The Fast Approaching 100G Era

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OPTICAL NETWORKS: A REFRESH IS DUE

The way optical networks are built is fundamentally changing yet again. These once-a-decade transformations remake service provider network architectures, and in turn reshape the equipment supplier landscape that provides them.

THE 2000s WERE A TIME OF INCREMENTAL CHANGE

During the last 10 years, major innovation in the network moved from the optical transport layer to the last mile: enterprise Ethernet services, cheap FTTH, widespread and cheap DSL, 100M cable modems, and—most dramatically—mobile broadband via wireless smartphone. These technologies opened the data spigot and launched a wave of transformational businesses that exploited cheap and readily available bandwidth to consumers and enterprises. Netflix, Facebook, YouTube, and iTunes would never have happened without faster pipes to the home. The data centers of Internet content providers at the other end of these connections are virtual fire hoses of data, particularly as more applications and data storage is moved into "the cloud."

Exhibit 1: Progression of Optical Networking

Stage	Timeframe	Main Technologies	Applications
Initial optical networks	1980–1995	SDH/SONET	Telephony, voice traffic, dial-up modem traffic
WDM/10G	1995–2005	Growing WDM, 10GbE	Internet traffic ramps
WDM/ROADM/40G	2005–2012	Widespread 10G and introduction of 40G/OTN; SDH/SONET recedes; ROADMs	FTTx broadband, video, ICPs, super data centers; Netflix, Facebook, YouTube, iTunes
Optical reboot	2013–2020	100GE, 100G, coherent optics, ROADM/OTN mesh networks, packet transport	Cloud computing; widespread video, mobile broadband, yet-to-be invented apps

These applications continue to create exponential data growth, and there will be many more applications invented that will add more. But this growth is outstripping the capacity and economics of 10G technology invented 15 years ago—all the low hanging fruit has been picked by engineering teams focused on reducing costs.

. . . LEADING TO THE OPTICAL REBOOT WITH ROADMS, OTN, ETHERNET, AND COHERENT OPTICS

As a result, the optical network can no longer change incrementally, and a new technology set must be employed. Bit rates are increasing from 10G to 40G and 100G, but there are more changes: the use of coherent optics, ROADMs, and the introduction of OTN switching and evenutally Ethernet/MPLS as a circuit replacement for traditional SONET/SDH client interfaces. Taken together, the introduction of these technologies is another transformational change of telecom network, something we call "The Optical Reboot."

10G WDM technology was really just a sped up version of previous technology at 2.5G, 622M, and 155M, but the move to 40G and 100G is different, with more sophisticated modulation schemes and the introduction of coherent technology. Coherent optics bring massive spectral efficiency over greater distance, improving the central metric of carrier optical transport economics: cost per bit per kilometer transmitted. Like WDM did 15 years ago, coherent optics change the economics of transport, simplifying network planning and increasing the capacity of installed fiber by at least an order of magnitude.

