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TECHNOLOGY

Breaking the optical glass ceiling

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Table of Contents

Table of Exhibits

Introduction

Successive rounds of optical innovation and investment have delivered higher capacity networks with significantly decreased cost-per-bit transmitted. In the near future, as we approach Shannon's limit of maximum capacity for a communications channel, gains will become more incremental, and the cost-per-bit of added capacity will become more linear. As an industry, will we be able to break through the optical glass ceiling to achieve terabit optical networks?

2018 is shaping up to be the year of 400G/600G for coherent optical applications with multiple vendors announcing products in this space. Acacia Communications has begun shipping customer samples of its AC 1200 modules that support two wavelengths of up to 600G each. Fujitsu announced its new 1Finity T500 and T600 transport blades with support for up to 600G uplinks. Nokia announced its next-generation coherent digital signal processor (DSP), the PSE-3, which employs probabilistic constellation shaping (PCS) to support 400G/600G wavelengths. Nokia will initially bring this technology to market via its recently announced 1830 PSI-M platform. Clearly, the industry has a path to achieving 400G/600G for metro applications, but what about for long haul and subsea applications? Is there a path for single wavelengths to get to 1T and beyond for real-world applications? At what cost?

This report explores some of the evolution paths being explored to enable the next step in evolution of coherent optical networking.

Continuing growth in bandwidth demand

There is a continuing demand to move to higher and higher speed wavelengths and technologies, fueled by insatiable consumer and enterprise demand for more and more bandwidth.

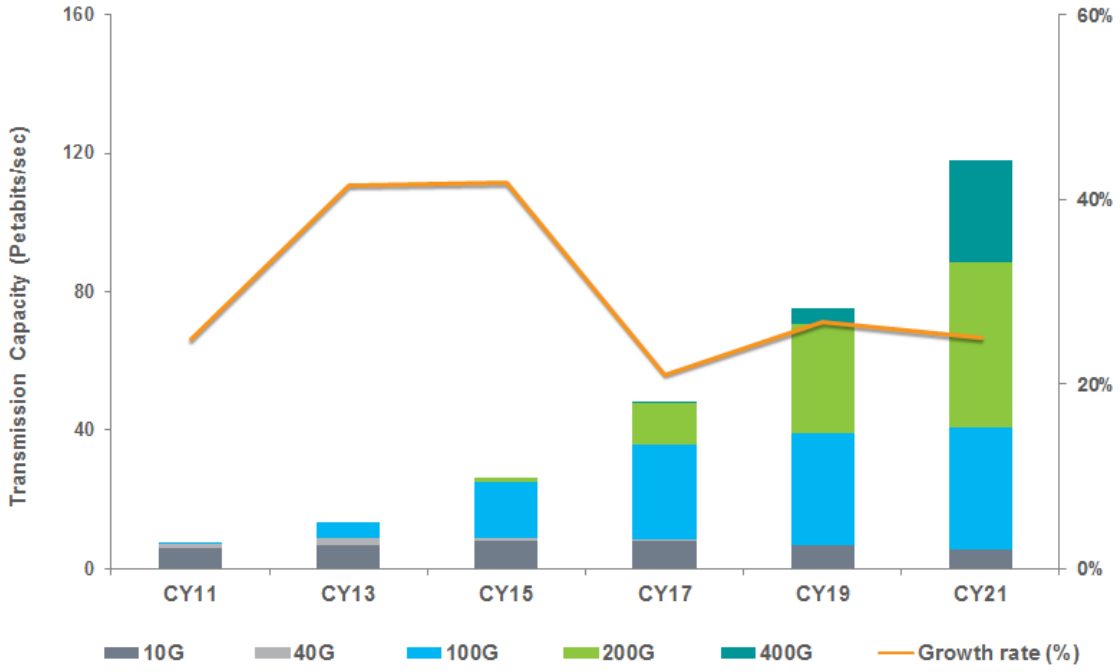
- On the consumer services side, preparation for broader adoption of consumer 4K and higher video content and services on a variety of devices will drive fiber access and deeper network investment. IHS Markit expects the shift from data to video to VR/AR will add yet another set of bandwidth intensive and latency sensitive services to the mix moving out to 2020 and beyond.
- The evolutionary shift in mobile network architectures in preparation for 5G (deeper fiber everywhere) and a range of new fixed and mobile M2M and IOT applications will set the stage for an investment cycle that will drive more bandwidth out to the farthest reaches of the optical access network, and in turn drive the requirement for more capacity in aggregation and backbone networks.
- In the enterprise space, digital transformation is driving a fundamental shift to adopt and leverage cloud-based applications and services. The result is burgeoning bandwidth demand to, from, and between DCs.

