



NEMI Optoelectronics Technology Roadmap

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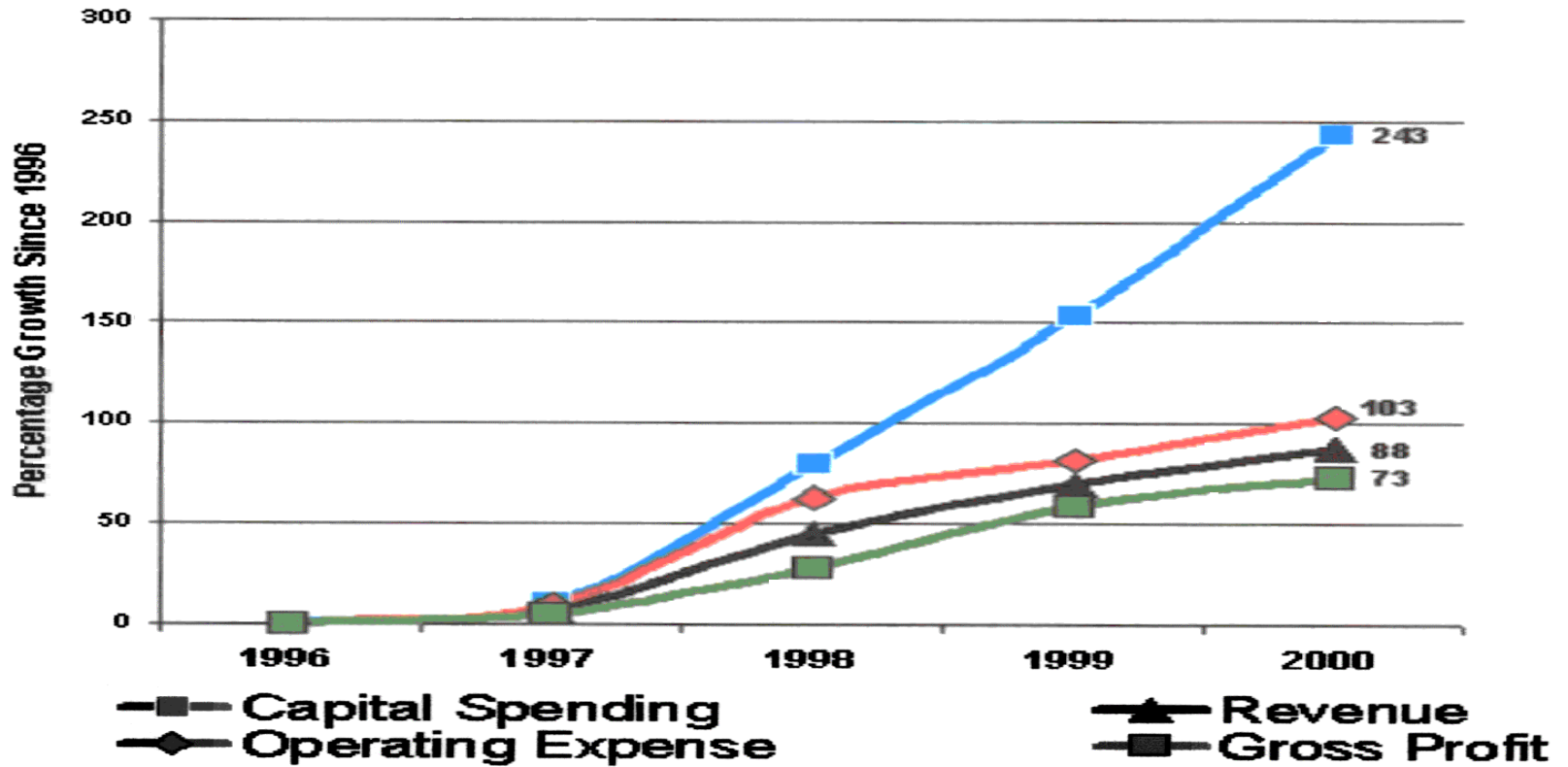


The Roaring 90's

- Telecommunications – Driving force behind the boom of the late 90's.
- Telecom industry grew at twice the rate of the national economy between 1996 and 2000
- By 2001 the telecom companies had reached a market value of \$3 trillion, and their share of the GDP rose to almost 6%.
- The Internet, wireless and other telecom services, spurred investment in information technology, which by 1999 accounted for 43% of private, non residential investment.

What Went Wrong in 2000?

