CIR
ENLIGHTENED ANALYSIS

Revenue Opportunities for Optical Interconnects: Market and Technology Forecasts 2013-2021
Vol. II

Chapter One

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Report Summary

The traditional architectural and material assumptions with regard to how integrated circuits are fabricated have been challenged in recent years and the semiconductor industry is looking for new solutions. Power and thermal issues add to this apparent crisis in the semiconductor industry.

One of the most important problems is the so-called "interconnect bottleneck," that is the tendency for data traffic jams to appear both on-chip and chip-to-chip. The interconnect bottleneck is emerging well before Moore's Law completely runs out of steam, but reappears in differing forms in some of the new architectures designed to make chip scaling easier.
The "obvious" solution is to deploy fiber optics; which is usually the way to go whenever and wherever there is a bandwidth problem. But fiber optic solutions to on-chip and chip-to-chip interconnection is something that will be hard to develop for commercial chip products. Producing photonic devices that are small enough and inexpensive enough to be used at the chip level is an immensely difficult requirement.

In this report, we analyze the latest developments in optical interconnection at the chip level and the progress in this area that is being made by important research teams throughout the world. Both R&D and commercial development are discussed.

The report looks at this issue from the perspective of classic CPU chips as well as the latest architectures, and the opportunities for optical interconnection are compared to a possible future for metal interconnects and interconnect alternatives that are even more exotic than photonics; carbon nanotubes, especially.

The report also contains a 10-year roadmap that explains where and when the commercial opportunities for optical interconnection at the chip level will emerge and how much they will be worth. We also profile the leading firms and research efforts involved in designing and implementing on-chip and chip-to-chip optical interconnection.

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Revenue Opportunities for Optical Interconnects: Market and Technology Forecast – 2013-2020. [Vol. I Board-to-Board and Rack-Based]

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Chapter One: Introduction

1.1 Background to this Report

CIR last published a report on the optical interconnect market in 2010. The goal of the report at the time was to provide a full analysis of the entire optical interconnect business. In this year's CIR analysis we are covering the market in two reports, focusing primarily on interconnects in the chip-to-chip and on-chip sector in this volume (Volume II). In our previously published **Volume I**, we covered the rack-based and board-to-board part of the optical interconnect market.

Many of the key drivers for optical interconnection in all parts of the network are the same; the usual suspects being faster processors, more video, big data, clouds, faster I/O and network, and so on. However, the character of the chip-to-chip and on-chip sector is sufficiently different from the rack-based and board-to-board to warrant a separate report. In the more established rack-based/board-to-board market segment it is also clear how one makes money; by selling off-the-shelf interconnect products to data center managers. In chip-based interconnection, new offerings look more like enabling technologies than sources of revenue generation.

1.1.1 Character of Chip-Related Optical Interconnection: Players, Products and Opportunities

There is a fuzzy line between the products and technologies used in optical interconnection at the chip level and that used at the rack-based and board-to-board level. Nonetheless, it is probably fair to say that the markets discussed in this volume of CIR's optical interconnection report focuses on newer types of technology, leading edge products, and involves a somewhat different group of players.

With regard to the participants in this market, we note that they tend to be either giant multinationals with huge R&D budgets (e.g., IBM and Intel) or smaller, technology oriented firms whose business proposition revolves around novel technology (e.g., Luxtera). And, although it is not always that obvious, CIR also believes that there is considerable interest in optical interconnection from materials firms of various kinds. There may be several aspects of optical interconnection that brings the materials firms to the market, but one important factor is certainly the prospects of using polymer waveguides in chip-level optical interconnection.

The products that can potentially generate revenue in the chip-related optical interconnection space include both sub-systems and components. Also overshadowing this whole market are various approaches to optical integration, including those that use high-priced semiconductors (principally InP) and also silicon photonics. With regard to the sub-systems, what we are talking about here is miniaturized optical assemblies (optical engines) as well as optical backplanes of various kinds. With regards to the components, what we are talking about are the afore-mentioned waveguides and especially lasers.

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1.1.2 Optical Engines and Optical Backplanes: Prospects for Immediate Revenues?

The two technologies in the chip-to-chip interconnect space that seem to have some real potential of short-term revenue generation—although for somewhat different reasons—are optical engines and optical backplanes.

Optical engines: The term "optical engine" has a number of different meanings, but in the context of optical interconnection, what we are talking about here are miniaturized optical assemblies. The firms that are important here are Avago, Kotura, Reflex Photonics and Samtec. CIR anticipates that more firms will be coming to join them in this part of the optical interconnect market in the near future. Indeed, some other firms already have solutions that are close to being an optical engine, but have not been productized as such.

