iNEMI

International Electronics Manufacturing Initiative

iNEMI OPTOELECTRONICS ROADMAP FOR 2004

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Outline

- Business Overview
- Traditional vs Jisso Packaging Levels
- Optoelectronics Level 0 (Jisso 1)
- Optoelectronics Level 1 (Jisso 2)
- Optoelectronics Level 2 (Jisso 3 and 4)
- Summary

Traditional vs Jisso Levels

Traditional Packaging Levels

- Level 0 – On Chip
- Level 1 – Chip to Package
- Level 2 – Printed Wiring Assembly
- Level 3 – Card to Backplane
- Level 4 – Rack to Rack
- Level 5 – Cabinet to Cabinet

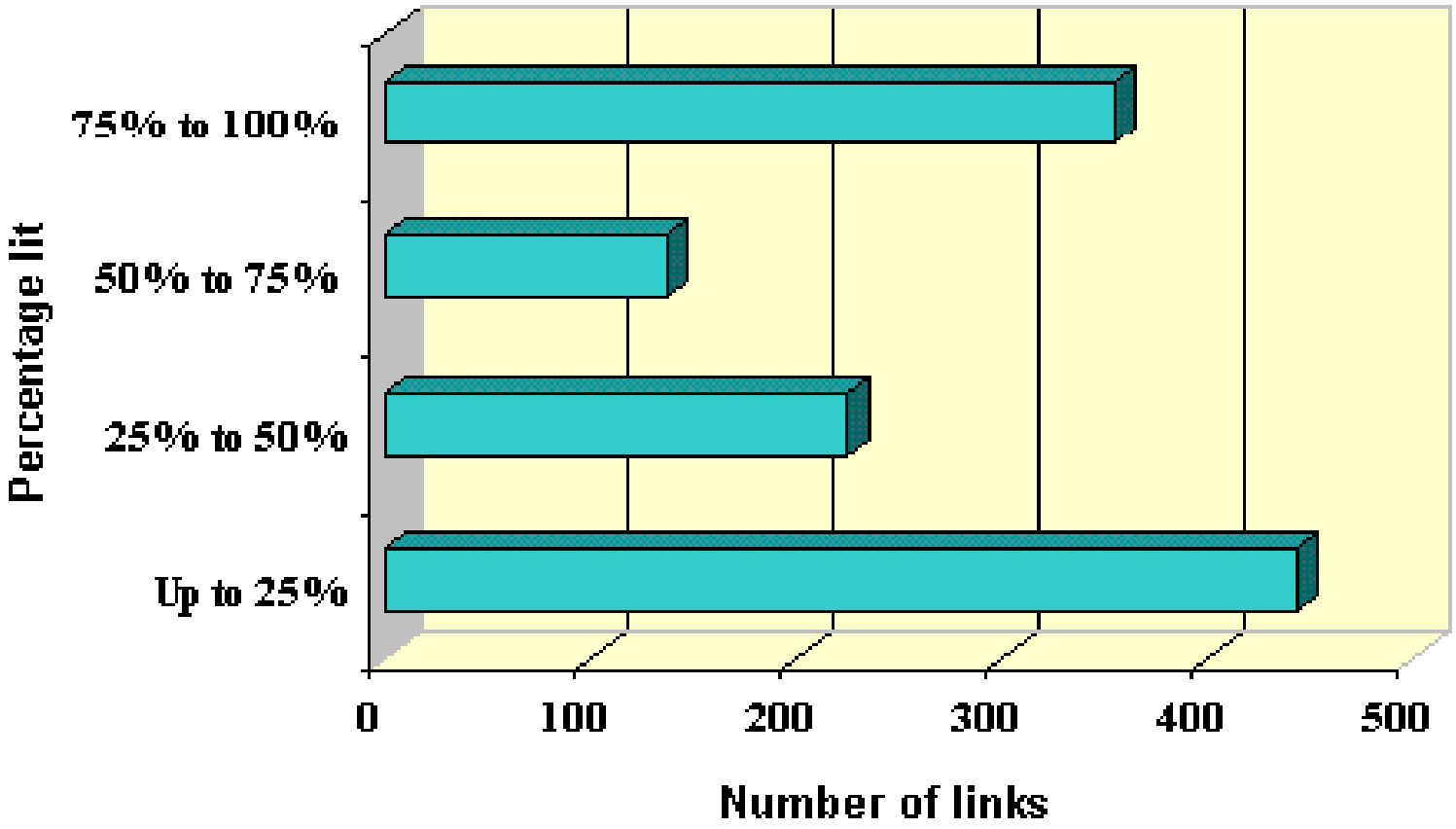
Jisso Packaging Levels

- Level 0 – Intellectual Property
- Level 1 – Electronic Element
- Level 2 – Electronic Package
- Level 3 – Electronic Module
- Level 4 – Electronic Unit
- Level 5 – Electronic System

Capacity Utilization

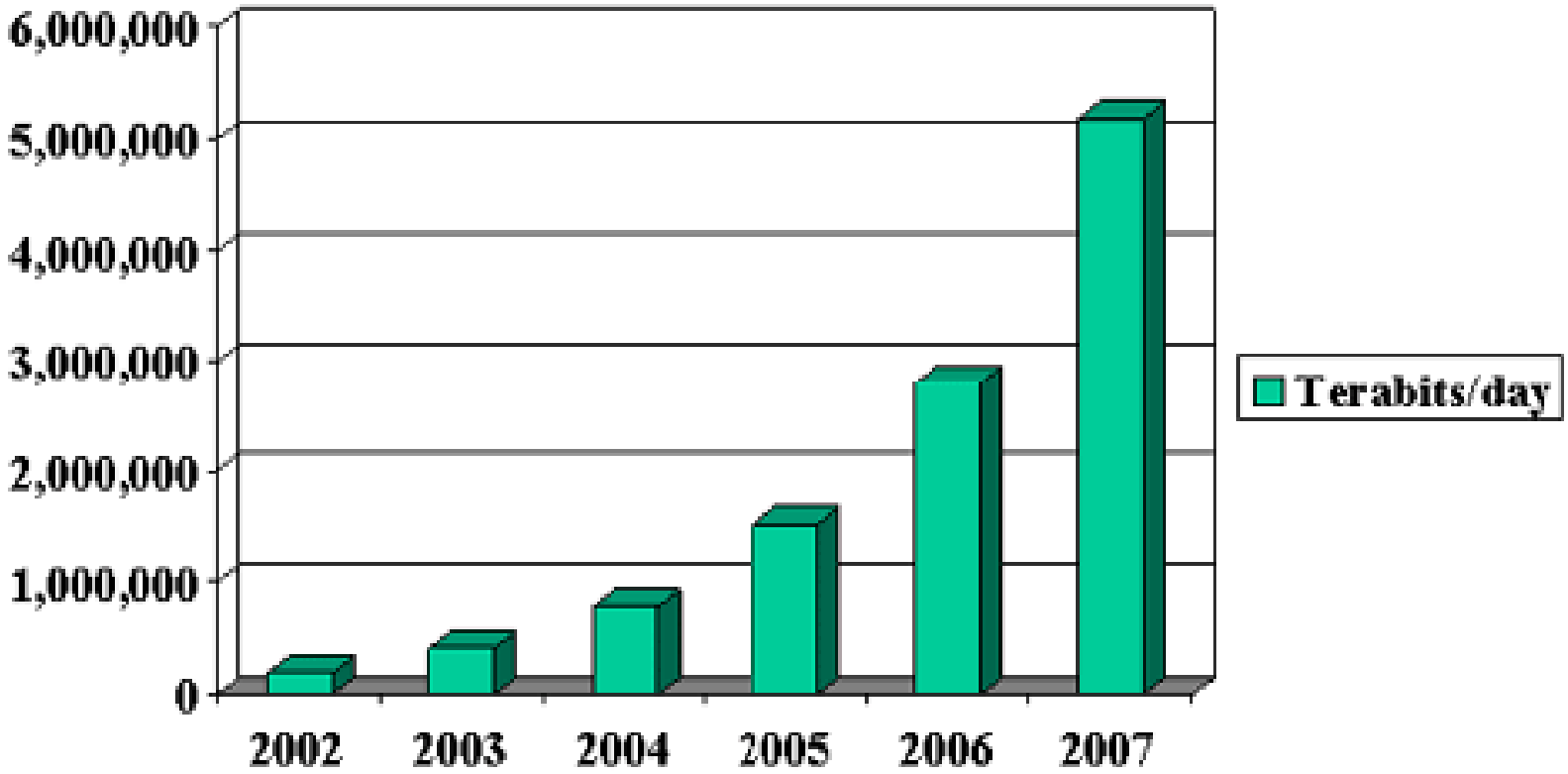
Capacity Utilization on 1,161 North American Long Haul WDM Links

