

---

***“Optoelectronics technology:  
New and exciting markets in  
consumer and entertainment”***

Michael Lebby  
President and CEO  
OIDA



OPTOELECTRONICS INDUSTRY DEVELOPMENT ASSOCIATION

---

***Overview***

- **Optimism** in the marketplace
  - Recovery from the bubble
  - Next decade for optoelectronics
- Optoelectronic Markets – a look today and what to expect
  - Overall worldwide market perspectives by OIDA in 2006
  - Consumer/entertainment – exciting developments
- Technical trends
  - Areas that will impact all of us; our lifestyle, our family
- Conclusion
  - Summary and overview



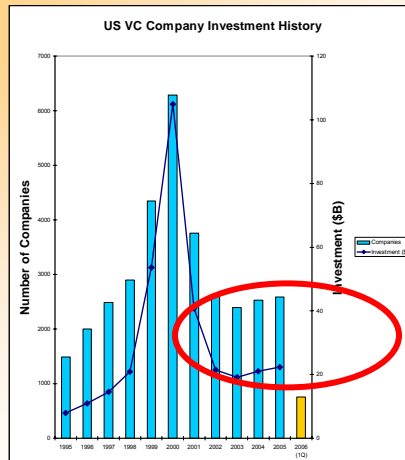
***Optimism is everywhere!***

# Optoelectronics: recovering from the bubble



OPTOELECTRONICS INDUSTRY DEVELOPMENT ASSOCIATION

## VC investment by company

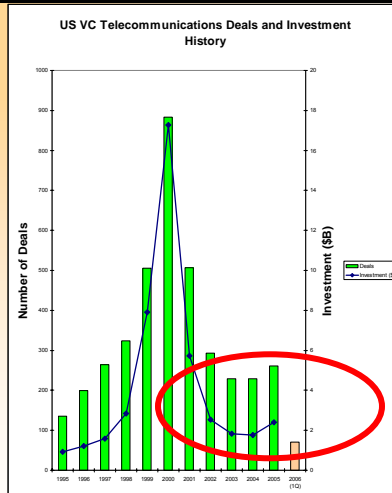


Sources: PriceWaterhouseCoopers, NVCA, Thomson Venture Economics



Slow climb to bubble levels in 2000

## VC investment in telecom



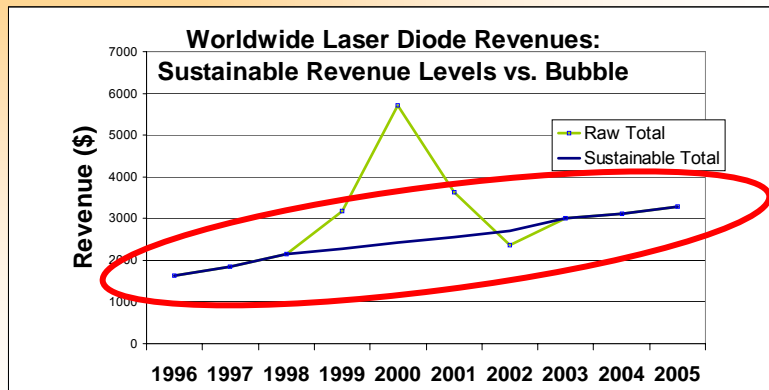
Sources: OIDA member companies, Display Search, ISupply, OIDA estimates



**VC investments on the rise again**

## One perspective of the bubble

- Worldwide laser diode revenues
  - 12% sustainable growth excluding bubble period



Source: OIDA, Pennwell, Laser Focus



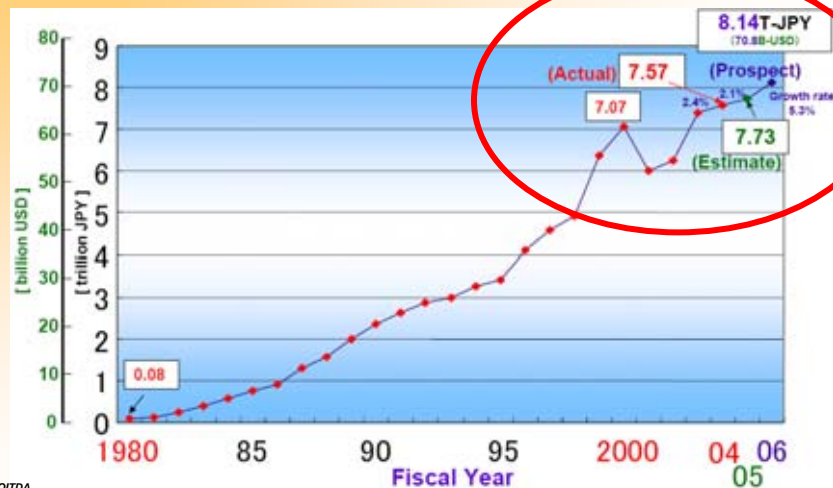
**Bubble had significant impact in the US**

# Global Perspective on Optoelectronics



OPTOELECTRONICS INDUSTRY DEVELOPMENT ASSOCIATION

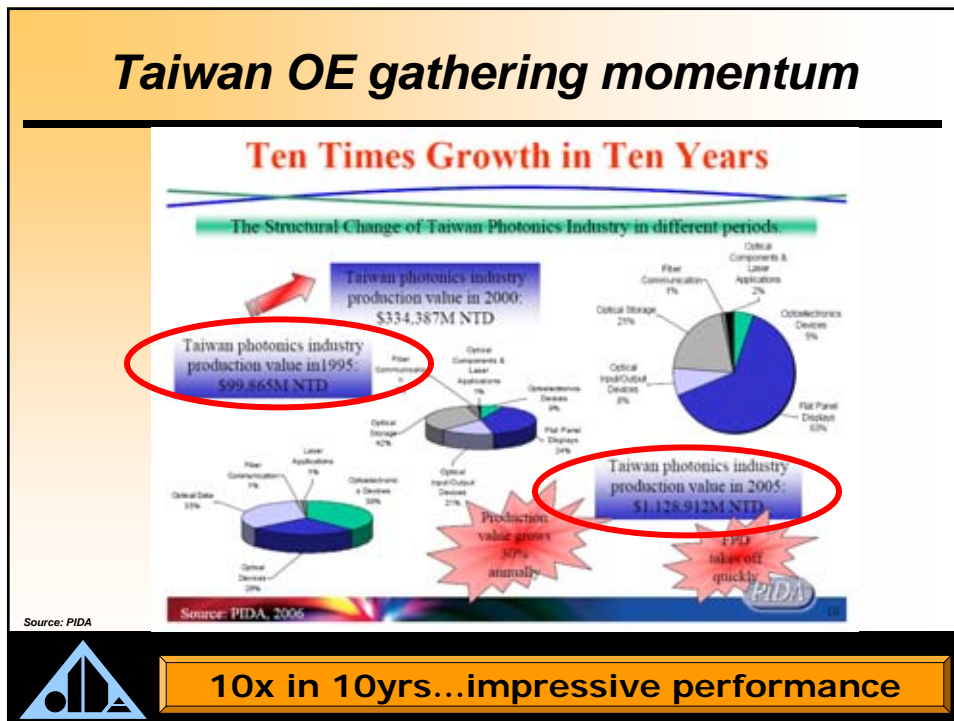
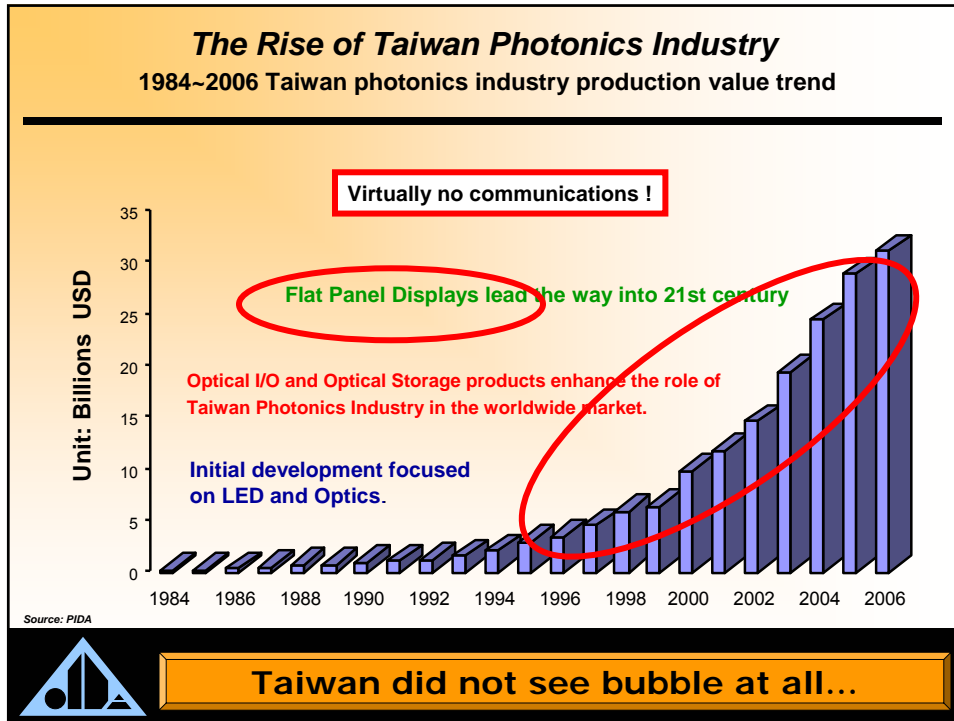
## Domestic output of Japan OE industry

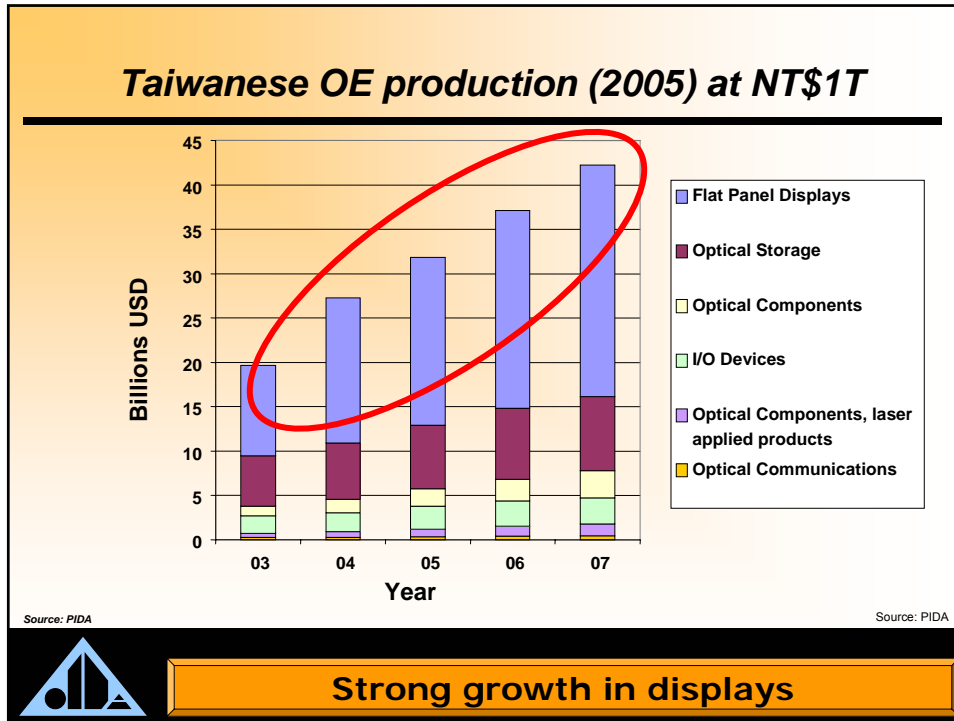


Source: OITDA



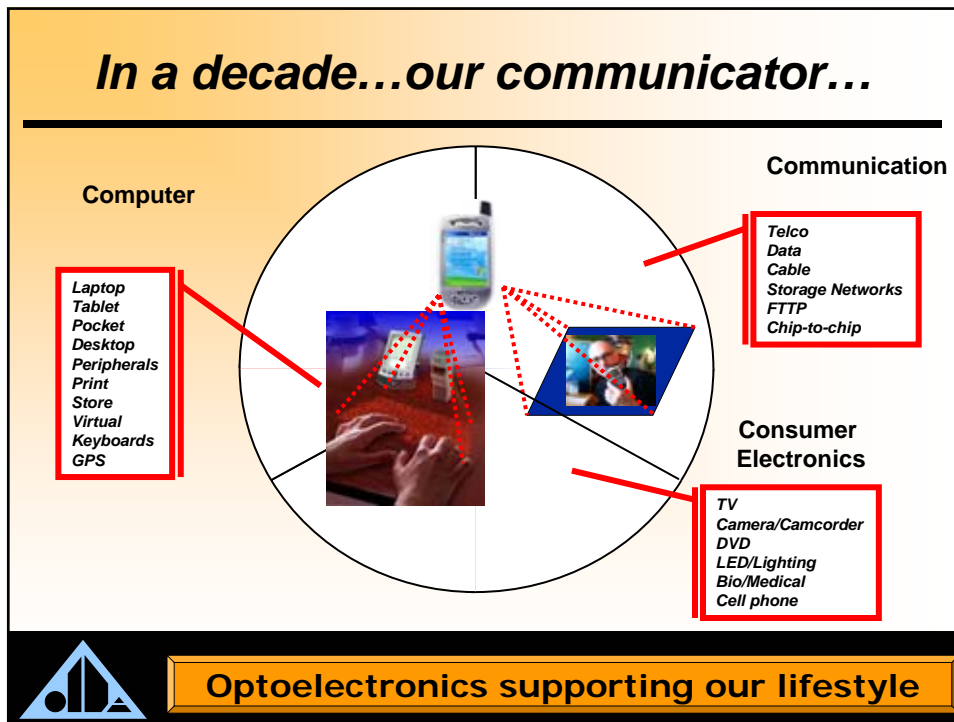
Growth in Japan strong for 2005





# Next decade in Optoelectronics

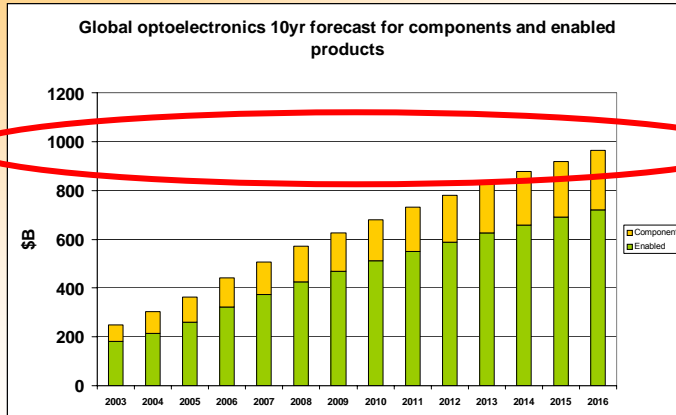
OPTOELECTRONICS INDUSTRY DEVELOPMENT ASSOCIATION



- ### ***A few drivers for our lifestyle in a decade...***
- **Convergence of applications**
    - Portability will increase; pc's shrink; virtual keyboards
      - Mobile functionality moves into medical/monitoring applications
    - Flat panel displays penetrate become ubiquitous
      - Over and above TV which will be primary driver
    - Video will allow mobile living
    - Storage and access to data will be key
  - **Humans seem to want to be connected...**
- Optoelectronics allows connection...**

## Next decade in optoelectronics

- Combined OE components and enabled products
  - 2004-16 CAGR 11%



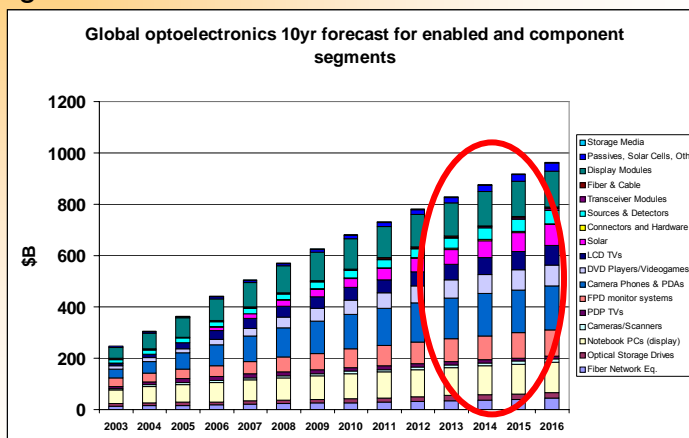
Source: OIDA



Is this a \$T industry?

## Next decade optoelectronics segments

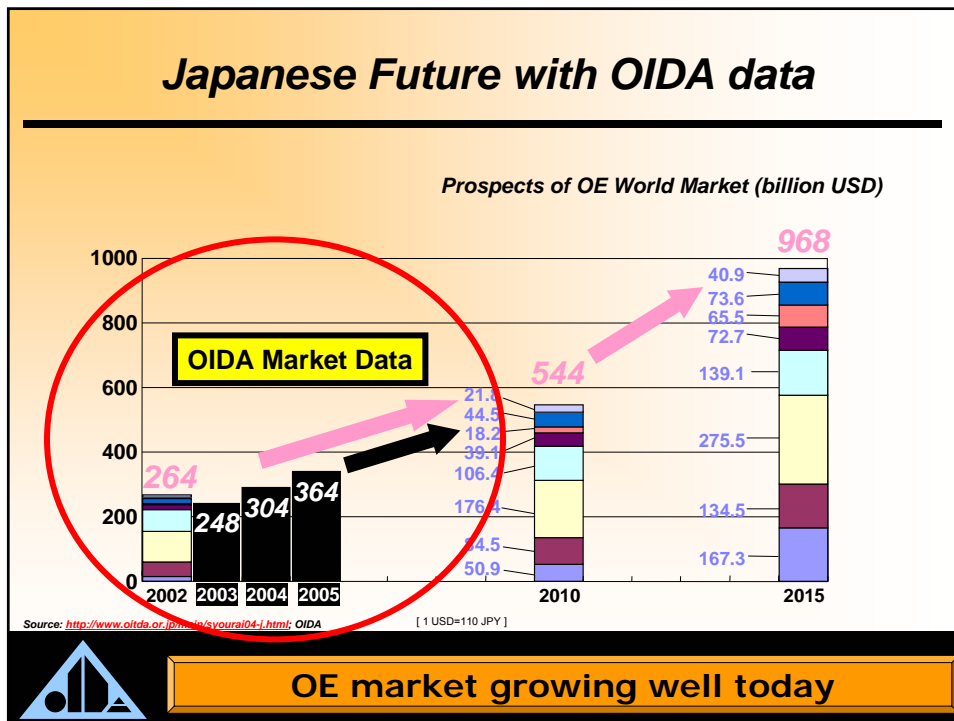
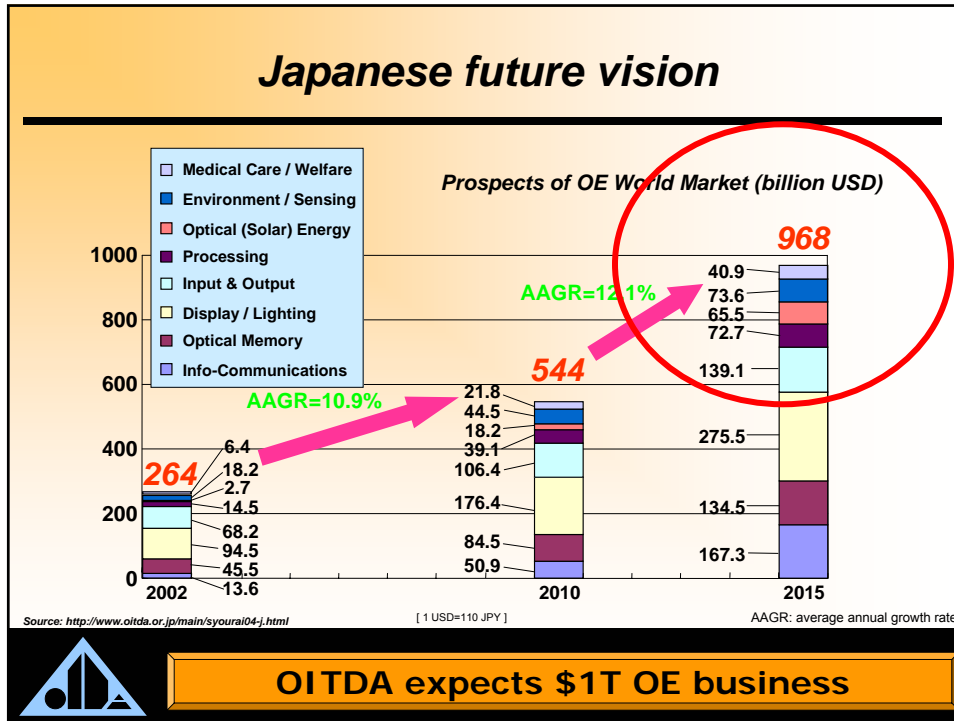
- Strong consumer/entertainment drivers

