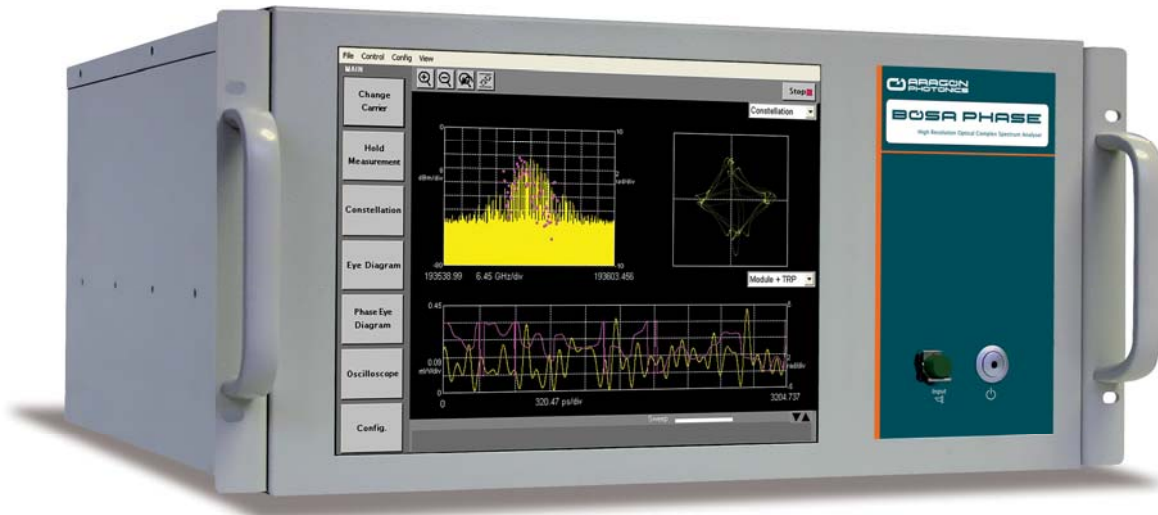


BOSA PHASE

High Resolution Optical Complex Spectrum Analyser



When the **Optical Phase** becomes
Essential for your **System**

Introduction

The BOSA PHASE High Resolution Complex Optical Spectrum Analyser is a laboratory piece of equipment which offers a complete analysis, amplitude and phase, of optical signals.

Based on an innovative optical technology, the unit performs high accurate amplitude and phase measurements of optical signals spectral components. From this information directly obtained in the frequency domain, a complete temporal analysis can be reached by using the inverse Fourier transform.

The BOSA PHASE offers its best when you pursue to analyze advanced modulation formats used in new transmission systems operating at 40 Gbits/s and 100 Gbits/s. Software functionalities offers complementary representations of the signal under test: complex spectrum, temporal evolution, eye diagram and constellation charts.

Applications

Amplitude and phase modulation analysis

The BOSA PHASE directly measures modulated signals with a pseudorandom pattern, offering the possibility to obtain the optical phase temporal variation with no need of demodulation. The BOSA PHASE offers all the information about the modulated signal to the user; the optical complex field, eye diagram, amplitude temporal evolution, instant phase or frequency and constellation diagram can be shown.

Any representation of the complex signal is possible. In Figure 1 and Figure 3 amplitude and phase eye diagram are shown for QPSK NRZ and RZ modulations. Four phase levels and all the transitions between them are clearly seen. In Figure 3 the amplitude eye diagram is shown. It can be observed how the phase become random when there is no signal and the pulses have different phase values depending on the transmitted symbol.

