Opportunities in Board-Level Optical Interconnects: Optics Enabled Circuit Boards, Optical Engines and Optical Backplanes

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Chapter One: Introduction

1.1 Background to this Report

The deluge of data from streaming UHDTV video, the Internet-of-Things (IoT) and especially cloud services continues to push the envelope in terms of faster processors, which in turn is creating a need for circuit board-level optical interconnects. The makers of big boxes, it seems, never tire of providing us with dramatic data illustrating how much the large data center of the future will have to cope with.

For example, according to Cisco, by 2020 Internet traffic will have reached 194.2 Exabytes per month, compared with 108.5 in 2017—an increase of almost 80 percent. And it is not just growing demand for existing services that is pushing the data center community towards optical interconnection. Soon, CIR believes, other novel services—such as those related to virtual reality and telepresence—will put even more pressure on data communications and telecommunications box makers.

The specific application/service that is cited in the literature as the *main* driver for board-level optical interconnects seems to have varied over the past few years. The fashion a few years back was to cite IoT specifically, while currently “clouds” are cited more frequently. Perhaps this is because the firms ultimately paying for communications boxes with internal optics tend to be data center management that are primarily concerned with managing clouds at the present time.

In any case, the explosion in demand for data centers that are capable of handling very large amounts of data has already resulted in rack-to-rack and rack-to-router/switch optical interconnects becoming mainstreamed, although far from ubiquitous. And this trend is already beginning to push through to board-level interconnection, which is where CIR is seeing a growing number of opportunities.

At the physical level, what is happening here is that faster processors are being deployed that bring with them faster I/O; doubling in bandwidth every couple of years, according to one source. This in turn puts pressure on interconnects of all kinds. Until very recently board-level interconnection could easily be handled by copper interconnects and mostly still can. But there are now a growing number of “sweet spots” where optical interconnection already makes sense and there will be more.

(Aside: Optical interconnection will presumably eventually spread to on-chip applications, but in this area, we would be discussing the concerns of the semiconductor industry as much as those of the data communications community.)

1.1.1 Emerging Opportunities in Board-level Optical Interconnection

While there is no accepted definition of “board-level optical interconnection,” where CIR is seeing opportunities that might be characterized by this term is essentially in two places:

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- *The most obvious is in providing point-to-point connectivity between or among boards.* This is already happening inside supercomputers, routers and switches, but CIR has every reason to believe that blade servers, at least those in an HPC context, will also adopt optical interconnection. The kinds of technology used for optical interconnects in this market segment will be a fairly natural extension of the optical interconnects for rack-to-rack applications. They thus represent an opportunity for those firms that are already in the rack-to-rack optics space.

- *As CIR sees it, this opportunity will extend to connectivity among devices on a board within a few years*. The commercialization of products that exploit this opportunity is at an early stage, but we note that optical backplanes are already productized to some extent. This is far less the case of other kinds of optical PCB, but we expect these also to get commercialized over time.

In this report, we use the term "board-level optical interconnection" to cover both these opportunities. However, we note that both the technology and the terminology in this space are very much subject to change and we suspect that in a year or so, CIR analysis of the board-level optical interconnect business will adopt different categories and segmentation approaches.

Until very recently board-lever optical connect was niche market at best and might be better characterized as an R&D effort in that board-level optical interconnects were often custom designed for large computers either by in-house teams at universities or by R&D-oriented firms such as IBM. However, CIR believes that the opportunities in the board-level optical interconnect space have now reached a sufficient size where manufacturers of components and cable assemblies should pay attention.

1.1.2 The "Productization" of Board-Level Interconnects: Slow but Steady

CIR believes the expansion of the applications activities that we have just listed are broadening the market for board-level optical interconnects and making such interconnects much more a part of the mainstream data center applications. This means that actual products are emerging that can be used to satisfy demand in this space. In Exhibit 1-1 we identify and profile the optical interconnect products that currently appear to be emerging.

