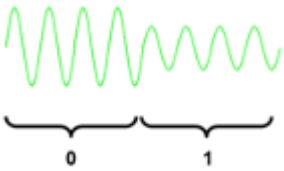
What is Coherent Optics?

Today, the world bandwidth need is getting higher and higher, it increases from 25 to 50 percent every year and the actual installation running at 10G or 40G are not enough to keep up with this huge demand and fast scalability requirement.

As of today, the most common way to send data with light is accomplished via simple amplitude modulation (on-off keying OOK). This means that the light is switched on and off to send data. But this simple way of proceeding has reached its limit because we cannot switch the light fast enough on and off to increase the data transmission rate. So, industry has been looking for more sophisticated ways of modulating the light. Many other proven modulation techniques already exist in the RF transmission world. So, industry is applying and adapting some of these techniques to modulate the light. Coherent optics regroups these techniques using the various properties of the light to send more data. These key properties of the light are its amplitude, phase, and polarization.

Amplitude modulation

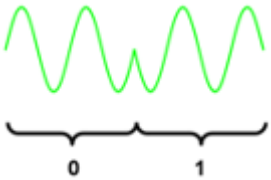
Instead of using the simple OOK modulation (black & white), we can use various intermediate levels of amplitude (grey levels). It's like a dimmer for a light bulb. We talk about ASK: Amplitude Shift Keying.



Amplitude Modulation

Phase modulation

Keeping in mind that the light behaves like a wave, each wave (like a water wave on a lake) has a front edge, a peak and a leading edge. To explain phase, let's imagine a constant wind blowing over a lake, it means that water waves will follow each other, and their peak will arrive at constant interval. With eye closed and a precise clock, we can even anticipate when each peak will arrive. It means that phase is constant because there is no change. Now, if for any reason, the water peak does not arrive at the predicted time, it means that something has happened. The phase has been changed; the phase has been modulated by one event. This event is a piece of information by itself. Now coming back to the light, imagine that we can detect its phase, then any well controlled light phase modulation can be used to send & detect data. It's the phase modulation. We talk about PSK: Phase Shift Keying. The phase of a carrier is varied between two states to represent zeroes and ones.



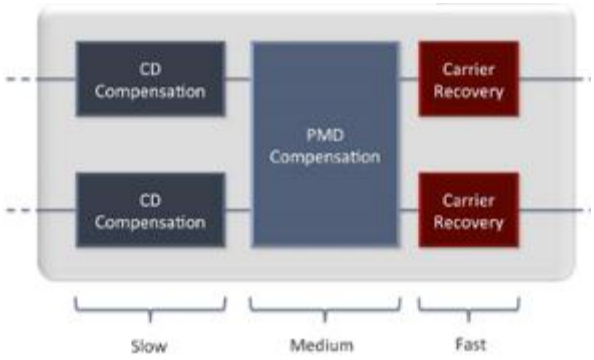
Phase Modulation

Polarisation Directions

With light carrier wave, there is one additional degree of freedom, which is the light polarisation; There are two main directions of polarisation: Vertical & Horizontal; Both are used independently to encode the message. These two directions could also be used to transport separated messages. It is the polarisation modulation. With coherent optics, we use the vertical & horizontal polarisation of the light to transmit data.

Polarisation Directions

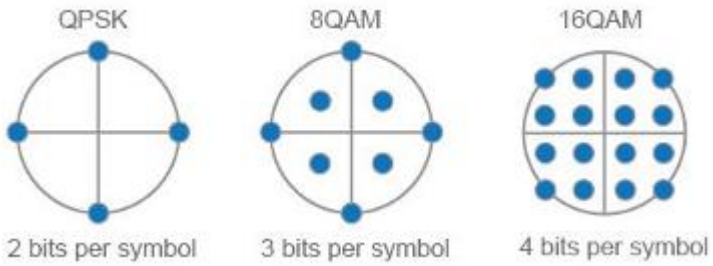
Coherent technology uses the three degrees of freedom (amplitude, phase & polarization of the light) to pack more data on the wave which is transmitted. By this way, we can reach much higher bit rates on a single wavelength under coherent modulation. To achieve this goal, we need coherent optical engine (coherent transmitter and receiver) supported by a sophisticated piece of electronics to make the job. This is the role of the DSP (Digital Signal Processor). This DSP has various functionalities like Chromatic Dispersion (CD) compensation, Polarisation Mode Dispersion (PMD) compensation, non-linearities compensation, symbol clock recovery, carrier phase recovery, frequency offset compensation, symbol detection, polarisation demultiplexing.



All these functionalities will lead to higher flexibility in lines rates, with scalability from 100G to 400G and beyond per single signal carrier

What about terms like QPSK or QAM?

QPSK means Quadrature Phase Shift Keying. In fibre optics, it means shifting the phase of the light wave with four different possibilities while keeping the amplitude fixed. QPSK is synonymous with 4 QAM where QAM stands for quadrature amplitude modulation and where we do not play with the amplitude of the signal. The technology allows to put more and more level of phase and amplitude to reach 8QAM, 16QAM, 32QAM and even 64QAM. The more levels you add, the higher bit rates you can reach. For instance, 64QAM packs 6 bits per symbol. It means that a flow at 100 GBaud/s would correspond to the transmission of 600 Gbit/s signal with OOK, which is technically not possible.



High-order modulation – Constellation diagrams

In Summary, the coherent optical technology comes with the below advantages:

- Programmability: This technology can be tailored for a wide variety of networks and applications and the same card can support multiple modulation formats and/or different baud rates, enabling operators to choose from a variety of line rates.
- High-gain soft-decision Forward Error Correction (FEC): Enables signals to traverse longer distances while requiring fewer regenerator points. It provides more margin, allowing higher bit-rate signals to traverse farther distances. This results in simpler photonic lines, less equipment, lower costs, and a significant increase of the bandwidth.
- Spectral shaping: Provides greater capacity across cascaded Reconfigurable Optical Add-Drop Multiplexers (ROADMs), resulting in increased spectral efficiency for super channels. Spectral shaping is critical in flexible grid systems because it allows carriers to be squeezed closer together to maximize capacity.
- Strong mitigation to dispersion: Offers better optical performance at higher bitrates. Coherent processors must account for dispersion effects after the signal has been transmitted across the fibre, including compensating for CD and PMD. The advanced digital signal processors in coherent optics take away the headaches of planning dispersion maps and budgeting for PMD by mitigating these effects. Additionally, coherent processors improve tolerances for Polarisation-Dependent Loss (PDL) and must rapidly track the State of Polarisation (SOP) to avoid bit-errors due to cycle slips that would otherwise affect optical performance. As a result, operators can deploy line rates up to 400G per carrier across longer distances than ever; high bit-rate signals can even be deployed on old fibre that previously could not support 10G.

Source:
Skylane Optics