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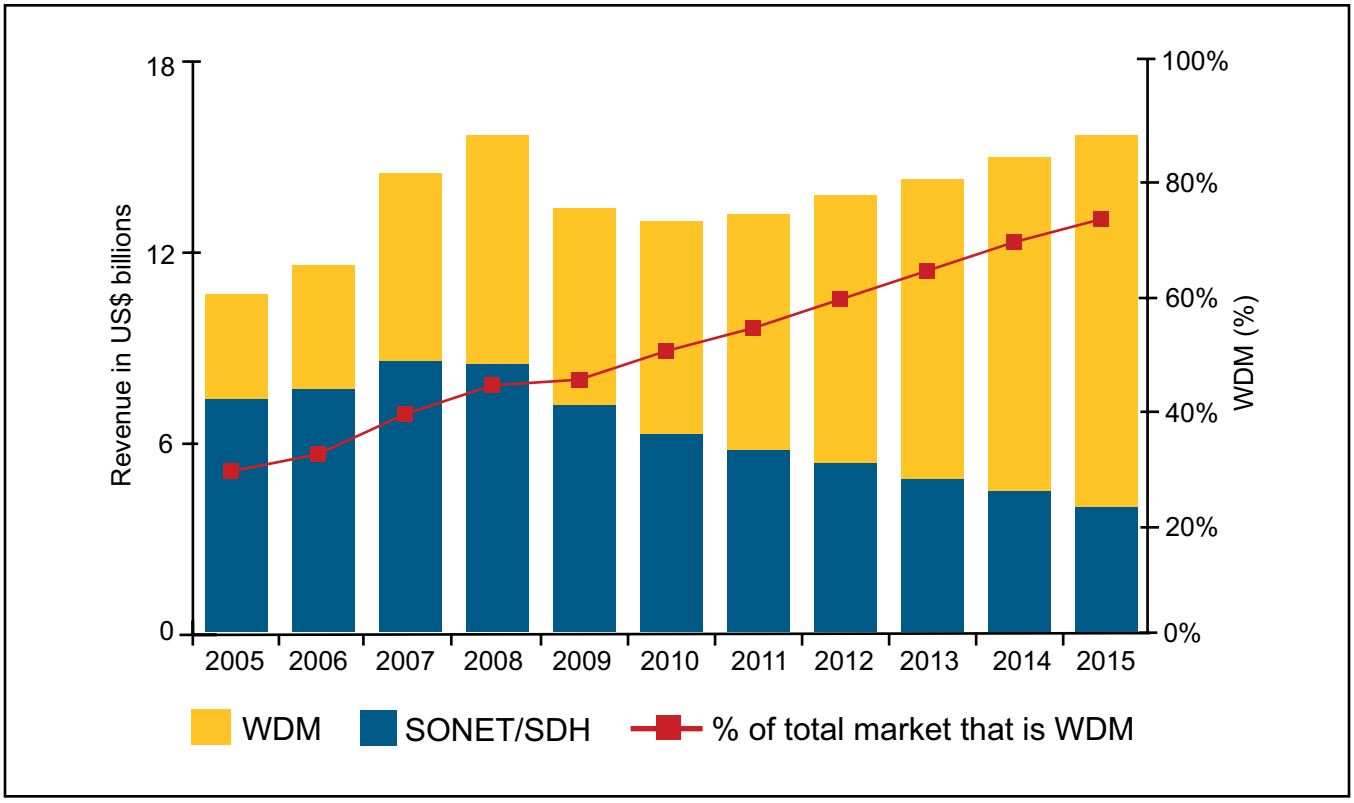
THE SHIFT TO WDM IS WELL UNDER WAY

The undeniable cost-per-bit benefits of WDM-based equipment vs. legacy SONET/SDH have resulted in a long-term secular spending shift in optical network equipment. As shown below, the compound annual growth rate (CAGR) of the entire optical market is 4% for the period of 2005 to 2010. Underlying this relatively low growth is a radical mix shift towards WDM equipment (CAGR +15%) and away from SONET/SDH (-4%).

Exhibit 2: Worldwide WDM and SONET/SDH Revenue



Source: Infonetics Research, *Optical Network Hardware - Worldwide, Regional, China, Japan, and India - Quarterly Market Share, Size and Forecasts*, February 2011

Looking forward, we see this trend continuing, with WDM accounting for 70% of optical spending in 2015, growing at a CAGR of 12% between 2010 and 2015. Companies that sell into the WDM market, such as optical component companies and pure play WDM equipment companies, are presented with excellent growth opportunities, while those who remain leveraged to legacy SONET/SDH face headwinds.

One thing is certain: equipment focused on 40G and 100G will grow faster than the underlying WDM equipment market. Carriers won't adopt these new speeds on a whim; they evaluate the relative costs of each technology and choose one using cost per bit as a guideline. We've surveyed carriers about their intentions and expectations surrounding this transition, to help us forecast the future of 40G and 100G.

40G/100G BRINGS NEW ECONOMICS TO CARRIER TRANSPORT

Service providers are in the midst of multiple-year planning cycles in preparation for a reboot of their optical networks, one component of which is a transition to higher speeds. Unlike other areas of change that are difficult to measure quantitatively, such as the use of optical transport network (OTN) protocols or converged packet-optical transport systems (P-OTS), the cost-per-bit metric provides a good tool for gauging carrier expectations.