Capital Spending Exceeds Revenue & Profit Growth



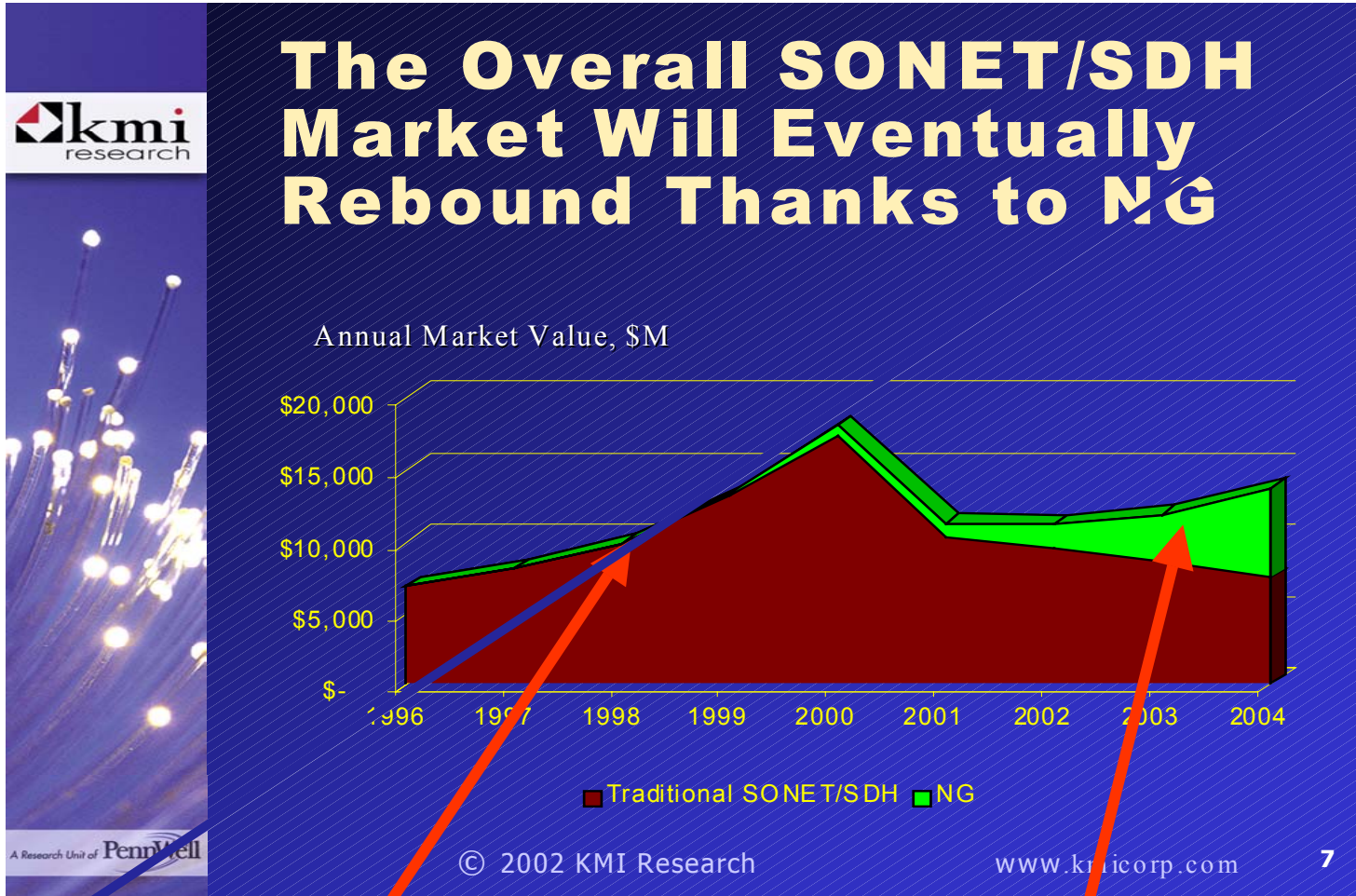
Source: Optical Oracle



The Status in 2002

- The Standard and Poors 500 Index reached a market peak of 1527 on 3/24/00 and on 4/11/03 stands at 868.
- The Telecom Industry has lost an estimated \$2 trillion on the stock market since 1999 (i.e. about 2/3 its market value).
- Telecom is purported to have thousands of miles of excess capacity in fiber-optic cable and as much as \$500 billion in questionable debt.
- 80% of businesses connected to the Internet use broadband; less than 10% of households with Internet service do so.
- The rate of growth in the Internet is decreasing.

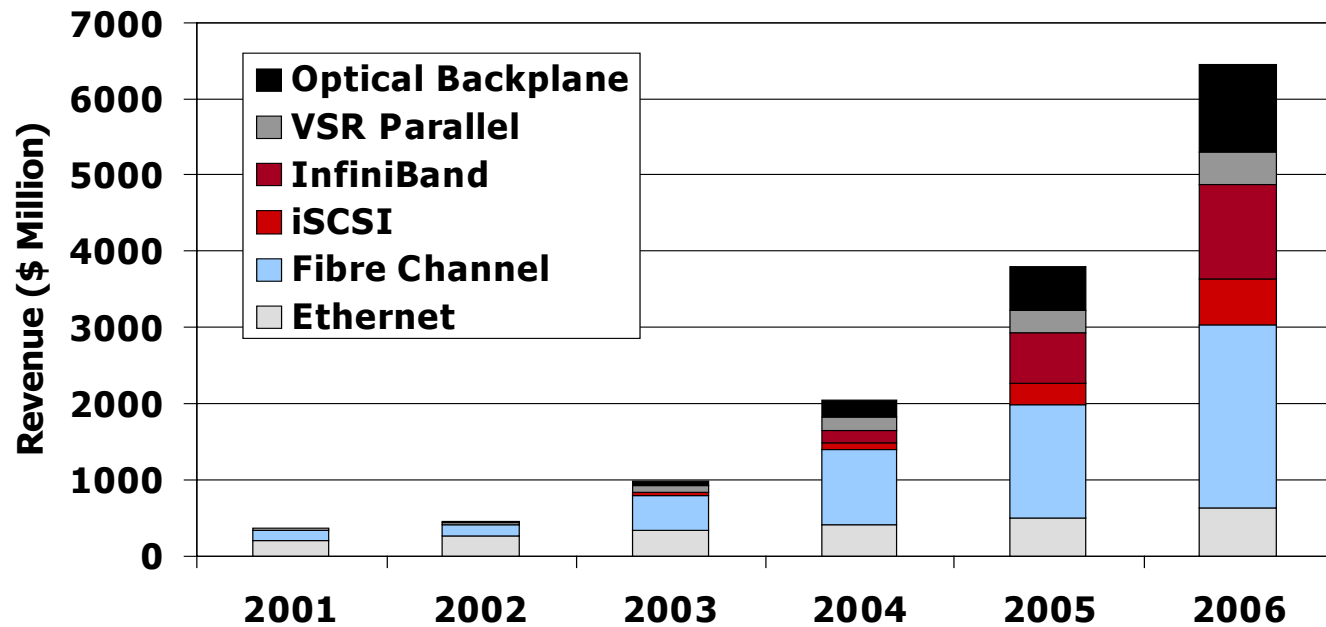
SONET Equipment Outlook



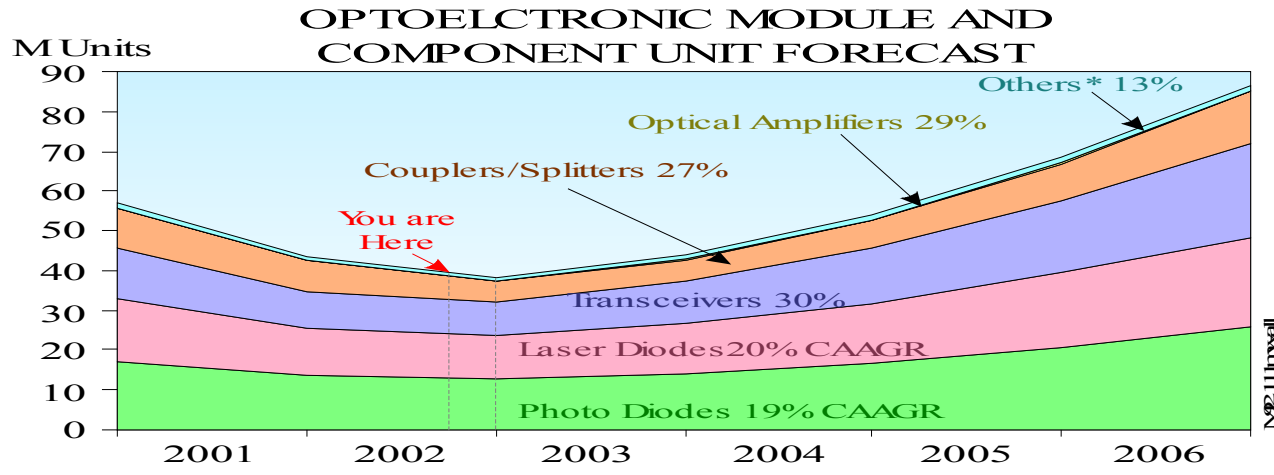
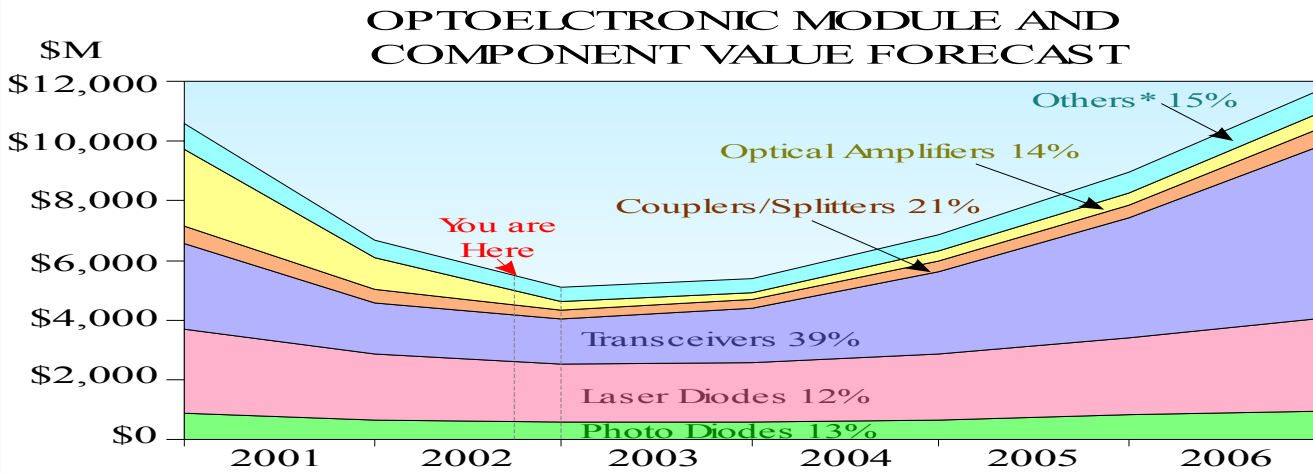
Traditional SONE Eq.