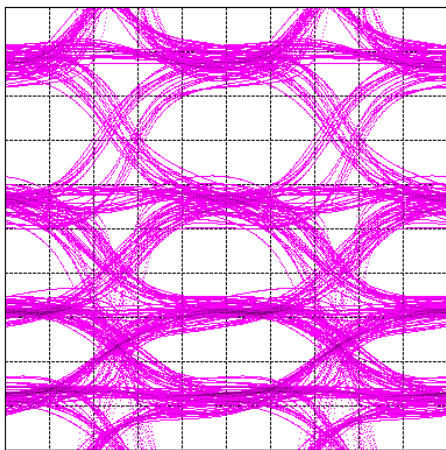


Figure 1. Phase Eye Diagram NRZ-QPSK

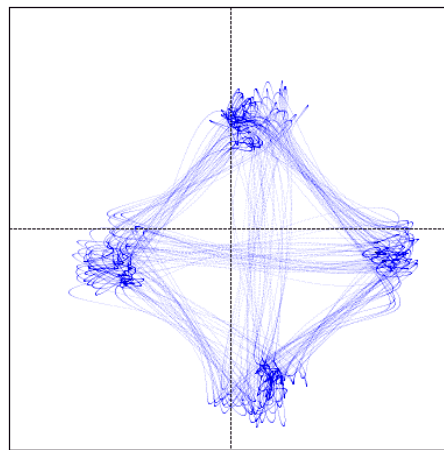


Figure 2. Complex Optical Field NRZ-QPSK

Figures 2 and 4 show the optical complex field evolution, the imaginary and real part of the signal are plotted in the vertical and horizontal axis respectively. The four symbols are separated 90° degrees. In the case of a RZ modulation all the transitions pass through the origin.

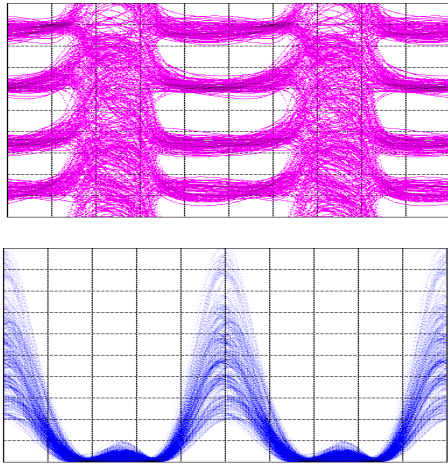


Figure 3. Eye Diagram RZ-QPSK

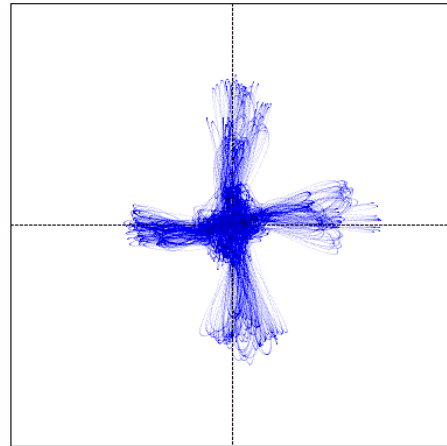


Figure 4. Complex Optical Field RZ-QPSK

TRC measurement in optical transmitters

The temporal frequency variation of the optical transmitters, known as dynamic chirp, is one of the most important parameter due to the impact it has on the transmission systems: pulse broadening, which limits the channel spacing in UDWDM systems, and increment of the transmission link penalty, due to the interaction between chirp and fiber dispersion.

The chirp parameter can be directly obtained from the inverse Fourier transform of the complex field.