One common industry metric is that technology shifts take place when 4x the bandwidth is available for 2.5x the price, or when there is a 38.5% reduction in the cost per bit. Though this metric may have been true for the transition from 2.5G to 10G, there is no reason to believe it will be for the transition to 40G/100G, particularly with the great benefits coherent technology brings. Our carrier surveys indicate pricing tolerance has changed with the new economics of 40G/100G.

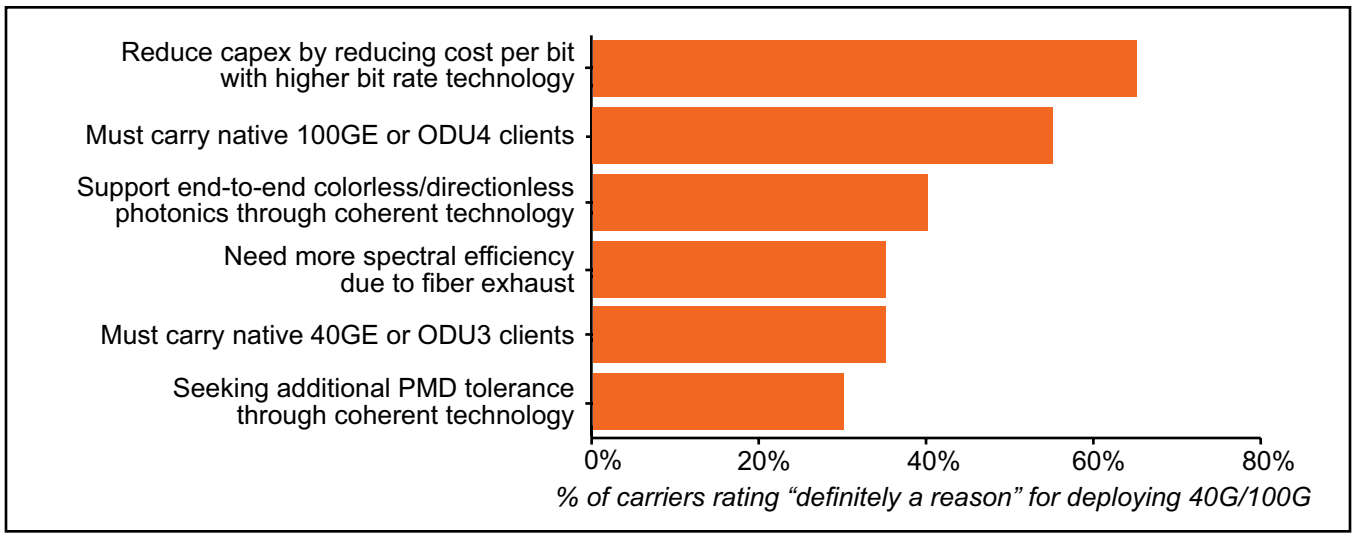
40G/100G SURVEY SHOWS A RESET OF PRIOR 10G PRICING EXPECTATIONS

In December 2010, we published *40G/100G Deployment Strategies: Global Service Provider Survey*, for which we interviewed key technical leaders at 20 global carriers. Respondents had knowledge of and decision-making responsibility for optical networking equipment. Our goal was to gain insight into:

- Their justification for deploying 40G and 100G technology
- The timetable and reason for deploying coherent optical technology
- The pricing inflection points that would result in adoption of higher speed technology

Together, participating carriers represented 21% of 2009 global telecom capex. We asked carriers to rate the reasons for deploying 40G/100G on a scale of 1 *(not a reason)* to 7 *(definitely a reason)*. A reduction in cost per bit was the greatest reason for deploying 40G/100G. Also of note in the responses (see graph) was the large gap in the importance of carrying 40GE/ODU3 (35%) and 100GE/ODU4 (55%) clients; one can see carriers are assigning more importance to 100G applications.

