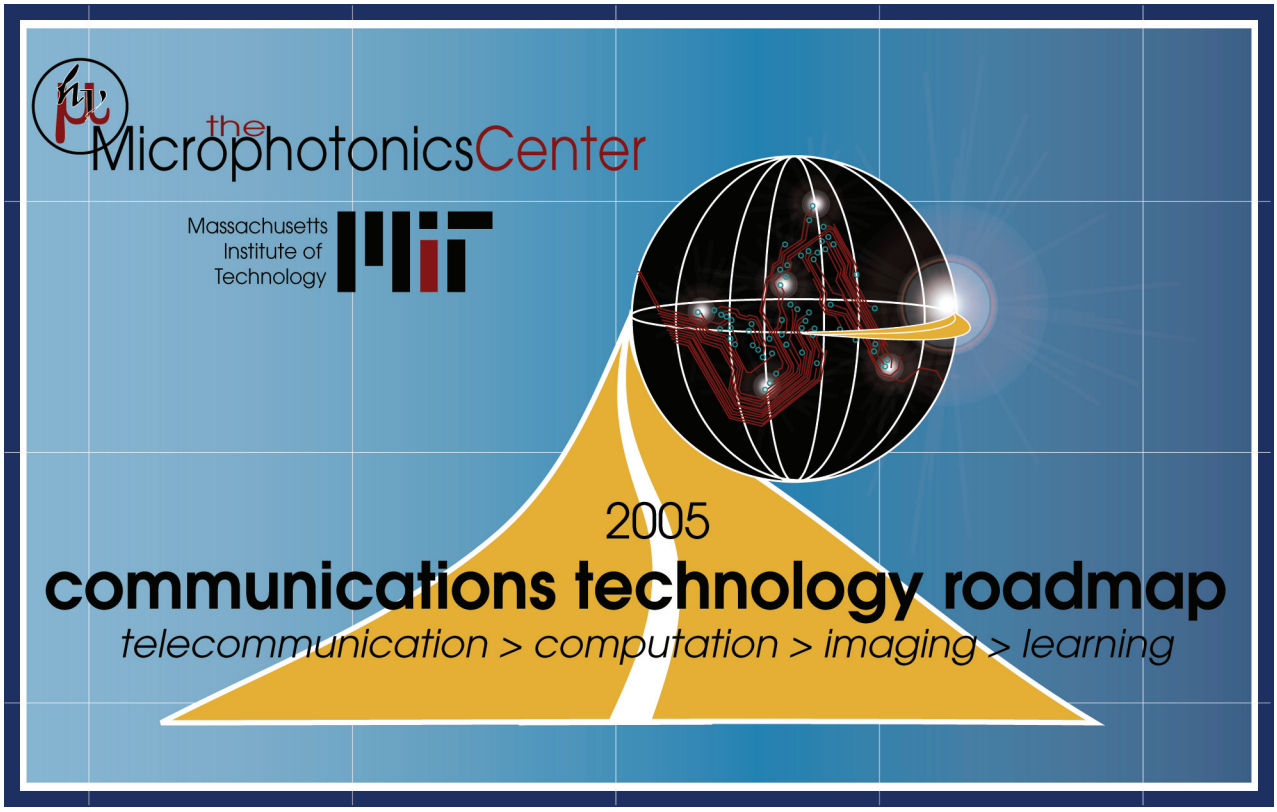
MIT Microphotonics Center Industry Consortium



Microphotonics: Hardware for the Information Age

Executive Overview

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Definitions

CMOS	Complementary Metal Oxide Semiconductor
CTR	Communications Technology Roadmap
DSL	Digital Subscriber Line
DWDM	Dense Wavelength Division Multiplexing
ETDM	Electronic Time Domain Multiplexing
I/O	Input/Output
InP	Indium Phosphide
MAN	Metro Area Network
MIPS	Million Instructions Per Second
MIT	Massachusetts Institute of Technology
R&D	Research & Design
SAN	Storage Area Network
TWG	Technology Working Group
WAN	Wide Area Network
WDM	Wavelength Division Multiplexing

Executive Overview

The MIT Communications Technology Roadmap (CTR) program, sponsored by the Microphotonics Center Industry Consortium, was commissioned to evaluate the vast array of new technology that has disrupted the telecommunications industry—to serve as a guide for R&D investment and for the rational restructuring of the industry. The CTR document, *Microphotonics: Hardware for the Information Age*, more than four years after its initiation has the same motivation, although the context has changed to reflect today's market. The CTR program is guided by industry-led Technology Working Groups (TWGs), with the support of MIT faculty and student analyses.