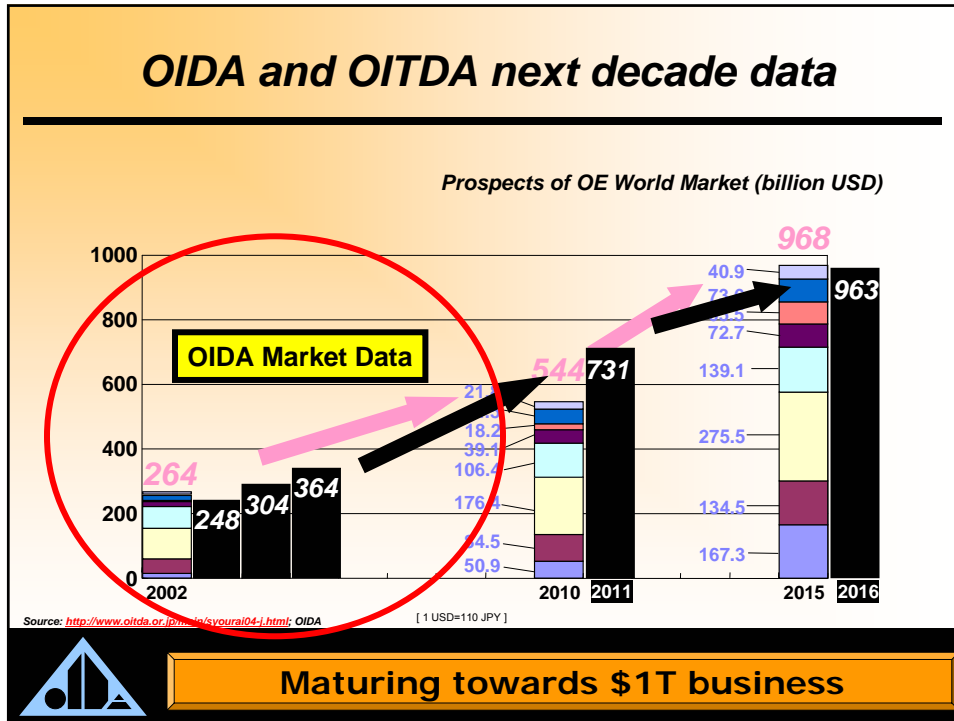


Source: OIDA



Displays grow more slowly



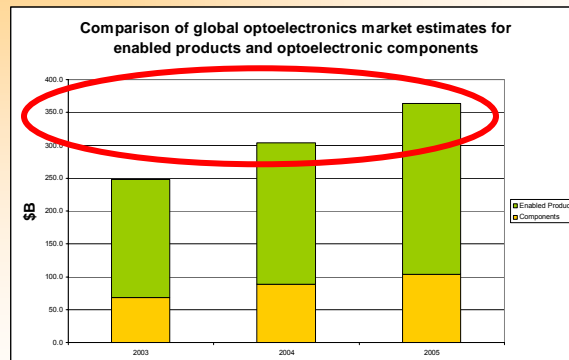


# Optoelectronics Markets

OPTOELECTRONICS INDUSTRY DEVELOPMENT ASSOCIATION

## Global OE markets for enabled products

- FPD displays big driver for enabled products (\$364B)



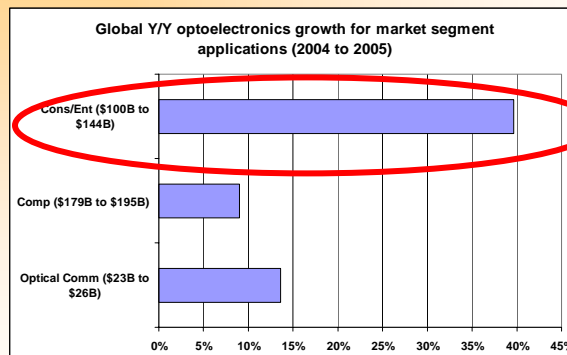
Sources: OIDA member companies, OIDA estimates, KMI, Infonetics, Ovum-RHK, TIA, IDC, CIR, Gartner, Dell'Oro, Aventis, Prudential Equity, Strategies Unlimited, CTIA, PIDA, OITDA, KAPID, Display Search, ISupply, MIC Japan



**Strong growth in OE enabled products**

## Global optoelectronics market growth

- Consumer/Entertainment driving optoelectronics
  - Liquid crystal display becoming ubiquitous



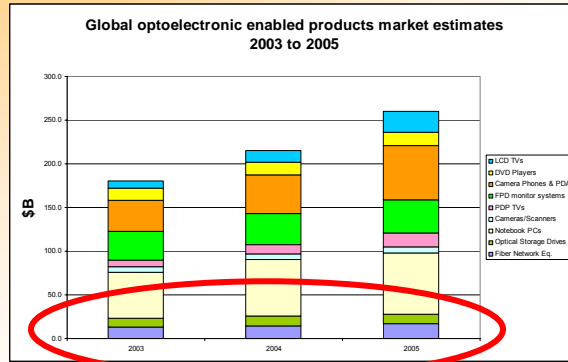
Sources: OIDA member companies, OIDA estimates, KMI, Infonetics, Ovum-RHK, TIA, IDC, CIR, Gartner, Dell'Oro, Aventis, Prudential Equity, Strategies Unlimited, CTIA, PIDA, OITDA, KAPID, Display Search, ISupply, MIC Japan



**Consumer/Entertainment dynamic...**

## Global OE enabled products market

- Communications steady compared to consumer and computer markets for optoelectronics



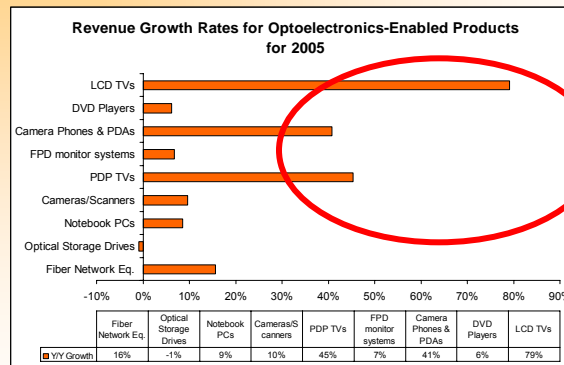
Sources: OIDA member companies, OIDA estimates, KMI, Infonetics, Ovum-RHK, TIA, IDC, CIR, Gartner, Dell'Oro, Aventis, Prudential Equity, Strategies Unlimited, CTIA, PIDA, OITDA, KAPID, Display Search, ISupply, MIC Japan



Communications: 'steady as she goes'

## Growth for OE enabled products

- Consumer products are jazzing the market in 2005




Sources: OIDA member companies, OIDA estimates, KMI, Infonetics, Ovum-RHK, TIA, IDC, CIR, Gartner, Dell'Oro, Aventis, Prudential Equity, Strategies Unlimited, CTIA, PIDA, OITDA, KAPID, Display Search, ISupply, MIC Japan



Flat panel displays are everywhere

# *Global geographical optoelectronics*

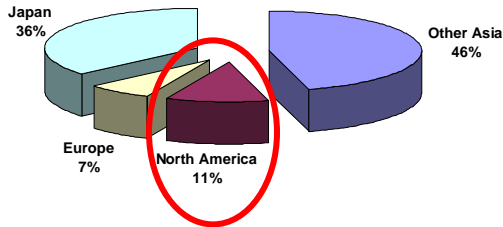


OPTOELECTRONICS INDUSTRY DEVELOPMENT ASSOCIATION

## *Geographic distribution of total global OE*

- North America ~\$40B out of \$364B

Global geographical distribution of Total OE Components and Enabled products in 2005 (Total \$364B)



Region	Percentage
Other Asia	46%
Japan	36%
North America	11%
Europe	7%

Sources: OIDA member companies, OIDA estimates, KMI, Infonetics, Ovum-RHK, TIA, IDC, CIR, Gartner, Dell'Oro, Aventis, Prudential Equity, Strategies Unlimited, CTIA, PIDA, OITDA, KAPID, Display Search, ISupply, MIC Japan

**Driven by displays in Asia and Japan**

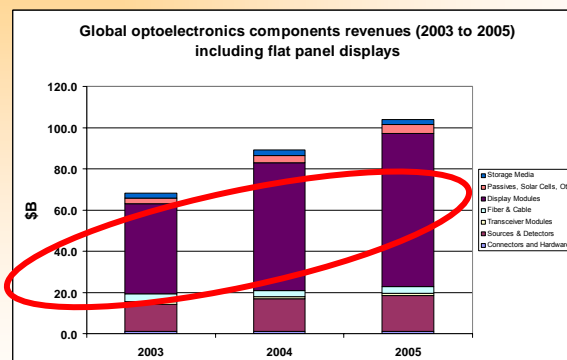
# Optoelectronics components



OPTOELECTRONICS INDUSTRY DEVELOPMENT ASSOCIATION

## Global OE components markets

- Displays dominate components (>\$70B)
  - Sources and detectors next with \$17B in 2005



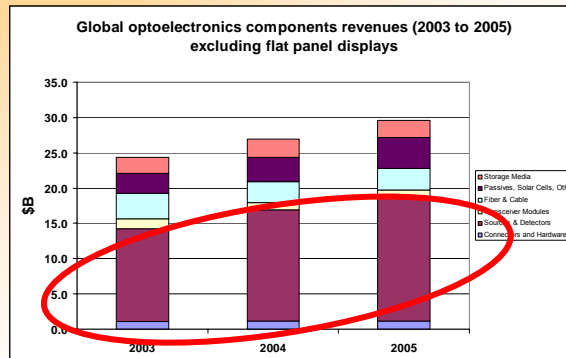
Sources: OIDA member companies, OIDA estimates, KMI, Infonetics, Ovum-RHK, TIA, IDC, CIR, Gartner, Dell'Oro, Aventis, Prudential Equity, Strategies Unlimited, CTIA, PIDA, OITDA, KAPID, Display Search, ISupply, MIC Japan



Displays dwarf traditional OE components

## Global OE components revenues

- Excluding FPD the revenue drops to \$29B
  - Sources and detectors driving the OE business in 2005



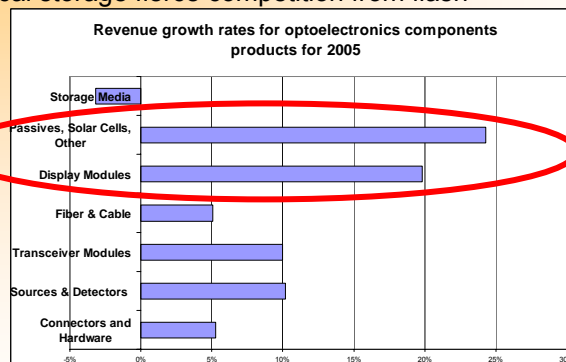
Sources: OIDA member companies, OIDA estimates, KMI, Infonetics, Ovum-RHK, TIA, IDC, CIR, Gartner, Dell'Oro, Aventis, Prudential Equity, Strategies Unlimited, CTIA, PIDA, OITDA, KAPID, Display Search, ISupply, MIC Japan



Sources and detectors good growth

## Year on year growth for OE components

- Solar cells and display modules drive the growth
  - Fiber and cable up in 2005 (-1% in 2004)
  - Optical storage fierce competition from flash



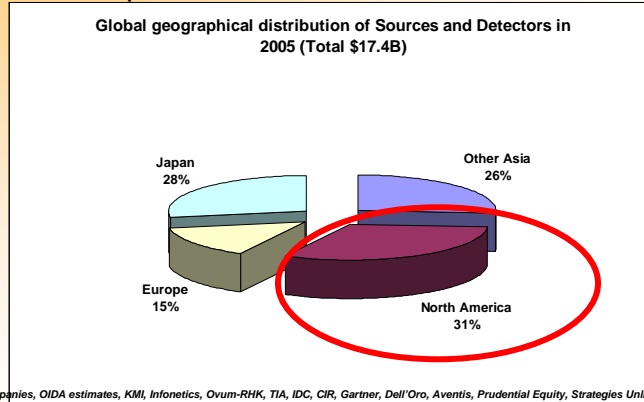
Sources: OIDA member companies, OIDA estimates, KMI, Infonetics, Ovum-RHK, TIA, IDC, CIR, Gartner, Dell'Oro, Aventis, Prudential Equity, Strategies Unlimited, CTIA, PIDA, OITDA, KAPID, Display Search, ISupply, MIC Japan



Overall, solid growth across segments

## ***Geographic distribution of OE components: sources & detectors***

- Includes laser diodes, nondiode lasers, LEDs, image sensors, couplers



Sources: OIDA member companies, OIDA estimates, KMI, Infonetics, Ovum-RHK, TIA, IDC, CIR, Gartner, Dell'Oro, Aventis, Prudential Equity, Strategies Unlimited, CTIA, PIDA, OITDA, KAPID, Display Search, ISupply, MIC Japan



**NA driven by strong telecom LD**

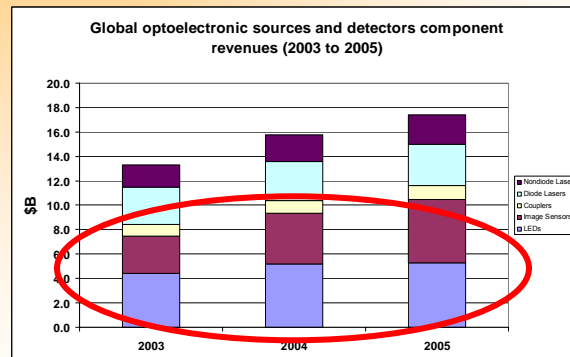
# ***Optoelectronics sources & detectors***



OPTOELECTRONICS INDUSTRY DEVELOPMENT ASSOCIATION

## Global OE sources and detectors

- Image sensors strong growth due to camera phones
- HBLEDS now penetrating many consumer markets



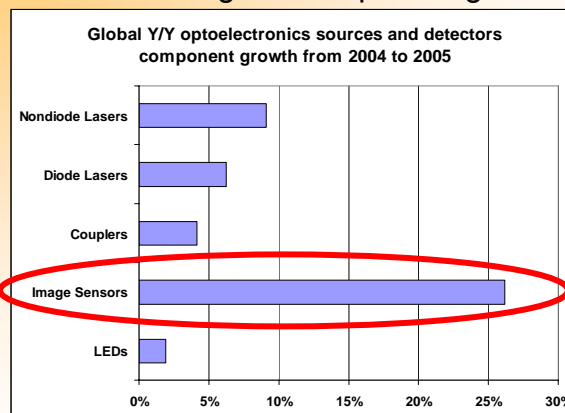
Sources: OIDA member companies, OIDA estimates, KMI, Infonetics, Ovum-RHK, TIA, IDC, CIR, Gartner, Dell'Oro, Aventis, Prudential Equity, Strategies Unlimited, CTIA, PIDA, OITDA, KAPID, Display Search, ISupply, MIC Japan



**Growth driven by consumer markets**

## Growth in OE sources and detectors

- Image sensors driving the component growth in 2005



Sources: OIDA member companies, OIDA estimates, KMI, Infonetics, Ovum-RHK, TIA, IDC, CIR, Gartner, Dell'Oro, Aventis, Prudential Equity, Strategies Unlimited, CTIA, PIDA, OITDA, KAPID, Display Search, ISupply, MIC Japan



**All segments showing strong growth**

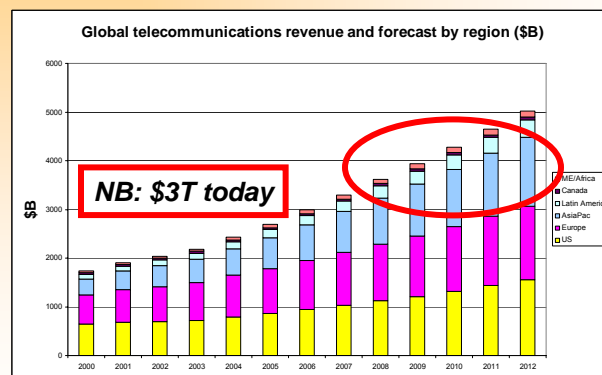
# Communications: exciting developments...



OPTOELECTRONICS INDUSTRY DEVELOPMENT ASSOCIATION

## Global telecommunications market

- Asia will become strong at the end of the decade
- Europe is already biggest than the US



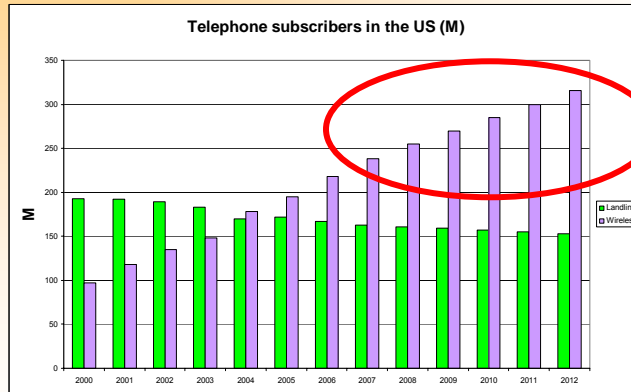
Sources: TIA, OIDA



Three major markets at end of decade

## US based telephone subscribers

- Landline propped up by broadband
- Wireless driving growth (>200M subscribers today)



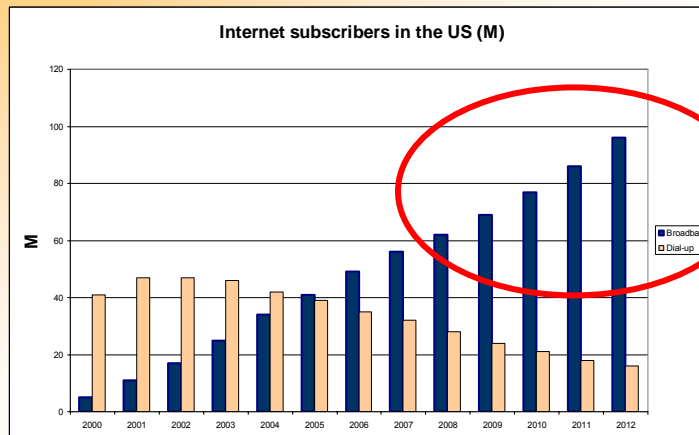
Sources: TIA, FCC, CTIA, OIDA



Exciting growth in wireless -> Quad play

## US based internet subscribers

- Strong growth for broadband access



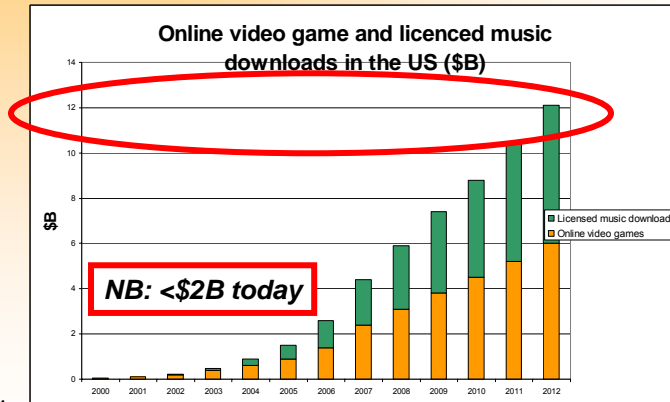
Sources: TIA, FCC, OIDA



Broadband replacing dial-up quickly

## US online video games/music downloads

- The exciting segment of the communications market
  - Vehicles to 'fill the pipes' and use in pricing packages



Key areas for leveraging the business

## Video on Demand (VOD) + IPTV is the biggest change in TV since color



- How many of us see going back to Black & White TV?
- Today's change to **High Definition TV** resolutions is minor compared to TV's change to **interactivity** via Personal Video Recorders, Interactive TV & VOD

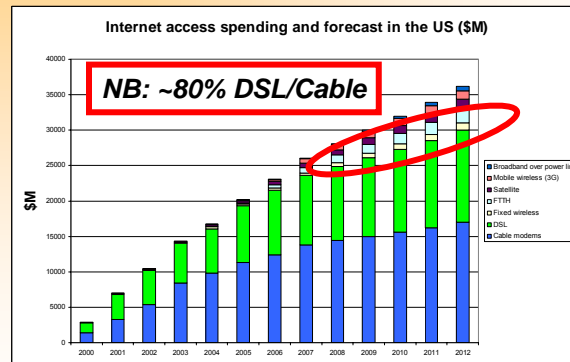
Source: Cisco



CES 2007 – TV mobiles/PDA

## US Internet access spending

- FTTH will remain a minority access path to the internet by the end of the decade



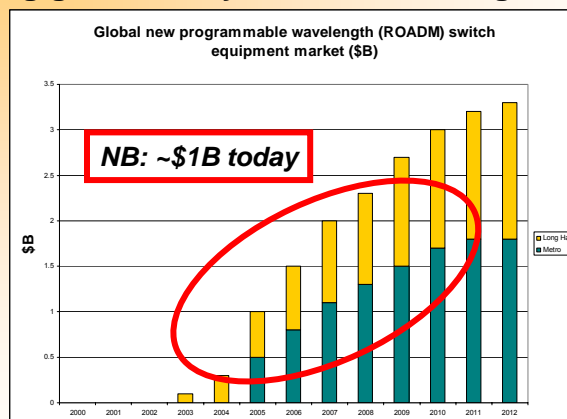
Sources: TIA, FCC, OECD, OIDA



Will recent FCC ruling impact progress?