Exhibit 3: Reasons to Deploy 40G and 100G Optical Technology

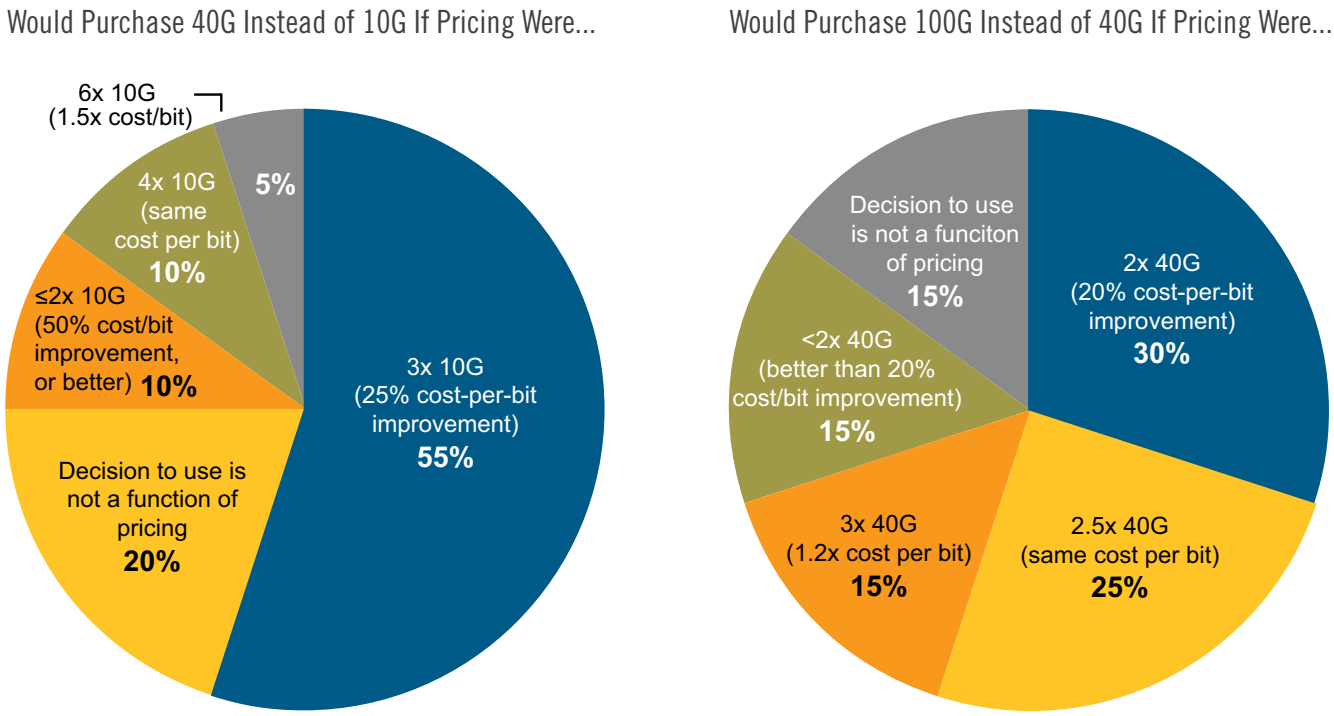


Source: Infonetics Research, *40G/100G Deployment Strategies: Global Service Provider Survey*, December 2010

"Carrier preferences are trending toward 100G technology over 40G."

We asked carriers at what pricing level they would deploy 40G as a transport replacement for 10G. 70% of respondents would switch from 10G to 40G with only a 25% cost-per-bit improvement relative to 10G. Of note were the 20% of respondents who indicated they would not deploy 40G for pricing reasons; it turns out they decided not to deploy 40G at all and wanted 100G.

Exhibit 4: Price Levels at Which Carriers Would Switch to a Higher Transport Speed



Source: Infonetics Research, *40G/100G Deployment Strategies: Global Service Provider Survey*, December 2010

When asked at what pricing level they would deploy 100G transport rather than 40G, again 70% of carriers said they would move from 40G speeds to 100G speeds with only a 25% cost-per-bit improvement. Compared with the results of our 2009 version of this survey, carrier preferences are trending toward 100G technology over 40G.

Survey data shows that carriers are willing to move to higher speeds at cost points higher than the traditional 4x capacity at 2.5x cost. The effect of this will be a more rapid shift to higher bit rate technologies; carriers appear to be willing to forgo large cost-per-bit reductions to move to higher bit rates.