Source: PointEast Research



Internet Demand

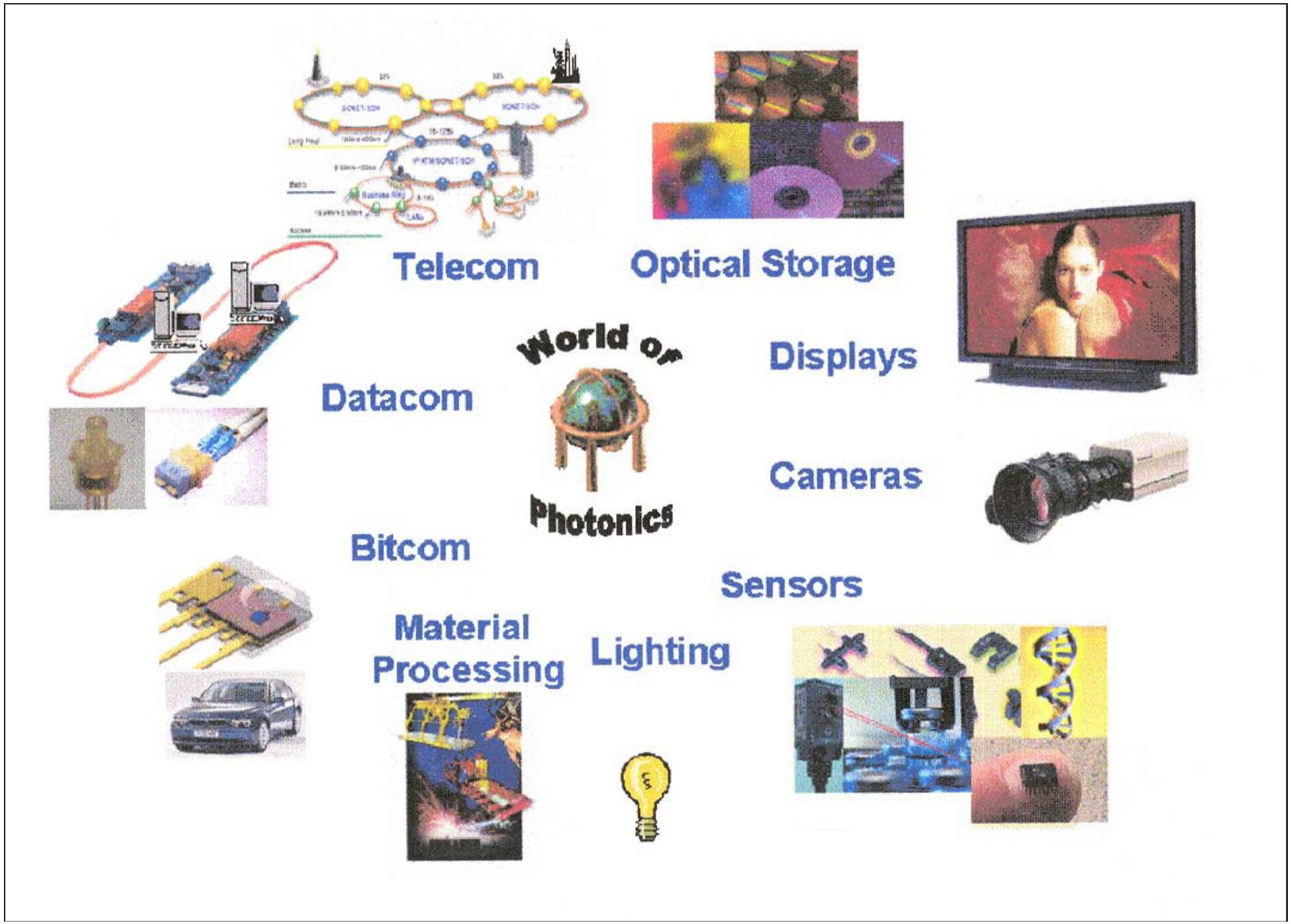
Worldwide Internet Bandwidth End-Use Demand, 2002-2007 (Terabits/day)