## Global new programmable wavelength (ROADM) switch equipment market (\$B)

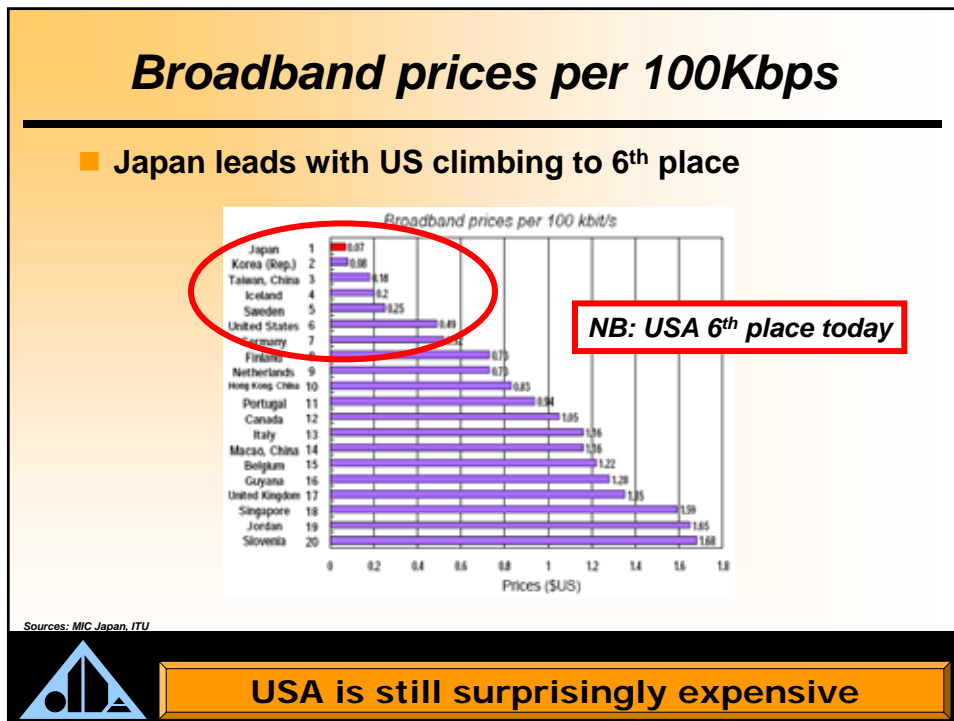
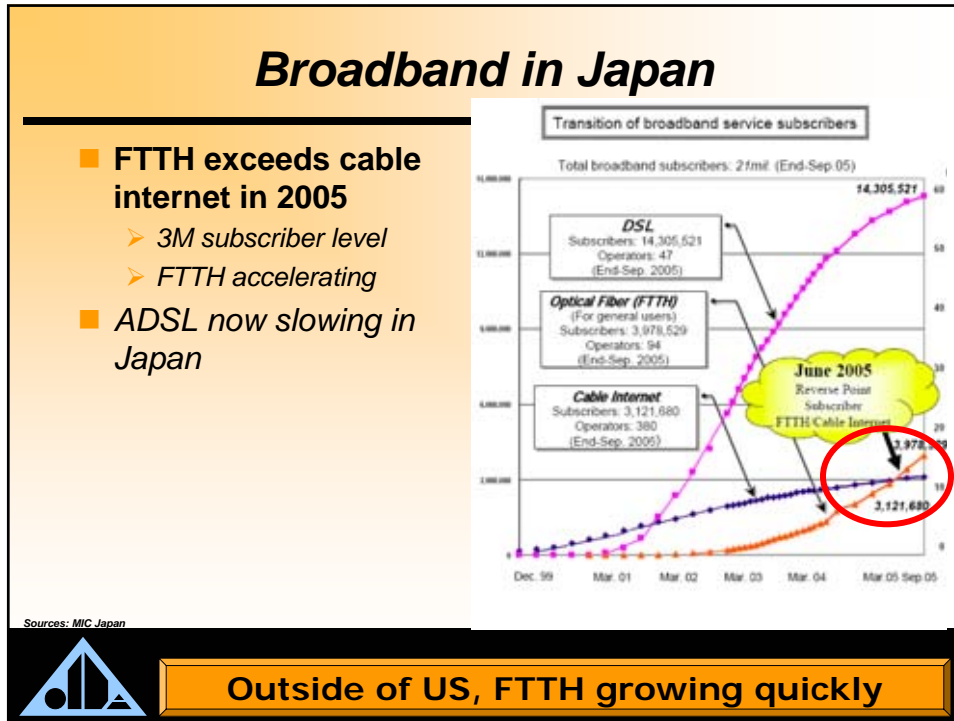
- Strong growth in dynamic networking to \$3B in 2012



Sources: OIDA member companies, KMI, Infonetics, Ovum-RHK, TIA, IDC, CIR, Gartner, Dell'Oro, Aventis, Prudential Equity, OIDA estimates

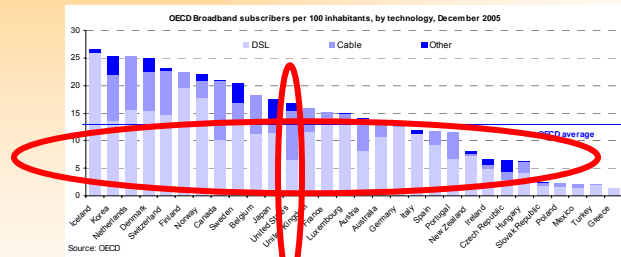


Trend towards more cost efficient OpEx



## Broadband subscribers per 100 inhabitants,

■ By technology, Iceland now new leader with DSL



**NB: USA 12<sup>th</sup> place today**

Sources: OECD



**DSL playing strong role internationally**

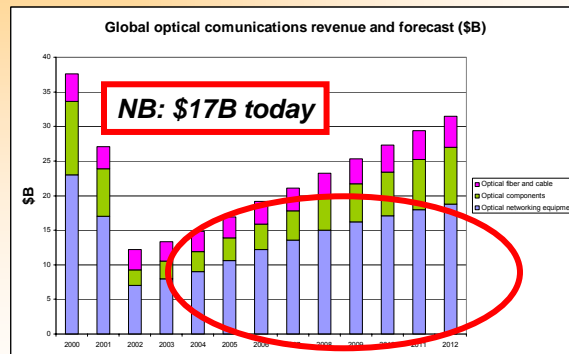
# Communications: clawing back from starvation



OPTOELECTRONICS INDUSTRY DEVELOPMENT ASSOCIATION

## Global optical communications revenue

- Optical networking and components increasing



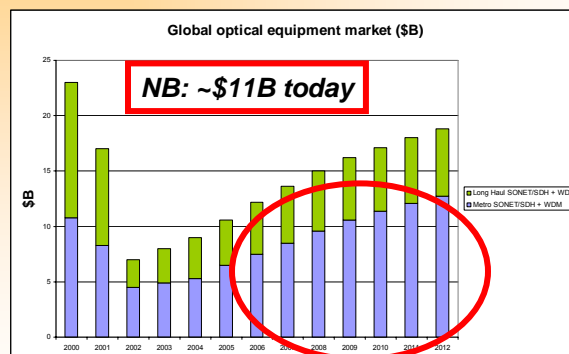
Sources: MIC Japan TIA, Ovum-RHK, Infonetics, IDC, CIR, Gartner, KMI, Dell'Oro, Aventis, OIDA estimates, OIDA member companies



Positive growth but not that exciting

## Global optical equipment market

- Metro driving growth in optical equipment



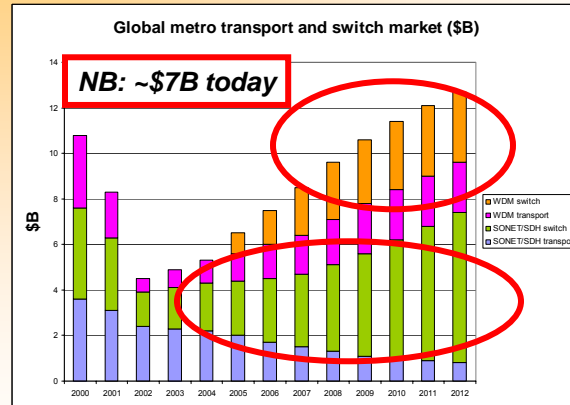
Sources: KMI, Infonetics, Ovum-RHK, OIDA member companies, TIA, IDC, CIR, Gartner, Dell'Oro, Aventis, Prudential Equity, OIDA estimates



Metro is where the action is...

## Global metro transport and switch market

### ■ Strong growth in SONET/SDH switch equipment

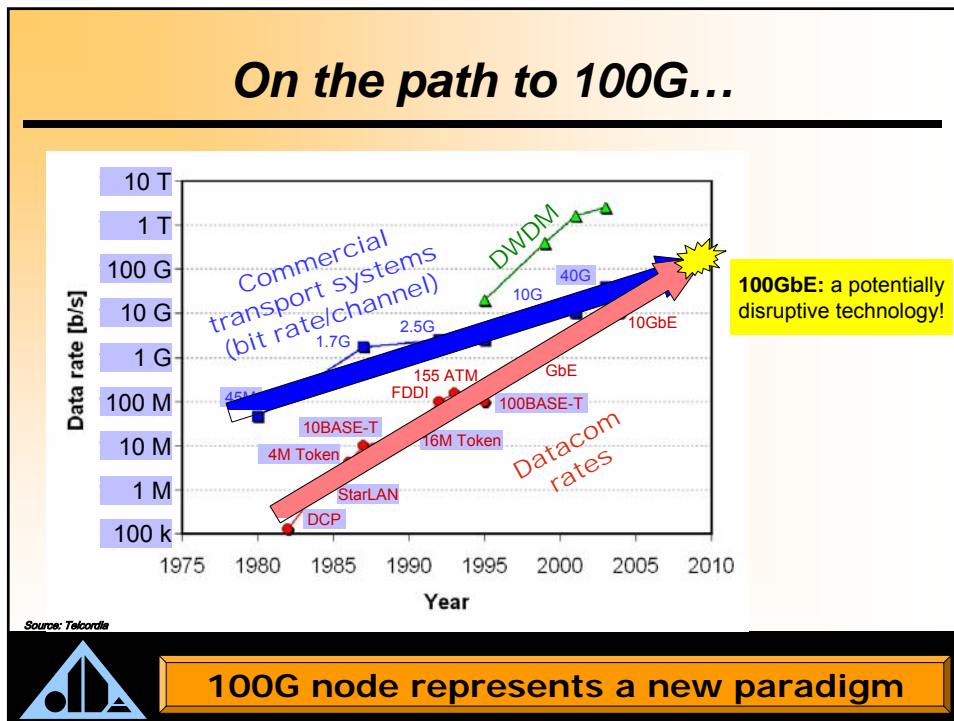
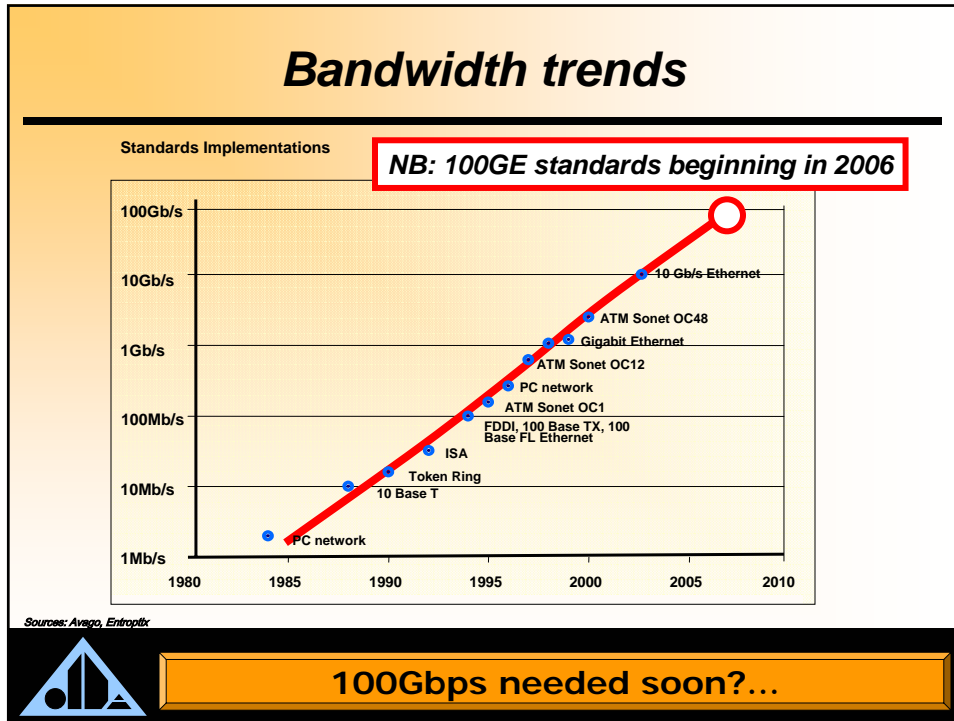


Metro switching exciting

## Transceiver market



OPTOELECTRONICS INDUSTRY DEVELOPMENT ASSOCIATION



## Is this what 2 petabits will look like?



How do we grow the network to handle this increased bandwidth demand, at a price point appropriate for the application?

Source: Cisco



100Gbps(?) and a disinterested cat...

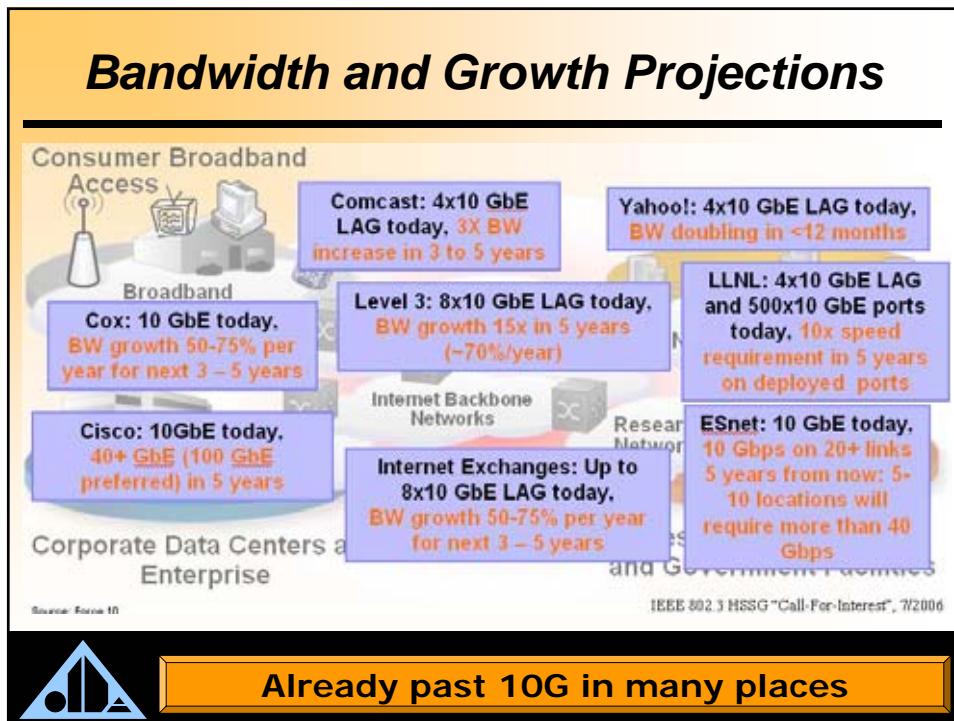
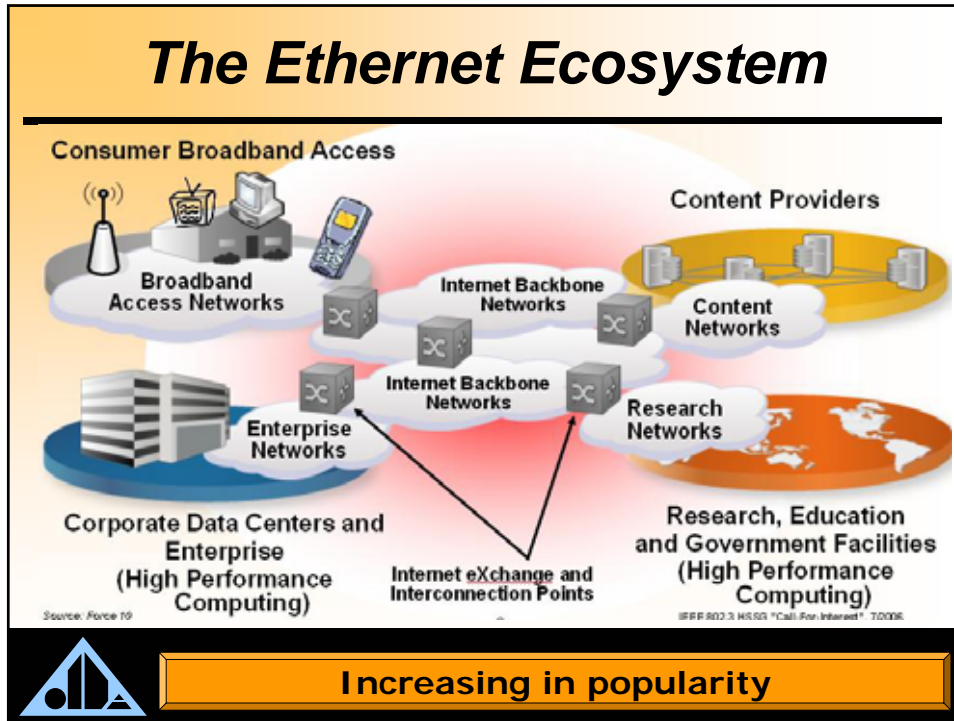
## Who wants "100GE"?

Market Drivers	10G	100G
<b>Data center / Internet media providers:</b> to support the growth of Internet multimedia content and web applications content providers have been expanding data centers pushing 10 GbE technology to its limits.	Largest driver behind today's adoption of 10GbE. Data center innovators.	Highest-volume (in relative terms) among early-adopters of 100 GbE.
<b>Metro-Video / Service Providers:</b> video on demand/3-play has been driving a new generation of 10GbE Ethernet metro/core network buildouts.	Largest 10GbE driver in metro/core networks. SP innovators.	High-volume potential (in relative terms). Need PMD optimized for metro/transport.
<b>Wiring Closet / Enterprise:</b> Design Goals for bandwidth oversubscription ratio in distribution/core	No early adopters, more a second wave of growth for 10 GbE.	Transition even slower than 1G->10G in relative terms, since desktop might not get past 1G anytime soon (no pressure in the access).
<b>Internet Exchanges - SP core routing bandwidth upgrade</b>	Significant factor for 10 GbE metro/core growth.	Early adopters, but impact on volumes unclear.

Source: Cisco



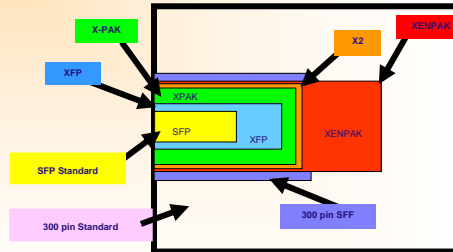
Video/media services over IP



### Network cost reduction implications for transceivers

- |  |                             |
|--|-----------------------------|
| Great port density requires:                 | Small size                  |
|  | Lower Power Draw            |
|  | Extended Temperature Ranges |
| Low first cost requires:                     | Low transceiver cost        |
|  | Hot pluggability            |
| Immunity to carrier forecast error requires: | Hot pluggability            |

The result is a move to SFP and SFP+ (10Gbps)



Source: Lebbby 1999



Trends are smaller pluggable designs

### Transceiver trends

What the customer wants:



What we can currently see:



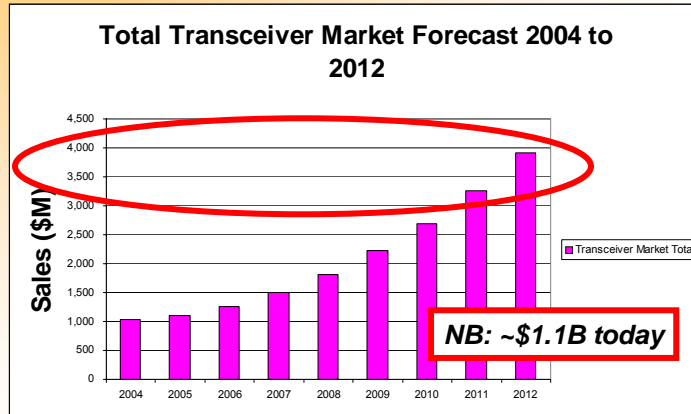
Source: Picolight



Issue: driven by front panel connects

## Total transceiver market forecast

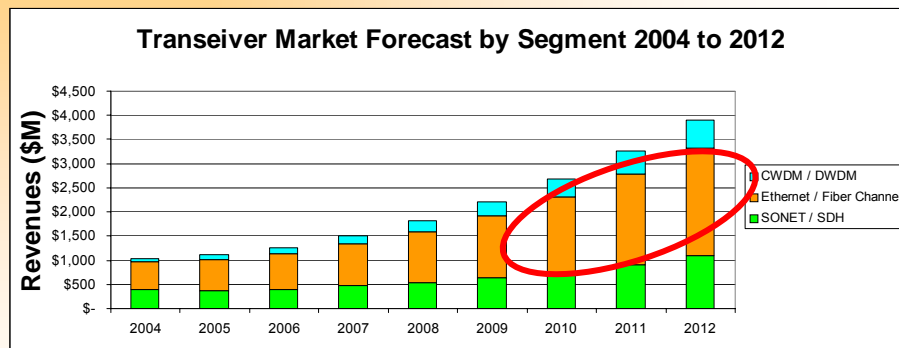
- Solid growth expected to the end of the decade



**Total approaching \$4B by 2012**

## Transceiver market forecast by segment

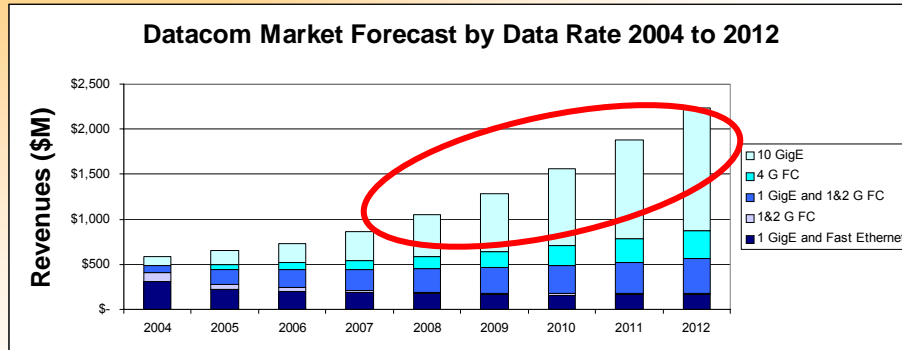
- SONET slows, C/D WDM grows, Ethernet/FC accelerate



**Ethernet/FC becomes dominant**

## Datacom market by data rate

10GbE finally becomes strong after 10years...