Challenges for board-optical interconnection: Electrical interconnection at the board level is running out of steam. Generally speaking, it is hard to achieve much more than 15 Gbps with electrical interconnection. In a world in which the IO speed of a processor is measured in Tbps, this seems woefully inadequate. Not only is speed an issue, but retimers may be needed in some cases for electrical interconnection, which adds to cost.

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Exhibit 1-1: Current Board-Level Optical Interconnect Products

Products	Description	Primary market	Other comments
Active optical cables	Active cable with electrical connectors at each end, OE conversion and optical cable between each end	Quick optical connectivity among existing electrical devices. Primarily rack-to-rack or uplinks to routers and switches. However, some board-to-board deployment	Widely available from numerous vendors. Usually specified in terms of MSA and cable
Optical engines	Integrated miniaturized transceivers.	Designed for on-board and board-to-board communications. Mostly for short-reach communications, but reach becoming longer	Used by a handful of major vendors, with one basic optical engine being used in a variety of products enabling development costs to be spread across product range
Optical backplanes	Boards are typically connected up in a box through a "backplane," which is essentially a matrix of connectors. These could be optical connectors, in which case, the backplane is an optical backplane	Optical backplanes have only just emerged from R&D efforts, but their primary market would seem to be large routers and switches as well as supercomputers.	Standardization efforts for optical backplanes have been ongoing for some time and CIR believes that these backplanes are just on the verge of significant deployments. Typically, they care categorized by the types of media they used and these include both glass fiber and polymer fiber/waveguides
Optical PCBs	Optical PCBs are just PVBs that use fiber optics rather than electrical connectivity on the board. An optical backplane is, in a sense, a one example of an optical PCB, but the optical backplane concept has developed somewhat separately	Optical PCBs are at a very early stage of development, so it is hard to be sure where they will be used exactly.	Even the R&D literature on this topic is quite limited at the present time. However, important standards work in this space is going on through the COBO organization.
Other fiber optic links	As noted in the main text, CIR believes that the product categories in the board-level optical interconnect space is in a state of flux.	Unclear yet how this will all shake out	

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It seems therefore that the next step forward must obviously be optical interconnection. As Exhibit 1-1 indicates, this is currently available in a number of forms and these forms may change in the near future.

But CIR also urges caution in assessing the pace of change in this area. The vast majority of optical interconnections at the board level are electrical and this will remain the case for many years – perhaps a couple of decades. CIR believes that during this period, optical interconnection will be used only where it can be used cost effectively. Our point is only that this is now in enough places to make optical interconnection at the board level a market worth pursuing.

1.2 Objectives and Scope of this Report

When CIR first began coverage of board-to-board optical interconnects, such items were mostly cobbled together in small numbers by HPC firms such as IBM and the technology was primarily a fairly crude form of parallel optics. At the time, we covered it for completeness sake and our estimates of revenues generated in this area were very low.

Times have changed. What CIR is seeing now is a wave of commercialization brought on by the growing need for board-level optics in the data center. Much of the commercialization interest is in optical engines, with many of the largest firms in the optical components business building a interconnect product arrange around a core engine technology. Optical engines could be thought of as next-generation optical interconnects.

Of growing importance in this area is the optical backplane area, which is also undergoing intense commercialization. Meanwhile, AOCs, whose primary market really lies elsewhere are also sold into the board-level optical interconnect space. Emerging products in this space are mostly optical PCBs of some kind; notably optical backplanes.

1.2.1 Goals of this Study

This report is designed to identify new opportunities for board-level optical interconnects and optical circuit boards over the coming decade. This is an area where CIR has provided coverage for many years and the forecasts and other data provided in this report are rooted in an insider experience of this interesting area. This report also provides an analysis of significant board-level optical interconnects by firms active in this space and discusses how such firms can distinguish themselves in the market through both technology and supply chain strategies.

A subsidiary goal of the report is to provide an assessment of the integration technology used in miniaturized optical technology. Integration and miniaturization is required in board-level optical interconnection both for economic reasons and because the real estate on a PCB is inherently limited.

