

## Infinite Capacity Engine – Extensible (ICE-X) Intelligent Coherent Pluggables

Delivering vertically integrated high-performance coherent optical subsystems and pluggables to the communications industry

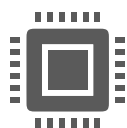
### Breakthrough Innovation in Multi-discipline Opto-electronics

With our world-class team of scientists and engineers, Nokia has a proven track record of delivering game-changing advanced optical solutions. With an in-house optical semiconductor fab based in Silicon Valley and revolutionary photonic integrated circuits (PICs), Nokia takes innovative solutions from concept to development to production.

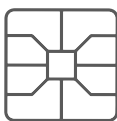
Nokia has a long history of industry firsts, including the first large-scale PIC, the first coherent PIC, the first commercial super-channels, the first Nyquist subcarriers, and the first point-to-multipoint coherent technology. Additional innovation highlights include SD-FEC gain sharing, long-codeword probabilistic constellation shaping (LC-PCS), and dynamic bandwidth allocation (DBA).



ASIC/DSP  
Design



Analog Electronics  
Design



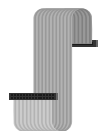
PIC  
Design



Packaging Design



Holistic Co-design



RF Interconnects



PIC Manufacturing



Packaging Manufacturing

### Indium Phosphide Compound Semiconductor Fab

At Nokia's optical semiconductor fab located in Sunnyvale, California, our engineers develop and manufacture industry-leading indium phosphide (InP)-based PICs for use in high-capacity optical networking solutions. InP is a compound semiconductor material ideal for optical functions. Nokia's revolutionary PICs integrate tuneable lasers, optical amplifiers, high-speed modulators and detectors, and other functions onto a single chip to deliver leading-edge coherent optical transceivers.

### Nokia's Portfolio of High-performance Optical Subsystems

- Advanced Coherent TROSAs – an award-winning line of TROSAs based on unique monolithically integrated photonic integrated circuits
- Intelligent Programmable Coherent DSPs – a line of DSPs designed with innovative features, generational interoperability, and leading performance
- Pluggable Coherent Optical Engines – a highly vertically integrated line of coherent pluggable solutions with industry-leading performance and a unique level of intelligence, automation, and programmability



## Advanced Opto-electronics Packaging Facility

Located in Allentown, Pennsylvania, our purpose-built facility supports the clean manufacturing and packaging of our advanced optical engine and fiber optic networking technologies. This facility includes more than 20,000 square feet of Class 10,000 manufacturing and lab space, as well as a Class 100 clean room.

## Nokia Core Disciplines

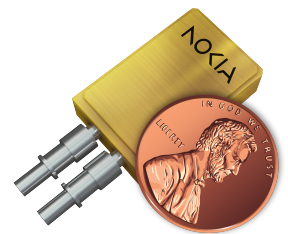
Our core disciplines include coherent ASIC/DSP design, PIC design and manufacturing, analog ASIC design, advanced packaging design and manufacturing, and holistic co-design, including the radio frequency interconnect. Developing all these component technologies in house, as well as packaging them into the final module in house, ensures that we can deliver industry-leading performance and capabilities in our final products.

## Nokia Subsystems Portfolio

### Advanced Coherent TROSAs

Leveraging our in-house InP fab, Nokia's award-winning line of TROSAs is based on unique monolithically integrated PICs. Unlike other technologies such as silicon photonics and discrete InP functions, Nokia's TROSAs reduce loss between components, provide increased control over optical functions, and enable greater flexibility in component design. The result is a solution with industry-leading physical size, power efficiency, flexibility, and optical performance. Nokia's line of TROSAs has been designed with a modular approach to enable easy integration into any advanced coherent optical engine. The initial set of products includes:

- **ICTR64**, a configurable TROSA with a nominal baud rate of up to 70 Gbaud
- **ICTR140**, a configurable TROSA with a nominal baud rate of up to 150 Gbaud



Nokia ICTR64 TROSA

### Intelligent Programmable Coherent DSPs

Designed with innovative features and leading performance, Nokia's DSPs provide a robust set of capabilities and flexibility to bring unique value to networking solutions. As part of our advanced coherent subsystems offerings, Nokia's line of high-performance DSPs includes the following solutions:

- **Wa'a 400™**, a software-programmable 7-nm CMOS Open XR Optics Forum-compliant DSP supporting point-to-point and point-to-multipoint applications
- **Tahoe™**, a high-performance 3-nm CMOS 800G-capable DSP optimized for point-to-point applications complying with Open XR Optics Forum, OIF, and Open ROADM specifications