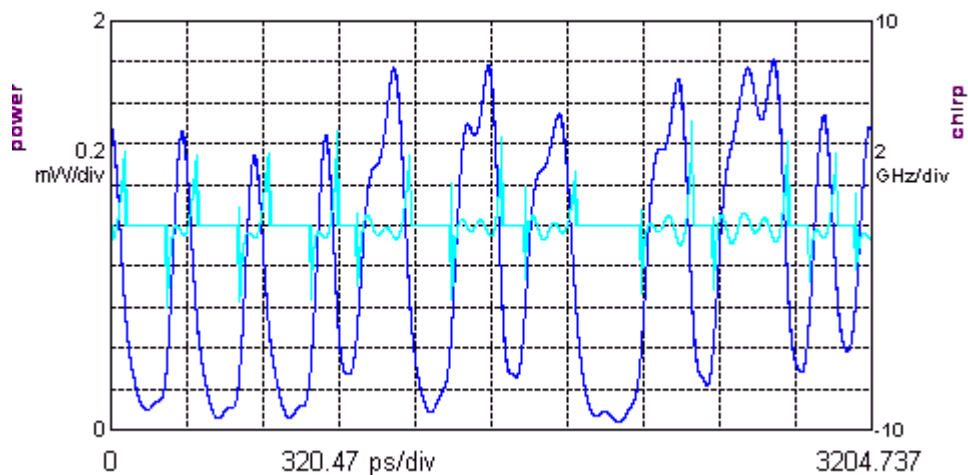


Figure 5. Complex Optical Field RZ-QPSK

In the above figure the temporal evolution of an amplitude modulated signal is shown. The optical intensity variation and the instant frequency are shown in the left and right axis. There are negative frequency peaks in the transitions 0-1, and positive peaks in the transitions 1-0. The chirp value is small because the modulation was carried out with an external MZ. In this situation there is no adiabatic chirp and only the transient one contributes. The chirp causes the broadening of the spectrum and constitutes a problem in association with the chromatic dispersion of the link.

Short pulses analysis

It is possible to measure a great number of optical frequency components, high bandwidth, to recover temporal evolution of short pulses repetitive signals. The measurement is carried out with an extremely high temporal resolution.

High resolution spectral analysis

The BOSA PHASE performs with the same amplitude measurement specifications as the BOSA does. It includes 10 MHz of resolution, 80 dB of dynamic range and an extremely high filtering performance with a close-in dynamic range of 40 dB at 0.33 pm and 60 dB at 0.44 pm.

The next four figures show the optical spectrum measured by the BOSA PHASE. The signals are modulated at 10 Gbaud using a pseudorandom pattern. The pattern length is 31 bits and the modulation format is RZ and NRZ DPSK and DQPSK. The DQPSK format has been obtained feeding the two arms of the modulator with the same pattern and delaying one of them 13 bits. It can be observed how the spectra are discrete and composed by frequency components separated 322 MHz. This value corresponds to the pattern repetition rate and can be obtained by dividing the symbol rate (10 GSymbol/s) by the pattern length (31 symbols). Thanks to the resolution of the BOSA the frequency lines of the spectrum are clearly measured. The phase value of every spectral component is shown as well. The measured values are represented between $-\pi$ and π .

