Optical Interconnects and AOCs for Consumer Electronics and Professional Video Applications: A Market Analysis

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Chapter One: Introduction

1.1 Background to this Report

Starting ten to 15 years ago, a burgeoning demand for bandwidth in the data center created a need for extensive fiber-optic interconnect deployment. What CIR is now seeing is a similar trend for optical interconnects in consumer and professional applications. In much the same way that the copper infrastructure paradigm began to collapse in the data center when InfiniBand data rates pushed copper cable far beyond what it could handle, CIR believes that the latest consumer communications— Thunderbolt 3 (40 Gbps) and HDMI 2.1 (8K video capable) in particular—are making it apparent that there will soon be a significant role for optical interconnects in residential and professional environments.

The point here is that at the data rates that are now becoming available to consumer and professional data communications—notably where video is involved—optical communications quickly become a consideration over quite modest distance. Thunderbolt, for example, officially runs over copper cable up to just 3 meters. Many applications need more than that.

1.1.1 A New Kind of Optical Interconnect

There are important similarities between the data center and consumer/professional market in terms of the demand for optical interconnects. Both sectors share a root cause—the growth of enhanced video and big data.

There is also an overlap in terms of the products that will be used to fulfill the need for interconnects in both the data center and consumer environment. Specifically, because of their user friendliness, active optical cables (AOCs) are often a major part of the optical interconnect deployment strategy in the data center (even in very large data centers) and in CIR's opinion AOCs will be the obvious choice for consumers and professionals looking for optical connectivity over the next decade. However, not all consumer optical interconnects will be implemented with AOCs: The opportunity in this space includes (1) proprietary optical interconnect products—notably traditional optical video extenders and (2) some instances of optical connectivity where the cable is "hard wired in."

There are also important differences between data centers and consumer/professional markets, and this means that the opportunities in each sector are also different in important ways both on the demand and on the supply side.

In CIR's opinion, three particular aspects of the consumer/professional optical interconnect business are significantly different from the data center optical interconnect business and create a different set of opportunities for consumer interconnects between the two segments going forward. These are discussed and

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analyzed below and consist of (1) the data rates and associated interfaces, (2) strategies for cost reduction and (3) emerging and diverse market sectors that can be addressed by optical interconnects that are a long way from those sectors that are more traditional users of optical communications.

Exhibit 1-1: Consumer/Professional Optical Interconnects – Differences from Data Center Interconnects

Issue	Difference from data center	Opportunity
Drivers for data rate increases and need for optics	For consumer/professional optical interconnects, driver is primarily high-definition video. In data it is aggregated data from IoT, 5G and other sources as well as video	Optical interconnects specifically targeted towards video requirements. An important opportunity here is video AOCs based around the latest HDMI and Thunderbolt versions
Interfaces	In the data center communication is primarily optical Ethernet and IB. There may be some Ethernet for consumer optical interconnects too, but primarily they will be USB, Thunderbolt and HDMI	Optical versions of USB-C and especially HDMI 2.1 and Thunderbolt 3 seem to present the biggest opportunity
Mass market	Although optical products are now being sold into the data center in large numbers, they could not be called mass market products in any meaningful sense. Based on the ubiquity of consumer/professional applications, the potential market for some of these interconnects could be in the millions or even tens of millions	Achieving the kind of volume for optical interconnects that would be needed to consider them mass market will take significant cost-reduction strategies. These might include (1) low-cost manufacturing, (2) silicon photonics, low-cost media. Adoption of these strategies may distinguish some firms in the marketplace
Emerging and diverse market sectors	Data centers have a few related subsidiary markets that may use the same optical interconnects – for example, campus and enterprise networks. There are numerous subsidiary markets for consumer/professional optical interconnects	Opportunities for specialist optical interconnect products include video editing, news gathering, digital cinema, digital signage, A/V installations, tele-education and telepresence, medical applications, etc.

Source: CIR

A digression on terminology: Before taking that route, however, it is worth examining the appropriate terminology for the kinds of optical interconnect that we are concerned with in this report. Here we note that there is no broadly agreed on name for this kind of optical interconnect.