Next Gen. SONE Eq.

Enterprise Module Forecast



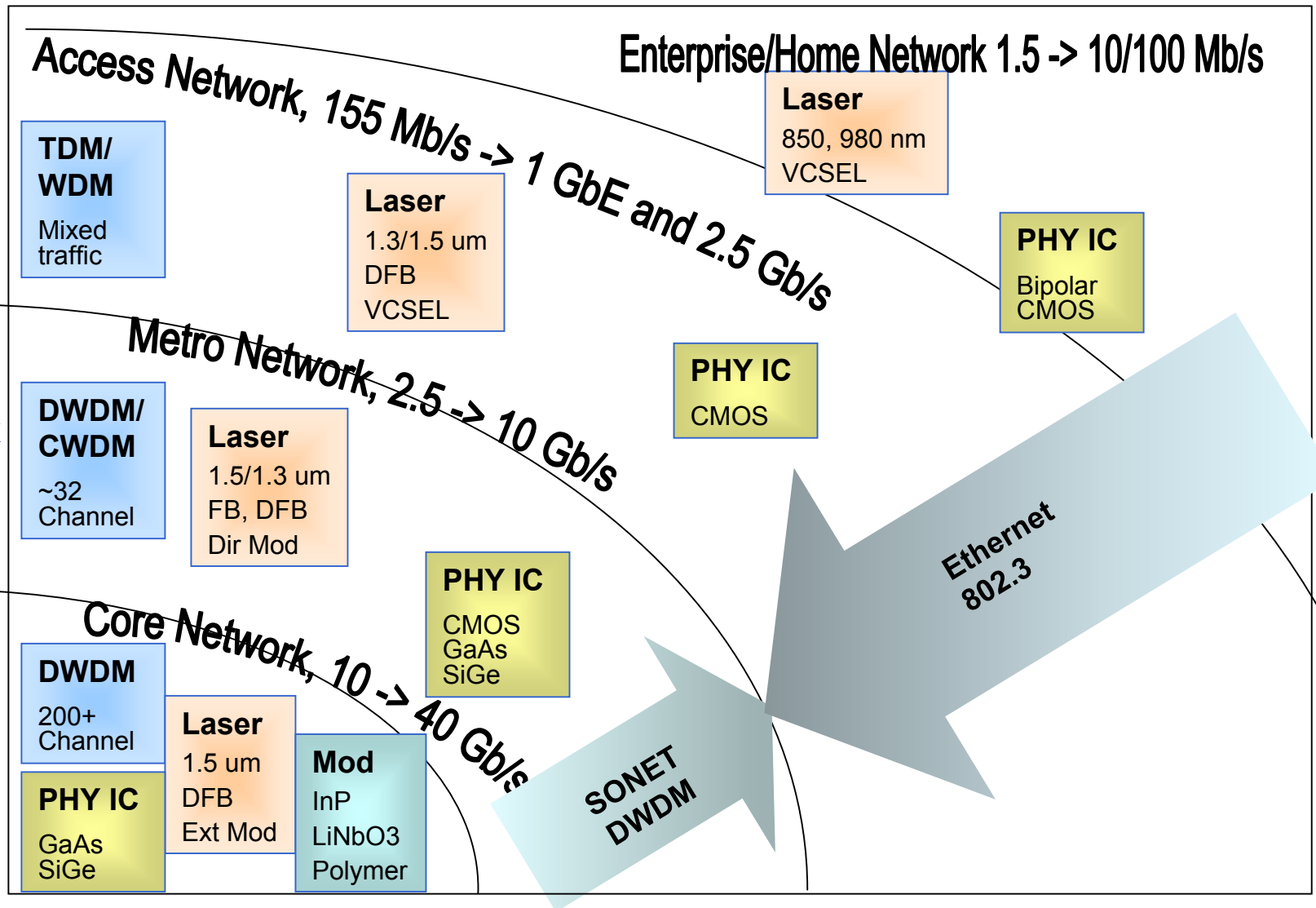
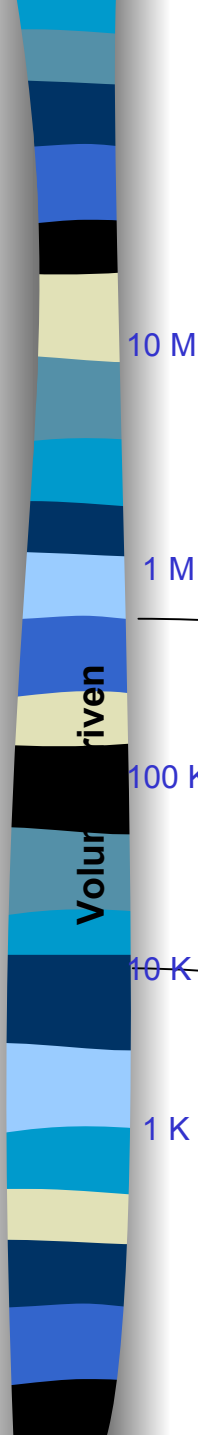
Optoelectronic Communications Component Outlook



*Other includes Modulators, Variable Optical Attenuators and Optical Multiplexers