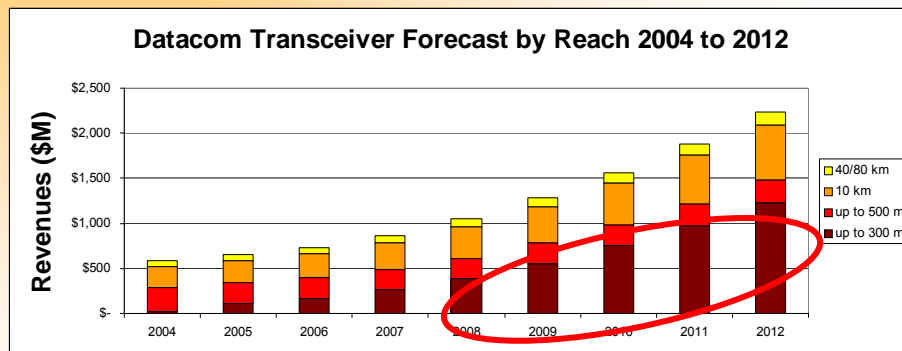
Source: OIDA, Lightcounting, Strategies Unlimited, Ovum-RHK, Pennwell, iSupply, PIDA, OITDA



10GbE becomes the '747' platform

## Datacom market by reach

Slowly fiber optic TxRx's penetrate short distances



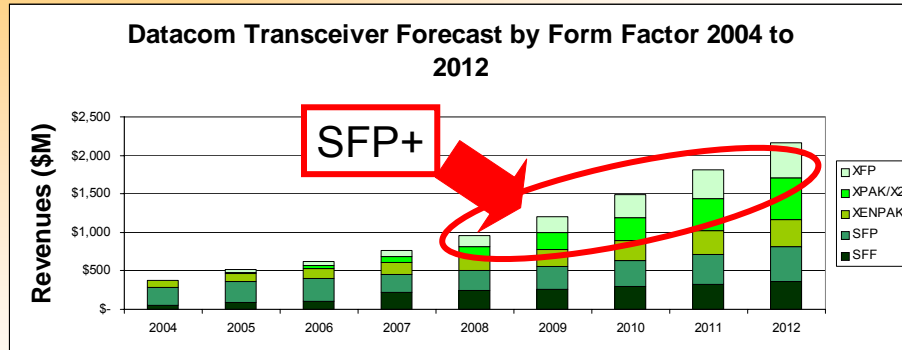
Source: OIDA, Lightcounting, Strategies Unlimited, Ovum-RHK, Pennwell, iSupply, PIDA, OITDA



Shorter links become optical

## Datacom market by form factor

- 10Gbs solutions found in at least 3 form factors



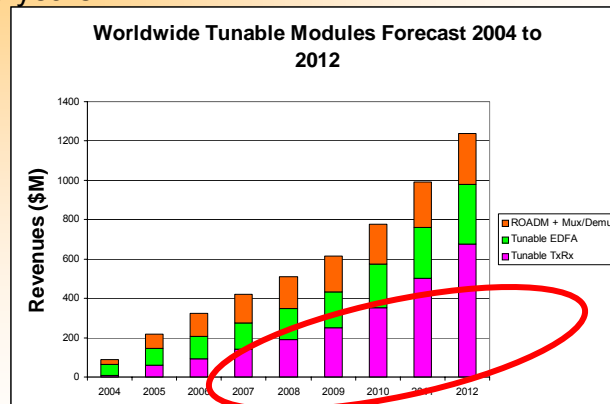
Source: OIDA, Lightcounting, Strategies Unlimited, Ovum-RHK, Pennwell, iSupply, PIDA, OITDA



**10Gbps form factors drive revenues**

## Wavelength programmable modules forecast

- Wavelength programmable technology accelerates over next 5 years



Source: OIDA, Lightcounting, Strategies Unlimited, Ovum-RHK, Pennwell, iSupply, PIDA, OITDA



**Growth to over \$1B in 2012**

### Form factor & transceiver costs

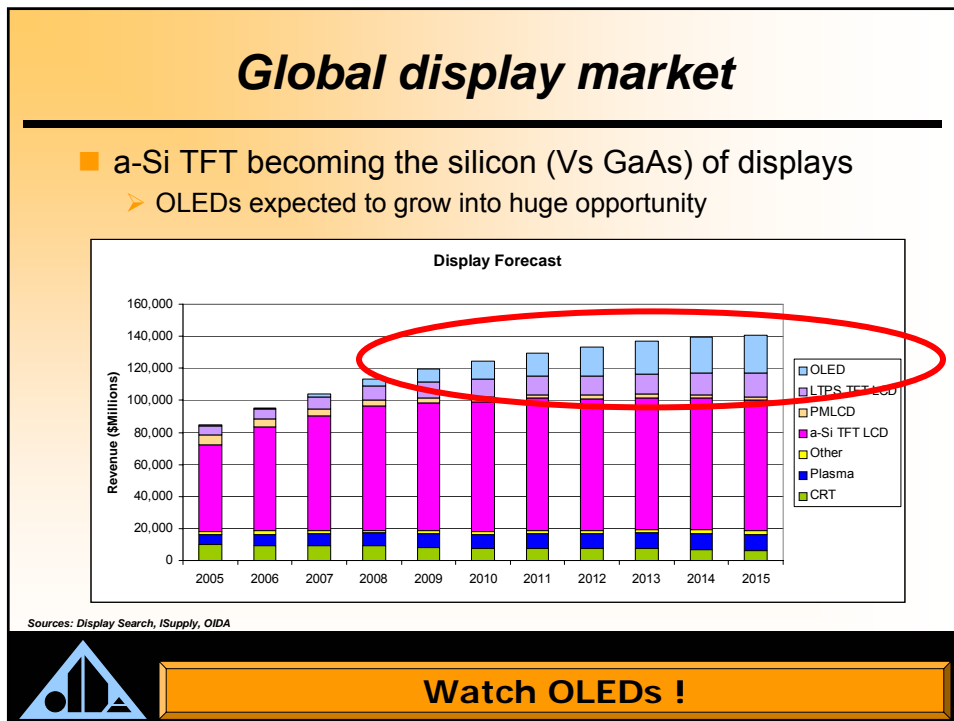
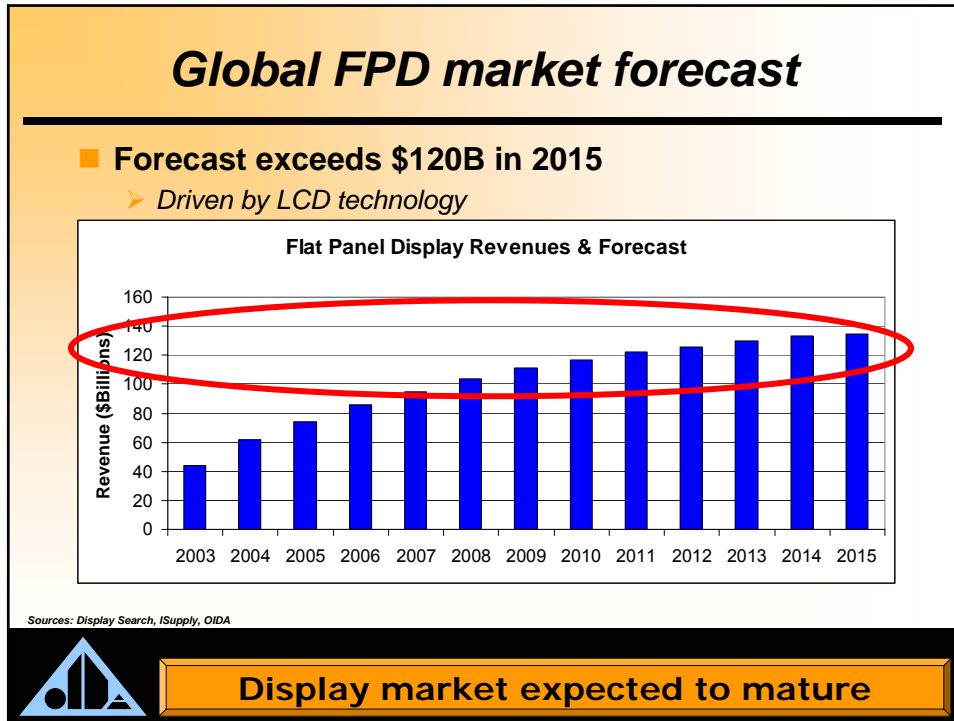
Form	Board/ Host	Optics Module
<b>GBIC</b> Xnpk X2	Serdes XAUI 4x 3.125	Serdes CDR (EDC) TOSA: LD ROSA:TIA+PD
<b>XFP</b>	Serdes XFI 1x 10.3125	CDR (EDC) TOSA: LD ROSA:TIA+PD
<b>SFP+</b>	Serdes CDR (EDC) XGMII 1x 10.3125 1 x 8.5G 1x 4.2G	TOSA: LD ROSA:TIA+PD
<b>SFP</b>	Serdes CDR SGMII 1x 4.2G 1x 1.25	TOSA: LD ROSA:TIA+PD

Source: Cisco IC integration will lower costs; IC on host will enable in the long run quad/ octal Serdes

**IC becomes key enabler...**

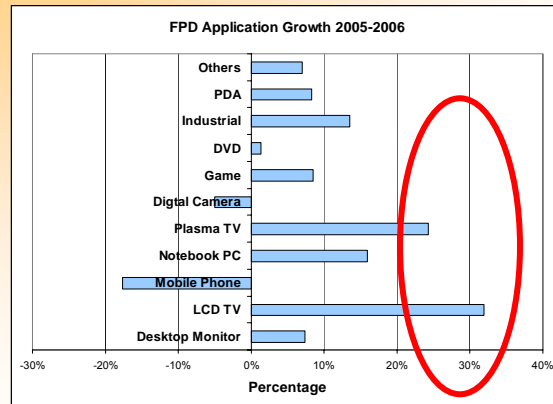
# Display trends

OPTOELECTRONICS INDUSTRY DEVELOPMENT ASSOCIATION



## Flat panel display applications

- Strongest growth in the consumer TV markets

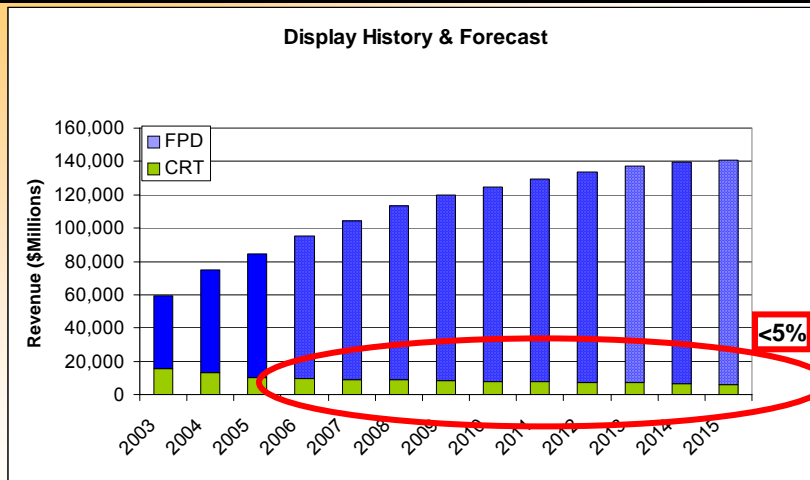


Sources: Display Search, iSupply, OIDA



Consumer again

## FPD vs CRT forecast to 2015



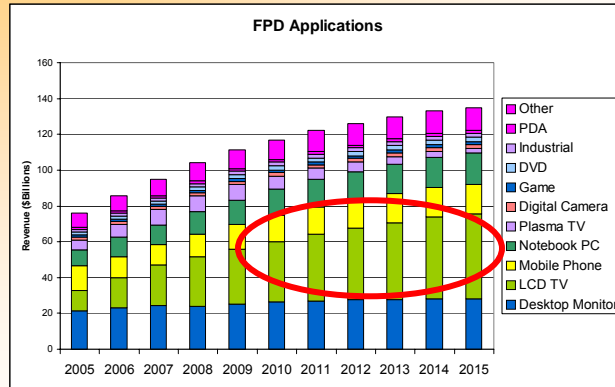
Sources: OIDA, Display Search, OIDA member companies



CRTs find fewer applications...

## Global FPD market by application

■ LCD TVs and mobile phones strong growth profile



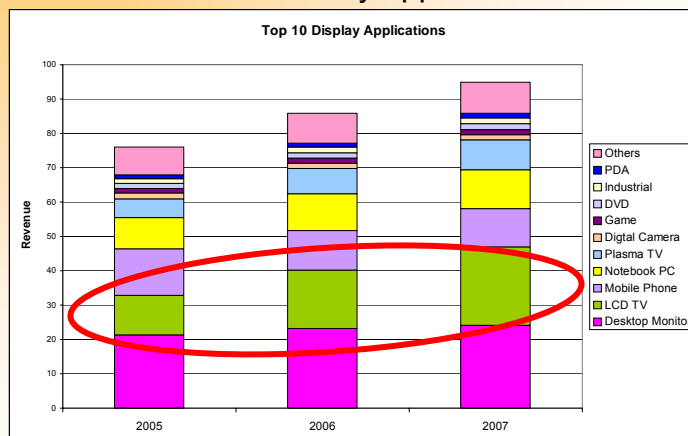
Sources: OIDA, Display Search, OIDA member companies



Consumer applications grow next decade

## Top 10 display applications

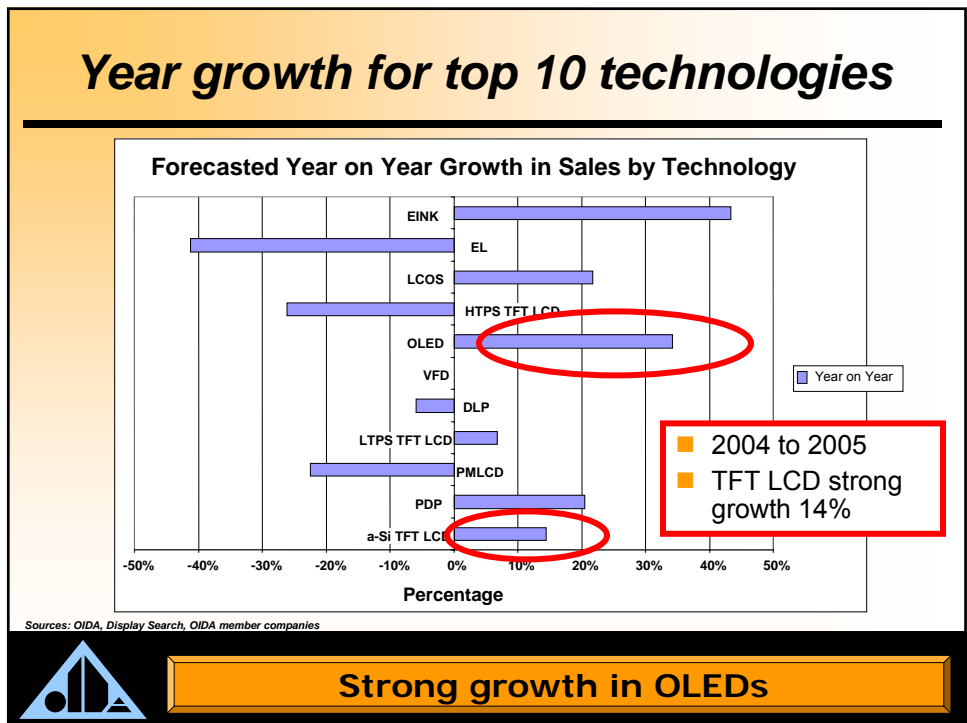
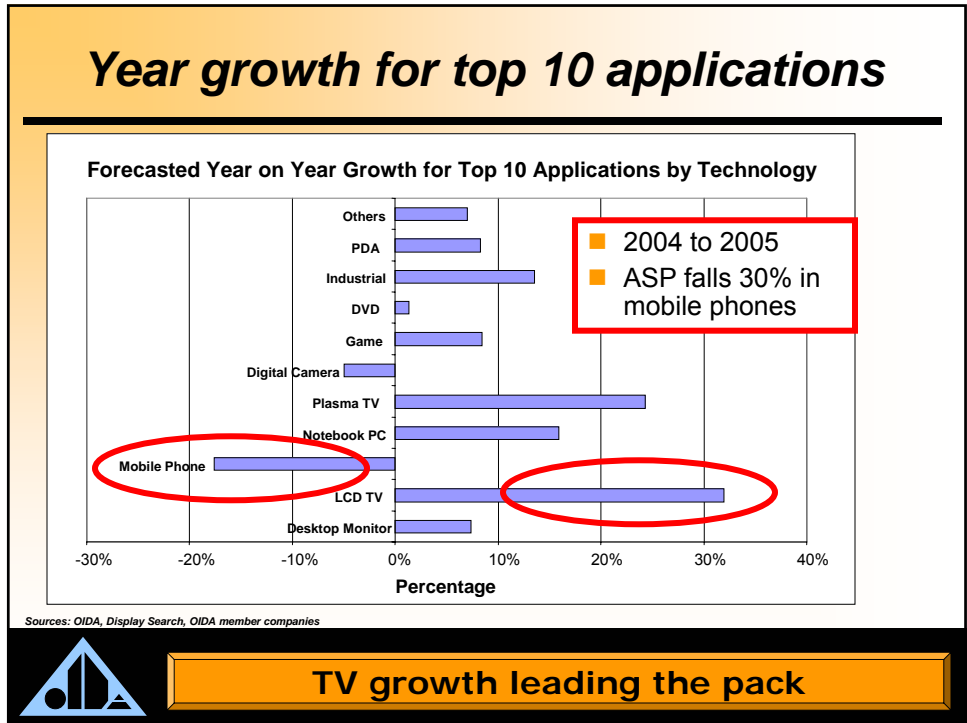
■ LCD TV 29% CAGR as key application



Sources: OIDA, Display Search, OIDA member companies







Top 10 mostly consumer/entertainment




## LCD "Glass" Size for Perspective

---

<p>Year: 2000 Largest "Glass" size = 3.5G Optimized for Monitors and Notebook Screens</p>	<p>Year: 2004 Largest "Glass" size = 6G Monitors and Larger TVs (and Digital Signage / Public Displays)</p>	<p>Year: 2006 Largest "Glass" size = 7G Larger TVs and Digital Signage / Public Displays</p>
		
2000	2004	2006


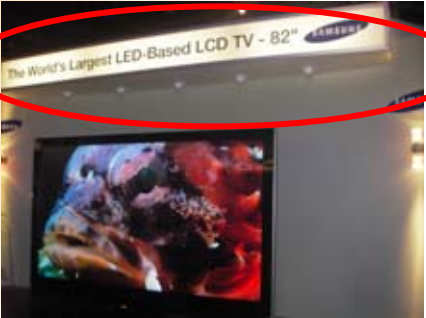


Source: DisplaySearch, LG.Philips LCD


**6G & 7G technologies poised for ramp**

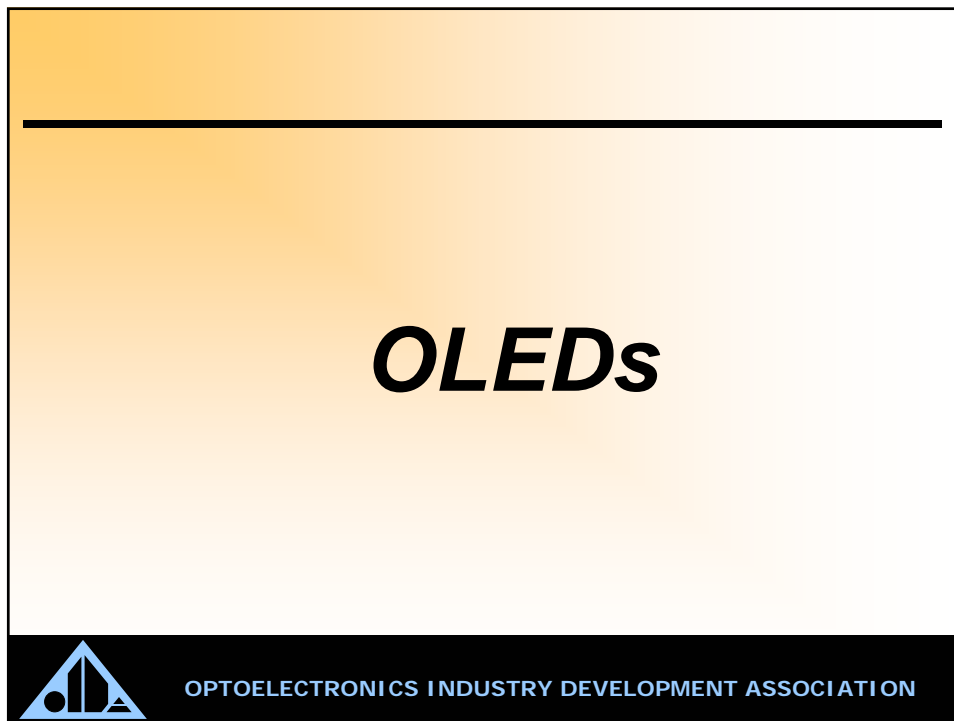
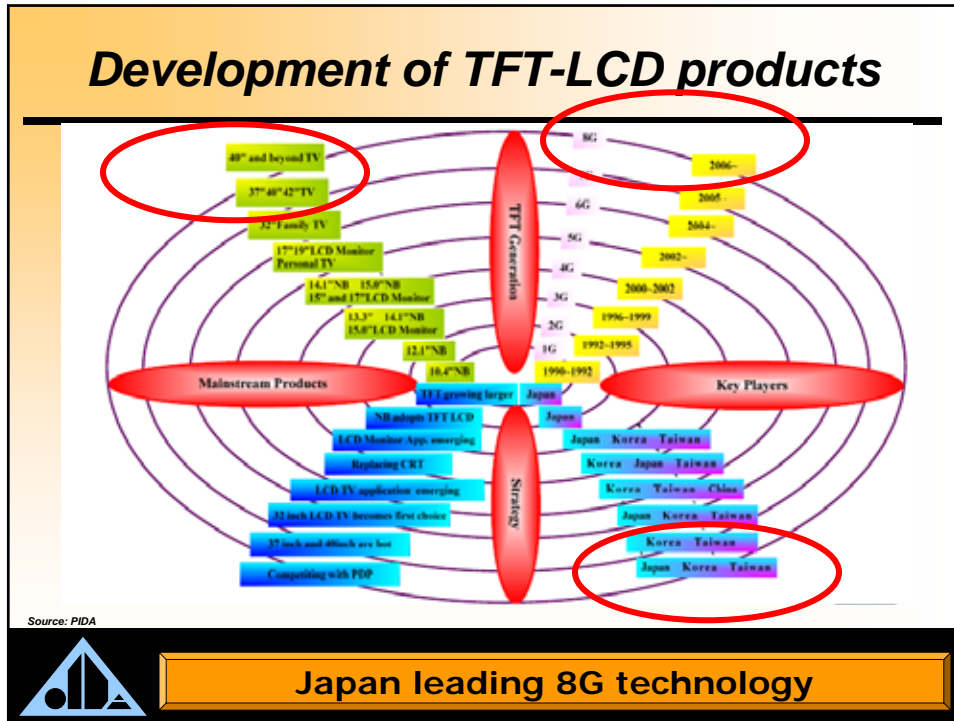
## This year 108" LCD-LED displays

---

	
--	--

Sources: OIDA, Samsung

**Still require OE innovations...LEDs**



## Organic display features

- Flexibility allows use in new applications



Sources: iSupply, USDC, Display Search



How fast will we see flexible substrates?

