Anatomy of a Coherent Optical Engine

Coherent optical engines have revolutionized the optical networking industry by enabling massive improvements in capacity and reach. Coherent optical technology is now being used in almost all optical networks, including metropolitan, submarine, and data center interconnect networks.

Key Building Blocks

Photonics

An optical semiconductor-based laser that generates light. A modulator then adds the data to be transmitted onto that light. The photonics also detects the received light and converts it to electrical signals.

Analog Electronics

Drivers adapt the electrical output of the digital ASIC/DSP to the requirements of the modulator in the photonics. TIAs take the electrical output from the photodetectors in the photonics and adapt it for the digital ASIC/DSP. This block of technology is typically referred to as RF analog ASIC.

Digital ASIC/DSP

A digital semiconductor that encodes the host device data that is to be transmitted and generates an electrical signal that will be used by the photonics to add that data to the light. A DSP compensates for optical impairments on the receive signal then decodes the data for the host device.

Photonics

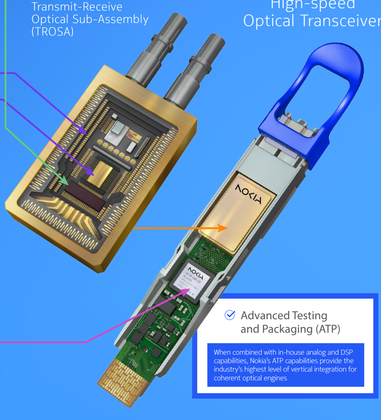
- Free-space optics*
- Tuneable filter (TOF)*
- Wavelength locker
- Laser
- Rx passive photonics
- Photodetector
- Modulator
- Optical amplifier*

Nokia uniquely combines the largest number of these components into a single photonic integrated circuit (PIC)

*These components are or are not required based on the technology used in the engine

Transmit-Receive Optical Sub-Assembly (TROSA)

High-speed Optical Transceiver



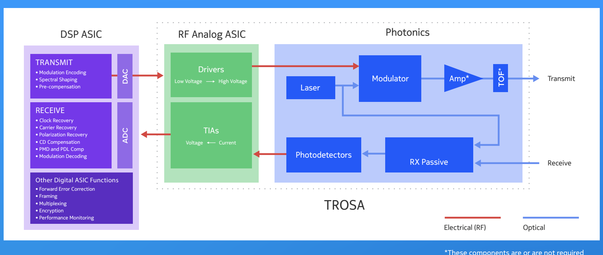
Digital Signal Processor

Nokia uniquely integrates a high degree of intelligence to streamline operations and manageability

Advanced Testing and Packaging (ATP)

When combined with in-house analog and DSP capabilities, Nokia's ATP capabilities provide the industry's highest level of vertical integration for coherent optical engines

Optical Engine Signal Flow



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Digital ASIC/Digital Signal Processor (DSP)

Transmitter

Tells the TROSA how to encode the data onto the light

Receiver

Extracts and decodes the data from the incoming signal

Digital-to-Analog Converter (DAC)

Converts the digital signal from the transmitter to the analog signal required by the TROSA

Analog-to-Digital Converter (ADC)

Converts the analog signal from the TROSA to a digital signal that the receiver can understand

TROSA

TROSA stands for transmit-receive optical sub-assembly and is a single package containing both the analog electronics and the photonics

Radio Frequency (RF) Interconnects

Electrical connections between the digital ASIC/DSP and the analog electronics, and between the analog electronics and the photonics

Packaging

How the components of the device are put together leveraging the latest materials, design methodologies, and manufacturing techniques

Analog Electronics

RF Analog ASIC

Made from silicon germanium (SiGe); contains a driver to amplify the analog signal from the DSP to drive the modulator and a transimpedence amplifier (TIA) that amplifies the signal from the photodiode before it goes to the ADC part of the DSP

Photonic Integrated Circuit

Nokia pioneered photonic integration with the industry's first large-scale PIC in 2005 and continues to lead the industry with its sixth-generation PIC in ICE6. Leveraging high-performance indium phosphide (InP), Infinera's PICs integrate a wide range of optical functions on a single chip. This reduces cost, footprint, and power consumption while improving performance and reliability. In addition, Infinera has invested heavily to build its own state-of-the-art indium phosphide PIC fab and is the only equipment manufacturer to have done so.

Photonics

Laser

Generates light at the required frequency

Optical Amplifier

Amplifies the optical signal, enabling high transmit power

Non-InP-based solutions typically require a discrete amplifier

Modulator

Encodes the data onto the light by changing its amplitude and phase

Photodetectors

Detect the light and convert it to electrical current

RX Passive Photonics

Distributes the components of the light to the correct photodetectors

Tuneable Optical Filter (TOF)

Required by some devices to remove excess noise from the amplifier (not required by Nokia due to the sophisticated InP PIC-based design)