

Coherent Optics Explained

In the always-evolving world of communications, coherent optics deeply improved our ability to transmit at high capacity over vast distances. Coherent optical fiber communications were studied extensively in the 1980s to improve optical transmission reach, but the high complexity of receivers made the technology not so cost-effective to deploy. After 2005, a [technological breakthrough](#) made coherent systems more economically viable, and ever since, they've become a big part of optical networks. Since then, coherent technology has slowly but surely spread out from the network core and become more widely available on the network edge, which is a transition that EFFECT Photonics believes in.

This article delves into the fundamental principles behind coherent optics and why it's become indispensable in modern telecommunications infrastructure.

The Basics of Coherent Transmission

Let's start by discussing some basic concepts.

An optical transceiver is a device that converts electrical signals into optical signals for fiber transmission and vice versa when the optical signal is received. It interfaces between fiber optical networks and electronic computing devices such as computers, routers, and switches.

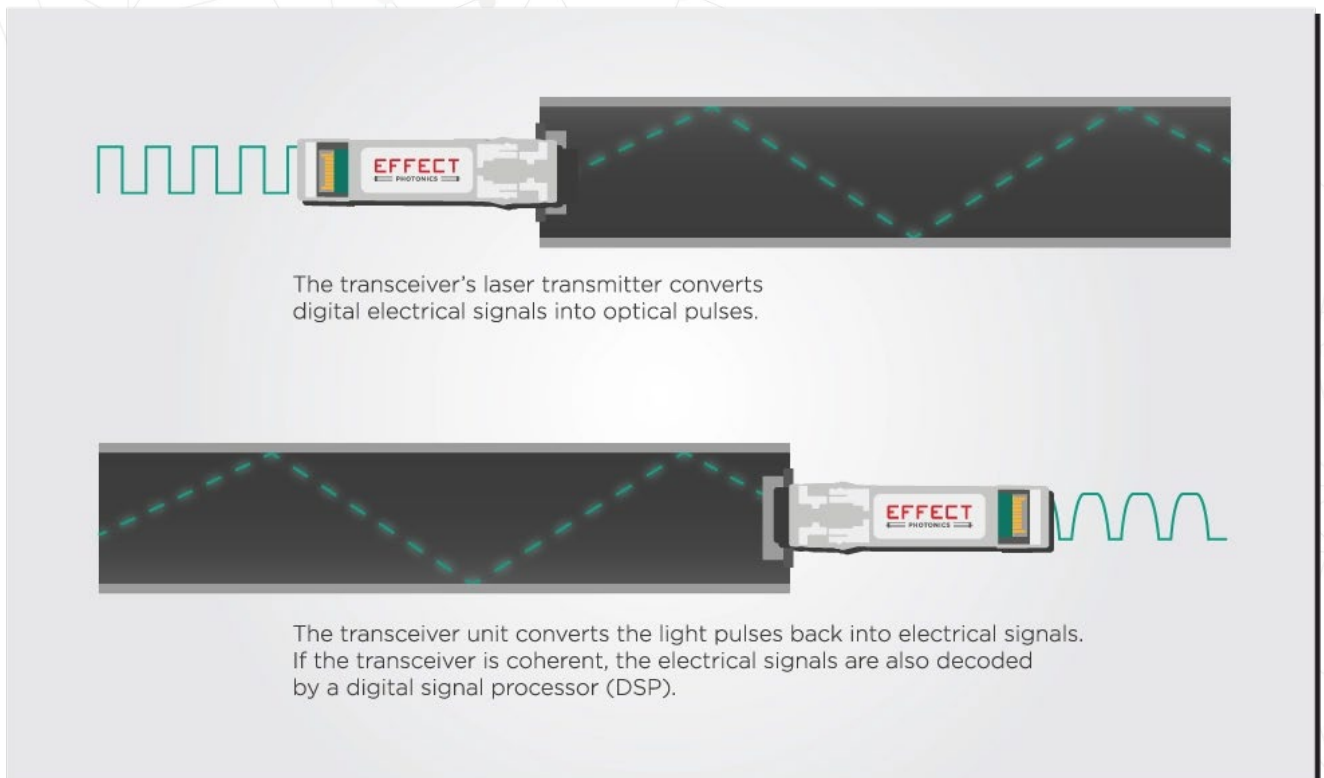


Figure 1: How transceivers convert electrical data signals into light pulses and vice-versa. The transmitter has a laser or LED that generates light pulses representing the electronic data signal. On the receiving end, the receiver detects the optical signals and converts them back into electrical signals, which electronic devices can further process.