## OLEDs – emissive displays



- A flat radiating surface
  - New functional and design opportunities in comparison to point light sources. 150x150 mm<sup>2</sup> products available



- A wide viewing angle
  - Excellent readability from all perspectives (e.g. self emitting logos)



- An integrated luminaire
  - The fusion of the lamp and luminaire world

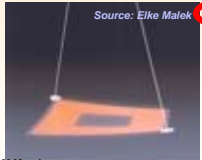


Sources: EDM, Marck



Differentiation has to be strong...

## OLED device design


---



Source: Elke Malek


Sources: EDM, Merck

- **Rugged light source**
  - No gas, no filament
  - Solid state technology is shock resistant
- **Any 2D-shape**
  - Any rectangular shape and 2D free-form devices
- **Thin, lightweight**
  - The emitting polymer is 100 times thinner than a human hair. So overall thickness depends on the glass substrate.

**Device design allows flexibility**

## OLED future prospects


---



Source: Elke Malek

Sources: EDM, Merck

- **More rugged light source**
  - White light
  - **Potential for very high efficiency > 50 lm/W**
  - Ultra thin (<< 0.5 mm)
  - Large area diffuse >> 40x40 cm<sup>2</sup>
  - 3D shaped
  - Bendable light source
  - Transparent in off-state

**OLEDs promise to have a bright future**

### ***OLED becomes #3 in Taiwan...***

#### Taiwan's Worldwide Top 3 Photonics Products

Source: PIDA

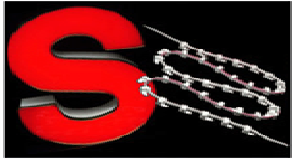
**OLED applications accelerate**

# ***HBLEDS***


OPTOELECTRONICS INDUSTRY DEVELOPMENT ASSOCIATION

## Already many applications


Signs & Channel Letters




Emergency Vehicles




Home Lighting



Traffic Signals



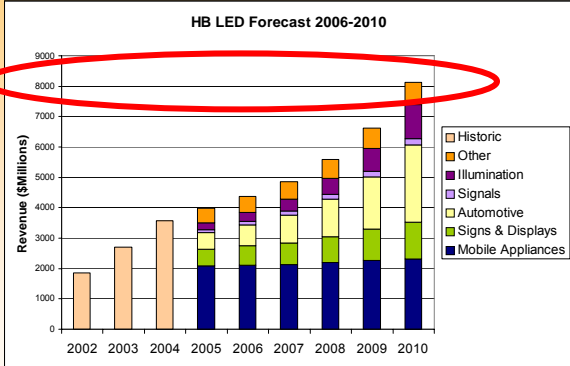
Architectural



Source: CREE

**Niche opportunities...**

## New market dynamics for the HBLED...



Sources: OIDA, Strategies Unlimited (historic data), iSupply, IoP, Yole Development, OITDA, PIDA, OIDA members

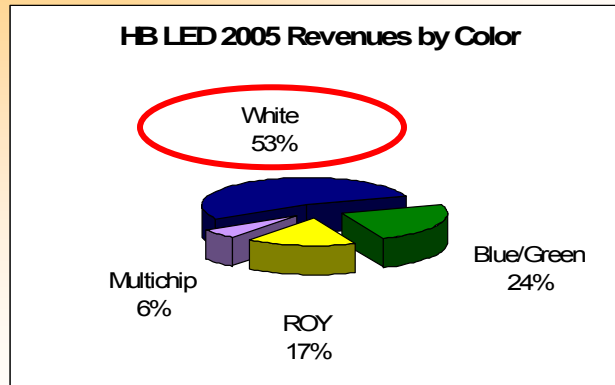
**Assumptions**

- Maturing Mobile Appliance Market
  - Continuing ASP price erosions
  - Offset by unit growth
  - OLEDs boost segment 2008
- Signs & Displays growth
  - Brighter, full color +
- Expanding deployment Automotive applications
  - Tail Light adoption 2006
  - 2008 - Forward Lighting
- Illumination enters commercial general lighting market slowly
  - increasing momentum 2010

**Opportunities are now outside comms**

## White LEDs fuel next wave of growth

- Over 50% of HBLEDs are now white

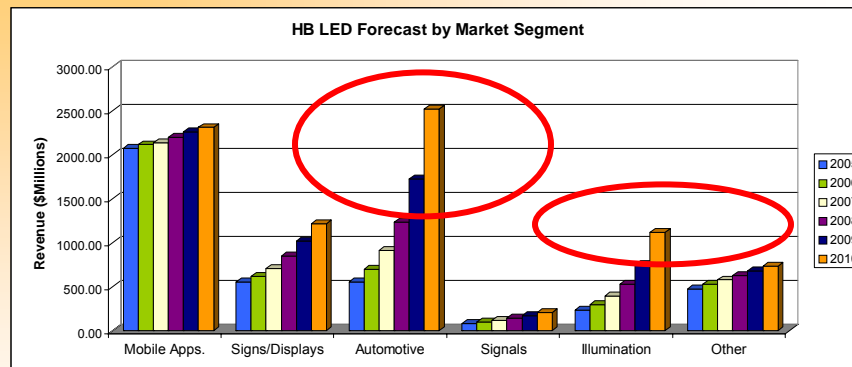


Sources: OIDA, Strategies Unlimited (historic data), iSupply, IoP, Yole Developpment, OITDA, PIDA, OIDA members



**White LED becoming dominant**

## HBLEDs forecast to grow quickly



- Complex market segments
  - Mobile Appliance segment more mature
  - More growth still ahead for Signs & Displays, Automotive, & Illumination
    - Illumination may get further kick from government initiatives

Sources: OIDA, Strategies Unlimited (historic data), iSupply, IoP, Yole Developpment, OITDA, PIDA, OIDA members



**All segments with positive vectors**

## ***Architectural lighting examples***

- 72,000 HBLEDs for Saks Fifth Avenue dancing snowflake display



Source: Philips



**Now 6% of total HBLED market**

## ***Surgical lighting applications***

- Adjustable light characteristics, low heat generation, shadow correction, long component lifetimes



Source: ILED from Trumpf



**Opportunities with high value on reliability**

## Furniture lighting



Source: Wustlich Design AG

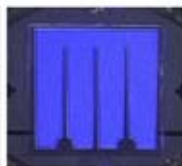
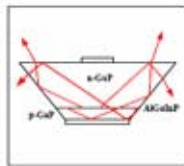


**HBLEDs increase design flexibility**

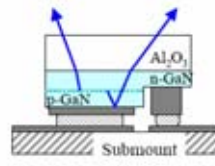
## HB-LED Technology



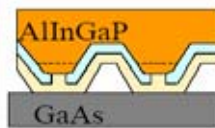
AlGaInP/GaP truncated inverted pyramid (Lumiled)



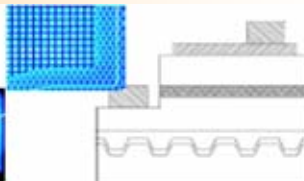
AlInGaN flip-chip (Lumiled)



AlInGaP micro mirror (Osram),



AlInGaN patterned substrate and mesh electrode (Nichia)



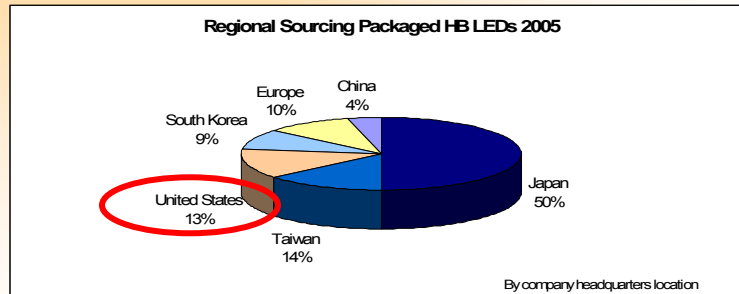
Source: LumiLeds, Osram, Nichia



**Complex tricks for high brightness**

## Asia driving manufacturing

- Over 75% of manufacturing in Asia
  - Large volume, low margins, high yields
  - IP still plays a role in manufacturing



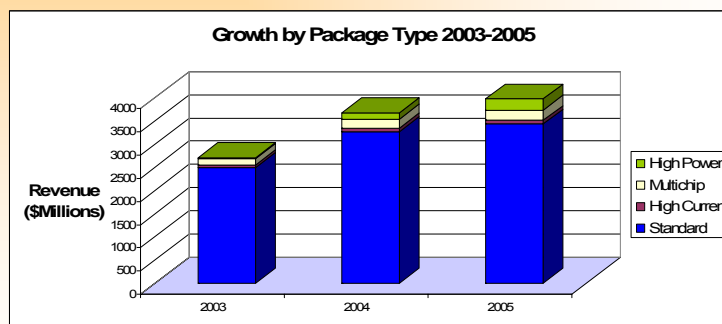
Sources: OIDA, Strategies Unlimited (historic data), iSupply, IoP, Yole Developpment, OITDA, PIDA, KAIST, OIDA members



Driven by low margins, high volume

## Standard packaging strong

- Standard package type dominant in 2005, grew 4%
  - High power and multichip packaging accelerating



Sources: Strategies Unlimited, OIDA



New package designs take hold

## LED sourcing more balanced

- USA beginning to focus on high end LED technologies
  - Areas where IP allows protection
  - High margin Nitride based techniques
  - High power devices and high power packaging

**Regional Sourcing of Merchant Epitaxial Wafers & Chips (2004)**

Region	Percentage
United States	44%
Taiwan	44%
Rest of Asia	12%

Source: Strategies Unlimited

**USA focus toward high end LEDs**

## LED Backlight for Monitor

- Advantages: high color saturation
- Issues: costs, and current constraints to high-end products today

Monitor	LCD Size	Panel Supplier	Luminance	LED#
NEC LCD2180WG-LED	21.3" UXGA	NEC LCD	200 Nits	48
Sony Vaio D23-HD13	23" WUXGA	AUO	200 nits	85
Samsung Prototype	17" SXGA	Samsung	220 nits	100
Samsung Prototype	21.3" UXGA	Samsung	200 nits	100


1H'05

21.3"  
23"


➔

2H'06

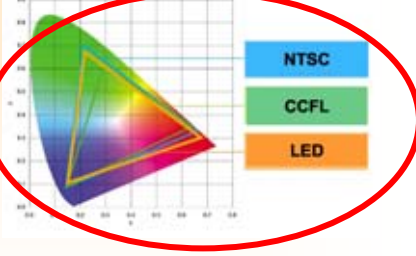
23"  
24"



**SONY VAIO  
D23-HD1**



**NEC Display  
MultiSync LCD2180WG-  
LED-BK-SV**



**NTSC**  
**CCFL**  
**LED**

Source: DisplaySearch

**High performance will drive volume**

### Cost Comparison

**Base: Q4'05, 32" 1366x768 TFT LCD TV applications**

Light Source		CCFL	EEFL	LED	FFL*
Size		32"W	32"W	32"W	32"W
Lamp	CCFL# or LED#	16	20	150	1
	Unit Price	\$2	\$2	\$2	\$42
	Total Price	\$26	\$32	\$270	\$42
Diffusion board	for direct type	\$11.2	\$11.2	\$11.2	\$11.2
Diffusion sheet	Normal	\$7.8	\$7.8	\$7.8	\$7.8
Reflective sheet	Normal	\$6.0	\$6.0	\$6.0	\$6.0
BEF	BEF3	\$10.7	\$10.7	\$10.7	\$10.7
	RBEF				
	BEF2				
	DBEF				
Metal Bezel Backt		\$8.5	\$8.5	\$8.5	\$8.5
Key Materials Subtotal		\$70.6	\$76.6	\$314.2	\$80.2
Other Materials Subtotal		\$8.8	\$7.8	\$25.0	\$6.0
BOM Cost USD		\$79.4	\$84.4	\$339.2	\$86.2
L.O.P., SG&A, Package USD		\$10.0	\$8.0	\$8.0	\$7.0
Total Cost (w/o inverter) USD		\$89.4	\$92.4	\$347.2	\$93.2
Inverter Cost USD		\$28.0	\$12.0		\$10.0
Total Cost (w/h inverter) USD		\$117.4	\$104.4	\$347.2	\$103.2

\* Assuming a stable yield rate of FFL, and semi-automatic assembly of the FFL  
\* Samsung Corning claimed to eliminate the Optical Film of FFL from 2H'06 which drives FFL cost down further

Source: DisplaySearch BEF = Brightness Enhancement Films DBEF = Dual Brightness Enhancement Film

LED cost structure high : lowered in 2006

### Future growth areas: Automotive

**Today:**

LED Daytime Running Lights and LED Direction Indicators





**2008:**

Fully integrated LED Headlamps with ECE Permission

Sources: OpTech-Net, Hella KGaA

White lights for driving – huge mkt

## ***HBLEED automotive interior lighting***

- Configurable clusters in Ford's Mustang
  - Dashboard lighting allows color change depending on mood
- Alternative uses include ambient, door, ceiling, map lighting



Source: Ford Motor Company



**Additional attractiveness for vehicle**

## ***Simulation of LED Signal System for Road Test***



Source: Kaist



**Government driven opportunities**

# *Projection displays using HBLEDs*



OPTOELECTRONICS INDUSTRY DEVELOPMENT ASSOCIATION

## *Rear projection TVs lit by LEDs...*



'The Samsung HL-S5679W is an impressive 56-inch "LED light sourced DLP RPTV" '

PC Magazine

Source: Philips

"At CES 2006, LED Projection Gets Real"

Insight Media




AKAI PT52DL27L




More intense at CES 2007

## PDA size LED projectors

**Mitsubishi PK-10**






**Toshiba TDP-FF1A**




Size	5.04" x 2.09" x 3.35"
Volume	38 inch <sup>3</sup>
Microdisplay	0.55" DLP™
Resolution	SVGA (800x600)
Power	10 - 25 W
Weight	1-1.5 lb
Battery life	2.5 hrs with ext. battery

**Samsung SP-P300M**





Source: Philips



Opening new consumer markets

## Projection increasing it's value proposition

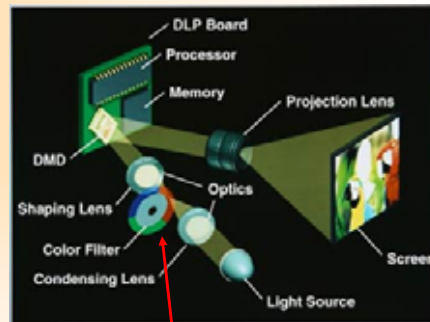
- High color gamut – dynamic color Management
- Long life - no bulb replacement
- Instant on/off - no waiting!
- Less noise (No color wheel, easier cooling)
- Environmentally friendly – No mercury or radioactive materials
- Low voltage – Lower cost, safe operation, simple approbation
- Low pressure - safe operation, no explosion

Source: Philips


Competing with LCDs?

## Rear projection TV with LEDs



Need red, green and blue in sequence

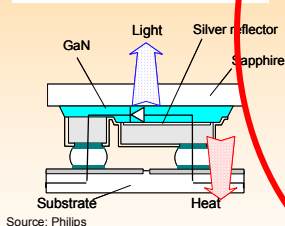
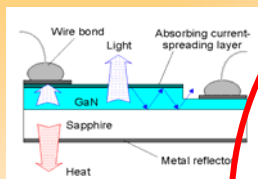
rotating color wheel

Source: Philips



**Driver to increase LED radiance levels**

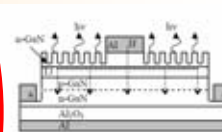
## Factors determining LED radiance



Source: Philips

Source: Philips

- Efficiency
  - Internal Quantum Efficiency
  - Extraction Efficiency
  - Electrical Efficiency
- Power Density
  - Drive Current
  - Thermal Resistance
  - Cooling
- Optical
  - Collection Efficiency
  - Radiation Pattern
  - Photonic Crystal LEDs



**Complex packaging challenges**

### The good news...

- Display illumination is a very attractive opportunity for solid state light sources
- Performance of High Power LEDs is reaching performance requirements for both large panel direct view LCD and projection displays
- High brightness LEDs enable new display products, accelerating growth of the display market



Source: Philips




**Projecting will grow quickly**

### HBLED Projector Demonstration


Display

- Benq LED projector
  - Need dark room for demonstration

Projector



Sources: Benq, OIDA



**Consumer Electronics Show 2006**

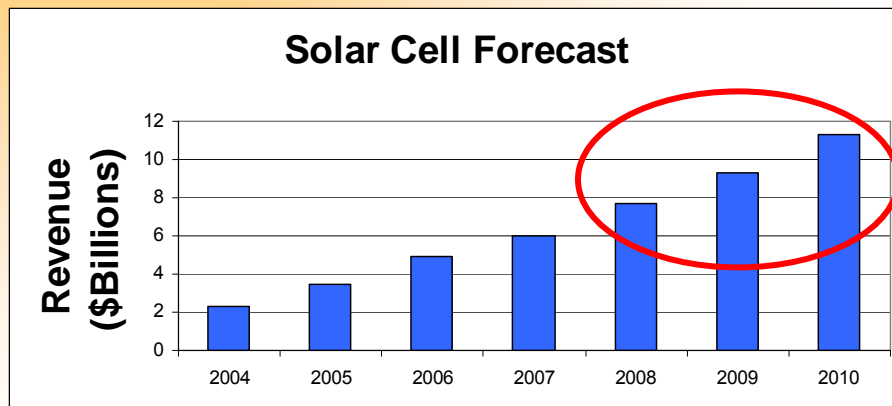
# Solar Cells



OPTOELECTRONICS INDUSTRY DEVELOPMENT ASSOCIATION

## Global solar cell forecast

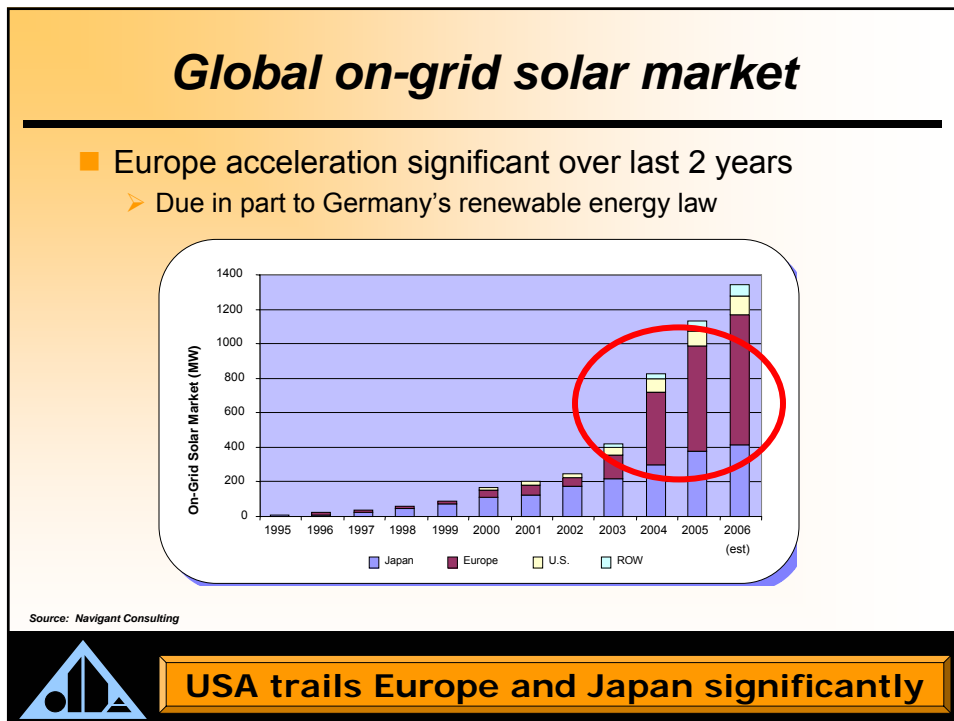
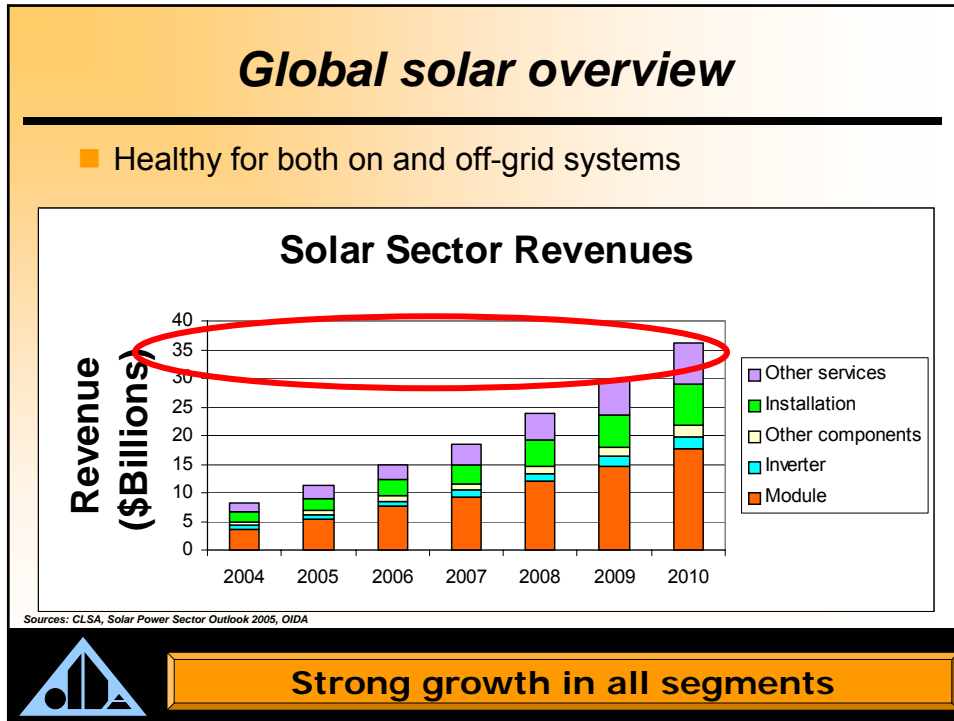
■ Fueled mostly by Japan and Germany