Business Drivers

- Global internet data traffic continues to grow 50-100% annually
- Traffic growth will be supported by
  - turning on unlit fiber for the next few years,
  - increasing data rates
  - increasing the number of useable wavelengths.
- Backbone capacity will push out the need for 40 Gbps transmission for several years
- HDTV may be the driver for fiber to the home (FTH)

The World of Photonics



Level 0 – Jisso 1

- Level 0 (Jisso 1) focuses on chip technology developments
  - Optical communication
  - Solid-state lighting.
- Transmitter components
  - Lasers including vertical-cavity surface emitting lasers (VCSELs)
  - High speed modulators.
- Receiver components
  - Pin photodiodes, avalanche photodiodes
  - Large area metal semiconductor metal (MSM) photodetectors.
- Integration on chip level to increase performance and decrease system cost.

Level 0 – Jisso 1

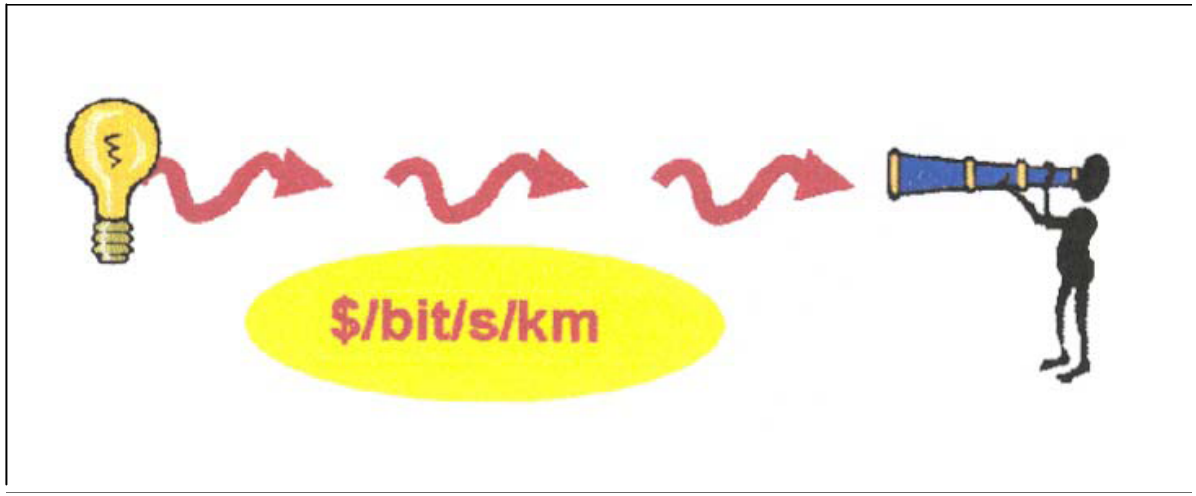
VCSELs – Vertical Cavity Surface Emitting Lasers

- Operating at 850nm offer cost advantages for packaging.
- Currently used in multimode fiber systems for datacom applications.
- Maximum distance a few hundred meters
- Speed 2.5 to 4 Gb/s

Solid State Lighting Advantages

- Low voltage operation (for battery and humid environment)
- Small size
- Long lifetime
- High environmental stability
- Low power consumption
- Easy control (low EMI noise)

Economic Technology Drivers



- **The economic figure-of-merit (EFM) is:**
  - » **The cost ($) per information (bit)**
  - » **Per time transmitted (s)**
  - » **Per distance (km)**

Roadmap of Integration Technologies

Level 0

2005	2007	2009	2015
Tunable lasers and high speed modulator	1310 nm electro-absorption modulated laser (EML), uncooled	Multi-channel tunable lasers	Multi-channel laser array
Tunable laser integrated with op-amp and modulator	1550 nm EML with op-amp and photo-detector	Tunable laser array with op-amp and optical switch	Pin/avalanche photodiode (APD) with integrated electronics for 100GB/s
	Pin/APD with integrated amplifier for 40 GB/s	Photo detector array with integrated demultiplexer	