This first public release of the CTR data supports the following primary findings:

1. The future of components technology will be driven by electronic-photonic convergence and short-reach (< 1 km) interconnection. This direction will ignite a major shift in the leadership of the optical component industry from information transmission (telecom) to information processing (computing, imaging).

2. The skill set required for this path does not exist at any single institution.

3. We recommend that the Microphotonics Center Industry Consortium expand its focus toward the creation of the necessary competence and the recommendation of standards.

The analyses performed by the TWGs yield three common insights:

1. Traditional revenue sources cannot support sustainable innovation due to long term, cyclical network capital investment, total addressable market reduction by product differentiation, and loss of pricing power with the inventory excess of 2002.

2. High-volume applications will drive standardization at the network edge and from the data (computation) appliance.

3. The convergence of electronic and photonic functionality will deliver high volumes, create new markets, and drive integration and standardization. The electronics and photonics markets—and their technology roadmaps—will merge.

Technology Analysis

Information technology has four frontiers: telecommunication, computation, imaging, and learning. Each is gated by performance expectations of bandwidth, power efficiency, footprint reduction, and cost reduction. The demarcation metric for optical interconnection was established by fiber deployment at 10 Mb/s × km (Figure 1). This crossover point has been maintained with limits both on electronic interconnection for DSL, Ethernet, and backplanes, and on the insertion of optical interconnection for WAN, MAN, and SAN applications. As the bit rate for short-range (< 1 km) interconnection increases beyond 10 Gb/s, optical technology will

be required at product volumes and price points that are 2–3 orders of magnitude away from current market offerings. Pervasive deployment in this major market driver is expected in the 2010–2015 time-frame and the required R&D must be done now.

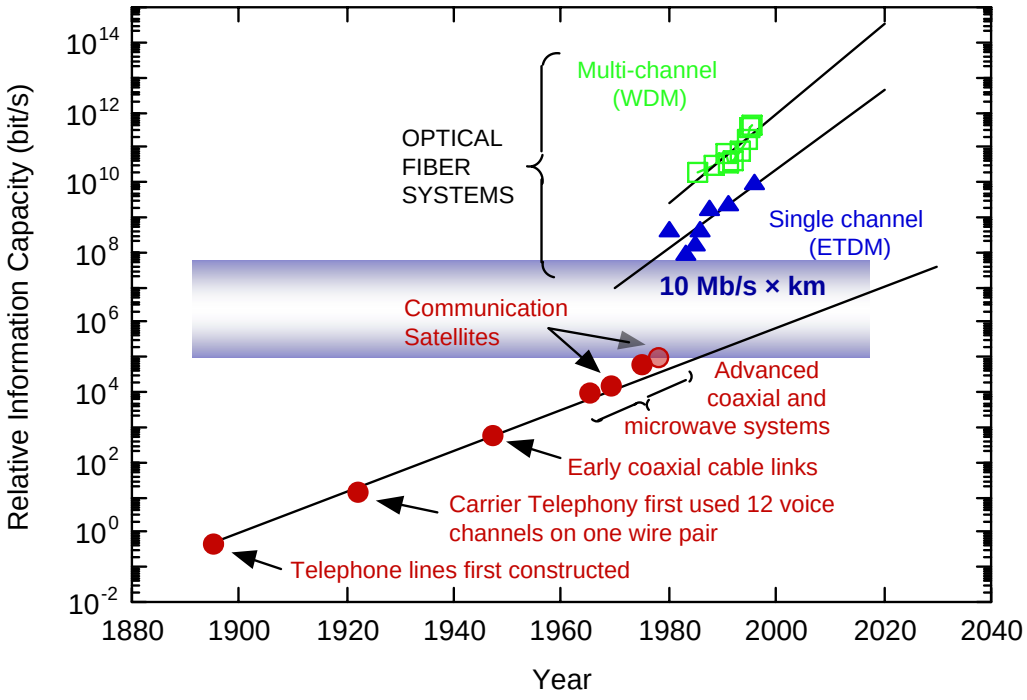

Figure 1. Across a range of communications technologies, 10 Mb/s × km has been the cross-over point to optical technology.