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One possibility is simply "consumer/professional" interconnects. Another is a "video interconnect." Both are correct to some degree, but the former misses the importance of video in the driving the market for these interconnects. The latter terminology—video interconnect—seems to ignore the fact that non-video drivers such as the Internet-of-Things, data clouds, etc. play an important role in the rise of this kind of optical interconnect. For now CIR is not being completely consistent, using terminology that seems most appropriate to the point we are making at any given time.

1.1.2 Bandwidth, Data Rates and Terminations

If the need for video interconnects emerges in the way that CIR believes it will, we think the major driver will be the shift to higher resolution video. In particular, we believe that the next few years will see the arrival of 8K UHD TV. This standard is already widely accepted in broadcasting and production environments and we think it will begin to impact the televisions bought for homes in the next few years. 4K UHD has already been immensely successful in this way and we have little doubt that 8K will follow suit.

If this prophesy turns out to be correct, it will put considerable pressure on already bandwidth hungry networks. 8K UHD has two times the horizontal and vertical resolution of the 4K UHD with four times as many pixels overall, or sixteen times as many pixels as Full HD. In another words, if a consumer gets rid of his or her old Full HD television set to replace it with a new 8K set, he or she has, in a sense, staked a claim on four times as much bandwidth as before.

New types of bandwidth demand are also likely to emerge in the consumer/professional environment that could eventually lead to more consumer/professional optical interconnects being deployed. For example, the Internet of Things (IoT) will demand more bandwidth in home networks and will growth the demand for optical networks at the margin. However, IoT will not have an immediate demand impact in favor of optics outside of the data center. The ubiquity of very high-definition video is really the main argument for the products discussed in this report.

When trying to estimate the size of the opportunity for consumer/professional optical interconnects it is therefore important not to exaggerate the impact of IoT and other big-data at the user level (as opposed to the data-center level). It is also important not to be too futuristic about where video may take us. For example, while 8K video may be a relatively sure thing, although it could yet turn into overkill, 3D video has been a huge disappointment—and is unlikely to be much of a bandwidth driver. Similarly we don't think that vendors should build a business case for advanced consumer/professional optical interconnects based on futuristic innovations such as holographic television.

Thunderbolt 3 and HDMI 2.1: The opportunities for optical interconnection that flows from the trends mentioned above can be fulfilled in a number of ways. For example, optical interconnection could be achieved with some kind Ethernet AOC. However, the video orientation of the demand in this area suggests that more specialized solutions will dominate this market space.

The main body of this report discusses several possible options here, but CIR firmly believes that the two standards that matter in this context are Thunderbolt 3 and HDMI 2.1. Both are very high speed and are likely to be implemented over optical cable at relatively short distances. Both are video oriented and only just beginning to be implemented, although they are both incarnations of older rules.

At the time of this writing, the HDMI 2.1 is particularly new and isn't expected to be released until Q2 2017. It will, however, specifically support 8K video, while remaining backwardly compatible with previous versions of HDMI. In fact, our forecasts assume that HDMI 2.1 will gradually take over the space now occupied by earlier versions of HDMI and will continue to gradually shift away from earlier video standards.

There are already optical versions of earlier versions of HDMI 2.0 from (for example) Chromis, which uses its plastic optical fiber to implement them. Chromis says that these AOCs are a "practical solution for ultra-high-definition A/V distribution in conference rooms, classrooms and lecture halls, churches, digital signage and many other commercial applications."

CIR believes that much will change with the arrival of the latest version of Thunderbolt 3. This version will operate at 40 Gbps and is designed to create one cable technology that allows users to connect every type of peripheral to their computers, and to do so with as much bandwidth but as little cabling as possible. Some observers believe that this will let Thunderbolt 3 eventually replace HDMI and USB, although we think this sounds a little fanciful at the present time.

CIR believes that the revisioning of Thunderbolt as a low-cost consumer electronics-oriented interface running at 40 Gbps will win Thunderbolt support from other OEMs. Intel—which designed the chips for Thunderbolt 3—certainly believes that this new Thunderbolt will move beyond the Apple world, and we are already seeing a slew of laptop makers adopt Thunderbolt 3. In the past, only Apple has adopted this technology.