Another way to look at bandwidth growth is by monitoring the deployed supply, not the demand. IHS Markit has tracked the deployment of line-side optical transceivers/transponders for well over a decade and has created a proxy model for bandwidth deployed in a given year based on optical capacity shipped.

The following chart shows the results of this modelling. From CY11 through CY16 we had significant levels of network investment—generally ranging from 20 to 50% of YoY growth in any given year. CY17 had a bit of a drop off in growth rate after a banner 2016 led by investment in China.

Looking forward, we model a more conservative growth rate in the range of 25-35%. But of note here, even at these more conservative rates, there is a steep appreciation on the requirement for new transmission capacity to be deployed.

Exhibit 1: Annual deployed telecom bandwidth and YoY change



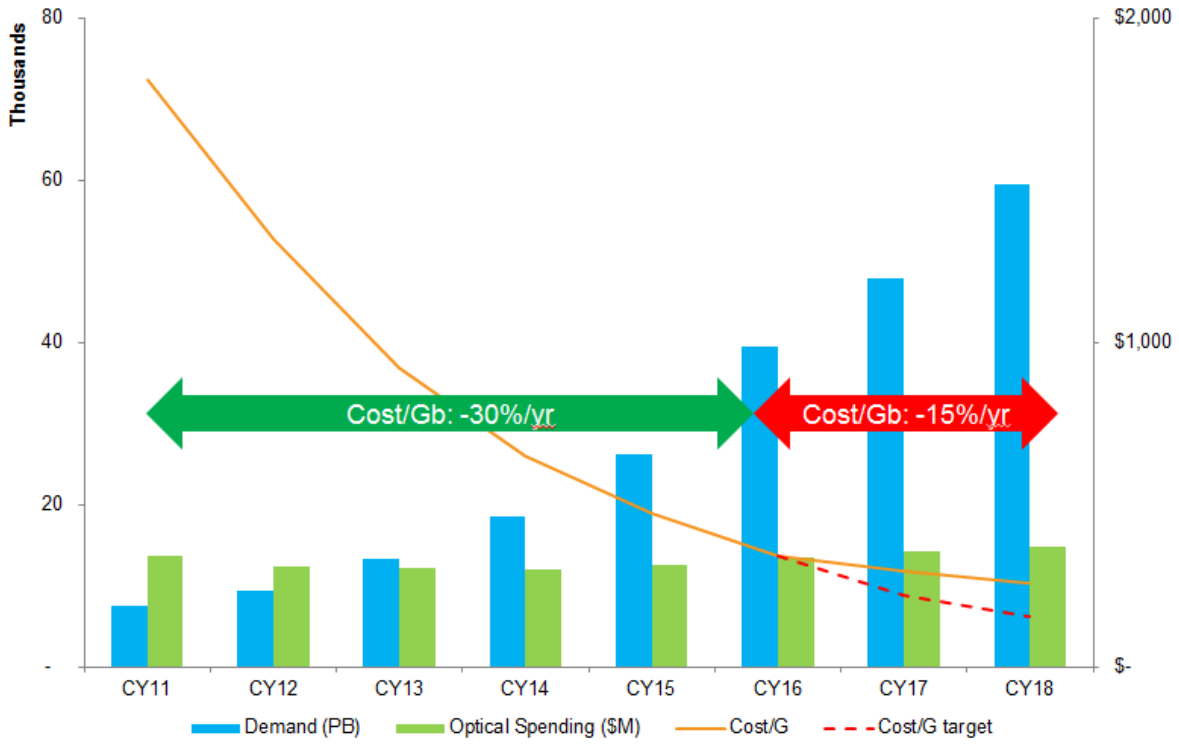
Source: IHS Markit "Telecom Optics and Components", 2017

Historically, we have had successive generations of faster technology to address this growth in a most cost-effective way: 1G, 10G, then the leap to coherent with huge investment in coherent optical networks. Moving forward, we are seeing more modest increments: 200G, 400G in sight, beyond that, for the longer reaches, many questions and ideas on how to get there.