Now that carrier pricing expectations are understood, the next exercise is to understand how the cost of these technologies will align. This can be accomplished by looking at the relative optical component costs required to make the hardware for 40G and 100G links.

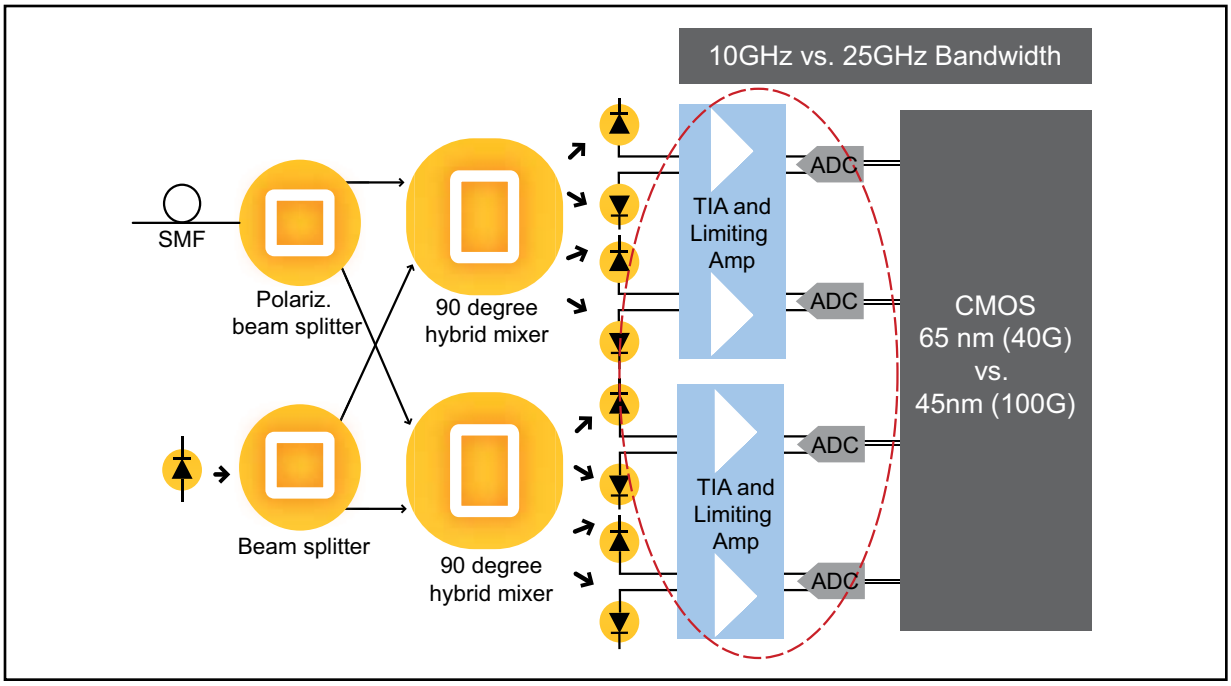
100G WILL REACH 2X THE COST OF 40G

In a competitive marketplace, price ultimately correlates with costs, so understanding the cost relationship of 40G vs. 100G allows us to draw conclusions about which technology will be adopted by carriers, given what we know they are willing to pay. The most significant cost of 40G/100G WDM transport systems is in the optical subsystem, or module assembly, inside WDM equipment, which is responsible for interfacing between the electronics and optical domain. These modules typically contain integrated circuits made from silicon as well as more exotic materials, coupled with tunable lasers, photo detectors, and modulators that shutter the laser light on and off.

Though 100G optical technology is still in the earliest stages of production deployment, it re-uses almost all of the optical components found in existing coherent and non-coherent 40G systems. Since the same components are used for both optical module speeds, one can estimate the cost of a 100G vs. 40G optical module. It is important to note that these costs are the main driver of the price differentials of the WDM systems (linecards), but the system cost will be significantly higher.