Sources: CLSA, Solar Power Sector Outlook 2005, OIDA



Revenues grow to >\$11B by 2010



## ***Growth drivers***

---

- In 2005, PV market exceeded forecasts and grew significantly to above 1200MW
- Primarily driven by growth in subsidized markets
  - Growing adoption of subsidies global
  - California solar initiative is an additional boost to already strong market
- Market forecast a function of polysilicon availability
- Growing adoption of thin-film technologies could accelerate growth

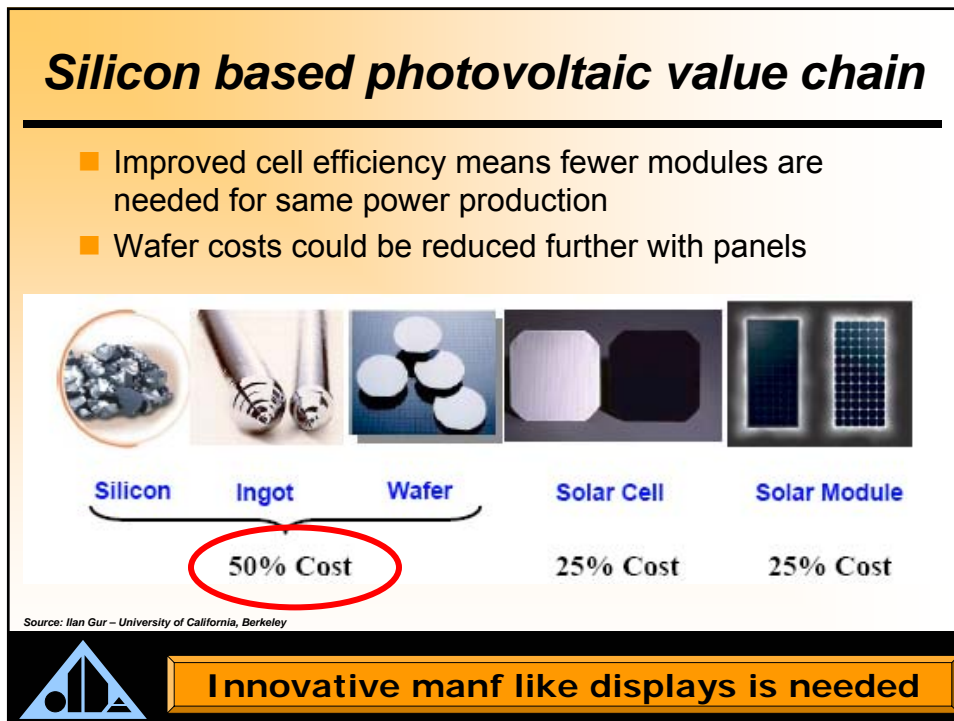
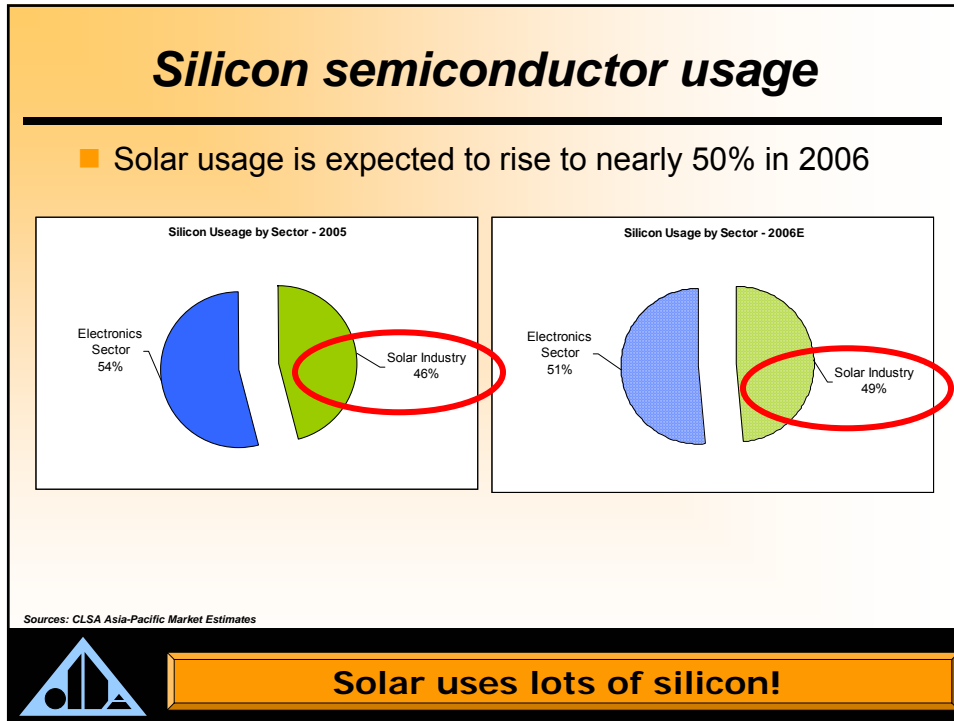


**Exciting area today...**

## ***Technology***

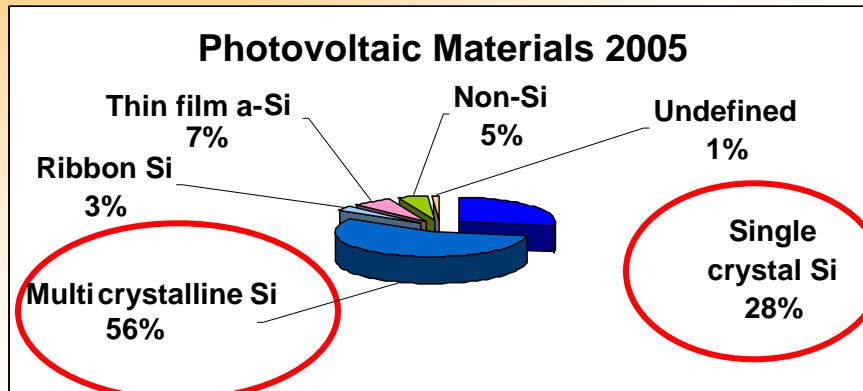


**OPTOELECTRONICS INDUSTRY DEVELOPMENT ASSOCIATION**



## Photovoltaic materials in 2005

- Over 87% of solar cells are based on silicon materials



Sources: PV Energy Sources, CLSA, Ilan Gur - University California Berkeley, OIDA



**Silicon semiconductors dominate**

## Solar cell material efficiencies

- Best research results todate



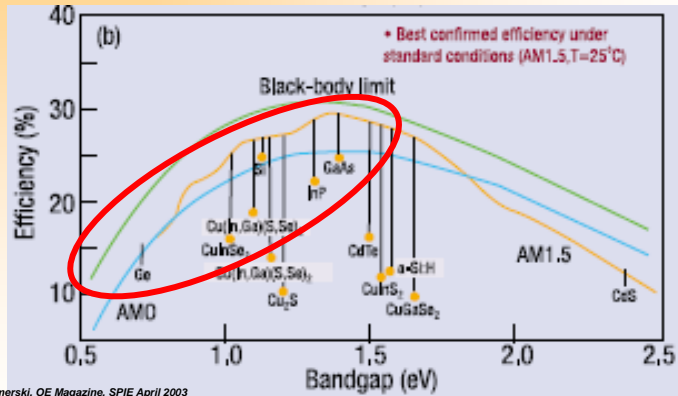
Sources: NREL - National Renewable Energy Lab



**Multi-junction concentrators lead**

## Bandgap and efficiencies for solar

- Materials arranged in decreasing bandgaps to accommodate different frequencies



Source: Lawrence Kazmerski, OE Magazine, SPIE April 2003



Use of InGaP, GaAs and Ge materials

## Triple junction solar cell x-section

- Classic InGaP triple junction with GaAs, Ge substrate
  - Lattice matched, 4" wafers



Source: NREL



Complex epitaxial growth

### III-V material efficiencies

- Lattice matched materials with concentrator
- III-V materials still expensive compared to silicon

Projected real-world efficiencies at 500 suns

Design	Efficiency	Layers (from bottom to top)	Bandgaps (eV)
In production	39%	Ge, GaAs, GaInP	0.7, 1.4, 1.8
Future generation	42%	Ge, New, GaInP	0.7, 1.25, 1.8
Future generation	42%	Ge, New, GaAs, GaInP	0.7, 1.0, 1.4, 1.8

Sources: NREL

**Future designs offer quad-junctions**

### Concentrators tracking sunlight

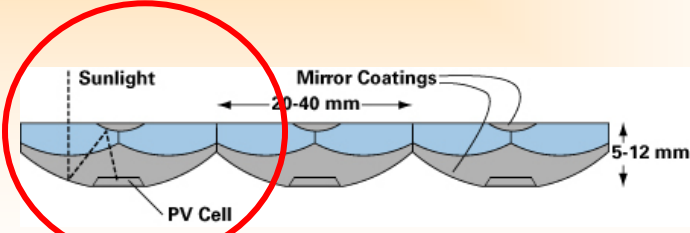

- Eliminates need for plumbing oil or other liquids

Source: Energy Innovations


**Active tracking innovations**

## Photovoltaic concentrators

- III-V PV efficiency increases when manufactured with concentrator arrays
  - 1/1000<sup>th</sup> of the PV material needed of other modules
- Designs with no moving parts or cooling systems
  - Higher reliability and lower maintenance

Source: PARC - Palo Alto Research Center


Concentrators increase efficiency

## Very High Efficiency Solar Cell

Architectures	Device Design	Core Platform	Diverse Approaches		
Lateral solar cell	Static Concentrator	GaInP-based materials	III-nitride materials	Reusable Substrates	Nano-structured virtual band gap solar cells
Vertical junction independent contacts	Solar cells for higher energy	High-Perfor-mance Silicon	Thin n base Silicon		
Vertical junction series connected	Solar cells for mid-energy	TPV solar cell materials	SiGe solar cells		
	Solar cells for low energy				


Independent materials responding to different spectral bands, combined with low cost high efficiency optics, for efficient (50%) solar energy conversion

Challenges:

- Efficient low-cost lateral optics - 90% efficient lateral optics design already demonstrated
- High band gap (1.8-2.8eV) material processes and fabrication
- Performance effective nanomaterial components
- System design & integration

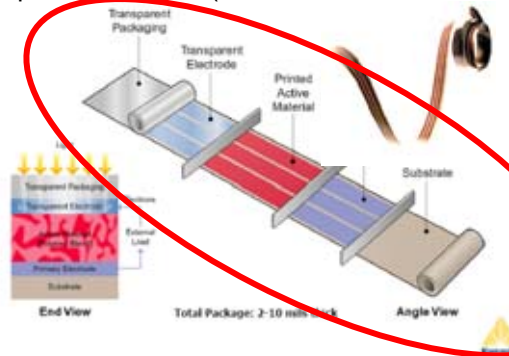
- Multiple material systems approaches to optimize performance in very high/high/med/low bandgaps
- Novel materials manufacturing concepts including biomimetic nano synthesis materials processing routes

Sources: OIDA, DARPA


WDM to increase solar efficiency

## Printing approaches to solar cells

- Organic carbon based inks technology
- Printing process allows continuous roll process
  - Lower capital investment (no clean room, vacuum, or silicon)



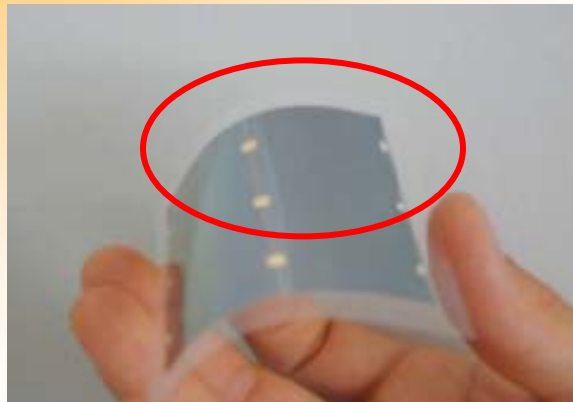
Source: Konarka



Capital investment in plant: big driver

## Thin film solar cell innovations

- Challenge to the dominance of silicon by reducing manufacturing costs



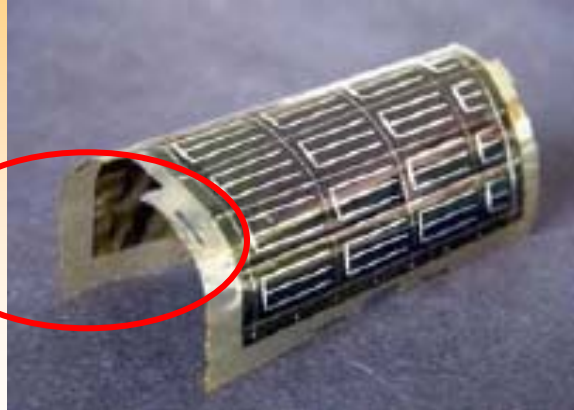
Sources: Sharp



Efficiencies still hover ~10% today

## ***Manufacturing focused***

- CIGS (copper indium gallium diselenide) materials



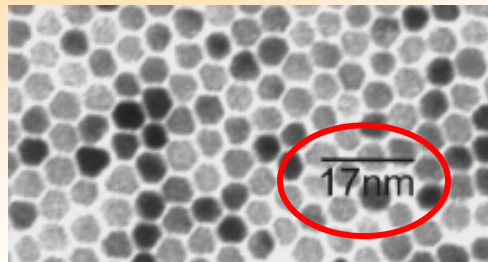
Source: Thin Film Physics Group – ETH Zürich



**Improved efficiencies ~20% today**

## ***Inorganic solar cells***

- Ultra-thin solar cells from colloidal inorganic nanocrystals based on CdSe/CdTe
- Low-cost power generation, tunable absorption
- Polymer based manufacturing as semiconductor inks



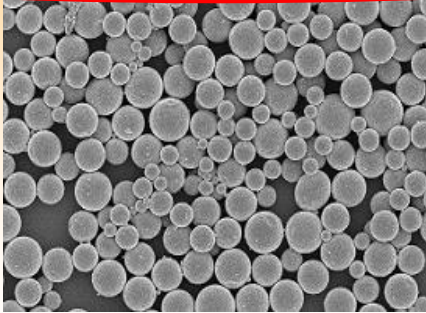
Source: Ian Gur, University of California, Berkeley



**High potential for low cost manf**

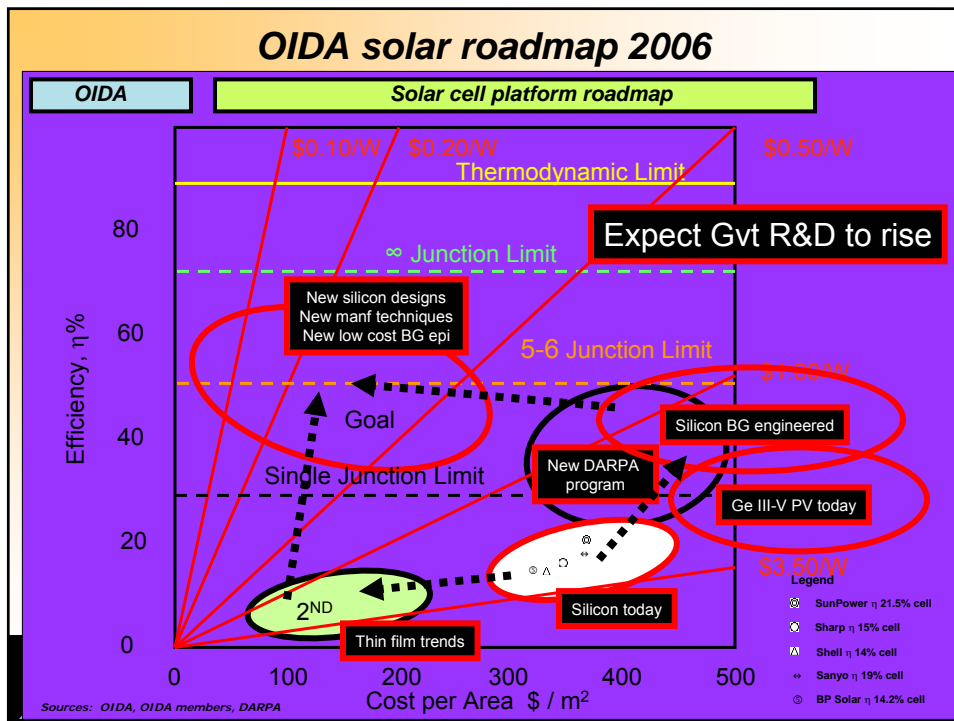
## Driving new innovations in solar

- Printing of CIGS thin films will extend to flexible substrates
  - Solution coated nano-composite material (ink)
  - CIGS thin film material deposited by vacuum onto s/steel



Source: Nano solar

Printing cells opens new opportunities



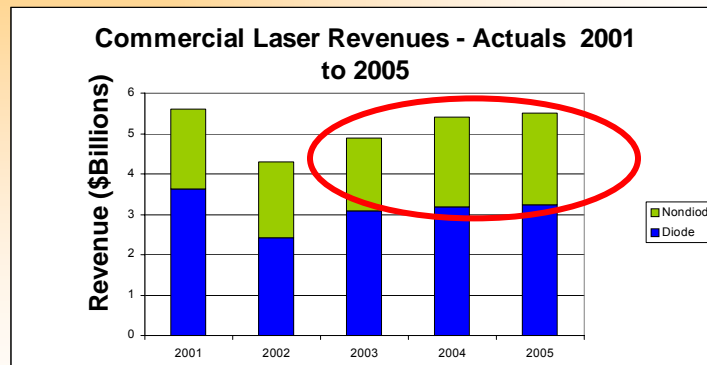
# ***Lasers***



OPTOELECTRONICS INDUSTRY DEVELOPMENT ASSOCIATION

## ***Total laser market***

- Now surpassing \$5B with continuing growth in nondiode



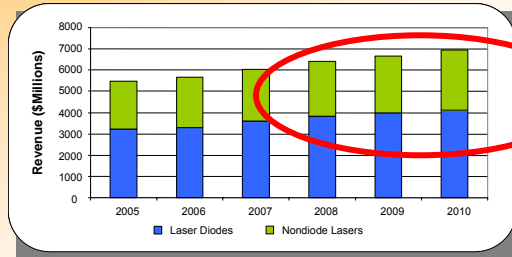
Sources: Laser Focus, OIDA members, OIDA data