One takeaway here is that with Thunderbolt 3, personal computing is now reaching communications data rates that are comparable to those of data centers. Many data centers, for example, are in the process of implementing 40 Gbps.

What also encourages us about the future of Thunderbolt is that an optical version of Thunderbolt 3, which will extend its reach to 60 meters from today's two meters, is expected to arrive in 2017, which is when the first big wave of Thunderbolt 3 products are also expected to appear in dealers. We think that, as a result, Thunderbolt AOCs may turn out to be the first mass-market consumer AOC.

1.1.3 The First Mass Market for Optical Interconnects?

The biggest potential opportunity established by the rise of optical interconnects for consumer and professional markets as opposed to data centers is that these optical interconnects may well represent the first time that fiber-optic products can be sold into

mass markets. There is the *potential* to sell billions of optical interconnects, matching the volumes that are typical in the consumer electronics market. Of course, no one expects this to happen quickly.

Whether such a market evolves will be dependent on whether suppliers can get pricing to an acceptable level for the consumer market. Some of the current active optical cabling currently being sold into the consumer/video space can cost hundreds of dollars, while the consumer market is more used to paying less than $50 for a cable. Even given that, consumers are likely to expect to pay more for optical interconnects.

Getting a consumer optical interconnect product down to this price level is not going to be easy. In the past, the most obvious strategy has seemed to many to substitute plastic optical fiber (POF) for glass fiber and LEDs for lasers. This certainly produces the desired cost reduction, but also a reduction in performance levels. Despite many years of trying, this strategy seems not to have succeeded for cabling and components makers outside of the automotive market. Also, mass market consumer fiber optics has been prophesied before in the form of fiber-in-the-home, but has never come to anything. So, as we see it, there is a significant element of risk in trying a similar strategy again.

CIR believes that if a mass market is going to emerge for the kinds of products that we discuss in this report it is going to take technological innovation.

New types of optical fiber or simply cheaper fiber: We note that a growing number of firms from China are offering very low-cost optical HDMI, USB and (to a lesser extent) Thunderbolt cabling. For the most part these do not include the very latest version of these standards, however, it seems inevitable that these firms will move up to the newer standards within a very short space of time.

Many of these Chinese firms will not offer the quality that rival firms based in the U.S., Europe or Japan can offer. However, the tradeoff between price and quality may make perfect sense in consumer markets. There are also high-tech solutions in this area, too. For example, Chromis' next-generation POF technology began with the application of an amorphous perfluorinated polymer—polyperfluoro-butenylvinylether—to GI-POF. Because this polymer has very low attenuation (around 10 dB/km) in the near infrared, it is immediately compatible with gigabit transmission sources, and can be used over distances of hundreds of meters.

The importance of optical integration: CIR believes that in the long-term much of the cost reduction that will enable consumer/professional optical interconnects to become a mass market will occur through optical integration.

This will mean different things to different people. That said, we strongly suspect that the future of the kind of optical interconnect that we discuss in this report will rest in silicon photonics technology. Indeed, it is hard to come up with another technology that could have such an impact on cost, since it can (1) capitalize on the vast infrastructure already

in place for silicon device manufacture and (2) is already proving itself capable of reducing costs for data center components and subsystems. Optical integration, which is, in any case, at the core of much of optical manufacturing these days may also help optical interconnects come down to the price points that will be necessary for mass market/consumer optical interconnects to emerge.

We note, however, that there are few, if any, companies that are as yet using silicon photonics for consumer products, but think this is a significant opportunity and could eventually provide a way forward for specialist firms to play in the consumer/professional optical interconnect market going forward.

Here we note that some firms such as Corning and Cosemi are already trending towards becoming suppliers of optical interconnects to professional and consumer video markets and this distinguishes them from (say) Finisar, which is the largest supplier of AOCs for the data center and appears to have little or no interest in mass markets for similar products.

1.1.4 Rapidly Emerging Niche Markets for Professional/Video Optical Interconnects

The data-center market for optical interconnects does have a number of related markets in which the same—very similar—optical interconnect products play. Optical interconnects designed for the data center may also find applications in central offices, in- building networks and even campus networks, for example.