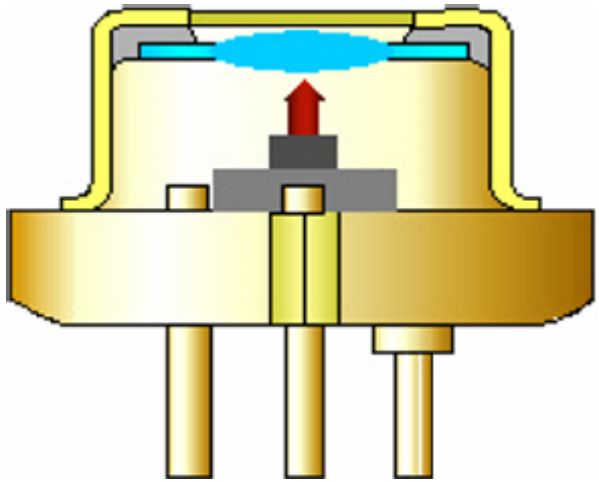
Level 1 – Jisso 2

Level 1 – Jisso 2 is focused on interconnecting and packaging

a variety of devices

for various applications

Packaged VCSEL



Transistor outline (TO) packaged VCSEL

Courtesy of Torsten Wipiejewski (ASTRI)

Level 1 – Jisso 2

Optoelectronic Packaging Strategies

- **3 Year:**
  - **Hermetic Packages, higher levels of optical and electronic integration, System in a Package (SIP).**
  - **Non-hermetic packages for cable tv, premise network**
  - **Plastic and molded optics**
- **5 Year:**
  - **Increasing use of SIP and "System on a Package" (SOP)**
  - **wide adoption of plastics and composite materials for packaging and optics**
- **10 Year:**
  - **"System on a Package" technologies with a mixture of III-V materials and organics embedded for electrical and optical functions**
  - **Plastic packages**

Automation Technology Characteristics

Level 1 Assembly

2002	Machines/ Operators	Time/Parts	Yield	Cost	Market Share
Manual	1	Up to 1 hour	50-75%	$5K-$50K	70%
Semi	1-3	1-15 min	80-90%+	$50K-$200K	24%
Full	5-10	1-5 min	90-99%	250K-$350K	>5%
In-line	Several	2-4 min	90-99%	>$400K	rare

New Areas for Development

- Functionality oriented polymers for better multimode data transmission
- Wavelength oriented optical chip-to-chip interconnections
- Combined processing of high frequency and micro optical components
- SMT compatible assembly processes with accuracies < 10 µm
- Specific optical connectors and package interfaces
- Wafer level packaging for optoelectronic systems
- New test procedures to
  - monitor optical components
  - assess functionality in electro/optical and/or complete optical systems

Level 2 – Jisso 3 and 4

- **Level 2 – Jisso 3 and 4 refers to the sub-systems that comprise one or more packaged optical or optoelectronic component**

- **Components are usually interconnected optically by fiber connectors or pig-tails and mounted on a substrate (PWB) or held by an optical carrier.**