Declining cost curve hits a speed bump

It is not enough just to meet bandwidth demand, but service providers need also to be able to do so in a profitable fashion in order to sustain ongoing network investment. As improvements in coherent technology become more incremental and expensive to implement, there will be impact on the cost reduction curve. We are already starting to see some evidence of this impact in our research on the optical equipment market. As an example, prior to 2016, we observed a remarkably consistent reduction in cost per GB deployed in the range of -30% per year. In 2017, we observed a sharp drop off to -15% YoY. Moving forward, we are not seeing a reversion to historical rates of annual cost reduction, and the cost curve is likely to flatten out even more. The net result is that network operators already faced with the challenge of meeting bandwidth demand in a profitable manner will be even further challenged to finance the addition of new network capacity moving forward.

Exhibit 2: Trending of cost per Gb deployed in optical transport networks



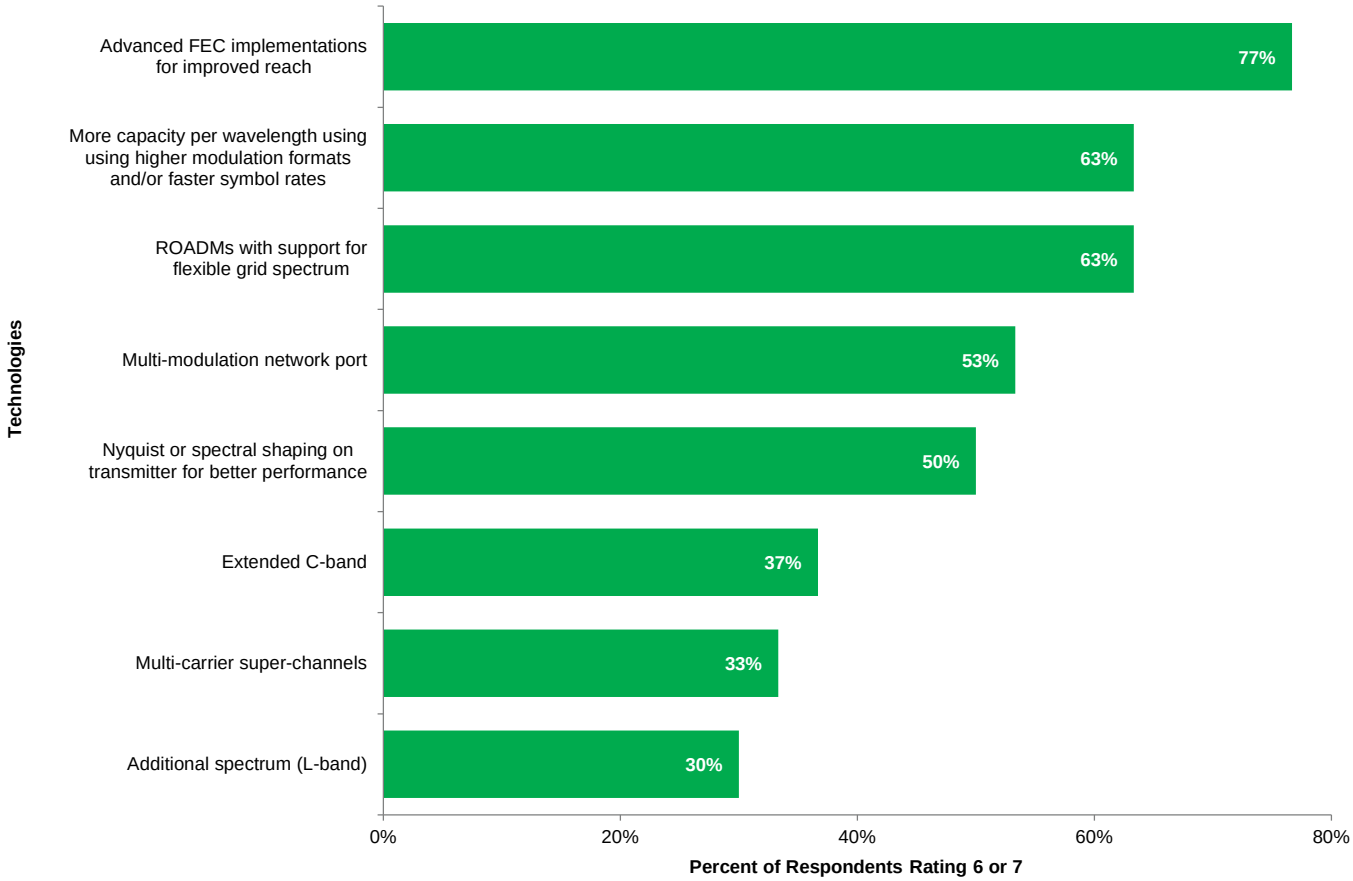
Source: IHS Markit 2018

Service provider survey: key technologies for optical network evolution

For the 2017 edition of our service provider survey on optical network evolution strategies, we structured our questions to explore the continuing evolution of metro and core optical network technologies including wavelength speeds, ROADM configurations, expanded spectrum, and more. In our interviews with service providers, it is clear that although 100G remains a key technology in metro and core optical networks, the market is already looking at what comes next. 200G and 400G deployments have started and will become increasingly important by 2020. Service providers are actively preparing for this jump in wavelength speed by moving to flexible grid ROADMs in a big way.

In addition to the evolution of wavelength speeds, we were interested in what other technologies service providers considered valuable for evolving optical backbone or core network capacity. For this question, respondents rated the importance of certain technologies when deploying coherent optics for core spans of 600–10,000 km on a scale of 1 to 7, where 1 is not important, 4 is somewhat important, and 7 is critical. The next chart shows the percentage of respondents rating each technology 6 or 7, or very important.