These applications are, however, something of an afterthought. An occasional campus network may have been built with an AOC that has a reach of several kilometers, and such AOCs are available. However, no AOC maker is ever going to target campus networks as an opportunity. This is different to what we are seeing in the consumer/video optical interconnect space. Here again, there is a core market (consumer electronics), but the related markets are quite valuable and worth strategizing separately about.

These “related markets” include professional video editing, news gathering, digital cinema, digital signage, A/V installations, tele-education and telepresence, medical applications, etc. (While each of these markets for the type of optical interconnect that we cover in this report have distinct business characteristics, they share the fact that they are mostly only just turning to optical interconnection and that they can, for the most part support higher price points than the purely consumer sector.)

As CIR sees it, the strategies for cabling around these markets are rather fluid. Cabling firms can see these markets as just icing on the cake for their mass-market consumer cabling products, for example. Or they can specifically target one or more of these “related markets” with high-performance cabling, perhaps making up for the relatively small size of the subsidiary market with a value-added package that includes systems and installations services/technology advice as well as cabling itself.

1.2 Objective and Scope of this Report

This report provides a ten-year roadmap and competitive analysis of the emerging market for optical connectivity products for consumer electronics applications and closely related video and professional applications as discussed in the overview above.

The primary goal is to identify where the money will be made in this segment of the fiber optics market and where the risks are to be found. The latter is especially important since fiber optics outside of telecommunications, the data center and enterprise networks has been talked about before but has never really gone anywhere in terms of revenue generation.

With this in mind, we have focused on new technologies, products and applications that are supposedly game changers for the kinds of optical interconnect products that we discuss in this report. We have analyzed the applications, which are mostly video-oriented and discussed the degree to which they are likely to require optical interconnection in the next decade and, in addition, just what kinds of optical interconnect product will be used in each case. Our analysis also considers—and tries to filter out—the hype in this space. In this context, we note that just a few years ago 3D video was supposed to be a major bandwidth driver; now it barely exists.

Throughout the report we consider a broad range of standards and media options. However, we concentrate on the opportunities in the optical HDMI and Thunderbolt space, which is where we think that many of the opportunities are likely to arise. We also take a look at new developments in the optical media and integration strategies that can help bring down the cost and help create mass markets for these products.

The report includes a ten-year market forecast for optical interconnects aimed at the consumer and professional space. Also in this report, readers will find comprehensive discussions of the product strategies of firms that are looking to be players in the consumer/professional optical interconnect space.

1.3 Methodology of this Report

The methodology used in this report is similar to other reports published by CIR. The core data comes a variety of sources both primary and secondary. With regard to the primary sources, we have interviewed major players in the cabling and transceiver market specifically with this report in mind. In addition, we have interviewed numerous other fiber optics and CE firms to better understand how fiber optics are, and will be, used in the consumer and professional markets.

Much of the primary information used in this report was sourced through attendance at major industry trade shows. In particular, CIR researchers attended the 2017 Consumer Electronics Show (CES 2017) in Las Vegas and the 2017 Optical Fiber Conference in Los Angeles (OFC 2017). Although these are both U.S. trade shows, we were able to develop considerable insight from these shows and conferences into the role of Chinese firms

active in the markets considered in this report. Their strong presence at these events and extensive product showcases reveal increasing strength and product offerings.

This primary information was supplemented with an extensive search of secondary research. We have been especially concerned with material from companies that explain how they expect to market interconnects into the areas with which we are concerned. We have also examined the technical and business literature on the future of those markets more generally. Other secondary literature consulted include a full range of corporate and government websites that seem relevant to the task at hand.

This data is also in the ten-year market forecasts that are a central feature of this report. The actual forecasting methodology is discussed later in this report and is based not just on this data, but also our internally developed proprietary forecasting models.

1.4 Plan of this Report

The Executive Summary of this report is designed to profile the key opportunities that are emerging in field of consumer and professional optical interconnects. In Chapter Two we have examined in depth the markets that have opened or are just now opening for these kinds of products

In Chapter Three, we examine the technical side of the story, showing how the latest technologies and standards are either enabling or retarding the market for the type of optical interconnects discussed in this report. Finally, in Appendix A we include our ten-year market forecasts and a discussion of how our proprietary market forecast is built.

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