**Now back over \$5B**

## Global laser forecast

- Extended Forecast for Combined Laser Revenue, 2005-2010



Sources: Laser Focus, OIDA members, OIDA data



**Steady growth next 5yrs to \$7B**

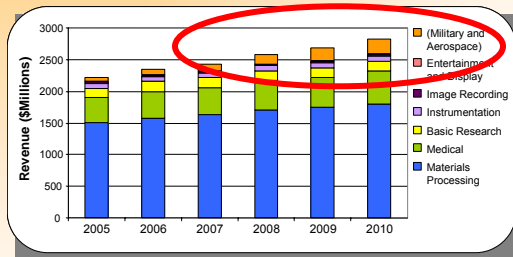
## Non-diode Lasers



OPTOELECTRONICS INDUSTRY DEVELOPMENT ASSOCIATION

## Non-diode laser global forecast

- Military and aerospace strong growth by end of decade



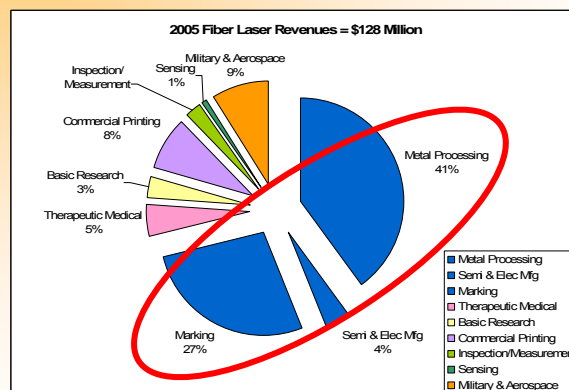
Sources: Laser Focus, OIDA members, OIDA data



Revenue approaching \$3B by 2010

## Fiber laser revenues for 2005

- Industrial becoming huge opportunity



Sources: Laser Focus, OIDA members, OIDA data



Non-communications opportunities

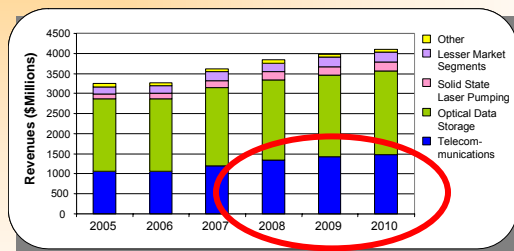
# Diode lasers



OPTOELECTRONICS INDUSTRY DEVELOPMENT ASSOCIATION

## Diode laser global forecast

- Telecom grows steadily to \$1.5 by 2010



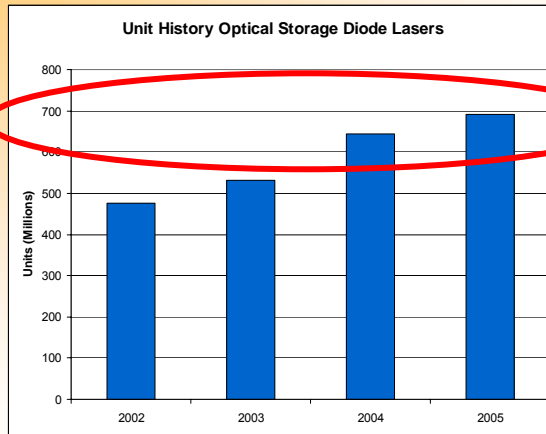
Sources: Laser Focus, OIDA members, OIDA data



Laser diodes reach \$4B by 2010

## Optical storage volume

- Unit growth strong in 2005



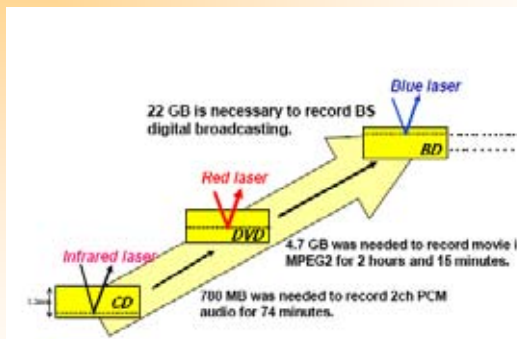
Sources: Laser Focus, OIDA members, OIDA data



ASP competition, but volume up

## DVD evolution

- The drive to 30GB optical storage using 405nm laser diodes



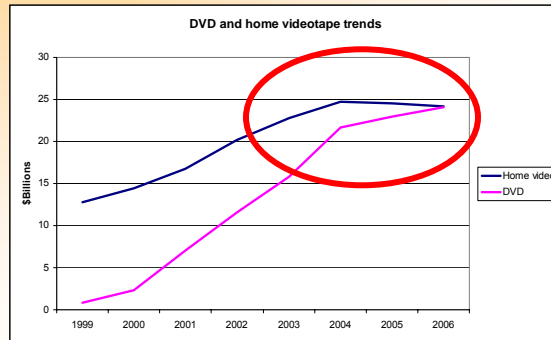
Sources: Blu-ray disc association



Poised to ramp in 2007...

## Stifled growth (USA today 9<sup>th</sup> Jan)

- Blu-ray vs HD DVD stifled while VHS withers
  - Over 200M players purchased in USA since 1997
    - 33M in 2006 alone



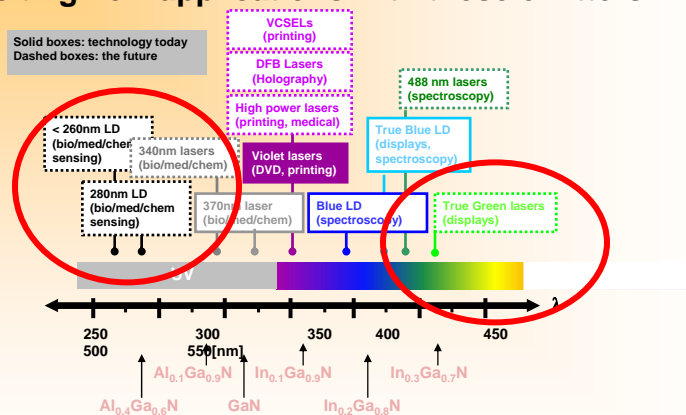
Sources: Digital Entertainment Group



However format 'war' is an impedance

## Next generation visible and UV LDs

- Exciting new applications with these emitters



Source: Noble Johnson, Palo Alto Research Center (PARC)



We need UV and green sources...

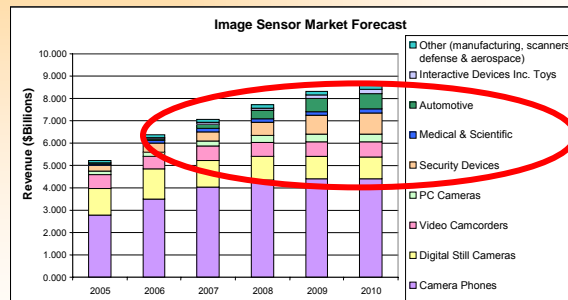
# Image sensors



OPTOELECTRONICS INDUSTRY DEVELOPMENT ASSOCIATION

## Image sensor market

- Driven by camera phones
  - Security and automotive exciting areas to watch



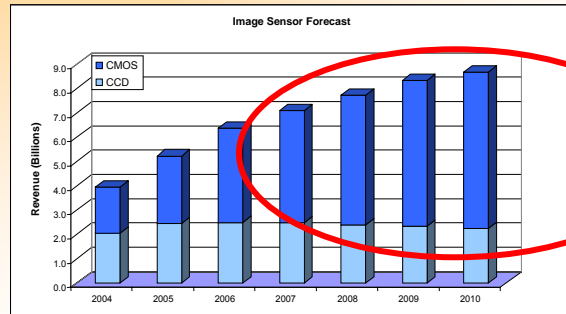
Sources: Strategies Unlimited, Micron, IC Insights, NE Asia, OIDA



New opportunities emerging

## Image sensor technology

- CMOS is now dominant through consumer volume applications



Sources: Strategies Unlimited, Micron, IC Insights, NE Asia, OIDA



**CMOS now cost effective**

## Nanophotonics



OPTOELECTRONICS INDUSTRY DEVELOPMENT ASSOCIATION

## Today's nanotechnology market...

- Generally agreed that:-
  - Nanotechnology represents an enormous market
- Considerable disagreement on the market size
  - Estimates of current market size range from \$1M – \$45 B
  - NSF estimates \$1 Trillion by 2015
  - Hitachi estimates a Japanese market of \$300 Billion by 2010
  - Criteria for what would be considered revenue is unclear
    - OIDA exploring this in 2006
- Nanotechnology breakthroughs will have value beyond the intended market
  - Market is remarkably volatile
    - Unprecedented scale of government funding and involvement
    - Rapidly growing corporate and investment capital funding
    - Nanotechnology affects numerous markets including displays
    - New industries will be born (some may replace or change existing industries)
    - Old industries may collapse

Sources: OIDA, Ultradots

### Big numbers...what's real?

## From macro- to nano-

Sources: UCSD, DARPA

Optics

Electronics

1700's
1800's
1900's
2000
Future

### Denominator: lithography

## Technological impact of lithography!

**What are the opportunities for nanophotonics?**  
Engineering nanoscale inhomogeneous materials with unique properties (optical, electrical, acoustic, etc.) necessary to create a new class of devices for future information microsystems

Sources: UCSD, DARPA, ITRS

**16nm → new litho device types**

## Nanophotonics challenges in systems integration

Optical table

Optical chip

- Engineer inhomogeneous composite materials (dielectrics, semiconductors, metals, organics, quantum dots) with unique properties (e.g., birefringence, dispersion, negative refraction, nonlinear polarization, quantum effects)
- Construct optical components and devices exploiting near field physics of interactions on the nanoscale
- Since cascading nanophotonic devices leads to near field interactions → develop tools to model and optimize functionality of the whole "circuit"!
- Explore integration of various functionalities into the same volume (e.g., integrating optical/electronic devices into sub-systems)
- Create optical "knobs" (use E-O, fluidics, nanomechanics, heat, etc. for control of near field interactions)


Sources: UCSD, DARPA, Intel

**New techniques are needed**

### Nanotechnology for scalability and system integration

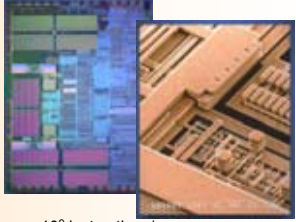
**Microprocessors**

IBM Mark I (1944)



~1000 instructions/sec

PowerPC 750™ Chip (1999)




~10<sup>9</sup> instructions/sec

Si technology

**Optical Networks**

Wavelength Router (1999)



256x256 OC-48 (2.5 Gb/sec)

Sources: UCSD, DARPA, Intel, IBM

**Next-Generation Photonic Chips**

- Higher performance
- Greater functionality
- Better reliability
- Improved manufacturability
- Smaller size
- Lower cost

Nano-technology?

**Integration for switching/routing**

### Key nano-phonic applications

Application	Relevant Nanotechnologies	Key Issues
Displays	Carbon nanotubes, nanoparticles	Meeting performance and manufacturing cost requirements, partnering
HB LEDs	Nanoparticles, photonic crystals	Low-cost manufacturing, partnering
Solar cells	Nanoparticles, nanowires, carbon fullerene, organics	Reliability, efficiency, low-cost manufacturing, partnering
Biochemical fluidic sensors and markers	Nanoparticles, nanowires, photonic crystals, nanofluidics, SPR, microstructured fibers, silicon photonics	Identifying and winning niche applications, industry standards, partnering
Biomedical lasers	Quantum dots, photonic crystals	High performance (beam profile, output power, etc.), compact, low cost
Diode lasers	Quantum dots, photonic crystals	Low-cost manufacturing, identifying niche applications
Passive devices	Photonic crystals	Low-cost manufacturing, identifying niche applications
Chip interconnects	Nanoparticles, photonic crystals, silicon photonics	The Red Brick Wall, low-cost manufacturing, partnering
Optocouplers and sensors	Nanoparticles, silicon photonics	Low-cost manufacturing, identifying niche applications
Specialty fiber	Microstructured fibers	Low-cost manufacturing, partnering
Lithography tool lasers	Subwavelength optics	The Red Brick Wall; applications in biology, etc.

Sources: OIDA, OIDA members, Strategies Unlimited

**Nanophotonics as an enabler...**

# Textiles



OPTOELECTRONICS INDUSTRY DEVELOPMENT ASSOCIATION

## Textile applications

- Clothing
  - Resistant to stains, water, bacteria, odor, wrinkles, etc.
- Fluorescent clothing
- Combines the comfort of cotton or natural fibers with strength and durability of synthetics (nylon)
- Nano-Tex (parent company Burlington Industries) have commercialized these products
  - Agreement with Eddie-Bauer, Lee Jeans
  - Nano-care™, Nano-dry™, Nano-touch™, Nano fresh™
- Nanotube-based fabrics proposed to change according to weather conditions or a person's vital signs



Source: Ultradots



Smart clothing (napkin works well 😊)

# Consumer



OPTOELECTRONICS INDUSTRY DEVELOPMENT ASSOCIATION

## Consumer applications

- Two examples of nanoparticles creating value in a wide variety of markets.
  - Tennis balls
    - Wilson's Double Core tennis ball (using InMat's nanotechnology) lasts ~ twice as long
    - Works by putting a thin coating of nanoparticles on the ball interior
    - Creates significant potential for enhancing product margins.
  - Sunscreens
    - Nanophase uses nano-structured zinc oxide in sunscreens
    - Small particles scatter UV light; allows visible light to pass
    - Creates even more interesting opportunities in cosmetics, which have very high margin products
    - It may also have uses in UV protectants for windows and eyeglasses



Source: Ultradots



From sports to health maintenance

# Fiber Sensors



OPTOELECTRONICS INDUSTRY DEVELOPMENT ASSOCIATION

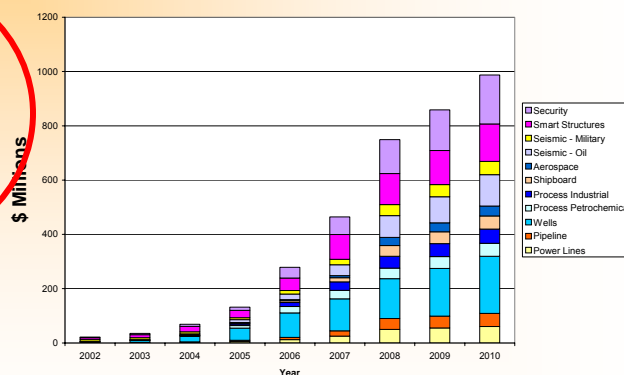
## Optical Fiber Sensor Market

Automotive, medical not included

### Areas to watch

- Security
- Aerospace
- Shipboard
- Wells
- Power & Pipe lines

Distributed Fiber Optic Sensor Market Potential



Source: D. Krohn Light Wave Venture, OIDA



Sensing growing to \$1B market in 2008

## Photonic Sensor Market

- Portable (remote) optical spectroscopy market segment
  - Market size 2010 > \$400 Million
  - Segments
    - Homeland security
    - Industrial
    - Military
- Expanded chemical / intrusion sensor (alarms) market for port / cargo container security – Homeland security
  - Market size 2010 > \$1 Billion (Includes biotoxins)
- Biometric measurement: Rapid non-contact identification
- Nano photonics: Bio-sensors: Bio-imaging

Source: D. Krohn Light Wave Venture, OIDA



Applications increasing

## Military Fixed Perimeter Sensing Application




Source: Fiber SenSys



Fiber sensors ideal for distributed apps

# *Silicon photonics status*




OPTOELECTRONICS INDUSTRY DEVELOPMENT ASSOCIATION

## *Silicon photonics progress*

1980 ~ ~ ~ ~ ~	2000	2002	2004	2006	
<p>Pioneering work by Soref et al</p>	<p>Low Loss Strip MIT</p>	<p>SRS UCLA</p> <p>Si LEDs STM, Trento</p> <p>Integrated APD+TIA UT</p> <p>Inverted Taper NTT, Cornell</p>	<p>Raman I Conversion UCLA</p> <p>Modeled GHz PIN Modulator Surrey, Naples</p> <p>PBG WG &lt;25dB/cm IBM</p>	<p>Raman Net Pulsed Gain 9/6: Intel</p> <p>9/20: Cornell</p> <p>9/29: UCLA</p> <p>9/29: CUHK</p> <p>30GHz SiGe Photodetector IBM</p> <p>GHz MOS Modulator Intel</p> <p>PBG WG &lt;7dB/cm IBM, FESTA, NTT</p>	<p>QCSI in Si Stanford</p> <p>Stim-Emission Brown</p> <p>CW Raman Laser Intel</p> <p>10Gbps Modulator Intel, Luxtera</p> <p>1.5Gbps Ring Mod Cornell</p> <p>39GHz Si-Ge PD Stuttgart Uni</p> <p>PBG Wg &lt;3dB/cm NTT</p>

Source: Intel



**Extend boundary to 40Gbps**

## Silicon's situation wrt photonics

### Disadvantages

- No efficient light emitter (either LED or laser)
- No detection in the traditional communications wavelengths
- High index contrast means coupling issues
- No electro-optic effect

### Advantages

- Compatible with CMOS
- Volume drives the cost structure very low
- High refractive index contrast – small devices
- Transparent in the 1.1um+ region (inc 1.3 and 1.55um)
- Used in volume in image sensors, LCD-TFTs, and <1um PD

Source: Intel, Translucent



Mixed bag: some real opportunities

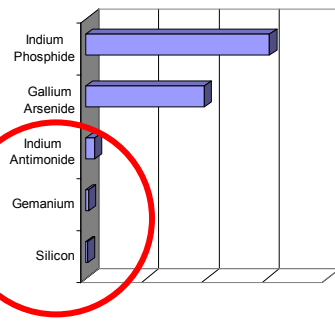
## Silicon as an emitter

### Silicon is a poor light emitter

### Research today

- Er-doped oxides
- Quantum cascade structures
  - Si/SiGe
- Si nanocrystals
- Si based superlattices

Relative recombination coefficient  
(for stimulated emission)



Sources: Intel, Translucent, OIDA members, DARPA



Light source is the tough problem...

## Options for light sources

- Silicon photonics will still need external light source

Sources: Intel, Translucent, OIDA

**Economics will drive the solution**

## Topology

- Depth of focus shrinks as litho increases
- Many optical devices bigger than FETs

Depth of field vs Litho technology

0.25	0.18	0.09
↓	↓	↓
0.5um	0.35um	0.2um


Source: Intel, Translucent

**Integration is major challenge for CMOS**

## **Silicon photonics workshop** (Feb 22<sup>nd</sup> San Jose)

---


■ Silicon Photonics: Challenges and Future	
■ February 22nd, 2007 – Santa Clara, CA	
■ (Preliminary)	
■ 7.30 – 8.00 a.m.	Registration and Continental Breakfast
■ 8.00 – 8.10	Welcome <i>Michael Leiby</i> – OIDA
■ 8.10 – 8.15	Introduction – <i>Bill Ring</i> , WSR Optical Device Solutions
■ 8.15 – 10.05 a.m.	<b>Silicon Photonics</b>
■ 8.15 – 8.35 a.m.	Strategies Unlimited – <i>Tom Hausken</i>
■ 8.35 – 8.55	Intel – <i>Mario Paniccia</i>
■ 8.55 – 9.15	IBM – <i>Jeff Kash</i>
■ 9.15 – 9.35	University of Ghent – <i>Pieter Dumon</i>
■ 9.35 – 9.55	University of Trento – <i>Lorenzo Pavesi</i>
■ 9.55 – 10.15	Sun Microsystems – <i>Ashok V. Krishnamoorthy</i>
■ 10.15 – 10.25	Moderated Discussion
■ 10.25 – 10.45	<b>Coffee Break</b>
■ 10.45 – 12.30 p.m.	<b>Silicon Photonics</b>
■ 10.45 – 11.05 a.m.	Luxtera – <i>Cary Gunn</i>
■ 11.05 – 11.25	Kotura – <i>Jean Louis Malinge</i>
■ 11.25 – 11.45	Arch Ventures – <i>Patrick Erniss</i>
■ 11.45 – 12.05	BAE Systems E&S – <i>Steve Jost</i> or <i>Dan Carothers</i>
■ 12.05 – 12.25 p.m.	National Science Foundation – <i>Ron Hui</i>
■ 12.25 – 12.35	Moderated Discussion
■ 12.35 – 2.00	<b>Lunch</b>
■ 2.00 – 4.00 p.m.	<b>Silicon Photonics</b>
■ 2.00 – 2.20	National Research Council of Canada – <i>Siegfried Janz</i>
■ 2.20 – 2.40	Massachusetts Institute of Technology – <i>Franz Kaertner</i>
■ 2.40 – 3.00	UCLA – <i>Jalali Bahram</i>
■ 3.00 – 3.20	Translucent – <i>Vijit Sabnis</i>
■ 3.20 – 3.40	UCSB – <i>John Bowers</i>
■ 3.40 – 4.00	DARPA – <i>Jag Shah</i>
■ 4.00 – 4.10	Moderated Discussion
■ 4.10 – 5.45 p.m.	<b>Breakout Discussions</b>
■ 4.00 – 5.15p.m.	Break out Discussions
■ 5.15 – 5.45p.m.	Reports from breakout leaders
■ 5.45 – 6.00pm	Workshop summary and concluding remarks



