STUCK IN THE MIDDLE?

SPEEDING UP MID-REACH OPTICAL NETWORKS

There is a technology gap opening up in mid-reach optics, those that span reaches beyond 10km and up to approximately 100km. Until now, the lack of dedicated technology for this application has not been a problem but a coming collision between new applications and physical limitations looks to be about to change that. 5G and edge datacentres are expected to increase demand for links that span tens of kilometres just as data rates increase to speeds of 100+ Gbps where the optics become more physically challenging, writes **Karen Liu**, VP of sales and marketing at Lightwave Logic.

The main original application for 40km optics is for metro telecom networks that connect adjacent central offices. A similar application in the cable network distributes data to head-ends. According to market research firm LightCounting, about a million units of merchant 1G and 10G Ethernet transceivers for 40km and 80km ship every year and the number continues to increase. Adding in other types of transceivers and captive shipments, LightCounting estimates about three million units of 40km and 80km optics ship annually.

MID-REACH OPTICS STAND AT A TECHNOLOGY BORDER

The history of 40km, and to a lesser extent 80km Ethernet, traditionally called ER (extended-reach) and ZR, illustrates the forces at play. This part of the optical interconnect market has long been a border zone between shorter and longer-reach approaches. The history of something as simple as wavelength choice between 1310nm and 1550nm anecdotally illustrates the technology border that exists at 40km. For all speeds of Ethernet optics from Gigabit up to the latest proposed IEEE standards for 100G, the 10km wavelength has been 1310nm. Until now, 80km has been non-standard but universally 1550nm, the fibre loss minimum point, was also used for long-haul links of hundreds and thousands of kilometres. At 40km, both 1310nm and 1550nm solutions are offered. The IEEE did standardise 10GBASE-ER with 1550nm but the more popular solution in the market proved to be 1310nm. The 10G technology was reused in the next generation by ganging together four data streams to implement 40G Ethernet. At 40G, both 10km and 40km were standardised on four coarse-wavelength division (CWDM) wavelengths clustered near 1310nm each carrying 10G. Meanwhile 80km remained at 1550nm for 10G, though about half the market has not been exactly 1550nm, but adjacent wavelengths that enable dense-wavelength division multiplexing (DWDM) sharing of fibre.

Technically, solutions for 100G and above, implemented as multi-wavelength 25G, now have good reason to be in the ~1310nm CWDM camp. Increased chromatic dispersion effects at higher speeds force them to stay near the fibre minimum dispersion point. But note that the shift from 1550nm to 1310nm for 40km happened when both solutions were technically feasible, pointing to market forces as the root cause. The shorter-reach 10km products sell in much higher volumes than longer-reach products. It is cost-effective to 'import' components such as lasers to also service 40km. By 'binning' or selecting the best of the manufacturing distribution for devices designed for 10km, manufacturers can use slightly higher power transmitters and slightly

better sensitivity receivers to stretch performance to longer-reach. (This simplified story neglects that the receiver end has no such benefit, as APDs instead of PIN detectors are typically needed.)

THE BORDER CONFLICT HAS INTENSIFIED

It may seem like the 40km products benefit from the best of both worlds, borrowing from either 10km or 80km, but industry dynamics have been pulling the two sides further apart. As the datacentre market grew to dominate market demand for 40G, 100G and now 400G optics, even shorter-reach and higher-volume products have emerged. The 10km products themselves are now binned versions of 2km products. There is not yet a standard or even a de facto standard for 80km for 100 Gbps (using 25G optics).

Meanwhile, long-haul DWDM technology has become ever more capable but also ever more complex. Its technology has no trouble with the reach but struggles to match the cost expectations of the mid-reach market. The cost challenge has increased over time as the technology has become less modular. Once upon a time, 80km could “import” long-haul lasers and add link amplification only as needed. Now, long-haul products have shifted from direct detection methods to highly sophisticated and therefore expensive coherent technology reliant on digital signal processing (DSP) chips made in the latest advanced CMOS process.

As the industry grapples again with the physical challenges of pushing the data rates up even further to 400G (and single channel 100G), the limitations of both short-reach link budget and long-haul cost are apparent. At this point, it appears that the ‘40km’ will continue to side with the short-reach technology – even if it can only reach 30km. It also appears that the ‘80km’ will side with coherent DWDM technology –even for applications that don’t need multiple channels.

AN OPENING FOR POLYMER PHOTONICS

Direct-detection technology struggles to perform, yet coherent technology struggles with cost points and the first gap has emerged at 40km. This emerging crack in solution coverage threatens to widen going forward as the link budgets at even 10km become challenging. The technology gap is an opportunity for a generational turn-over to new technologies. There are a number of interesting candidates of which polymer optics is one. Passive polymers are being explored for high-density optical interconnect, particularly for nonplanar connections which can be added to electrical circuit boards. Active polymers have the potential to integrate optical components with electronics more efficiently.