Nokia Wa'a 400 DSP

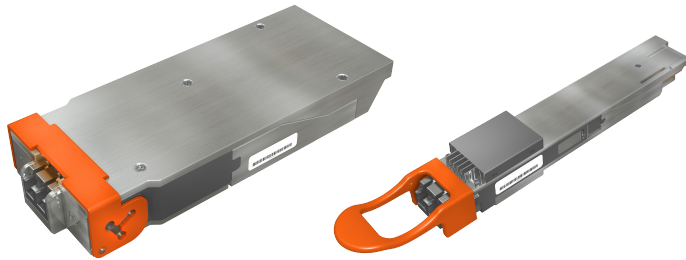


Nokia Tahoe 800 DSP

### Intelligent Coherent Pluggable Optical Engines

Combining Nokia's vertically integrated TROSA and programmable DSPs, our line of Infinite Capacity Engine – Extensible (ICE-X) pluggable DCO solutions is designed to support a diverse set of network applications from regional to metro, DCI, and access, including single-fiber bidirectional configurations and PON overlays. In addition to industry-leading performance, Nokia's ICE-X line of pluggable DCO solutions supports a unique level of intelligence, automation, and programmability to enable network operators to deploy coherent solutions more effectively in a wider variety of networking scenarios without compromising on performance, visibility, or network resiliency.

All products in Nokia's ICE-X portfolio adhere to the open and collaborative approach to the management of pluggable coherent optical engines defined by the Open XR Optics Forum's Management Architecture Specifications.



Nokia ICE-X 400G ZR+ and XR in CFP2 and QSFP-DD intelligent coherent pluggables

The ICE-X portfolio includes the following solutions:

- **ICE-X 100G XR**, an innovative solution enabling edge-optimized transmission, software configurability from 25 Gb/s to 100 Gb/s, and support for both point-to-point and point-to-multipoint configurations. Enabling 100G transmission in only 25 GHz, ICE-X 100G XR provides twice the capacity per fiber when compared to traditional 100G transport connectivity solutions. ICE-X 100G XR is available in both QSFP-DD and CFP2 form factors.
- **ICE-X 100G ZR+**, a high-performance, point-to-point-optimized intelligent coherent pluggable capable of supporting 100 Gb/s transmission on most industry fiber routes. ICE-X 100G ZR+ is available in a QSFP-DD form factor. It enables seamless integration, simplified management, and networking flexibility. ICE-X transceivers support a unique level of integrated intelligence and system-level functionality, simplifying deployment in a wide variety of network scenarios without sacrificing performance, visibility, or network resiliency.
- **ICE-X 400G XR**, a high-performance, intelligent, and programmable pluggable solution capable of supporting both point-to-point and point-to-multipoint configurations. ICE-X 400G XR uniquely enables seamless bandwidth upgrades from 25 Gb/s to 400 Gb/s connectivity. ICE-X 400G XR is available in both QSFP-DD and CFP2 form factors.
- **ICE-X 400G ZR+**, a high-performance, point-to-point-optimized, intelligent, and programmable pluggable with record-setting performance capable of supporting 400 Gb/s transmission on approximately 80% of industry fiber routes. ICE-X 400G ZR+ can be flexibly configured to support 100/200/300/400 Gb/s-based connectivity. ICE-X 400G ZR+ is available in both QSFP-DD and CFP2 form factors.
- **ICE-X 400G ZR**, an efficient transport solution, is an application-optimized 400G intelligent coherent pluggable designed for point-to-point metro and data center interconnect applications. ICE-X 400G ZR is available in a QSFP-DD form factor.
- **ICE-X 800G ZR/ZR+**, an advanced pluggable solution that leverages the power and efficiencies of 3-nm-based CMOS technology coupled with advanced multi-vendor interoperability, including open probabilistic constellation shaping. ICE-X 800G ZR/ZR+ will provide long-haul-capable performance in a low-power, pluggable form factor, including 800G transmission over 1,000+ km. ICE-X 800G ZR/ZR+ is planned to be available in both QSFP-DD800 and OSFP form factors.

For more information on these or any other Nokia solutions, please contact your Nokia sales representative or visit us at [www.nokia.com](http://www.nokia.com).

#### About Nokia

At Nokia, we create technology that helps the world act together.

As a B2B technology innovation leader, we are pioneering networks that sense, think and act by leveraging our work across mobile, fixed and cloud networks. In addition, we create value with intellectual property and long-term research, led by the award-winning Nokia Bell Labs.

With truly open architectures that seamlessly integrate into any ecosystem, our high-performance networks create new opportunities for monetization and scale. Service providers, enterprises and partners worldwide trust Nokia to deliver secure, reliable and sustainable networks today – and work with us to create the digital services and applications of the future.

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