Note: Percentages refer to CAAGR for 2002 through 2006

Optical Components Trends

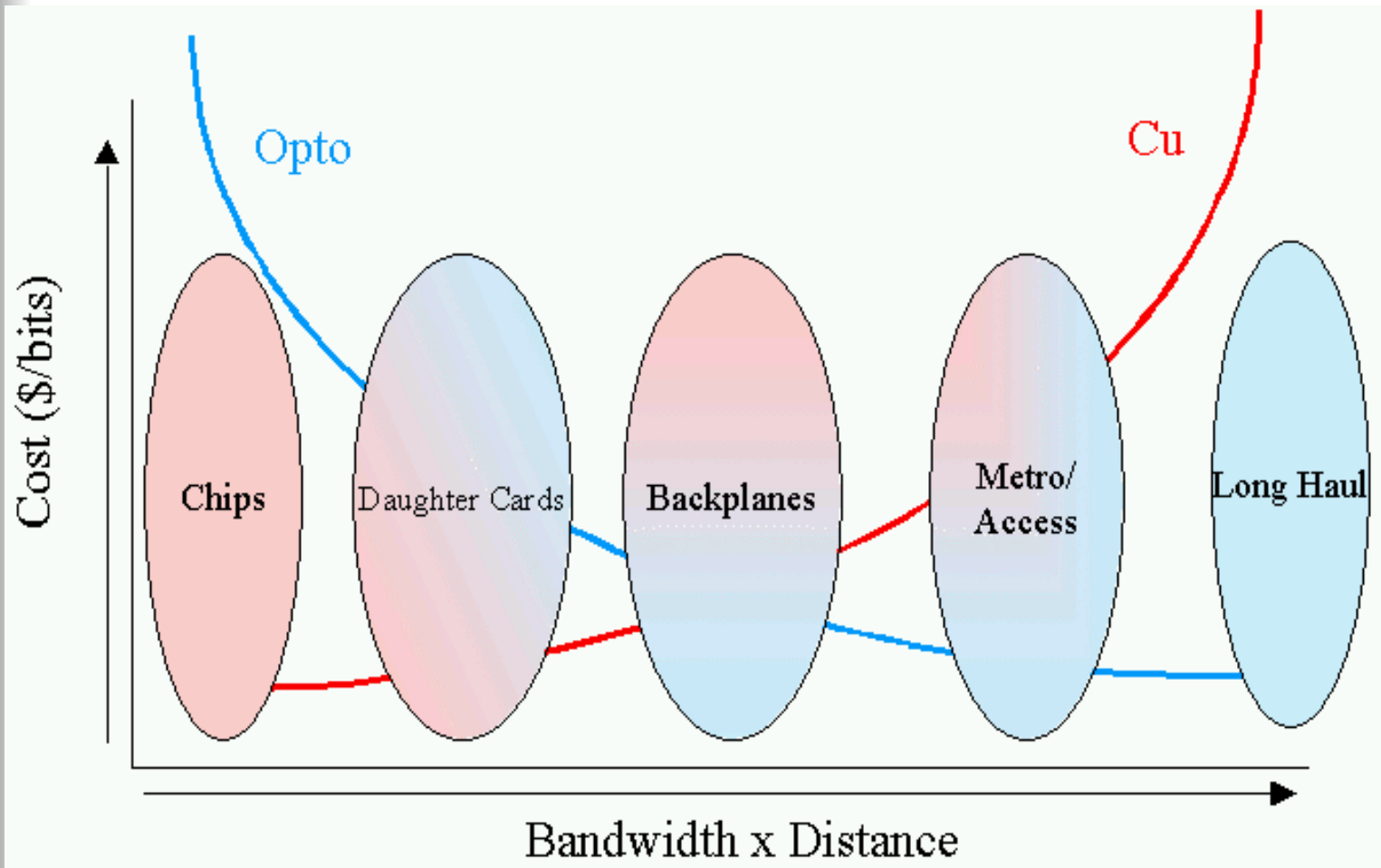




“The Last Mile Problem”

- **DSL/ADSL**
- **Cable**
- **Fiber to the Curb (FTTC)**
- **Fiber to the Home (FTTH)**
- **Wireless-Terrestrial and Satellite**
- **Of the Household That Have Broadband:**
 - 66% have Cable
 - 31% have DSL
 - 3% Other
- **Fiber to the home expected to grow from 100K lines in 2003 to nearly 300K lines in 2004**

The Copper Optical Trade Off





NEMI Optoelectronic Roadmap Focus

- **Optical communications, related photonic components and the manufacturing and assembly technologies.**
- **Products for long haul, metro-regional, metro- enterprise and home networks.**
- **Chapter covers:**
 - **Level 0 – uncased devices**
 - **Level 1 – single device or multiple devices in a package**
 - **Level 2 – product boards**
 - **Level 2 – systems and networking**