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1.2.2 Scope of this Report: Products and Topics Covered

These tasks are carried out with the main interconnect products specifically in mind. As we have already discussed, as CIR sees it, the relevant products here are AOCs, optical engines, optical PCBs and optical backplanes. Although, board-level optical interconnects can be defined to include a fairly broad range of optical cabling. The realities are that this terminology is used primarily in the context of the circuit boards used in data center boxes and this is the position that we take in this report too.

We also think that this area is important, because lessons learned in the board-level interconnect space should also have some lessons for those involved in providing optical on-chip interconnection at some point in the future. Another subsidiary goal is identifying the high-speed electronic ICs that will be needed to support the growth of board-level optics. In addition, we provide a critical analysis of the standards and MSA work that is being done in this space.

The objective of the *forecasts* provided here is to provide a ten-year revenue and volume shipment forecast for the board-level optical interconnect products listed above. For the forecasts, breakouts are by (1) type of board that forms the addressable connection (backplane, server boards, etc.), (2) the type of optical connectivity provided (board-to-board and on-board), (3) data rates and (4) type of media. The forecasting sections also discuss the kinds of equipment—switches, routers, servers, etc.—from which the demand for board-level optical interconnect emerges.

Finally, this report provides forecasts and analysis of the optical interconnect business in various national and regional markets, with the focus being on North America, Europe, Japan and China. We also pay special attention to the China factor, since we think that the influence of Chinese suppliers in this area will transform the AOC sector in important ways.

The bottom line is that this report examines what it will take to be successful in the market for board-level optical connect space and we believe that it will be a high-value resource for marketing and business development managers in the components, cable, HPC, data center and IT industries. We also see the report as being highly useful to serious investors examining the emerging opportunities in the latest generation of optical communications.

1.3 Methodology and Information Sources for this Report

This report is strongly focused on business strategy, analyzing the sectors in which board-level optical interconnects are likely to find a market and examining the most important marketing issues faced by the AOC makers, such as the importance of branding and product differentiation.

The methodology used to compile this report is similar to that used in other reports published by CIR. That is to say that—in order to prepare this report—CIR has collected

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and analyzed data from third-party sources including (1) corporate websites, financials and presentations, as well as (2) reputable trade and technical publications, including papers delivered at conferences.

The analysis presented here is also based in part on interviews with different players in this space ranging from key suppliers and users of AOCs in the U.S. and throughout the world.

1.3.1 Forecasting Methodology

Over the decade that CIR has been covering the interconnect and related markets we have developed a sophisticated forecasting model for these and have been able to test our estimates against the views of industry insiders and announced shipments, where these are available—which isn't often the case. This model and our accumulated understanding is the basis of the forecasts in this report.

Our forecasting methodology is based on estimating the size and growth of the underlying addressable markets for interconnects and then adopting plausible penetration rates for each segment of the board-level interconnect markets as well as estimate of acceptable price points for each sector.

- The size of the addressable market is determined based on extrapolations and triangulations from publicly available data.
- Our penetration numbers are based on CIR's long experience of market adoption patterns in the data communications business.
- With the exception of AOCs (perhaps), pricing is not easily available in this sector. We have therefore estimated pricing based on similar products and the general pricing available in the fiber optics market.

Using this data, we construct a model that serves as the basis for both our projections and our overall analysis of the AOC market. For each of the AOC applications forecast we breakout the market by the following features and functions of the AOCs:

1.4 Plan of this Report

This report consists of two main chapters, an Executive Summary, and a forecasting appendix. Chapter One, the chapter you are reading now, is intended to set the scene for the rest of the report.

The Executive Summary is supposed to summarize the key findings of the report, especially in terms of the business opportunities that CIR has discovered as part of this analysis.

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Chapter Two is intended to identify the and quantify the main markets into which optical interconnects are sold, while Chapter Three looks at the products and technologies—actual and emerging—that are being developed with the transition to an optical interconnection environment in mind.

Finally, in the Appendix we discuss our forecasting methodology in some detail and then, based on this, create a model of the interconnect market with the appropriate breakouts. Many of the goals of this report are fulfilled in this appendix.

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