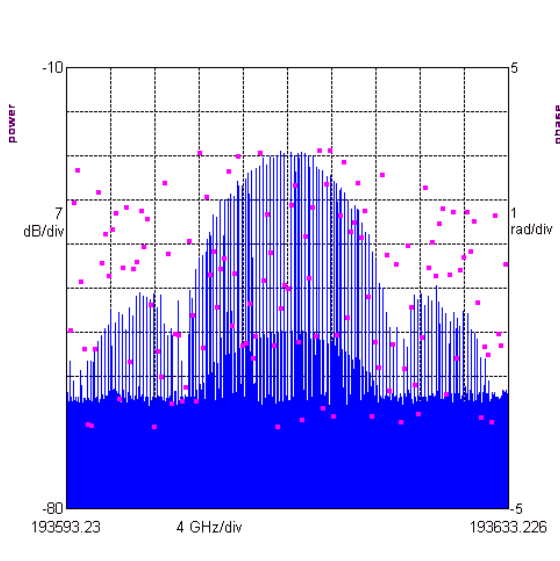


Figure 6. 9,8 Gb/s NRZ-DPSK

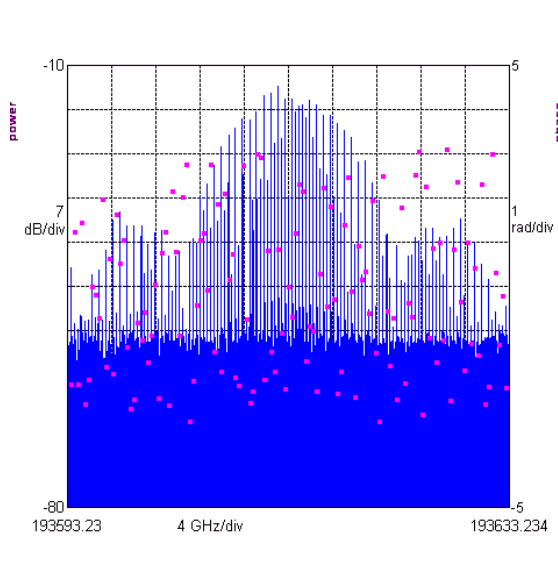


Figure 7. 20 Gb/s NRZ – DQPSK

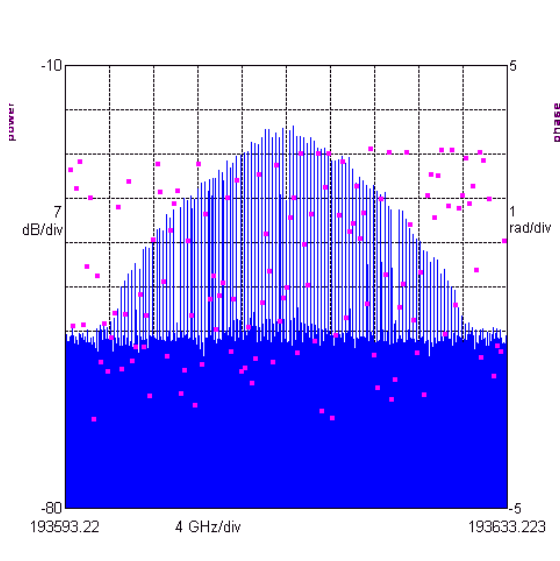


Figure 8. 9,8 Gb/s RZ DPSK

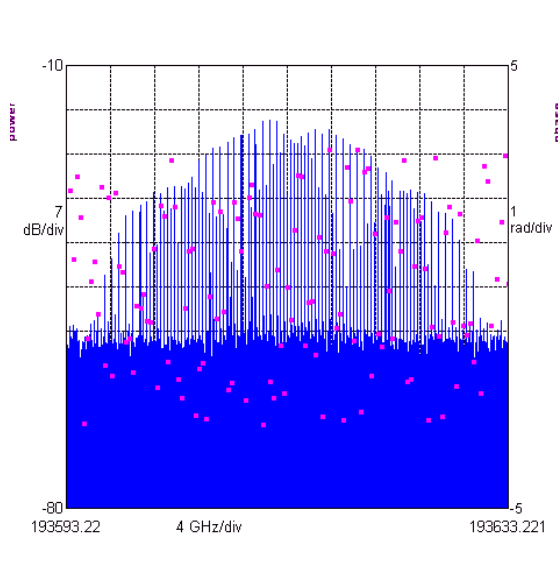


Figure 9. 20 Gb/s RZ-DQPSK

Please note how the spectrum is broadened in the RZ modulations in comparison to their equivalents NRZ. It can be observed as well how the multilevel modulations like the QPSK let double the number of transmitted bits per second while they use the same frequency bandwidth of the corresponding PSK.

The complex spectrum is very useful when medium dispersive effects want to be applied directly on the signal. The inverse Fourier transform of the modified complex field will lead to a temporal signal which can be used to derive the degraded eye or constellation.

BOSA and BOSA PHASE Technology

Stimulated Brillouin Scattering: Selective amplification

When a light beam with certain intensity propagates through a material media, a non linear effect known as Spontaneous Brillouin Scattering takes place. As a consequence, part of the transmitted light is backscattered. This situation is easily achievable if the propagation media is an optical fiber where high optical power can be injected in small areas.

If a second beam is introduced in the fiber in a contra propagating way, the non linear effect is known as Stimulated Brillouin Scattering. In this situation one of the beams acts as a pump to the effect and the Brillouin Scattering is intensified. There is an effective transmission of optical power between both signals. The amplification is wavelength selective and takes place in a small spectral range of only 10 MHz (0.08 pm).