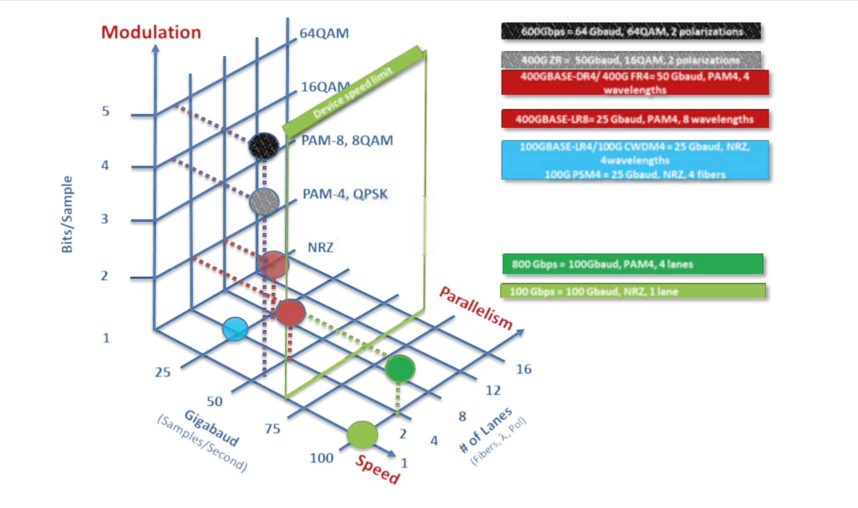

Figure 1: Limitations imposed by component speeds Source: Lightwave Logic

Components speeds, for transmitters more than receivers, is another challenge to continued speed increase. The speed of optics today is also limited by the capabilities of the electronics that drive them. As modulation speeds go up, typically the voltage required by the optical transmitter increases but the voltage available from the driver decreases. Electro-optic polymers have excellent velocity phase matching between optical and microwave propagation speed which results in unmatched speed. They also have high electro-optic response which results in lower drive voltage. For example, Lightwave Logic’s modulator roadmap starts with 50GHz modulators which is already faster than the~35 GHz used in the newest 100G and 400G Ethernet formats and coherent DWDM modulation schemes. 100 GHz modulators with 2 V drive have been demonstrated.

In response to limited component speeds, the industry has been forced to use complex modulations schemes such as PAM4. PAM4 encoding cuts the usable signal to a third of its original size which stretches them out to twice the time i.e. half the speed, and exacerbates the link budget problems. At a minimum, polymer photonics’ higher speed can improve the quality of today’s PAM4 signals and lower power consumption. Alternatively, they could enable the use of simpler NRZ modulation to get the same data rates, taking back that factor of three (5 dB) in link budget. Alternatively, they could extend the roadmaps to greater speeds and open up new design possibilities. Figure 1 is a view of how both short and long-reach technologies are constrained by components speeds to the design space behind the green wall. The solid balls represent short-reach options. The textured balls are long-haul technology. The details of how product roadmaps evolved to this current state are described in a whitepaper on Lightwave Logic’s website.

A TECHNOLOGY PLATFORM, NOT A MATERIAL

Polymer photonics presents a new technology platform which has other potential benefits at a time when the photonics roadmap needs innovation. It has been compared to lithium niobate, the incumbent electro-optic Mach-Zehnder modulator technology. A more relevant comparison is to Indium phosphide and silicon photonics which are used to make the newer more compact modulators. But even those are not direct comparisons. Lithium niobite, indium phosphide and silicon are specific materials. Polymers are complex engineered materials. They can be designed and optimised by application. To date, most of polymer photonic devices have been Mach-Zehnder modulators at 1550nm, a class of devices widely used in long-haul transmission including coherent. They could also be engineered for 1310nm applications.

Fabrication of devices from polymer uses deposition and photolithographic patterning techniques and equipment that are well established from older semiconductor fabs. They can also be added—literally on top of—devices made on InP, Si or GaAs to make hybrid photonic integrated circuits (PICs). Beyond the devices or PICs themselves, assembly and packaging is as important a determinant of cost and performance. Whether for 1310nm or 1550nm, PAM4 or coherent, polymer photonics can offer improved performance and most importantly, they open up possibilities of innovative component and package design.

INNOVATION IS NEEDED BUT WILL COME

The need for more data capacity everywhere in the network will continue to grow unabated. The mid-reach network promises to be a both a high-growth market and a critical technical challenge. New technology platforms such as polymer photonics can enable the optical communications industry to meet this challenge.