

## Measurement of the chirp parameter $\alpha$ in Mach-Zehnder Modulators using **BOSA**

*Abstract: Chirp parameter characterization in Mach-Zehnder modulators using the **BOSA** spectra*

The chirp parameter  $\alpha$  is critical to optical communication systems, because its interaction with chromatic dispersion introduces a limitation to the link distance without regenerating the signal. In this paper, we will show how to extract  $\alpha$  from measurements of the output spectrum of a Mach Zehnder modulator modulated with a sine wave.

The measurement set up for the measurements of the  $\alpha$  parameter in Mach-Zehnder modulators using the **BOSA** is shown in the Fig.1

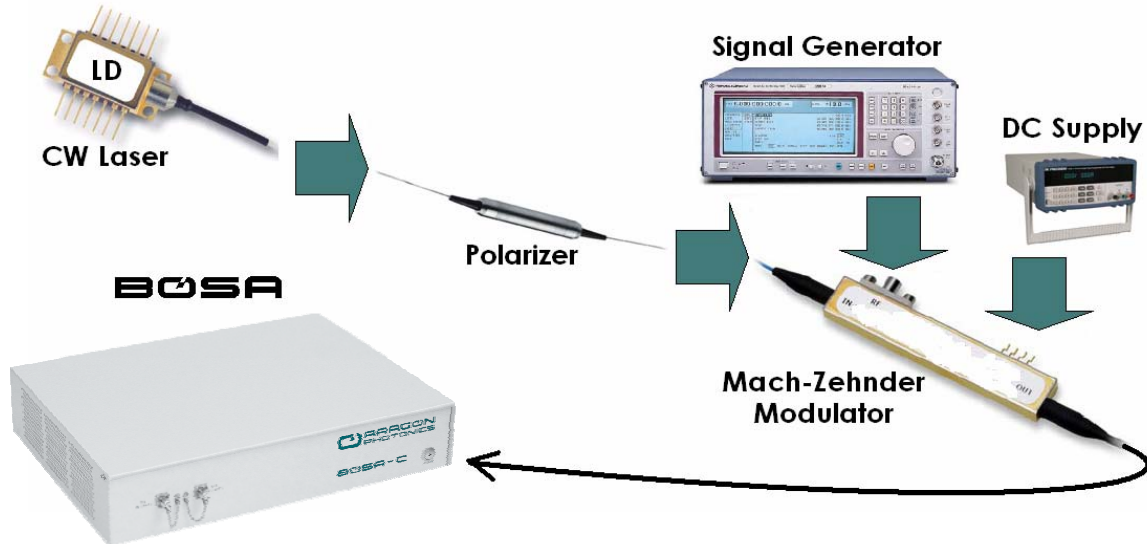


Fig. 1: Measurement setup for the measurement of the chirp parameter  $\alpha$ . Polarizer may not be needed depending on the type of CW Laser and modulator.

A Mach-Zehnder modulator (MZM) is an interferometer with variable retardation in one of its branches that is controlled by a bias voltage. It has a sine-like electrical-to-optical response (Fig. 2.) The operation point is tuned with the bias voltage, in normal operation to the quadrature point.

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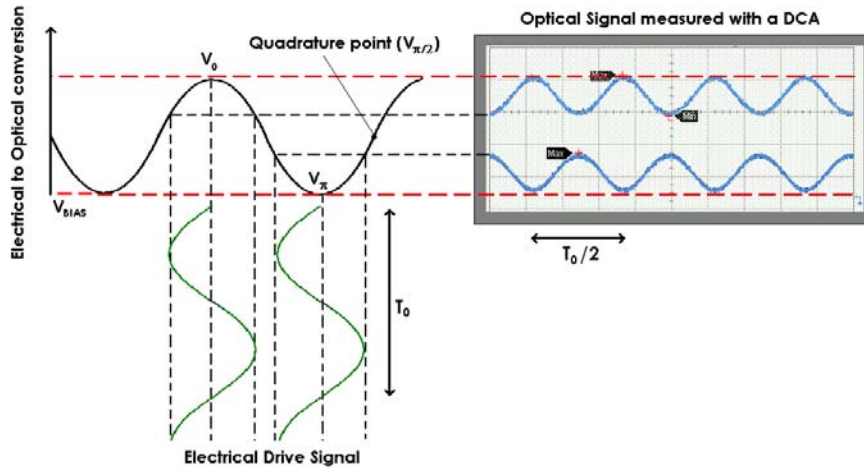
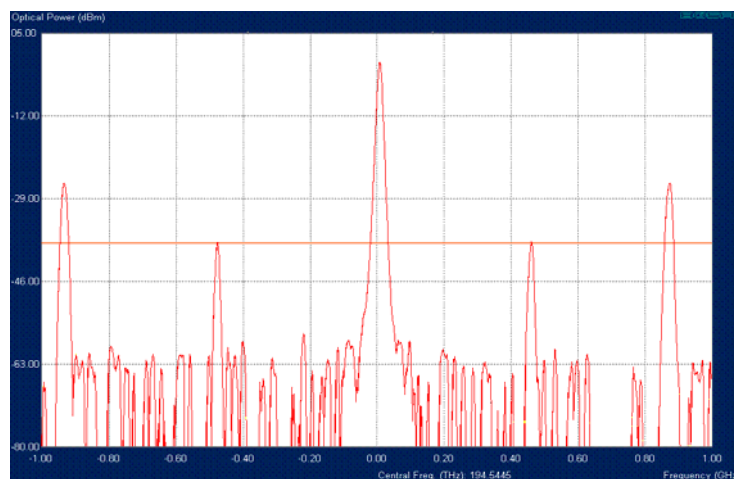