BOSA: Brillouin Optical Spectrum Analyser

The BOSA uses the non linear effect described above to obtain high resolution spectral measurements. Due to the intrinsic behavior of the Brillouin effect, other parameters like dynamic range or measurement time are not sacrificed. The measurement is performed by inputting the signal under test in an optical medium. In the contra propagating way a tunable laser is introduced, acting as a pump of the phenomenon, and generating the amplification and backscattering of the signal under test.

As the tunable laser is swept around the spectral region of the signal under test a backscattered optical intensity is obtained. It is proportional to the spectral density of the signal and is measured with a 10 MHz of resolution. Thus the unit is able to offer extremely high measurement sensitivity, due to the amplification obtained, as well as the highest resolution, due to the narrow Brillouin gain profile.

Complex Spectral Measurement: BOSA PHASE

Based on the same measurement technique, the BOSA PHASE measures not only the amplitude of the spectrum but also the relative phase between components of discrete spectra.

The Fourier analysis justify that any periodic signal is composed by a sum of sinusoidal signals with different amplitude, frequency and phase. The frequencies of the constituent signals are multiples of the fundamental frequency.

The phase measurement technique uses a double Brillouin tunable filter with a frequency separation equal to the fundamental frequency of the signal under test. When sweeping the filter over the signal under test, pairs of components are filtered simultaneously and relative phase information between them can be derived.

Preliminary Product Note

The complex spectrum provides complete information about the signal. By applying the Inverse Fourier Transform (IFFT) temporal variations of the amplitude, phase and instant frequency can be obtained.