The interdependency between computation and communication has been expressed as Amdahl's Law: every 1 MIPS of computing power requires 1 Mb/s of I/O. Computational power now demands distributed processing for reasons of speed and power dissipation. This architectural trend is driving high bandwidth interconnection, electronic-photonic integration with smart partitioning, and the emergence of low-latency, high-intelligence processing nodes.

Integrated component platforms will be driven by reduction of packaging cost and by increase in functionality (both optical subassembly and electronic-photonic partitioning). At the system level, smart links will lower the cost:function ratio. At the network level, complexity will continue to increase beyond electronic time domain multiplexing (ETDM) and dense wavelength division multiplexing (DWDM). Parallel processing for high speed computing will adopt an architecture based on low-latency optical interconnection.

Investment, markets, and technology standards are primed to emerge from computation and spread across other market platforms. Silicon needs a mixed signal platform; InP needs a common platform for electronics and photonics; organic materials need to provide solutions for

hybrid integration. Transceivers must adopt a standard that will allow transistor-like replication with WDM. Based on the prevalence of CMOS process technology, a silicon electronic-photonic platform will be the first to be tested by 2010. As InP fabrication facilities move to a foundry infrastructure, a complimentary common platform could emerge by 2015.

Economic Analysis

The impact of deregulation of the telecommunications industry continues to reverberate in the industry business cycle. The recent overbuild of the long-haul backbone has delayed the next network build and removed pricing power in the component replacement market. These conditions are amplified by the maintenance of performance expectations for a regulated monopoly. The traditional telecommunications customer metrics of “end-to-end” user service and high-reliability “quality of service” are less relevant in a disaggregated, competitive industry where “good enough” is the guide. Customized, discrete long-haul component design continues to dominate industry thinking, even though the value proposition has changed. Hundreds of companies now compete where fewer than five existed before. Continued consolidation must occur to bring the industry to a sustainable level of activity. R&D must efficiently target new technology to create more functional products with a performance:cost scaling of a factor of ten every ten years.

The overpopulated components industry has responded to present market conditions by focusing on market segments that will maintain a current revenue stream. This survival strategy triggers a system dynamic known as the ‘death spiral’. By targeting a smaller addressable market through customization, a lower potential revenue stream results, followed by reduced investment in R&D for the next generation products. Systems integrators are now concerned that they will be unable to provide the expected value to their network customers if the component value proposition does not scale appropriately with time. This challenge is a major driving force for standardization to a platform that can be leveraged on industry-wide R&D.

High volume consumer devices dominate revenues and innovation in the electronics industry. The reliable, 20-year component life standard of the telecommunications industry is inconsistent with the 3-year life cycle consumer expectation. The convergence of electronic and photonic technology will shorten technology life cycles, deliver more value to customers, and create a restructured, sustainable components industry.

Political Impact

Government must define a path to encourage both the availability of broadband to the populace and the commercialization of new technology. The photonic components industry is not at equilibrium with attrition and consolidation as products of the first Information Technology wave. Technology, markets, and regulation need to move as a coordinated whole. High volume production and standard component platforms will provide the performance:cost scaling to support pervasive broadband.

Summary

A technology roadmap represents a consensus vision and a guide to its realization. The process develops a framework for understanding how technology, markets, and policy dynamics interact. Incorporating two key methodologies—analytical modeling tools and industry-based working groups—the CTR program focuses on the definition of enabling technologies.

MIT's Microphotonics Center is pleased to present this document, *Microphotonics: Hardware for the Information Age*, which charts a course for the future of photonics technology and represents the culmination of a four-year effort by the Communications Technology Roadmap program.