The reason that we think that optical engines are so important from a business standpoint is that they offer something close to being an off-the-shelf solution to board firms, who would not normally have the expertise to do optics on the board. So they are an introductory solution where the market needs an introductory solution. And in many ways, the optical engine, despite that fancy name, is just an optical assembly; a concept that most people in the communications sector are familiar with.

In addition, optical engines, can be used for board-to-board interconnection, so this provides yet another source of revenue for manufacturers of optical engines.

Optical backplanes: The other prospect for early revenues in the chip interconnect space is optical backplanes. This is an old idea that has been attracting growing interest in the past year to two years. The consensus is that eventually backplanes on large servers, routers and switches must go optical; either because of the limits on electrical reach or on data rate performance. With data centers ramping up to support "big data" style computing requiring a high degree of parallelism and hence lots of interconnection, it may be that the era of the optical backplane has come round at last, with important firms such as Cisco and Juniper willing to pay the price of deploying optical backplanes.
Optical backplanes can be implemented in a number of ways. The simplest conceptually—and therefore perhaps requiring the least re-design—is to replace electrical wires with EO-converters and waveguides. But a more complete solution is a fully optical backplane, which is the complete equivalent of an electrical backplane but with optical chips. But in either case, CIR believes that we are past the point where optical backplanes are just a topic of academic discussion.

1.1.3 Deeper: Future Enabling Technologies for Chip-Based Optical Interconnection

Optical engines and optical backplanes have immediate revenue potential. However, they are really just the beginning of optical interconnection at the chip level. In the future, there will have to be innovations that take optical interconnection to a point where it can

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function on a chip. While current commercial products in this space have a clear conceptual link to current data center technology, CIR believes that some new leaps of technological "faith" are going to have to happen if optical interconnection is going to move to the next stage. With all this in mind, CIR believes that there are three promising enabling technologies that could help here.

Silicon photonics: Silicon photonics is really just a form of optical integration, which uses CMOS technology designed for the semiconductor industry as its basis. In addition to the ability to feed off the vast accumulated knowledge of silicon physics, silicon photonics makes it easy to create hybrid optical/electrical chips. This would be a huge step for optical interconnection at the chip level, because optical devices could be built into a monolithically integrated chip along with electronic functionality, making optical interconnects almost free.

The optical properties of silicon do not lend themselves easily to making optical components in commercial quantities. Nonetheless, silicon waveguides are already commercialized. The big breakthroughs, if they come, will be in active components using silicon. The use of silicon photonics to build lasers is very speculative at the present time and it remains a strong possibility that such lasers will never be commercialized. If silicon lasers do become a reality, however, they could enable the development of a transponder-on-a-chip, which would be a truly revolutionary development.

At this point, most of the work in this space seems to be coming from one company—Intel. However, in the last couple of years, Intel has given much less prominence to its silicon laser efforts than it once did. Nonetheless, a breakthrough in the silicon laser space could be the single most important development, creating opportunities for optical interconnection at the chip level.

Other kinds of optical integration: If silicon photonics does not get optical interconnection where it needs to be then probably it will be up to more conventional forms of optical integration to get it there. Optical integration can be defined by the kind of material it uses. Most optical integration uses the usual compound semiconductors that are associated with active optical devices; notably InP.

New forms of hybrid integration could emerge in which active optical components were combined with silicon devices. The end result would produce similar functionality to the silicon photonics devices just mentioned, but at a higher cost for the final device. The advantage is that the photonics community has a much clearer idea how to produce this kind of hybrid chip than the active silicon photonics chip just mentioned.

Quantum dot lasers: Finally, something of a long shot, but quantum dot lasers seem well suited for certain kinds of interconnection and they have been available commercially for about four years now. QD-enhanced VCSELs have also been proposed and these, too, may have applications in interconnection.

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1.2 Objectives of this Report

These are all fascinating possibilities and they become even more fascinating if there is a clear path to profits through their development. With all this in mind, this report i intended to provide in-depth analysis of the optical interconnect market at the chip-level, which is to say on-chip and chip-to-chip interconnection. In particular, the report is designed to identify the opportunities in this space for makers of optical assemblies, PCBs, backplanes, lasers, waveguides, fiber and other photonic components and materials,

The report also includes an eight-year forecast of the chip level interconnection with breakouts by type of application. From a geographical perspective this report is worldwide in scope. A companion volume covering optical interconnection at the rack- and board-to-board level is also available from CIR.

1.3 Methodology and Information Sources for this Report

Sensible forecasting and autonomous thinking are the staples of CIR's analysis. CIR has been forecasting developments in the optical telecom and data communications business since 1985. The details of our forecasting methodology are provided in the main body of this report.

Extensive secondary research for this report was accomplished by reviewing many sources. These information sources included research journals, SEC reports, standards bodies, trade show and conference material, corporate Web sites and previous CIR reports.

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