Fig. 2: Mach-Zehnder modulator operation scheme.

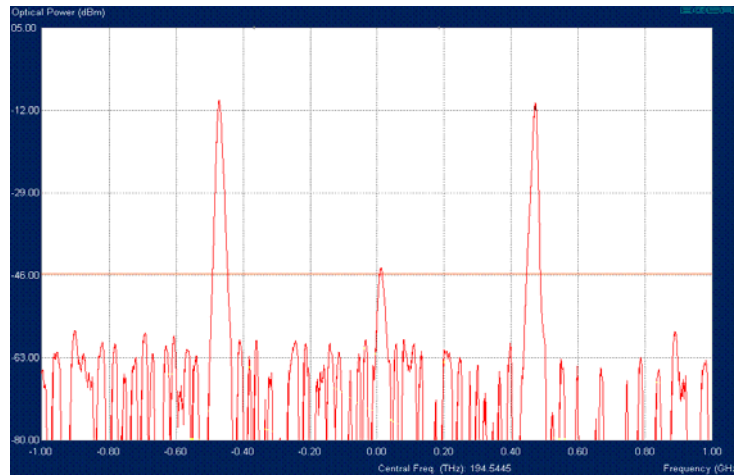
When biased to the extremes of the transmission function, a highly nonlinear response is obtained, resulting in a duplication of the modulation frequency, as can be seen in Fig.2. This has its effect on the optical power spectrum. Thus, when biased to the top of the response curve ( $V_0$  - Fig.3 a), the carrier is maximum and the 2nd order harmonics are higher than the 1st order ones. If we modify the bias in order to make the carrier minimum, we are now in the bottom of the response curve. The double frequency component is now obtained from heterodyne interaction of the 1st order sidebands.



(a)

Fig. 3: Measurement of the output optical spectrum of the MZM modulated with a 450 MHz sine signal biased (a)  $V_0$

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(b)

Fig. 3: Measurement of the output optical spectrum of the MZM modulated with a 450 MHz sine signal biased (b)  $V_{\pi}$

Measuring the amplitude of the carrier and the sidebands for these two situations,  $\alpha$  parameter for quadrature point can be obtained applying the following expression<sup>1</sup>:

$$\alpha_{\pi/2} = \frac{I_0^{1/2} \cdot I_0^{1/2}(f_m) + I_{\pi}^{1/2} \cdot I_{\pi}^{1/2}(f_m)}{I_0^{1/2} \cdot I_{\pi}^{1/2}(f_m) - I_{\pi}^{1/2} \cdot I_0^{1/2}(f_m)}$$

where  $I_0$  and  $I_0(f_m)$  are the carrier and sideband power, respectively at  $V_0$ , and  $I_{\pi}$  and  $I_{\pi}(f_m)$  the same for  $V_{\pi}$ .

These amplitude measurements and the calculation of  $\alpha$  parameter can be easily automated using the **Macro Tool function** implemented in the **BOSA**.

[1] N. Courjal, J.M. Dudley and H. Porte "Extinction-ratio-independent method for chirp measurements of Mach-Zehnder modulators" Optics Express Vol. 12, No.3 pp. 442-448, 2004

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## Benefits of measuring $\alpha$ in Mach-Zehnder with the **BOSA**:

- The high resolution of the **BOSA** allows measurements at relative low frequencies (hundreds of MHz instead of GHz).
- The high dynamic range of the **BOSA** gives a great sensitivity and precision to the measurement of  $\alpha$  not achieved with other high-resolution devices.
- The measurements can be easily automated using the Macro Editor built-in function of the **BOSA**.

*All the best*

*The Aragón Photonics Team*

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