An examination of a 40G vs. 100G optical receiver shows that the block diagram for each is the same, except that the electronics must operate at 25G vs. 10G. Though daunting, it is achievable with a move from silicon to Indium Phosphide (InP) electronics, as well as a bump in the silicon process (65nm -> 45nm) for the large complex CMOS digital signal processor. Companies such as ClariPhy are now sampling 40G coherent DSPs to partners, and will be sampling 100G versions of the same device within a year. Several systems companies also have developed these chips. Technical feasibility is not a concern—the significant barrier to entry is the availability of this CMOS DSP, and such silicon will be available from multiple sources in 2012.

Exhibit 5: PM-QPSK Coherent Electronics, 40G vs. 100G



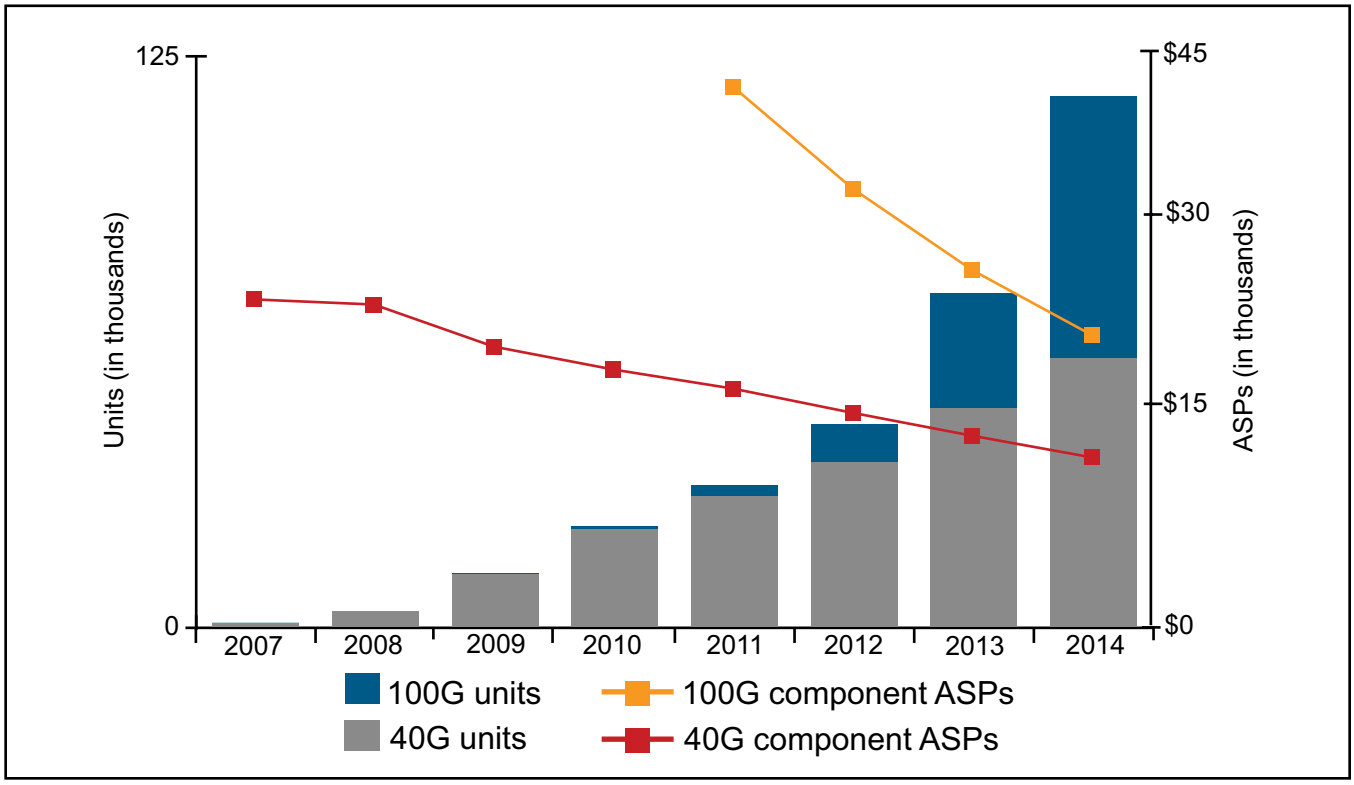
Source: InPhi and Infonetics Research

The faster electrical components (LiNb modulators, InP drivers, and receive amplifiers) are functionally identical to those used in 40G non-coherent DQPSK solutions, the highest volume 40G technology to date. Good historical pricing data exists for these components, and pricing continues to decline as 40G DQPSK shipments ramp.