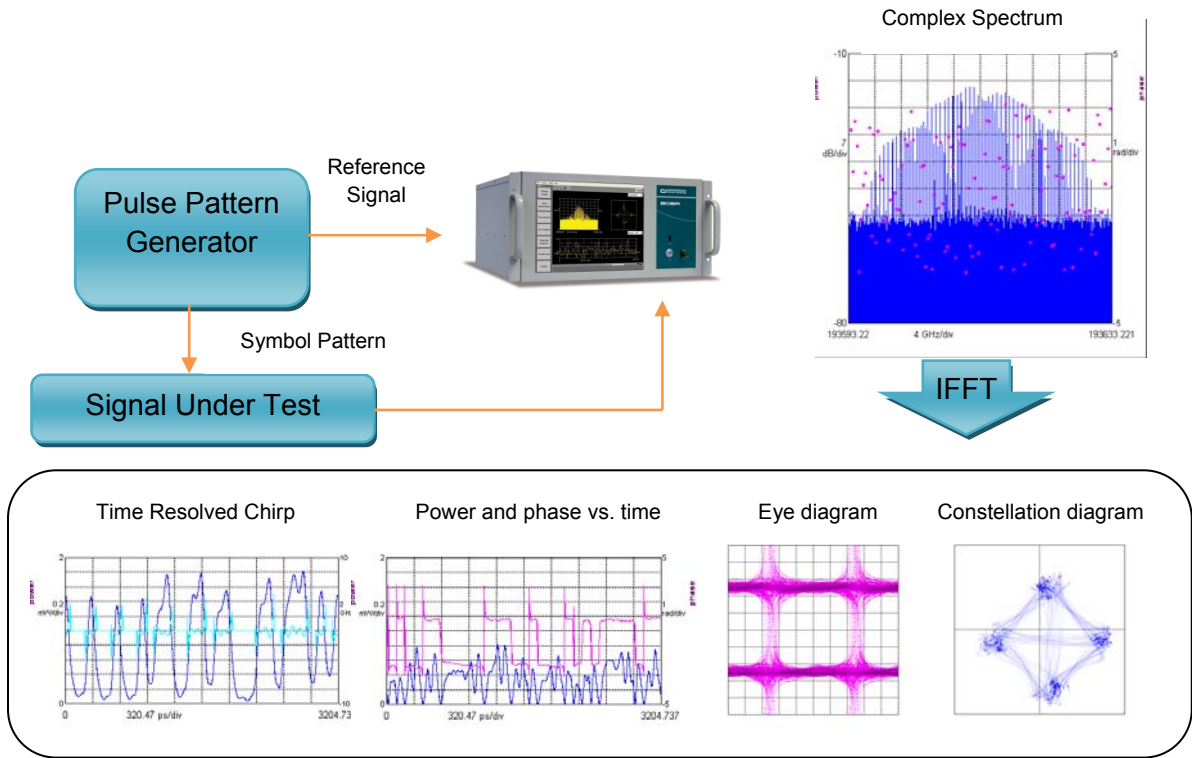


Figura 10. Measurement Setup BOSA PHASE

Advantages of measuring the complex spectrum

Independent on the transmission rate. Any transmission rate can be measured because there is no bandwidth limit. In order to measure high transmission rates it is required to increase the pseudorandom pattern length to obtain a frequency component separation suitable for the BOSA PHASE.

Independent on the modulation format. It is not required to demodulate the signal; the measurement is directly performed in the complex field. It does not matter if the carrier is modulated in frequency, amplitude or phase. The analysis of the complex spectrum allows recovering the temporal variation of any parameter of the signal.

Independent on the receiver. There is no need of demodulation since the information is directly obtained from the optical spectrum. So, the detection change does not contribute to modify or distort the signal as in other laboratory pieces of equipment occur.

Excellent technical features. Thanks to the use of the BOSA technology a high accuracy is reached in the relative phase and amplitude measurement. As a consequence higher measurement bandwidth is obtained than in other techniques for the same word length.

Technical Specifications

Optical Complex Spectrum Analyser BOSA PHASE	
Wavelength measurement range	1528 nm -1565 nm
Reference frequency ⁽¹⁾	Fr1 = 312 ± 50 MHz Fr2 = 1.25 ± 0.25 GHz
Reference power	> -10 dBm
Optical power measurement range ⁽²⁾	-58 dBm to +10dBm
Phase measurement repeatability	±1° (+10dBm to -30 dBm)
Measurement refresh time ⁽³⁾	2s
Pattern length ⁽⁴⁾	R/Fr

High Resolution Optical Spectrum Analyser BOSA	
Optical Resolution (@3dB)	80fm (10MHz @1550nm)
Wavelength measurement range	1528-1565nm
Wavelength span	1 pm to complete wavelength range
Wavelength Accuracy	+/-2pm (@1550nm)
Dynamic range	>80dB
Close-in dynamic range	>40dB @±0.33pm (filter width @ 40dB depth) >60dB @±0.44pm (filter width @ 60dB depth)
Power range	+10 to -70dBm
Maximum Safe Total Input Power	+20 dBm
Sensitivity ⁽⁵⁾	-70dBm/0.1pm
Power Accuracy ⁽⁶⁾	±1.5 dB
Polarization Dependence	±0.5 dB
Measurement time	1s for 10 nm

- (1) Reference frequency must be the same as the pattern repetition frequency
(2) Optical power of spectrum components to obtain accurate measurement of phase
(3) Measuring 80 GHz span w/o polarization control, independent of the number of spectrum components measured
(4) Where R is the transmission bit rate (bits/second) and Fr is the pattern repetition frequency(Hz)
(5) Sensitivity is defined as signal value > 6x RMS noise value, after averaging, polarization control and with *Lock Trace* on.
(6) Valid for any wavelength and power value (polarization dependence included). Valid for measurements made with polarization control, in high sampling rate mode and averaging. For 1σ (63 % of the cases) typical value: ±1 dB.

These specs are subject to change without further notice. Check out the latest status in www.aragonphotonics.com.

Examples of Analyzed Transmission Bit Rates R(*)				
Transmission bit rate R	2.5 Gb/s (±0.401)	10 Gb/s (±1.603)	25 Gb/s (±4.006)	40 Gb/s (±6.410)
Nominal Pattern Length (Fr2)	2 bits	8 bits	20 bits	32 bits
Nominal Pattern Length (Fr1)	8 bits	32 bits	80 bits	128 bits

(*) Other transmission bit rate R can be analyzed following the relation R/Fr