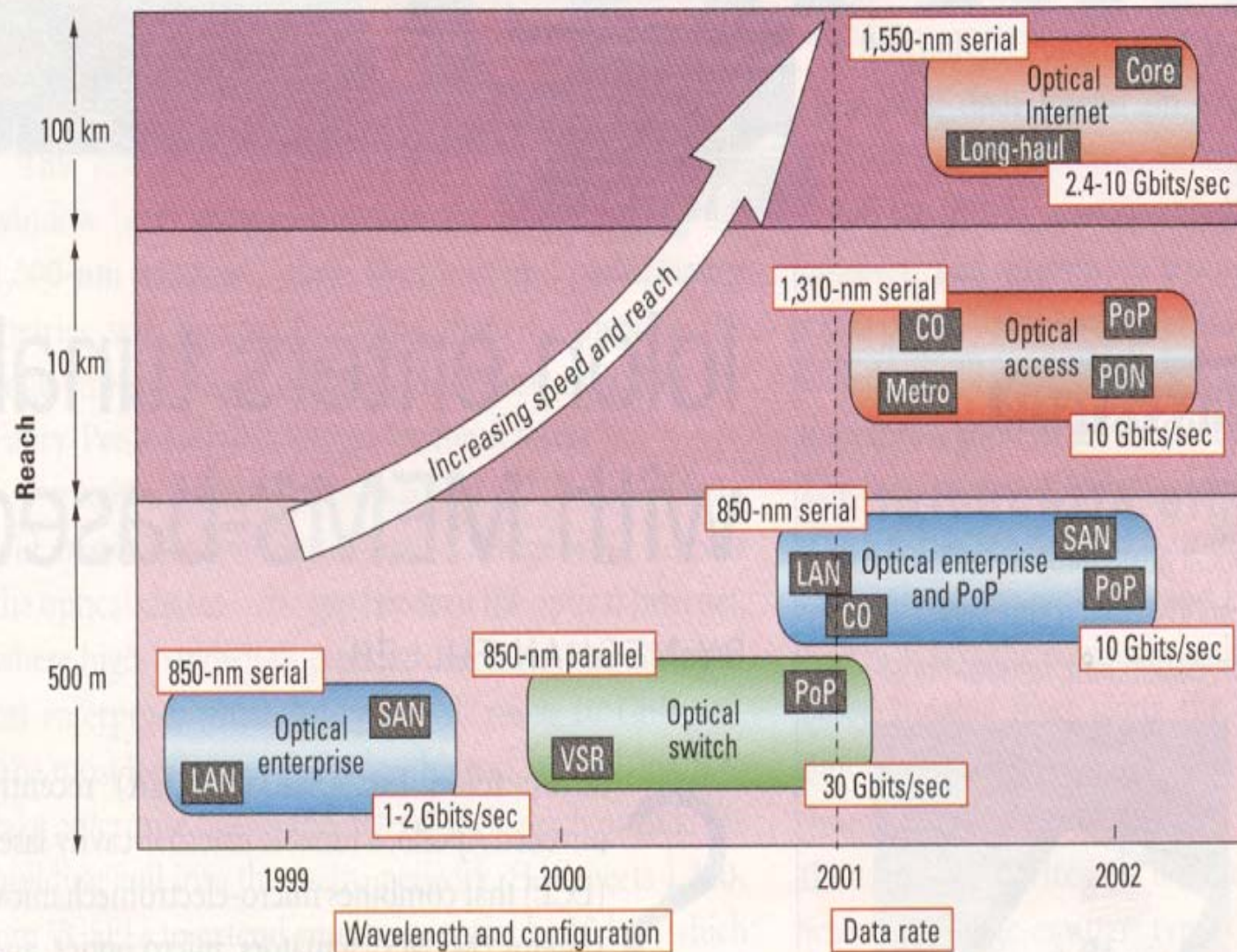


Level 1

Cost Performance Drivers

- **Hermeticity**
- **Optical alignment Issues**
- **Partitioning and Integration**
- **Packaging Material Selection**
- **Thermal Management**
- **Assembly Challenges**

Evolution of VCSEL technology



CO - Central office PoP - Point of presence VSR - Very-short-reach
 PON - Passive optical network SAN - Storage-area network

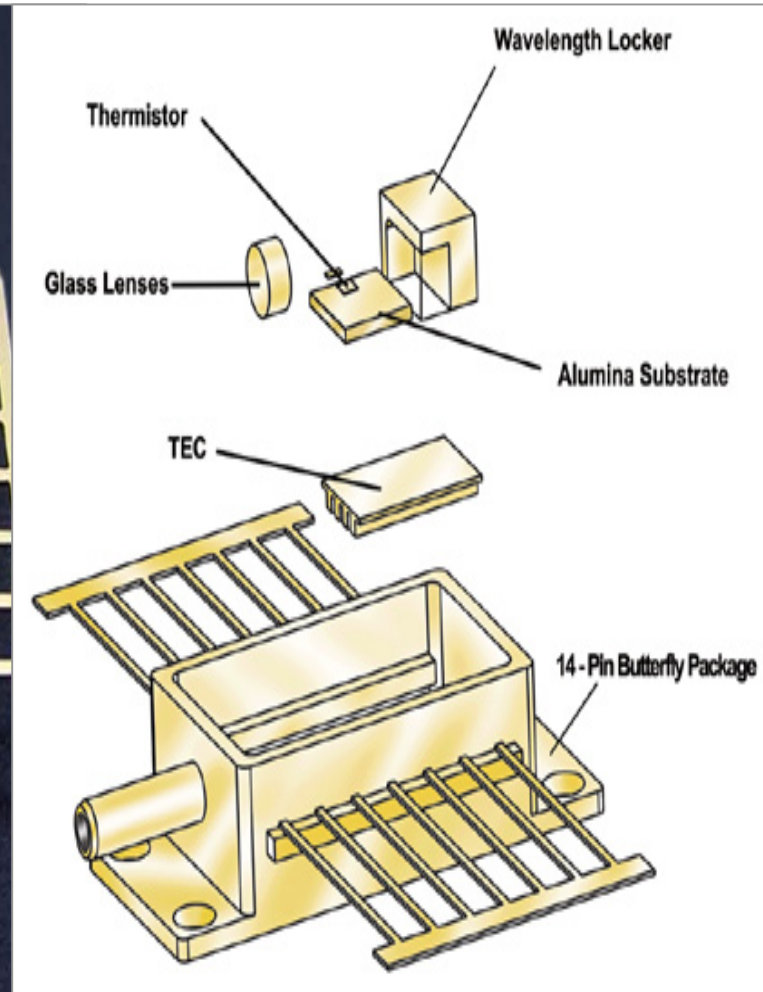
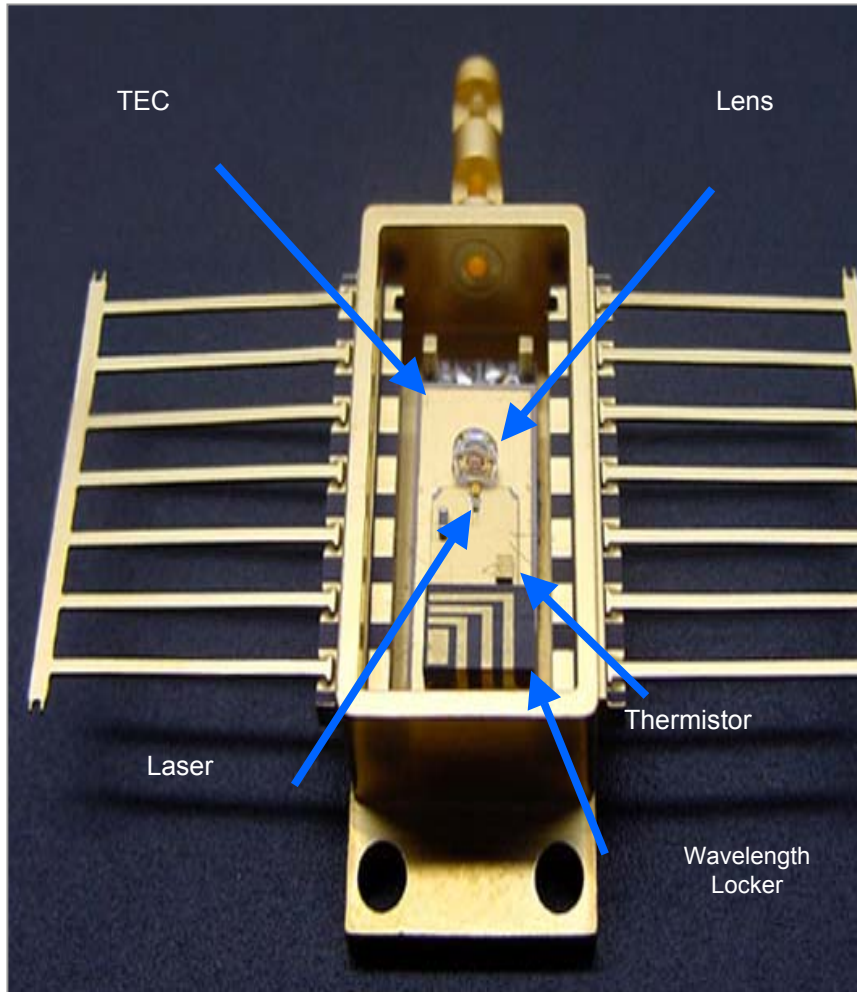
VCSELs have rapidly evolved over the past few years, increasing in speed and reach and moving into the optical enterprise, optical access, and optical Internet spaces.



