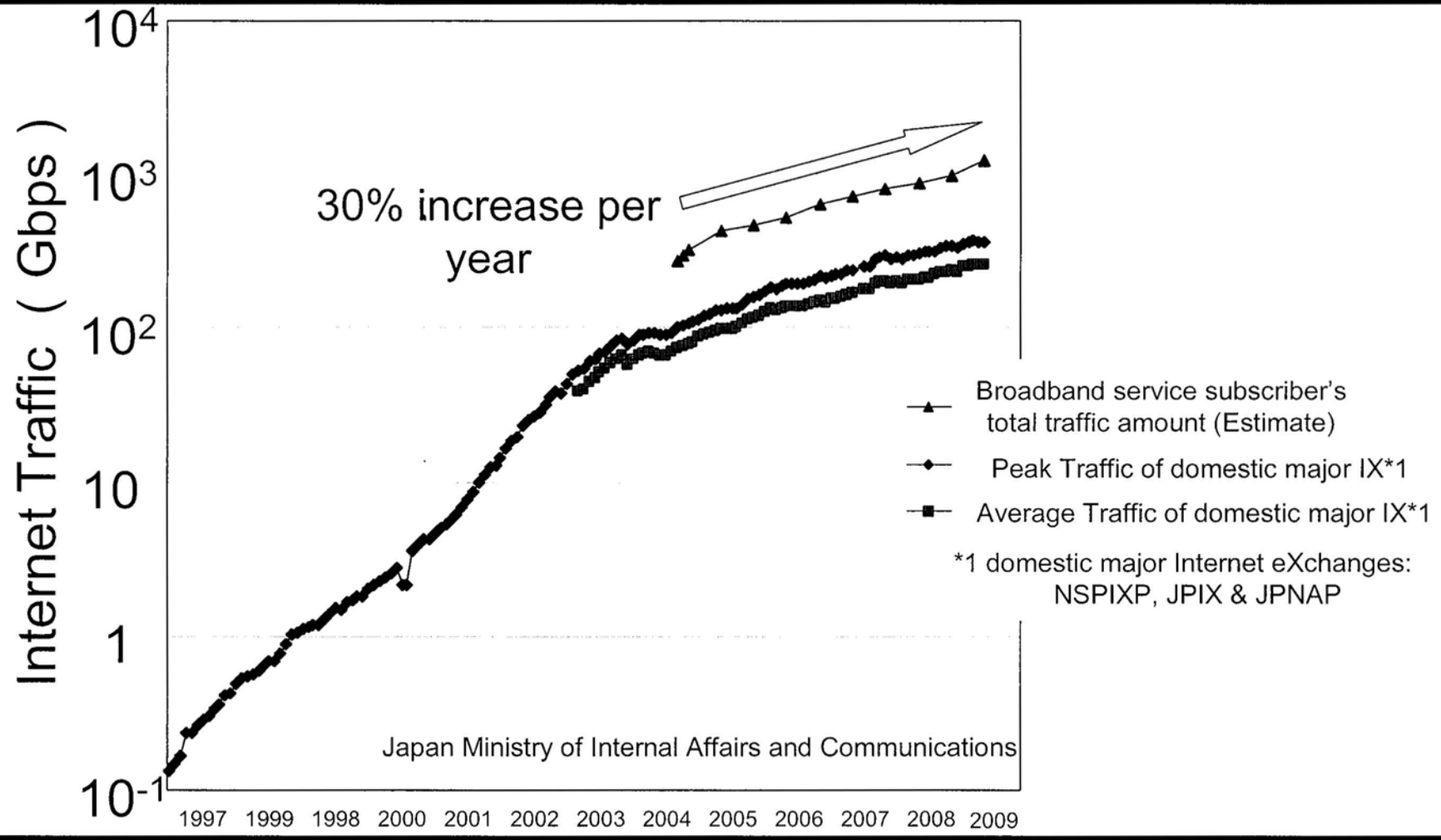


Source: Donn Lee, Facebook, Sept 09

400G+ solutions are needed…

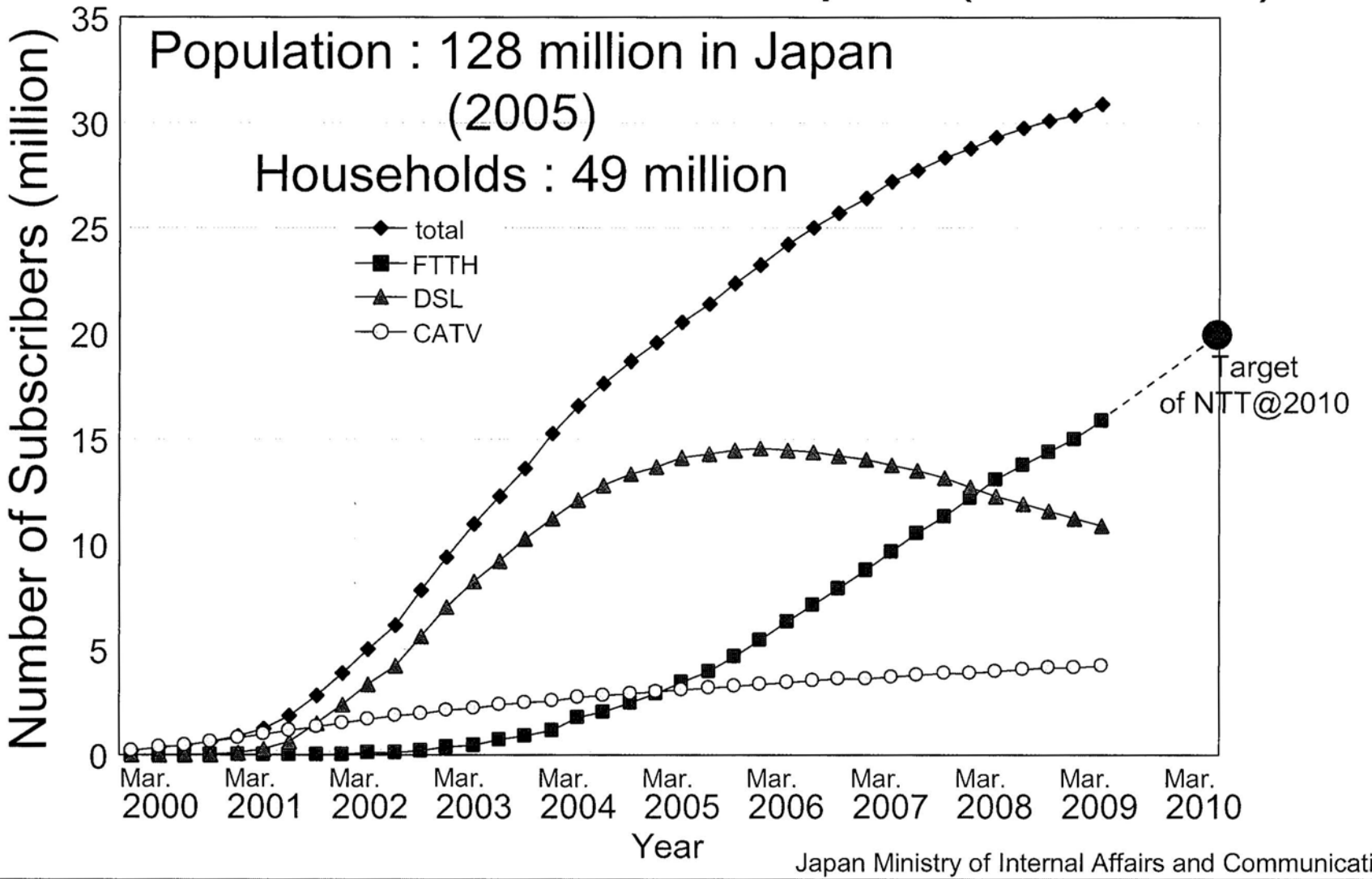
Calibration with broadband leader (Japan)

Expansion of Broadband Traffic Amount in Japan (Oct 2009)



Internet traffic in Japan → Tbps already

Broadband Services in Japan (Oct 2009)



Japan Ministry of Internal Affairs and Communications

Fiber based broadband → 'no brainer'

Japan's R&D example → 10Tbps

- Development of next-generation high-efficiency network device technology
  - ➢ The goal of this project is to increase the speed and efficiency of router switches and storage area networks for the purpose of energy conservation.
    - – Development of device technology to create edge routers capable of over 10Tbps
    - – Development of low-power-consumption device technology with a transmission capacity of 16Gbps on LAN-SAN, and demonstration of networks using such technology
- As noted by OITDA – Japanese trade association (as per OIDA in Washington DC), October 2009

Why Japan pursues R&D and not the US?

