# Infinera targeting PICs of 4Tb/s within 10 years

**At this year's OFC/NFOEC event, Infinera outlined its roadmap to integrating more components and wavelengths into InP-based photonic integrated circuits.**

At February's Optical Fiber Communication/ National Fiber Optics Engineers Conference (OFC/NFOEC 2008) in San Diego, CA, USA, Infinera Corp of Sunnyvale, CA, USA, which makes digital optical network systems incorporating its own InP-based photonic integrated circuits (PICs), unveiled its roadmap for PICs for telecom networks.

Ongoing growth in high-bandwidth services and Internet Protocol (IP) traffic is driving the need for significant scaling of optical transport networks, says Infinera, but scaling of network capacity alone will not meet the needs of carriers. What is needed is the simultaneous and proportionate advancement of capacity, cost, power consumption, size, reliability and complexity.

For the past decade the industry has focused on data rate per wavelength as a key measure of progress to address these challenges. While the jump from 2.5Gb/s to 10Gb/s led to a reduction in cost per gigabit-kilometer, the move from 10Gb/s to 40Gb/s using phase modulation architectures has addressed the question of spectral efficiency. However, it has not adequately addressed the issues of cost, power, reliability, and complexity associated with an increased number of optical components, says Infinera. "If you scale the capacity of a network without making that system simpler to manufacture, simpler to deploy, and more reliable, you haven't achieved anything," says chief marketing and strategy officer Dave Welch.

## Capacity per chip the key metric for capacity, cost and simplicity

Infinera believes that the fundamental driver of network cost is the number of components in the network, and claims that large-scale photonic integration is the only technology that can address the multiple challenges faced by carriers.

Since optical transmitter and receiver chips are the basic building blocks' of network bandwidth, increasing the capacity per chip enables carriers to scale their networks by raising the data rate of the system, in order to accommodate the growth in bandwidth demand. But, equally importantly, it simultaneously enables the system to reduce network complexity, cost, space and power consumption, while also improving reliability by reducing the number of components or packages within each line-card and reducing the number of line-cards per system. Fewer line-cards, or field replaceable units (FRUs), enables service providers to reduce installation and configuration tasks and eliminate failure points. If the capacity of the basic building blocks of bandwidth deployment are not continually increased, then network operators are forced into an inexorable increase in their operational workload and operating expenses as bandwidth grows, says Infinera. "Photonic integration is the only technology that can scale all the key parameters simultaneously," claims Welch.

By consolidating more than 60 optical components, Infinera's existing PIC has a capacity per chip of 100Gb/s (10 wavelength channels, each operating at 10Gb/s) integrated into the firm's DTN digital ROADM (reconfigurable optical add/drop multiplexer) and WDM (wavelength division multiplexing) platform. Just over three years after starting commercial shipments in 2004, the firm's PIC-based systems account for 13% of the multi-reach DWDM market, according to market research firm Ovum RHK. Infinera claims that the suitability of photonic integration technology to enable scaling in capacity per chip is underpinned by their PICs' track record for reliability in live commercial networks, with more than 50 million hours of operation now realized without a single failure.

Increasing capacity per chip further can be enabled by the application of several key technologies. These include: the integration of more wavelengths on a single chip; the use of advanced modulation techniques to code more data to each wavelength, and expanding the range of PIC operation across the full fiber spectrum. Photonic integration provides a technology platform that is well suited to the practical implementation of all these technologies, claims Infinera.

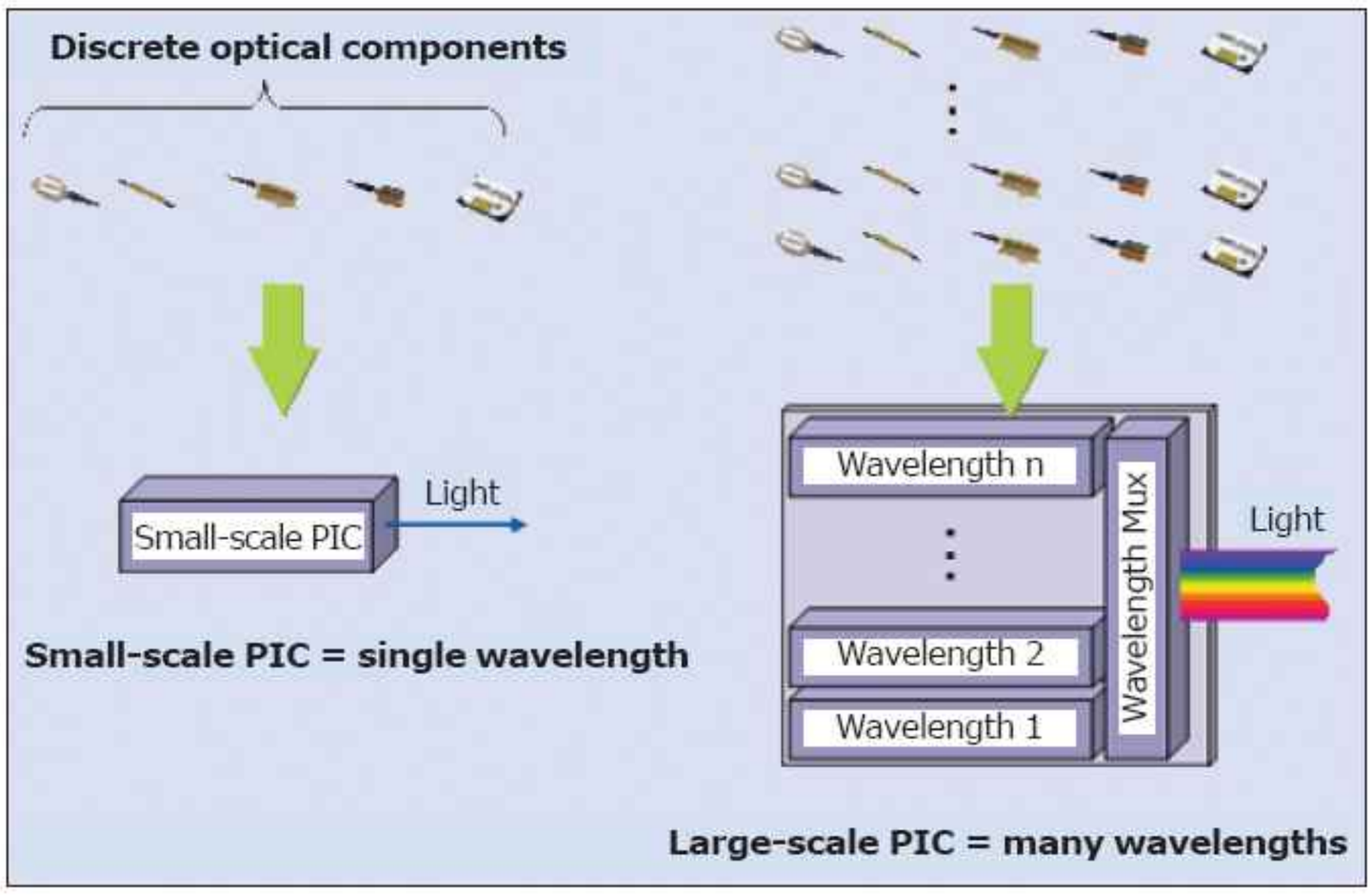
According to Infinera, advanced modulation techniques such as differential quadrature phase-shift keying (DQPSK) can enable an increase in the data rate on each DWDM channel to 40Gb/s, as it offers high spectral