There are a few ways to encode electrical data into light pulses. Perhaps the most basic way is called intensity modulation/direct detection (IM-DD). That's a fancy way of saying that the same digital 0s and 1s of your electrical signal will be imposed directly on your light signal. This method is akin to turning a flashlight on and off to send a Morse code message.

The advantage of IM-DD transmission is that its simplicity makes the transceiver design simpler and more affordable. However, there are limitations to how much data and distance this approach can cover.

Coherent transmission improves the range and capacity of data transmission by encoding information in other properties of a light wave. To summarize the key light properties:

- the **intensity** is essentially the height of the light wave
- the **phase** is the position of the wave in its cycle
- the **polarization** is the orientation of the wave

While IM-DD transmission only encodes information in the intensity of a light wave, coherent transmission encodes information into all three properties, allowing coherent systems to send far more data bits in a single light wave. A receiver's ability to read the phase and polarization also makes the optical signal more tolerant to noise, which expands the potential transmission distance. The following video from our YouTube channel explains briefly how this works in a more graphical way.



The Role of a DSP and Laser in Coherent Systems

A sophisticated digital signal processor (DSP) encodes and decodes electrical signals into light signals in a coherent system. This is the electronic heart of the system. The DSP does much more than that: it compensates for transmission impairments in the fiber, performs analog-to-digital signal conversions (and vice versa), corrects errors, encrypts data, and monitors performance. Recently, DSPs have taken on more advanced functions, such as [probabilistic constellation shaping](#) or dynamic bandwidth allocation, which enable improved reach and performance.

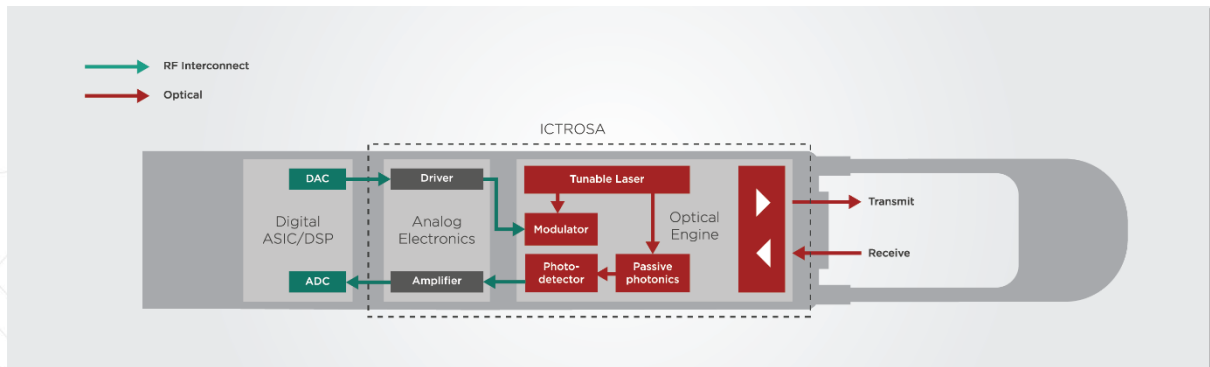


Figure 2: Simplified diagram of the building blocks of a coherent QSFP transceiver designed at EFFECT Photonics, which includes a DSP and tunable laser. A particularity of our company's implementation of the transceiver is that the tunable laser is integrated into the same optical engine chip as the other optical components.

The tunable laser is also a core component of all these optical communication systems, both IM-DD and coherent. The laser generates the optical signal encoded and sent over the optical fiber. Thus, the purity and strength of this signal will massively impact the bandwidth and reach of the communication system. For example, since coherent systems encode information in the phase of the light, the purer the light source is, the more information it can transmit.

The Miniaturization of Coherent Optics

In the past, coherent communications were the domain of complicated benchtop systems with many discrete components that were cumbersome to connect. When Nortel (later Ciena) introduced [the first commercial coherent transponder](#) in 2008, the device was a bulky, expensive line card with discrete components distributed on multiple circuit boards. Such technology was reserved for premium long-distance links where performance is everything.

As time went by, coherent devices got smaller and consumed less power. By 2018, most coherent line card transponder functions could be miniaturized into CFP2 transceiver modules that were the size of a pack of cards and could plug into modules with pluggable line sides. QSFP modules followed a couple of years later, and they were essentially the size of a large USB stick and could be plugged directly into routers. This reduction in size, power, and cost, as well as the ever-rising data demands of telecom networks, has made coherent technology increasingly viable in metro and access networks.