Exhibit 3: Desired technologies for coherent optics in core/long-haul spans

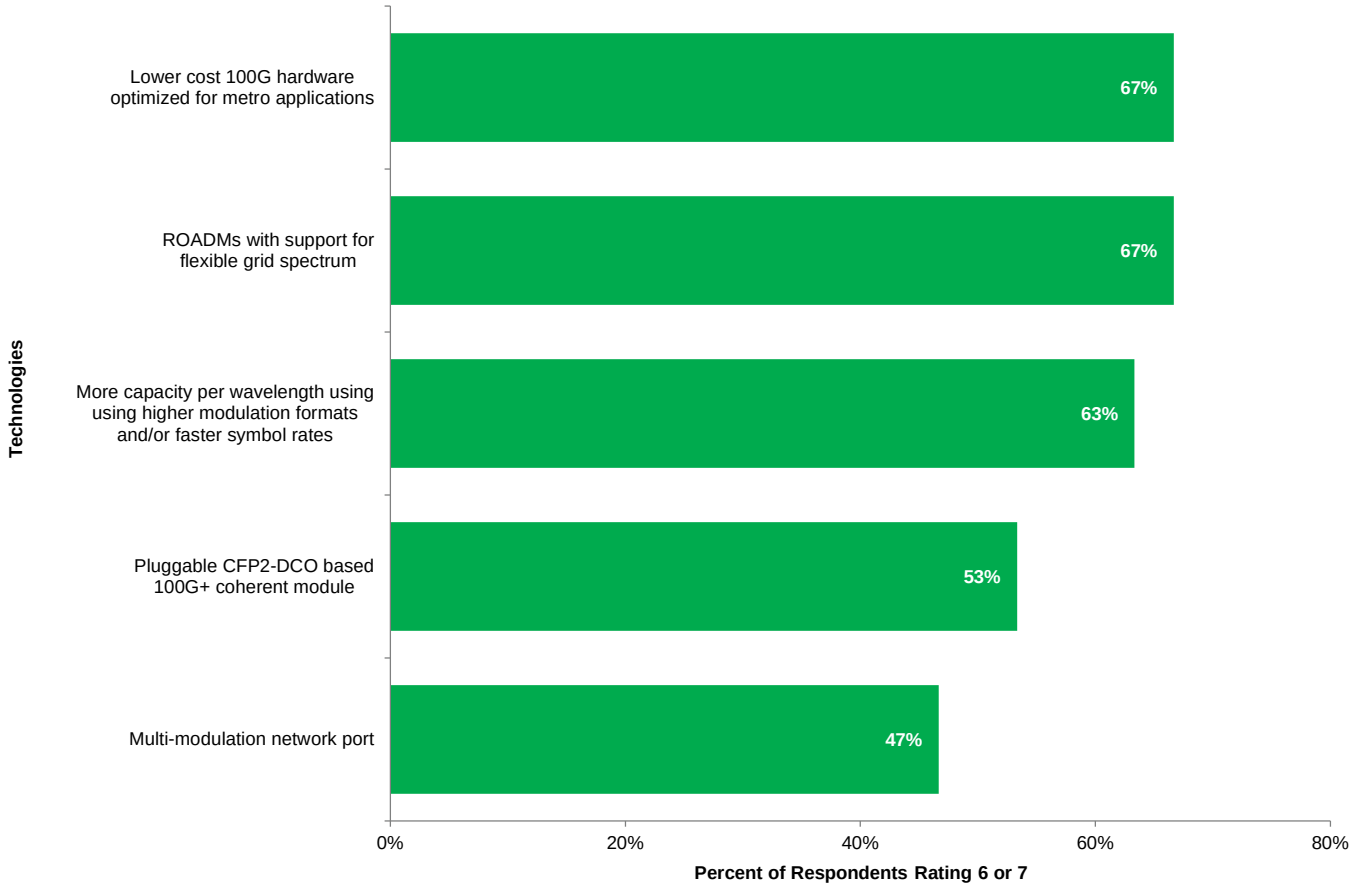


Source: IHS Markit "Service provider survey, optical network evolution strategies," 2017

Advanced FEC implementations for improving reach remained the top technology of interest in 2017 with 77% of respondents considering this to be very important. Similar to what we observed on the metro side, techniques for driving more capacity per wavelength and the corresponding flexible grid ROADMs rounded out the top 3 technology areas. Both technologies were considered very important to just under 2/3 of our respondents. Of the remaining technology areas listed for core/long haul networks, increasing the amount of spectrum for optical transport applications stood out as an area that increased in importance in 2017. 37% of respondents rated extended C-band as very important, up from 17% in 2016. Additional spectrum using L-band was rated as very important by 30% of participants, up from 8% last year.

We noted that the implementation journey will be different depending on the application. Solutions and technology approaches for metro network applications will differ from those employed in long haul and even subsea networks. Core and long haul solutions seek to maximize spectral efficiency as a top priority, not surprising given the scarcity and cost of deploying long haul and subsea fiber spans. The top 3 metro technology priorities for our service provider respondents were driving down the cost of 100G optical equipment in the metro, introducing flexible grid (or grid-less) ROADMs, and driving even more capacity per wavelength through techniques including higher modulation rates and/or faster symbol rates.

Exhibit 4: Desired technologies for optics in metro-regional spans



Source: IHS Markit "Service provider survey, optical network evolution strategies," 2017

Breaking the optical glass ceiling: a holistic approach to optical network evolution

As we can see from the service provider survey results above, there are a lot of technologies that can be leveraged to increase the capacity of metro and long haul optical networks.

Programmable FEC, Nyquist subcarriers, super-channel implementations, and other techniques can improve spectral efficiency on a fiber, but they are not necessarily the stand-alone breakthrough tools that will easily enable the jump to 1T wavelengths. Higher capacity carriers also require a tradeoff on amount of bandwidth required, so overall fiber capacity may not see as much of an increase. 100 Gbaud and beyond can help get to higher-speed wavelengths in less spectrum, but there is an impact in terms of cost.