"It is clear that 40G technology will be squeezed by cost-competitive 100G solutions from above, and low-cost tunable XFP solutions from below."

Using data for 40G DQPSK electronics and projecting the costs of moving from 65nm to 45nm CMOS DSPs, we can estimate the expected bill of material costs of both 40G and 100G coherent solutions and make forecasts of the cost and expected shipping volume of each technology.

Exhibit 6: 40G and 100G Component Module ASPs and Units



Source: Infonetics Research, *10G/40G/100G Optical Transceivers - Biannual Worldwide Market Size and Forecasts*, November 2010

Companies such as Infinera are taking an unconventional approach to pursuing a fundamentally lower cost architecture through photonic integration, a path that would—if successful—significantly disrupt the conventional approaches pursued by others.

Our conclusion is that within only 2 years, roughly 1 year after there is widespread availability of 45nm DSPs, 100G coherent component pricing will reach approximately twice that of 40G coherent. We expect the same price ratio to exist in the WDM systems (linecards) based on these modules. At this level, 70% of carriers indicate they would move away from 40G in favor of 100G. 10G technology will have staying power, particularly in the metro where tunable XFP technology will provide additional cost reductions. Carriers seeking to maximize cost per bit per km will move aggressively from 40G to 100G, whereas 40G continues to see stiff competition from 10G.

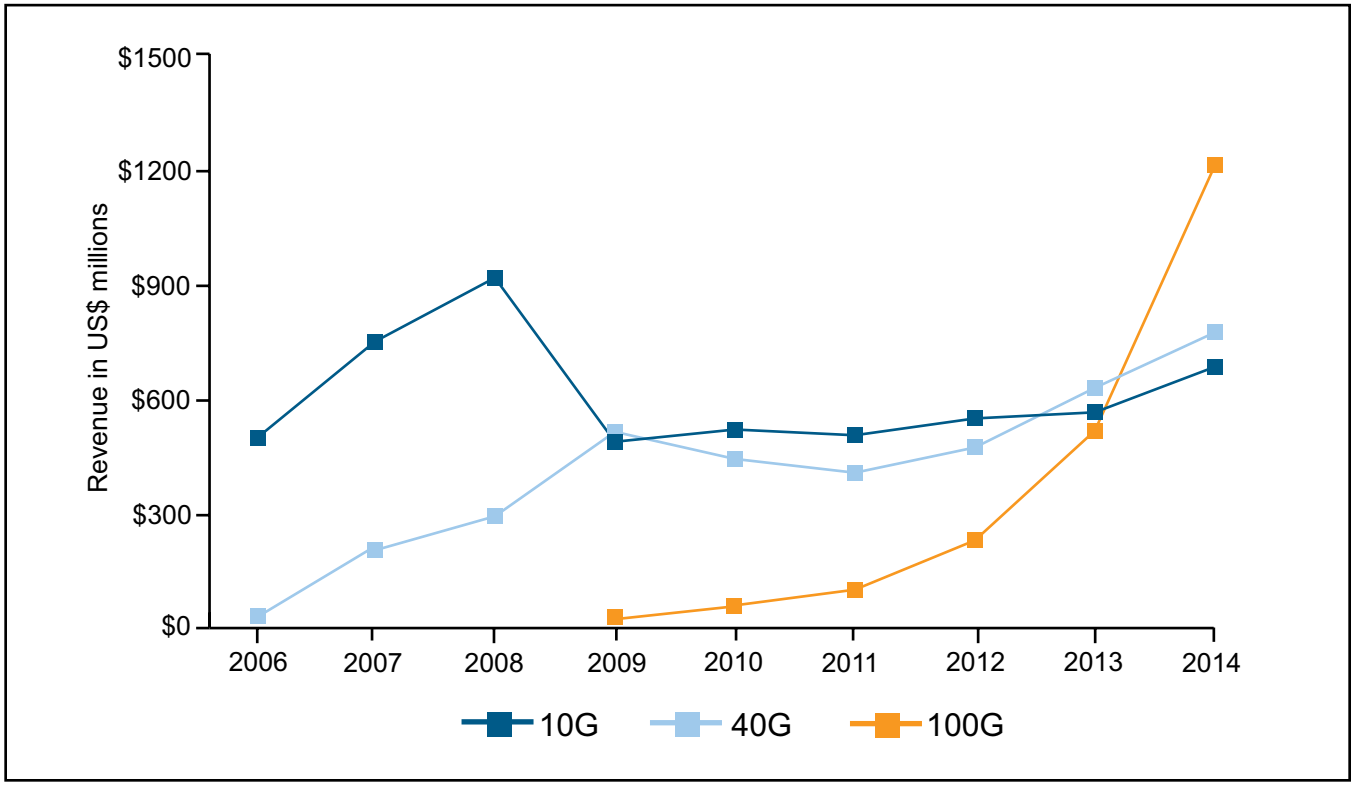
This reduction in the pricing gap should result in 100G unit WDM linecard shipments equaling 40G unit shipments in 2014 as carriers shift purchases to this preferred technology. Though the precise timing of this shift is difficult to predict, it is clear that 40G technology will be squeezed by cost-competitive 100G solutions from above, and low-cost tunable XFP solutions from below.