Device Technology

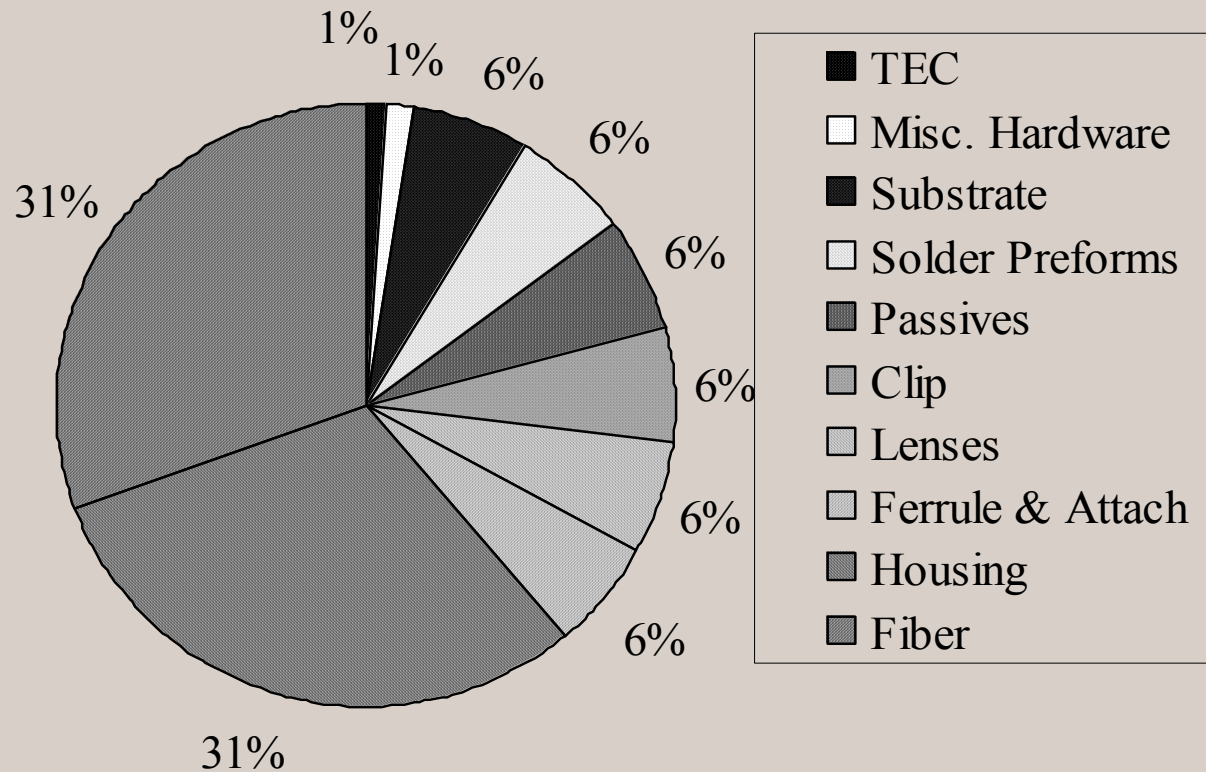
- **Continue development of low cost optical components such as SOAs, VCSELS, and switching products.**
- **Develop a system wide view of thermal management. Apply heat sinks and other cooling methods.**
- **Develop improved optical materials and designs.**
- **Develop photonic crystals and other technologies to reduce the size of OE product.**

Elements of Laser Package



Current Level 1 Costs

Sample Optical Module Materials Costs

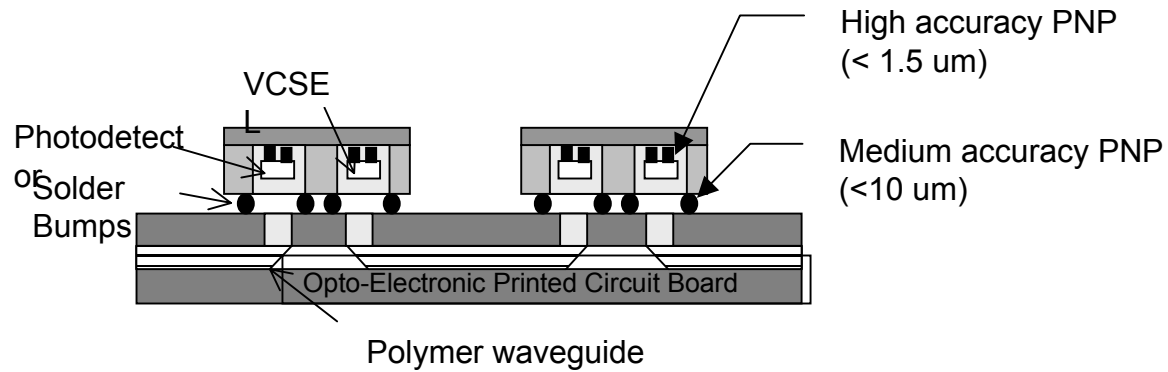




Level 1 Technology Trends

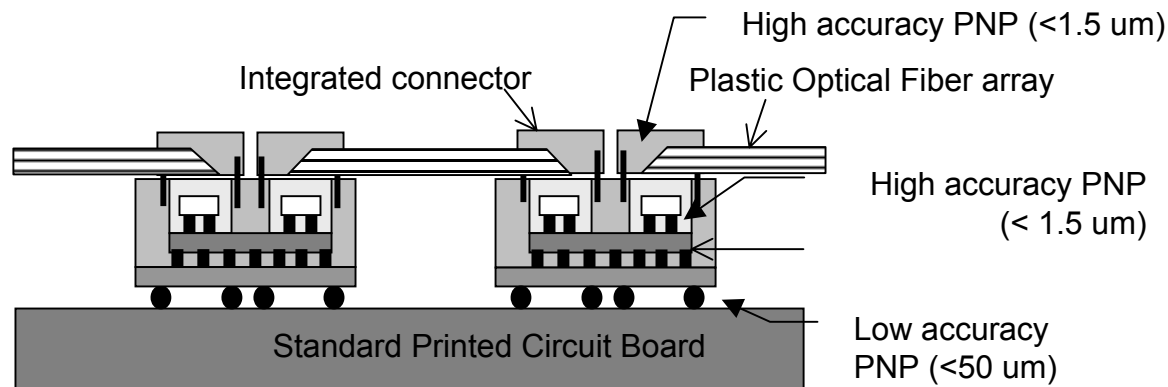
- **Hybrid and some monolithic integration incorporating O/E in the same package.**
- **In addition to hermetically sealed Kovar butterfly packages, there will be an increased use of lead frames, encapsulation, and BGA packages.**
- **Increased automation, including automated pigtailing.**
- **Active alignment replaced by passive alignment in all but high end devices.**
- **Standard test methods for adhesives properties and development of new UV curable, zero shrink materials.**

Passive Optoelectronic Substrates



- **Production within 3-5 years**
- **High accuracy placement inside optoelectronic package**
- **Medium accuracy placement on board**
- **Optoelectronic printed wiring board**