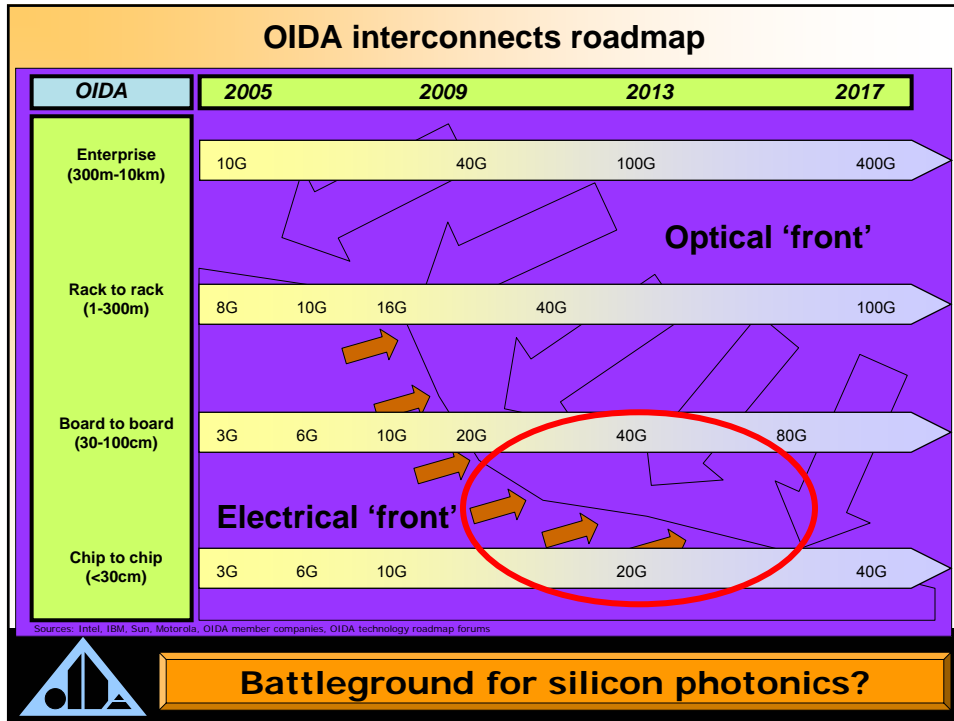
**The move to commercialization...**

# **Optical Interconnects 100G ++**

---



**OPTOELECTRONICS INDUSTRY DEVELOPMENT ASSOCIATION**



## 100G ++ Interconnects

(Feb 21<sup>st</sup> San Jose)

---

- 100Gbit Interconnects and above: The need for speed
- February 21st, 2007 – Santa Clara, CA
- (Preliminary)
- 7.30 – 8.00 a.m. Registration and Continental Breakfast
- 8.00 – 8.10 Welcome *Michael Leiby* – OIDA
- 8.10 – 8.15 Introduction – *Bill Ring*, WSR Optical Device Solutions
- 8.15 – 10.30 a.m. **Interconnects: Data Centers**
- 8.15 – 8.40 a.m. Hewlett Packard – *Terry Morris*
- 8.40 – 9.00 Zarlink – *Stan Swihun*
- 9.00 – 9.30 IBM – *Petar Papeljowski*
- 9.30 – 9.55 Intel – *Tom Willis*
- 9.55 – 10.20 Moderated Discussion
- 10.20 – 10.30 **Coffee Break**
- 10.30 – 10.45 **Interconnects: Electrical & Optical**
- 10.45 – 1.00 p.m. Intel – *Jerry Bautista*
- 10.45 – 11.10 a.m. TFCG Microsystems – *Erwin Bosman*
- 11.10 – 11.35 Massachusetts Institute of Technology – *Vladimir Stojanovic*
- 11.35 – 12.00 Tyco Electronics – *Mike Fogg*
- 12.00 – 12.25 Agilent Technologies – *Greg Le Cheminant*
- 12.25 – 12.50 Moderated Discussion
- 12.50 – 1.00pm **Lunch**
- 1.00 – 2.00pm **Interconnects: Active and Passive Optics**
- 2.00 – 4.00 p.m. Corning – *Luis Zenteno (or Alternative)*
- 2.00 – 2.25 Avago Technologies – *Olja Jugnu*
- 2.25 – 2.50 Dow Corning – *Michael Skinner*
- 2.50 – 3.15 EMCORE – *Ken Jackson or Rob Dallesasse*
- 3.15 – 3.40 Moderated Discussion
- 3.40 – 3.50 Organize breakout sessions
- 3.50 – 4.00pm **Breakout Discussions**
- 4.00 – 6.00 p.m. Break out and Road map discussions
- 4.00 – 5.15pm Reports from breakout leaders
- 5.15 – 5.45 Workshop summary and concluding remarks
- 5.45 – 6.00pm

**The need for speed...**

---

# *Lastly...*



OPTOELECTRONICS INDUSTRY DEVELOPMENT ASSOCIATION

## *Mission → Vision*

---

Current Mission

→

Vision


Promote optoelectronics worldwide, & Advance competitiveness of it's members

1. Focus on quality
2. Broaden horizon of OE
3. Leverage DC government center of mass
4. Grow membership base
5. Primary reference in OE

OIDA is the nexus for OE industry vision, transformation, and growth

Optoelectronics = OE

**Focus on the business of technology, not just technology itself.**



## Summary

---

- **Optoelectronics market is now vibrant**
  - Consumer/entertainment driving growth today
  - OE penetration in many new markets, driven by displays
- **Key trends**
  - Communications has now stabilized and growing
  - Displays are penetrating many new markets with LCDs
  - HBLEDs are growing quickly in automotive and lighting
  - Solar has seen recent injections of innovation
- **Optoelectronics growing well**
  - OIDA working to bring industry together and become a voice
    - Common platforms, issues and opportunities
    - Focal point for OE...



We at OIDA are *Optimistic* 😊

---

# End



OPTOELECTRONICS INDUSTRY DEVELOPMENT ASSOCIATION

# OIDA: optoelectronics roadmaps...

OPTOELECTRONICS INDUSTRY DEVELOPMENT ASSOCIATION

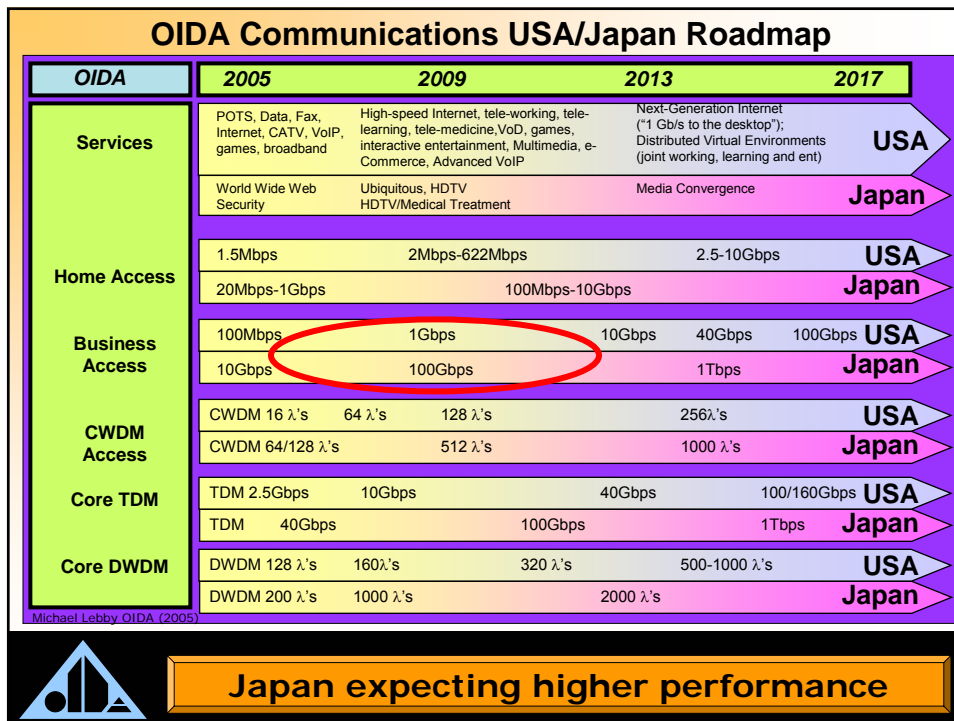
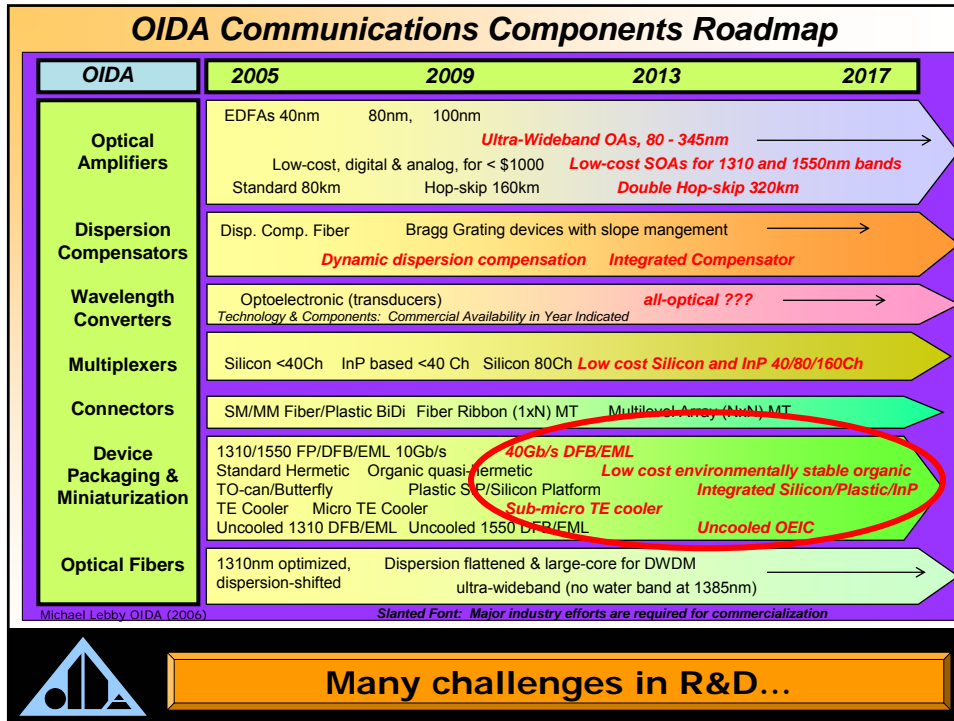
### OIDA Communications Technology Roadmap

OIDA	2005	2009	2013	2017		
<b>Bitrate (TDM)</b>	2.5-5 Gb/s	10 Gb/s	40 Gb/s	100/160 Gb/s (OTDM)		
<b>LAN/WAN -GbE</b>	1 Gb/s	10 Gb/s		40 Gb/s		
<b>Total Fiber Capacity (w/DWDM)</b>	100 Gb/s	400Gb/s 1.6 Tb/s	3.2 Tb/s	50 Tb/s 100 Tb/s		
<b>Router Capacity (electronic)</b>	100 Gb/s	2.4- 20 Tb/s	50 Tb/s	100 Tb/s		
<b># WDM Channels</b>	40	80	160	320	512	1024 ?
<b>Channel Spacing</b>	100 GHz	50 GHz	25 GHz	12.5GHz	<10GHz	
<b>λ Monitoring</b>		λ monitoring, control, and maintenance		λ selective		
<b>WDM Subsystems</b>	point-to-point	OADM (with Mux/Dmux, opaque/transparent )		OXC ???	All-optical network	
<b>Optical Switches</b>		16x16		256x256 ???	1024x1024 ?	
<b>OEICs</b>	Chip count ~10	Chip count ~ 100	ms → us	ns	Optical packet switching	
<b>Transmitters/ Filters for DWDM (MMF &amp; SMF)</b>	Discrete λ DFBs	Multiple λ DFB Arrays	Tunable lasers & λ arrays			
	850/980nm VCSEL	1310nm VCSEL	1550nm VCSEL			
	Discrete filters	Low channel AWGs	40/80 Channel AWGs			
<b>Transceivers (Pluggable)</b>	Discrete components (FP/DFB/PIN/APD/EML)	10Gb/s (XFP/Xenpak/Xponder)	10Gb/s DWDM	InP /Silicon based OEIC TxRx		
	\$500 TxRx	\$200 TxRx	<\$800 DWDM TxRX 80km	10Gb/s TxRx SR	100Gb/s TxRx	
				<\$1000 40Gb/s SR TxRx		

Michael Leebby OIDA (2006) *Slanted Font: Major industry efforts are required for commercialization*


Technology & Components: Commercial Availability in Year Indicated

## High speed & low cost via integration



---

# OIDA Overview




OPTOELECTRONICS INDUSTRY DEVELOPMENT ASSOCIATION

## OIDA membership thru Dec 7 2006

---

<p><u>Voting Members</u></p> <p>Avago Avanex Bookham Ciena Corning CyOptics Digital Optics Emcore General Dynamics Infinera IQE Telcordia Translucent</p> <p style="text-align: right;"><b>13</b></p> <p><u>Associate Members</u></p> <p>BinOptics Calient Networks Canadian Microelectronics Canadian Photonics Consortium CEA CRI</p>	<p>CSEM DTI EM4 Photonics Finisar Incubic Infotonics Center JDSU Kotura Light Wave Venture LxSix MergeOptics Nat'l Optics Institute, Canada Nat'l Research Council of Canada Opnext OptiComp Optiphase Panasonic Boston Lab Philips Lumileds Lighting Redfern Integrated Optics Rsoft Sandia National Laboratories SCHOTT North America</p>	<p>Silicon Light Machines Syntune Teraxion TRA-CON Xponent Xtellus</p> <p style="text-align: right;"><b>11</b></p> <p><u>University Affiliate Members</u></p> <p>Boston Univ. Photonics Ctr. Kent State University Lehigh University Michigan State University MIT Photonics Research Ontario RPI UCLA Univ. Estadual de Campinas Univ. of New Mexico-CHTM Univ. of N. Carolina, Charlotte</p> <p>In Process: Santur, Arasor, Azna, Princeton Lightwave</p>
---	---	---



**58 Members, 5 more have signaled intent**

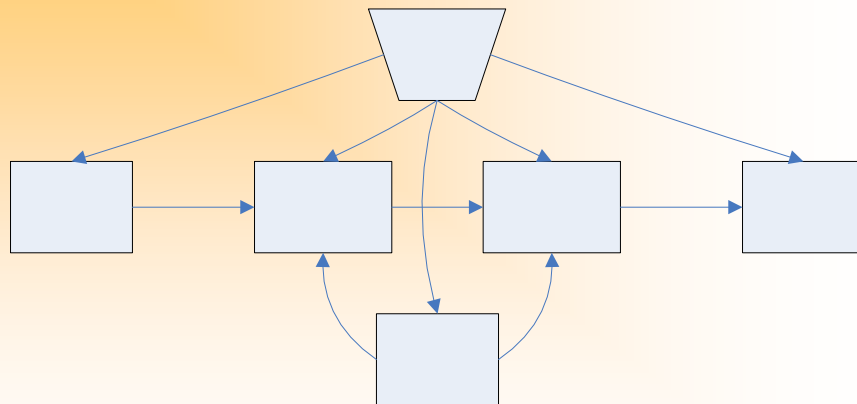
## OIDA-OSA Affiliate Members - 191

3M Company	Crystal Fibre	KoSearch Inc	Optics for Devices, SCHOTT North America	RPC Photonics Inc
4D Technology Corp.	Crystal Systems	Kotura, Inc.	Optics Technology Inc	RSoft Design Group
AcuLight Corp	CVI Laser LLC	LabNow, Inc.	OpticsProfessionals LLC	S.I. Vavilov State Optical Institute
ADE Phase Shift	Del Mar Photonics Inc	LaCrox Optical Co	Optigo Systems	Sacher Lasertechnik GmbH
Advanced Glass Industries	Delta F Corp	Lambda Research Corp.	Optikos Corp.	Santec Corp.
Advanced Photonix, Inc.	Deposition Sciences, Inc.	Laser Focus World	Optimax Systems Inc	Santur Corp.
Aerodyne Research, Inc.	Diamond USA Inc	Lasertel Inc	Optipro Systems	Scintera Networks
Aerotech Inc	Digital Optics Corp	Light Brigade, Inc	Optiwave Corp.	Scottish Development International
AFL Telecommunications	Directed Energy Solutions	LINOS Photonics Inc	Optometrics Corp.	SENKO Advanced Components Inc
Albert Einstein College of Medicine	DSS	Louis Ruzdinsky Associates Inc	OptoSigma Corp.	Siskiyou Corp.
Alpine Research Optics	Edmund Optics	Lumen Flow Corp.	Orbits Lightwave, Inc.	Special Optics Inc
Apogee Photonics Inc	Electro-Optics Technology Inc	Lumetrics	OZ Optics, Ltd	Spectra-Mat Inc
APPLIED IMAGE Group	Eliot Scientific Ltd	Luna Technologies, Inc	Pacific Biosciences	Spinicon Inc
ARIA Technologies, Inc.	ELS Elektronik Laser System GmbH	Lydall Inc.	Palomar Technologies	Summers Optical
ASML Optics LLC	EM4 Inc	MIT - Lincoln Lab	PD-LD Inc	Sutter Instrument Co
Aurora Optical	Engineering Synthesis Design Inc	Meadowlark Optics	Pennsylvania State University	Sydot Optics Inc
Avo Photonics	Essex Corp.	Melles Griot Inc	Pentax Corp	TeachSpin Inc
Barr Associates Inc	Fiberguide Industries, Inc.	Merck KGaA	PFG Optics	Technical Manufacturing Corp.
BinOptics Corp	Fiberxon, Inc.	Morgenthaler Ventures	Photonics Industries International Inc	Tempo Clean Room Foam
Biopigen	Fresnel Technologies Inc	MPB Communications, Inc	Photonics On-Fiber Devices Inc	TeraKion, Inc
Breault Research Organization Inc	Gemfine Corp	New Focus Inc	Photonics Spectra	The Institute of Optics
Bright View Technologies	Goodrich Corp.	New Scale Technologies	Photom Koncert, Inc	Thorlabs Inc
California Eastern Laboratories	Greater Rochester Enterprise	Newport Corp.	PI (Physik Instrumente) L.P.	Tinsley/SSG Precision
Cambridge Technology Inc	Griot Group Inc	nLight Photonics Corp.	piezosystem jena GmbH	Topica Photonics Inc
Cambridge University Press	G-S Plastic Optics	Northrop Grumman Information Technology	Polalis, Inc.	Tower Optical Corp
CDM Optics Inc	Hamamatsu Corp.	Nova Phase, Inc.	Polymicro Technologies Inc	u2i Photonics AG
Central Glass & Ceramics Res Inst	Hardin Optical Co.	NP Photonics, Inc.	Precision Photonics Corp.	Univ of Arizona Optical Sciences Center
CEYX Technologies Inc	Harrick Plasma	NSG America	Princeton Lightwave, Inc.	University of Central Florida, CREOL
Chang Chun Bo Xin Photoelectric	Headwall Photonics Inc	Nufem	Polaris, Inc.	US Conec Ltd
Checkpoint Technologies, LLC	Horiba Jobin Yvon Inc	Ocean Optics Inc	Quantronix Lasers	Verrillon Inc
Christie Associates	Ibsen Photonics A/S	OFR Inc, Optics for Research	QED Technologies	VPIsystems
Chroma Technology Corp	IMRA America Inc	OFS, Specialty Photonics Division	Quintessence Photonics Corp.	Water World Inc
Coherent Inc	InPhenix, Inc	Olympus Integrated Tech America Inc	R Bradley & Assoc LTD	Wardingham Technologies
ColorChip, Ltd.	INRAD Inc	Omega Optical Inc	Rainbow Research Optics, Inc.	Xponent Photonics Inc
Corionics Inc	Intel Corp	Ophir Optronics Inc	Raydiance, Inc	Zygo Corp.
Corning Inc	Ionic Systems	Opxnet Inc	RED-C Optical Networking	
Corning Tropel Corp.	IPG Photonics Corp	Optical Air Data Systems	Research Electro-Optics, Inc	
Covega Corp.	JDS Uniphase Corp	Optical Research Associates	Rochester Precision Optics	
CRI Inc	Kapleyn-Murnane Laboratories	Opticorp Inc	Rockwell Science Co LLC	



Affiliates enjoy access to GR website, discounts to OIDA Events

## How OIDA helps its members...



Uses all phases of business process

## OIDA Activities Overview

---

<p><b><u>Market Development</u></b></p> <ul style="list-style-type: none"> <li>▪ OE Market Trends</li> <li>▪ Annual OE Report</li> <li>▪ Industry roadmaps</li> <li>▪ Legislative/policy issues</li> <li>▪ Academic to market transfer</li> </ul>	<p><b><u>Improve Infrastructure</u></b></p> <ul style="list-style-type: none"> <li>▪ Manufacturing Infrastructure</li> <li>▪ Standards Promotion</li> <li>▪ Raise common issues, drive consensus</li> <li>▪ Photonics Foundry</li> </ul>
<p><b><u>Advance Technology</u></b></p> <ul style="list-style-type: none"> <li>▪ Technology Roadmaps and gaps</li> <li>▪ Promote Government R&amp;D Support</li> <li>▪ OE Centers</li> <li>▪ PTAP program with Universities</li> <li>▪ Agency relations (DARPA, NIST, etc)</li> </ul>	<p><b><u>Unified Voice of OE Industry</u></b></p> <ul style="list-style-type: none"> <li>▪ Forum for OE Users and Suppliers</li> <li>▪ Adviser to the U.S. Government</li> <li>▪ Interact with Industry Associations Worldwide</li> <li>▪ Liason to other organizations (OSA, SPIE, etc)</li> </ul>

Key value proposition to members

## OIDA Value proposition opportunities

---

<b>Value Chain</b>	Telecom Carriers						
Service Providers							
Systems	Telecom and Network Systems					Lighting Systems	Defense/ Security Systems
Modules	Telecom and Datacom Modules					Sensing, Industrial Hi Power Modules	Lighting Modules Defense/ Security Modules
Components	Telecom and Datacom Devices	Solar and Energy Devices	Medical and Bio Devices	Display and Vision Devices	Advanced Materials and Nano	Sensing, Industrial Hi Power Devices	Lighting Devices Defense/ Security Comp

Communications key focus for OIDA