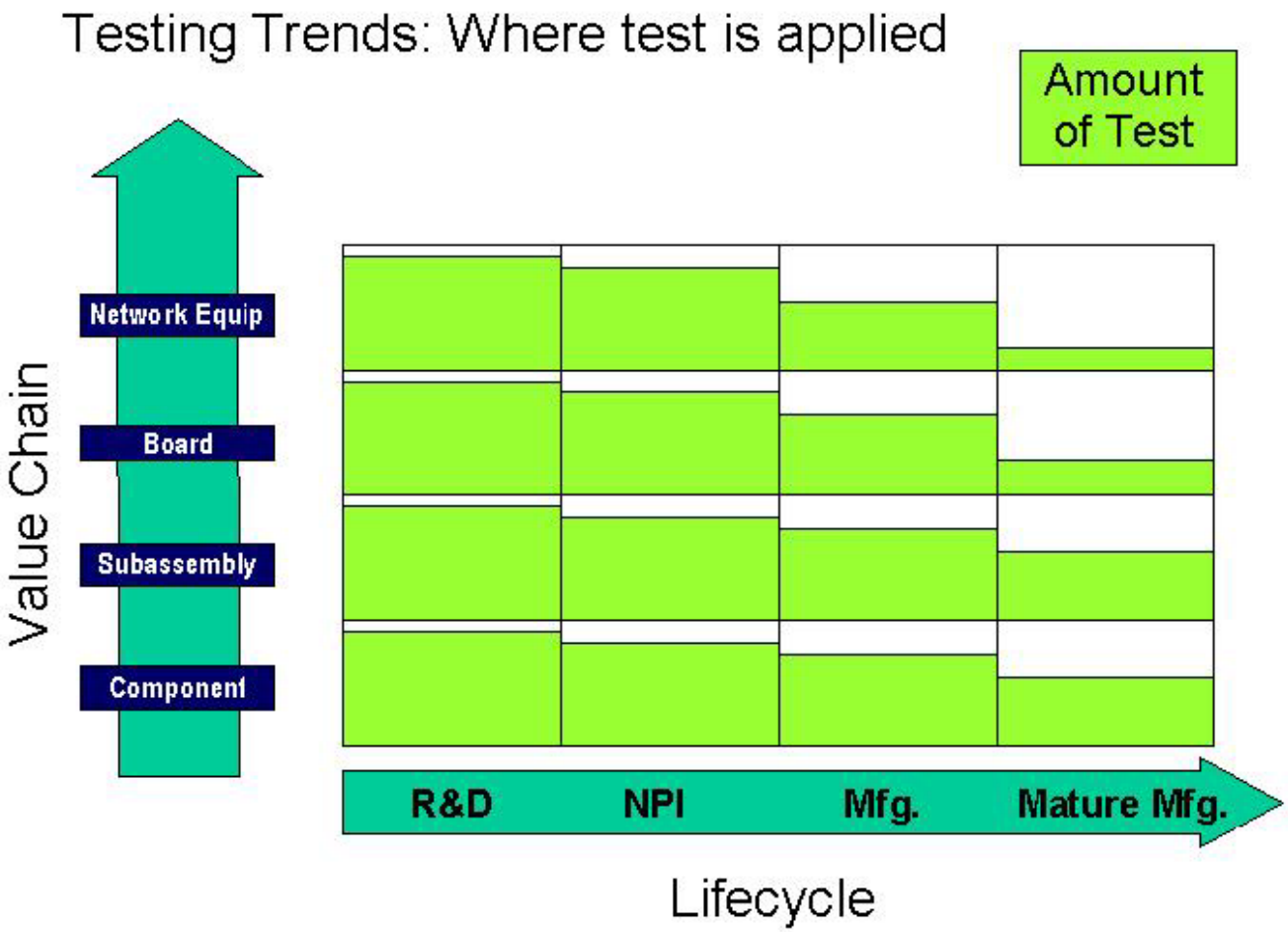
Key Industry Drivers

- Increased electrical and optical integration and functionality
- Automation focus replaced by the move to low cost labor and to pluggable modules
- Automation is viable for higher skill operations, such as fiber splicing, if volume and yield improvement justify equipment cost.
- The performance of copper systems continues to advance at the module and card-to-card level. Data rates of 10 Gbps over 0.5 meter in FR4 can be achieved using current technology.
- Interest in optical links at the chip or module levels, to overcome bandwidth bottlenecks, thermal dissipation and signal integrity issues.

Emerging Technologies

Technology	Possible Application
Photonic band gap materials	Wave guides, light turning
Grating Systems	Light manipulation in various geometries
Holograms	Fast optical switching (ns)
MEMs Devices	Wavelength switching and configuration in all optical networks
Semiconductor electronic optical modulation	Switching modulation to eliminate components
Negative refractive index materials	Multiple
Quantum entanglement	Secure communications
Tunable lasers	Real-time system and network reconfiguration
Carbon nanotubes	Heat spreader components
2-Photon absorption	Waveguides and optical elements
Silica nanowires	Sensors, small form factor OE devices

Testing Trends



Summary

- **Various packaging levels**
- **Business issues**
- **Key technology developments expected in the future for the various levels of packaging.**
- **The roadmap represents the input of almost 50 individuals from around the world.**

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