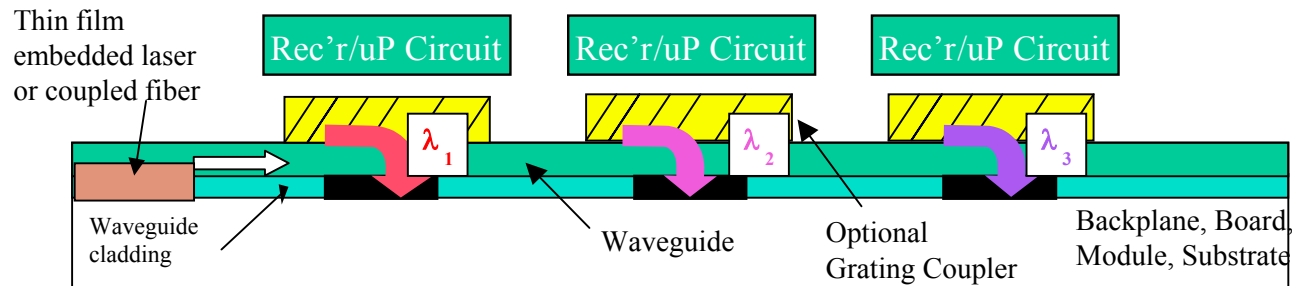
Passive Electronic Substrate



- **Standard printed wiring board (PWB)**
- **Optical connections above the board, between packaged devices.**
- **High accuracy placement required for optoelectronic interconnect.**
- **Low accuracy placement of components onto the PWB.**

Imbedded Active Optoelectronic

- **System in a package**
- **Embedded optical wave guide**
- **Multiple electrical and optical chips**
- **Build-up interconnect technology**
- **5-10 years out**





Polymeric Materials: Issues to be Addressed

- **Repeatability in dispensing small volumes**
- **Selective curing with UV or IR without distorting the assembly.**
- **Chemistries that cure at low temperature and produce $T_g \geq 95^\circ\text{C}$**
- **Low shrinkage adhesives**
- **Minimum volatiles escaping during cure**
- **Development of low CTE, transparent encapsulants.**
- **Determine effect of long-term exposure to low or high intensity light sources on the polymer.**

Level 2 Roadmap Highlights

Technology	2005	2010
Component & Module	<ul style="list-style-type: none">■ Standard package types – plugable■ Molded plastic packages■ Pick & place, SMT compatible	<ul style="list-style-type: none">■ Direct optical coupling between component and optical PCB,■ parallel I/O using VCSELs
Optical Interconnects: fiber connectors and splicing	<ul style="list-style-type: none">■ One step fiber termination “black box”■ Integrated automated splice process, for single or multi-up fibers	<ul style="list-style-type: none">■ Direct optical coupling between component and optical PCB■ Parallel optical PCB edge and surface connectors

Level 2 Roadmap Highlights

Technology	2005	2010
Substrates	<ul style="list-style-type: none">■ Surface laminated fiber planes, connector terminated■ First generation optical backplanes (passive optical interconnection)	<ul style="list-style-type: none">■ Embedded optical waveguides with any-point interconnects (connector and component)■ Optical backplanes, pluggable daughter cards
Assembly	<ul style="list-style-type: none">■ Bulk reflow, pick & place compatible components■ Automated data-driven selective solder attach for non-SMT compatible components	<ul style="list-style-type: none">■ Low temperature conductive adhesive attach (equivalent to solder electrical & mechanical performance)■ Passive place, self-alignment, direct optical coupling to PCB

Level 2 Roadmap Highlights

Technology	2005	2010
Test	<ul style="list-style-type: none">■ Low cost testing for high volume technologies – VCSELs■ Adoption of new protocol standards■ First generation optical BIST modules■ Forward error correction – short time BER testing, e.g. Q-factor	<ul style="list-style-type: none">■ Modular, reconfigurable multifunction and parallel testers■ On-board, network fault detection, e.g. OTDR



Level 2 Component and Material Challenges

- **Backplane to daughter board, parallel optical connectors that provide equivalent quality as current connectors (< 0.5dB loss per connection).**
- **Development of materials with low dielectric constants and low dissipation factor for printed wiring board laminates.**
- **Development of new organic materials for embedded optical waveguides.**



Automation

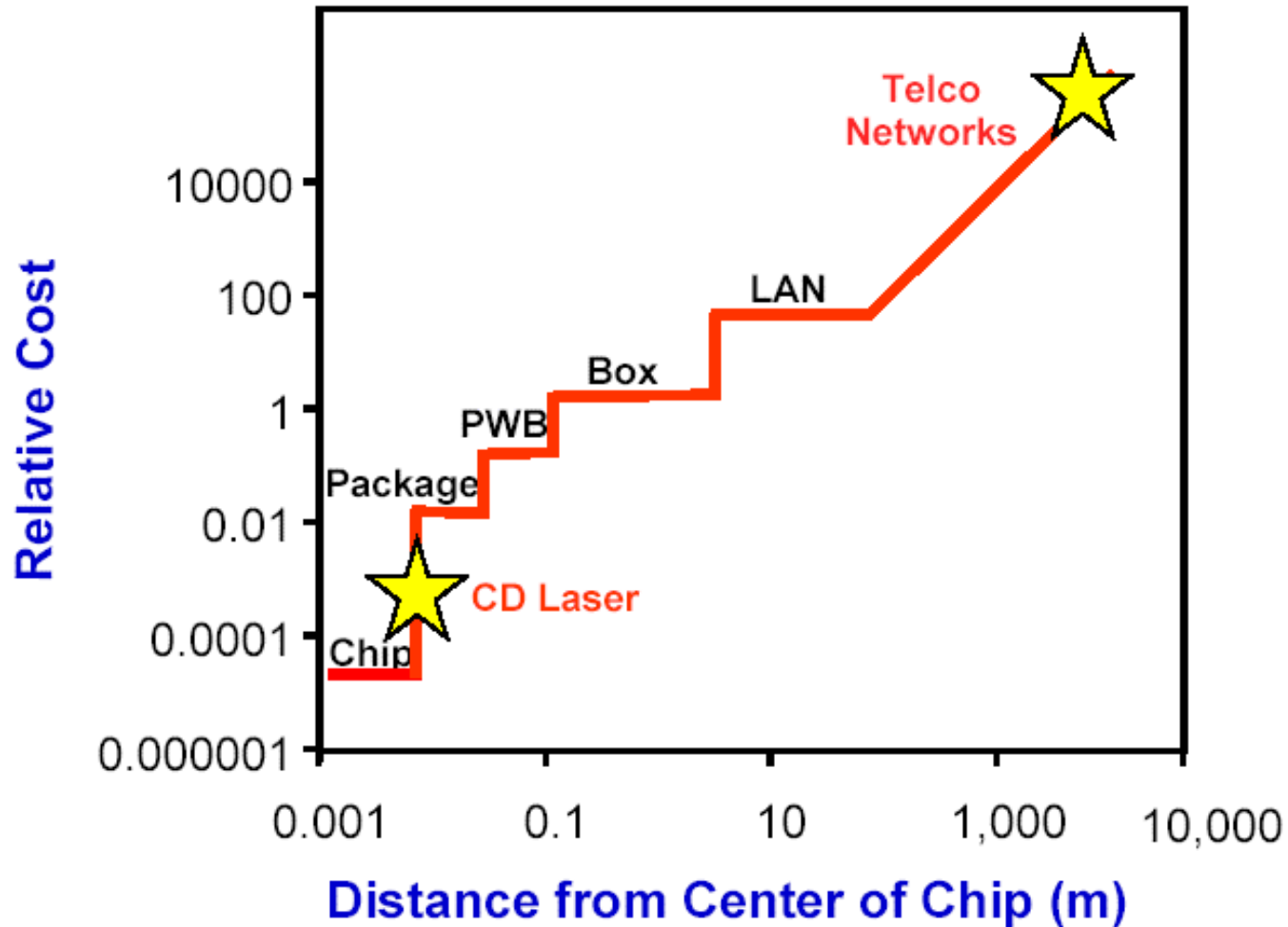
- **Develop subcomponents and materials that facilitate automation.**
- **Develop assembly processes and equipment that enable integration of electronics and optics within a single package.**
- **Improve fiber management, or eliminate fiber where possible.**