BIG SHIFT IS COMING: ALMOST HALF OF WDM LINECARD REVENUE WILL BE 100G BY 2014

The result is that 100G technology will grow at a faster rate than 40G did in its first years of introduction. In many ways, 40G has trailblazed for 100G, reducing risk at the component level and familiarizing service providers and test equipment vendors with coherent networking. Though 10G port shipments account for the majority of revenue today, by 2014 100G revenue should significantly outstrip 40G, and 10G technology will continue to claim significant share, particularly in the metro.

The picture becomes clear when one looks at the revenue contribution of each technology in the WDM linecard market.

Exhibit 7: 10G/40G/100G WDM Linecard Revenue (Worldwide)



Source: Infonetics Research, *1G/10G/40G/100G Networking Ports - Biannual Worldwide and Regional Market Size and Forecasts*, April 2011

As shown in the graph above, 40G revenue slows, and falls as a percentage of the WDM linecard market after 2011, and will never make up more than 25% of all WDM linecard revenue. Meanwhile, 100G will overtake 40G revenue by CY14 and is projected to account for 44% of all WDM linecard spending.

There is some uncertainty in our 40G forecast, as much depends to what degree Chinese service providers migrate to 100G. In 2010 the three Chinese carriers collectively accounted for roughly half of the entire 40G optical transport market. We are not forecasting a rapid move by Chinese carriers to 100G; if this were to take place, there would be a more rapid acceleration to 100G.

"Vendors will differentiate themselves not by the availability of 100G technology, but by the ability to tame these fat pipes with effective switching technology."

CONCLUSIONS: IF PRICE OF 100G IS TWICE 40G, THEN THE 100G ERA CAN BEGIN IN EARNEST IN 2013

Carriers are clamoring for higher speed optical transport to handle the growth in traffic from broadband and mobile applications, but will evaluate competing technologies on the basis of cost per bit per km transmitted. Their pricing expectations show a willingness to move to 40G and 100G technology at price differentials higher than conventional wisdom dictates, and their actions in 2008–2010 show a need to adopt 40G technology at prices that are far above these thresholds. We believe 100G coherent component technology inherently should not cost more than 2x 40G technology, which when translated to equipment pricing, should result in a rapid switch over to 100G transmission when it becomes widely available in 2013.

Once this transition is underway, vendors will differentiate themselves not by the availability of 100G technology, but more by the ability to tame these fat pipes with effective switching technology, whether that be OTN switching or full-blown IP/MPLS switching. Ultimately, the companies that will be successful at 100G are those with architectures that can reduce the amount of equipment and interconnect by collapsing hardware into single units shipped in high volume, while providing the best software and management tools to direct these resources. ■

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ABOUT INFONETICS RESEARCH

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