There is a lot of work being done within the industry to figure out how to move more bits more cost effectively. Looking at increasing the capacity delivered per wavelength, it is becoming apparent that gains are becoming more incremental with each successive generation of new coherent technology, and those incremental gains are coming at a higher cost. While a focus on higher capacity wavelengths will continue to be important, we also need to look at other approaches to drive the best utilization of the fiber and overall lowest optical equipment and network cost.

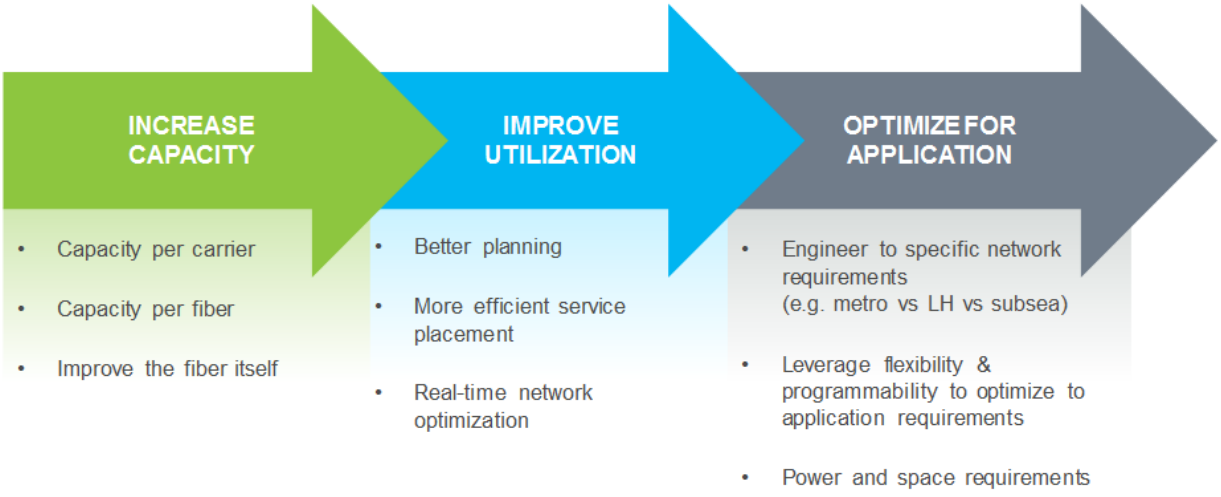
IHS Markit believes that these approaches can be summarized in three categories:

1. **Increase raw capacity of the fiber**: This category includes all techniques to improve capacity per carrier such as new modulation techniques, enhanced FEC algorithms, and faster serialization rates. It

also includes improving overall capacity on the fiber through techniques such as more efficient super-channels, reducing the required guard-band between carriers, increasing useable spectrum and even enhancing the fiber itself.

2. **Increase utilization of available fiber capacity**: This approach looks at improving the net payload transported to increase the overall utilization of wavelength and fiber resources. Techniques that can be incorporated here include the use of SDN and SDN techniques for real-time awareness of traffic flows, enabling more efficient service placement and higher capacity utilization; leveraging multi-layer service coordination to drive more efficient service redundancy schemes; and better overall network planning.
3. **Optimize solutions to applications:** This approach comes into play as a key mechanism to reduce cost of the solution. By engineering products and solutions to meet the requirements of a particular application, costs savings can be realized.

Exhibit 5: Holistic approach to optical network evolution



Source: IHS Markit 2018

Bottom line

When all is said and done, the end goal is economic. Agile companies must address growing capacity demand in the most cost-efficient manner possible. As we touch on the limits set by Shannon's Theorem, perhaps a 1T wavelength is not the main end goal. Breaking through the optical glass ceiling will require new and creative approaches that blend increasing wavelength capacity, improve resource utilization, and optimize to customer applications.

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To Learn More

Join us for "**Breaking the optical glass ceiling: the path to terabit optical networks**"
a free webinar presented by IHS Markit, Acacia, Fujitsu, and Nokia:

LIVE: Wednesday, May 16, 2018
8:00 AM PT, 11:00 AM ET, 15:00 UTC

REPLAY: Watch on-demand any time

Both the live event and replay can be accessed at:

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3231-CU-1016