Characteristics of Automation Methodologies

2002	Machines / Operator	Time/ Part	Yield	Cost	Market Share
Manual	1	Up to 1 hour	Poor	\$10K-\$50K	85%
Semi	2-4	5-10 minutes	Good	\$100K-200K	10%
Full	5-10	3-5 minutes	Best	\$250K-\$350K	5%
Inline	several	2-4 minutes	Best	> \$400K	Rare

The Cost of Interconnect

Interconnect Cost





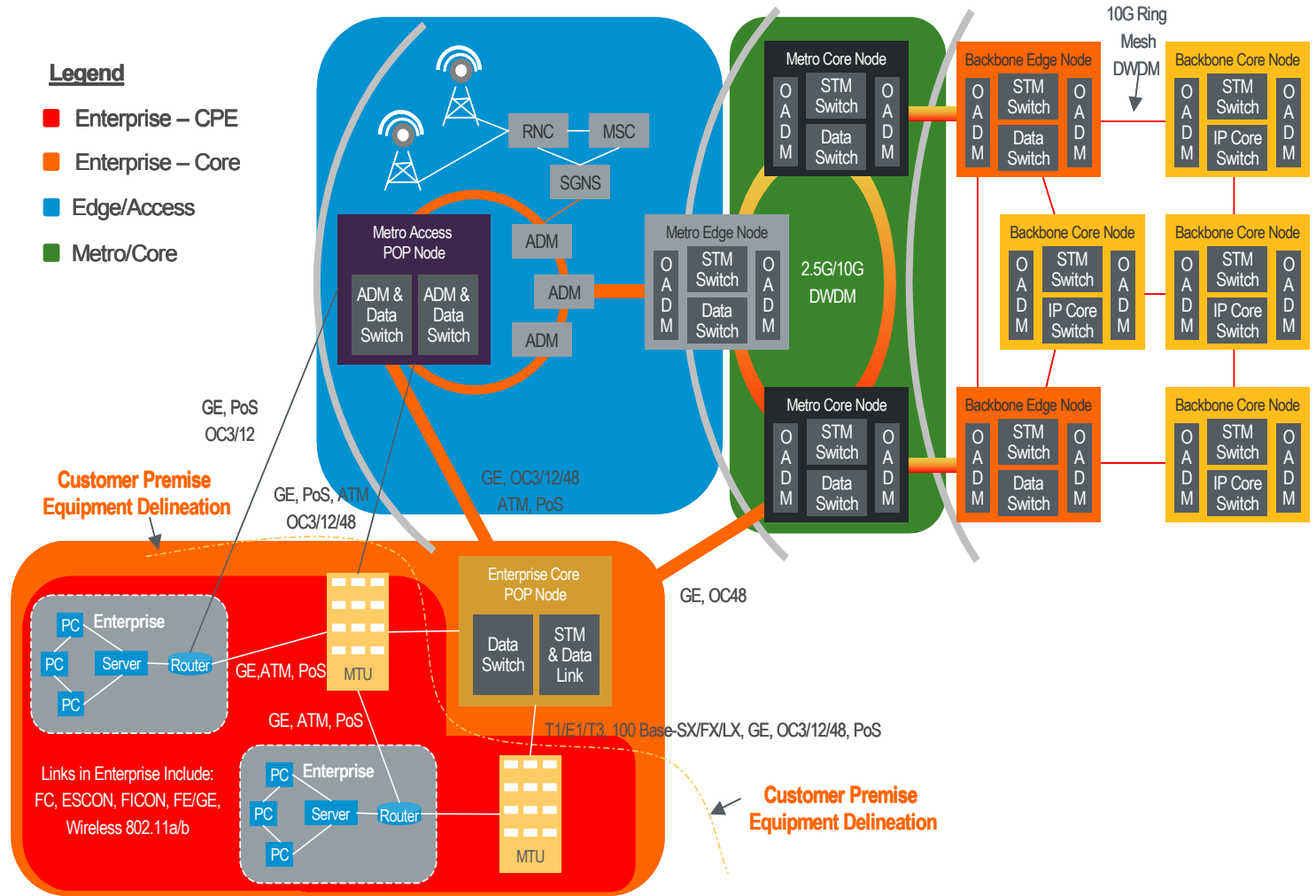
Level 3 Systems and Networks

- **Systems are broken into 4 network categories:**
 - Enterprise – end connection to people, computers and LAN
 - Access – on-ramp to larger network connectivity for city, national or global connectivity
 - Metro – the network managing access connections within a city
 - Core – the network providing connectivity nationally and globally

Network Overview

Legend

- Enterprise – CPE
- Enterprise – Core
- Edge/Access
- Metro/Core





Level 3 Critical Issues

New Systems Must Address:

- **Ease of use** – plug and play, automatic provisioning (multi-rate, multi-protocol)
- **Ease of management** – automatic fault isolation, sectionalization, and service level assurance
- **Enabling varied protocols** and end services with a simplified infrastructure
- **Maximizing utilization** of installed infrastructure
- **Incremental cost structure** – improve the return on investment for each service connection



Integration

- **Technologies must be developed that support integration of components (OEIC – Optoelectronic Integrated Circuit).**
- **Materials and fabrication research needed to support this integration, e.g. optical solders and board-level wave guides.**
- **Intelligent network management needed to improve network utilization.**



Standards

- **Packaging represents one of the highest costs of Optoelectronic components**
- **Reliability requirements for telecom standards for backbone network may be different from datacom and premise applications**
- **Need “Telcordia light” reliability standard**
- **Packaging standards must address changes in reliability, scope and usability**
- **MSA’s are band-aid, not a solution to having Component Physical Standards**



Emerging OE Technologies

- **Photonic crystals and photonic band gap materials for wave guides.**
- **Holey fibers for high NA (numerical aperture) waveguides, higher power transmission.**
- **MEMs devices for wavelength switching**
- **Holographs for fast optical switching (ns)**



Summary

- **The NEMI Optoelectronic Roadmap provides an overview of the business and technology trends.**
- **There are a number of challenging problems identified, which can be addressed through fruitful research to provide advances in the next 3-5 years.**
- **A full list of these challenges can be found in the NEMI roadmap.**