The challenges…

- Network interface rates will reach 10 Tb/s
  - Estimates range for 1Tbps in 2015 and up to 10Tbps in 2020
- Network traffic growth is outstripping system capacity growth
  - System deployments will accelerate strongly in the coming years
  - System capacity will become the most important factor
- Simple extrapolation of current methods will not meet the need
  - Progress needed on all fronts (electronics and photonics) simultaneously
- Market for core based systems will be robust

Source: R. Tkach Alcatel-Lucent

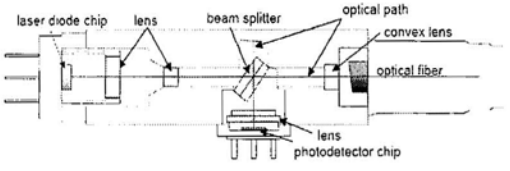
Driven by consumer internet…

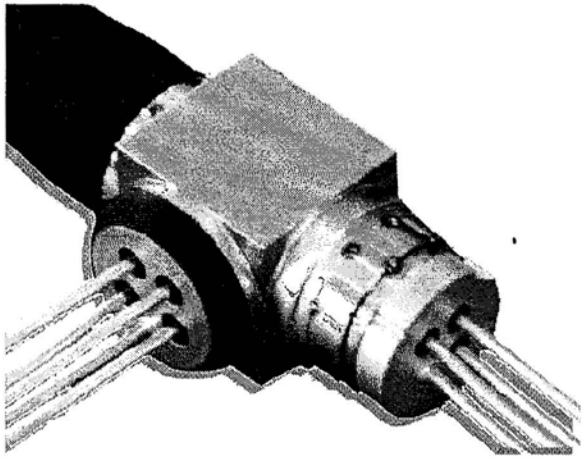
END

Technology Revolution

Free-Space Optics

optics assemblies from off-the-shelf discrete components

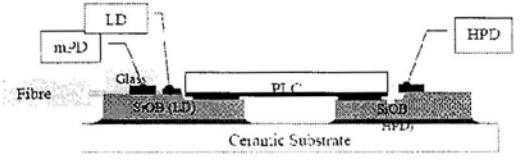


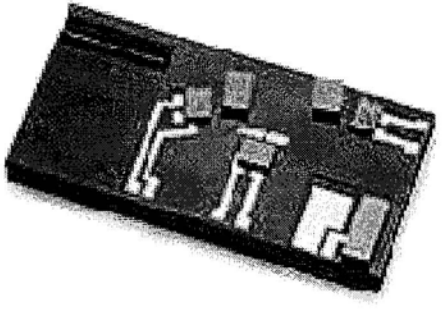


- discrete actives and passives
- up to 20 parts to assemble

Planar Lightwave Circuit

hybrid integrated SiO_2-Si based PLC (only passive)

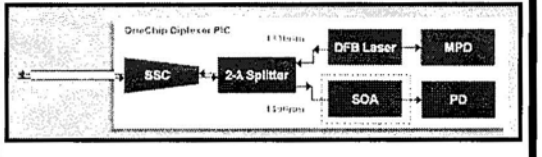




- discrete actives
- up to 10 parts to assemble

OneChip approach

Photonic Integrated Circuit (passive & active)



- **no discretes**
- **all functions in one part**

Key Advantages

Technical

- Smallest footprint
- NO active alignment even at 10G!
- Optical alignment for life
- Robust (e.g. vibration resistance)

Most Advanced

Economic

- Simplified production process
- Fully automated production
- Highest production scalability
- No dependence on active optical component lead times
- Reliable supply using standard production processes

Lowest Price

SFF Transceiver Anatomy