efficiency, high tolerance to impairments (including dispersion), and superior optical signal-to-noise tolerance (maximizing optical reach).

However, DQPSK requires the use of many optical functions per channel where simple modulation schemes often require just a single laser and modulator. By integrating all the optical functions for an advanced modulation scheme onto a single PIC, photonic integration simplifies the design and manufacture of an advanced modulation system, reducing the number of discrete optical components and fiber couplings required, says Infinera.

Based on its three years of experience producing PICs for commercial deployment, Infinera believes that PIC manufacturing can follow a learning curve analogous to that seen in silicon chips. The firm therefore anticipates steady growth in the number of devices integrated onto a chip — from dozens today to hundreds, and beyond, over time — driving a doubling in the data capacity per chip approximately every three years. It expects the next increment in its commercially available PICs to be from the existing capacity of 100Gb/s per chip to 400Gb/s (for production in 2009) by PICs integrating 10 wavelengths operating at 40Gb/s per wavelength channel (using DQPSK).

"Our vision of a 400Gb/s chip next year and a doubling of capacity per chip every three years is based on many years of research and development at Infinera and the knowledge we've gained after deploying thousands of PIC-based systems worldwide," says Infinera's CEO Jagdeep Singh.




**Integration of more components and wavelengths into PICs.**

## Demo: 40Gb/s DQPSK modulation on a PIC

Indeed, at OFC, Infinera announced the results of its lab demonstration of 40Gb/s DQPSK modulation on a PIC.

By integrating more than 100 optical devices on a single chip (double that of the existing 100Gb/s PIC), Infinera has developed and tested a PIC that, using DQPSK, integrates 10 wavelengths modulated at 40Gb/s per wavelength. This should enable the commercial production of the next generation of PICs, with a capacity per chip of 400Gb/s.

"This implementation of a 400Gb/s PIC using 10 sets of Mach-Zehnder modulators at 40Gb/s achieves performance similar to discrete implementations of 40Gb/s DQPSK," says Dr Fred Kish, VP of development & manufacturing.

Infinera expects the growth in PIC capacity per chip to continue, leading within the next 10 years to the commercial production of PICs with a capacity per chip of 1Tb/s in 2012 and 4Tb/s in 2018 (40 times the capacity of today's 100Gb/s PICs).

## Demo: PIC with on-chip SOA, enabling 100Tb/s fiber capacity

Furthermore, most existing DWDM optical transmission systems currently operate in only a portion of the total optical fiber spectrum (typically the C-band), limited by the use of erbium-doped fiber amplifiers (EDFAs), which can only amplify effectively at 1530–1560nm; the C-band range therefore accounts for just 4.4THz out of a full fiber spectrum of 55THz. By integrating optical functions such as amplification into PICs in the form of semiconductor optical amplifiers (SOAs), which operate over a much wider wavelength span, Infinera expects photonic integration to also enable optical data transmission across the full fiber spectrum (1240–1650nm), enabling scaling of total fiber capacity up to 100Tb/s. Infinera reckons that this will allow network operators to significantly scale total network capacity while avoiding or deferring costly fiber overbuilds.

At OFC, Infinera therefore also demonstrated the use of a 100Gb/s PIC (10 wavelength channels x 10Gb/s) with on-chip integrated SOAs for error-free transmission of data in the 1490nm range of the S-band over 320km, without external dispersion compensation.

"Opening up the full potential fiber bandwidth into spectral regions inaccessible with EDFAs is a significant innovation for optical networks," says director of optical systems Steve Grubb. "Photonic integrated circuits enable cost-effective use of SOAs and thus offer the possibility of scaling optical networks across the full fiber spectrum," he adds. "As we look for ways to economically scale network capacity to respond to increased demand from IP traffic, this significantly expands the current WDM tool kit."

"We believe photonic integration is not only here to stay, but will before too long become the dominant and ubiquitous technology in optical networks," adds Singh.

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