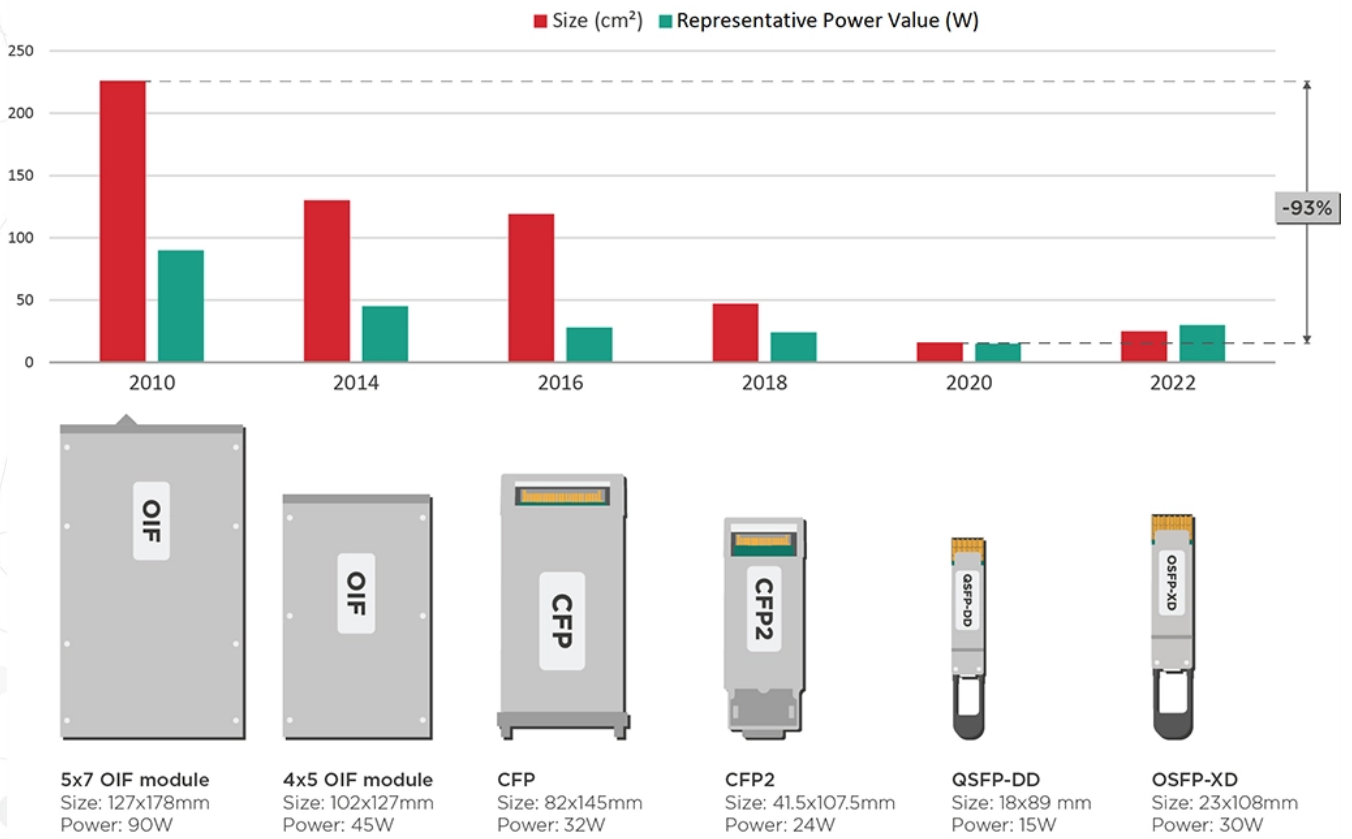


Figure 3: Coherent module size and power consumption evolution from OIF MSA line card modules to pluggable modules like CFP and QSFP.

Takeaways

Coherent optics transformed telecommunications, marrying complex theoretical foundations with practical engineering advancements to substantially enhance data transmission capacities and distances. The journey of coherent systems from benchtop experiments to the backbone of our digital infrastructure is an excellent example of how progress and evolution in optical communications work, always driven by the ever-increasing demands of our interconnected world.

EFFECT Photonics, with its focus on integrating advanced technologies like DSPs and tunable lasers into compact, efficient transceivers, strongly believes in making coherent optics more accessible and bringing them deeper into the network edge.

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