Time-Resolved Chirp Measurements Using Complex Spectrum Analysis Based on Stimulated Brillouin Scattering

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Abstract: A novel method to measure the complex optical spectrum of digitally modulated signals based on stimulated Brillouin scattering (SBS) is presented. Time resolved chirp measurements of a 10 Gbps modulation is performed using this technique.

OCIS codes: (300.6380) Spectroscopy, modulation; (290.5900) Scattering, stimulated Brillouin

1. Introduction

Measurement of the instantaneous power and frequency of an optical signal, frequently called time-resolved chirp (TRC), is a valuable tool for the characterization of optical signals, sources and modulators. There are two approaches to obtain TRC data: the use of frequency to intensity converters followed by an optical sampling oscilloscope [1], and the measurement of the complex spectrum and retrieval of the TRC data through inverse Fourier transform [2]. The former requires a measuring bandwidth for the frequency detection far exceeding that of the intensity modulation, while the latter is limited by the width of the analysis filter and the presence of spurious components.

In this paper we propose a method for the measurement of the complex spectrum of modulated signals using double Brillouin filtering and heterodyne detection. We apply this technique to the measurement of an externally modulated laser driven with a 2^5=32 bit NRZ pattern modulated at 10 Gbps.

2. Experimental setup

SBS is a nonlinear effect that appears when two counter-propagating signals are present in the fiber with a wavelength separation corresponding to the Doppler shift [3]. A power transfer is produced from the higher frequency wave, or pump wave, to the lower frequency wave, that we will consider as the signal under test (SUT), in a narrow bandwidth (10-30 MHz) with a gain profile that varies from Lorentzian to Gaussian depending on the pump power [4] and that can be used as a tunable narrowband optical filter for amplitude spectrum analysis [5].

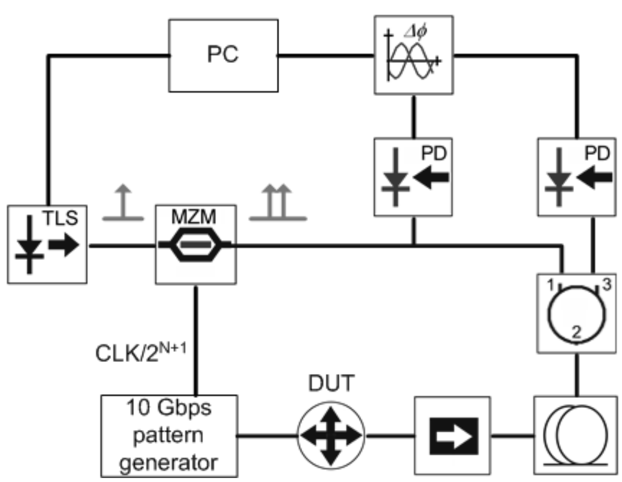

Fig. 1. Experimental setup for the measurement of the phase spectrum

To measure the phase spectrum, a double simultaneous filtering through SBS is produced by duplication of the pump. To achieve this double pump, a tunable laser source (TLS) is modulated by a Mach-Zehnder modulator (MZM) biased at Vπ to achieve carrier suppression. A divided clock signal at half the pattern repetition rate is used to drive the MZM, obtaining a scanning signal with two spectral components with the same frequency separation as the discrete components of the optical signal from the DUT. The doubled pump is used to generate a reference signal and to act as the pump for SBS over the SUT. When the pump and two spectral components of the SUT are separated by the Doppler frequency shift, those components pass through the filter produced by the acoustooptic wave. By heterodyne mixing in the photodetector, an electrical sine signal is obtained, containing the phase difference between the two mixed signals. By phase comparison of this signal with the detected reference signal, the phase shift between the components of the SUT is obtained.

3. Measurements

For this work we have measured a 10 Gbps NRZ modulation of a laser externally modulated by a MZM with a 32 bit repetitive pattern, giving 312.5 MHz separation of components. The amplitude spectrum is measured using a BOSA-C high-resolution optical spectrum analyzer from Aragon Photonics. To obtain the double-pump signal for phase measurements, the signal clock is divided by two times the pattern length (64), giving a 156.25 MHz square signal that is bandpass filtered to obtain a sine wave at that frequency.

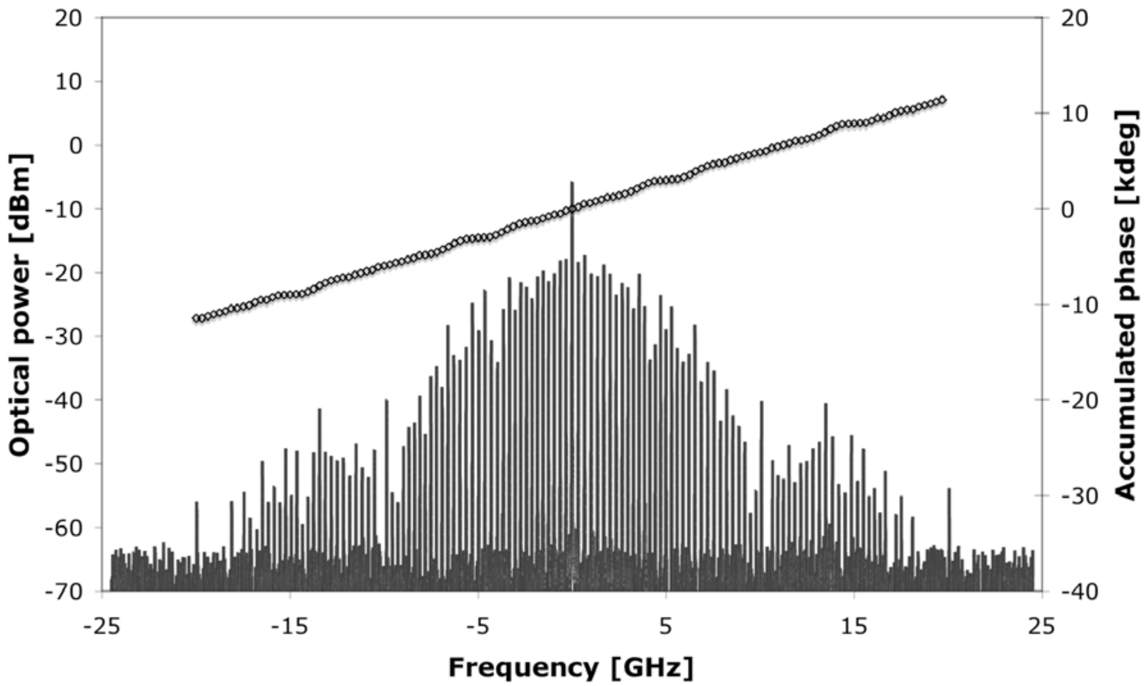

Fig. 2. Measured power and phase spectra for the SUT

With our setup we measure the phase difference between adjacent components, and by accumulating this differences we obtain the absolute phase values. The phase reference can be placed arbitrarily, as it only determines the starting point of the pattern. As a rule we set the carrier to phase 0º. With the amplitude and phase of each component we can perform an inverse Fourier transform to obtain the time-domain optical field and, thus, the instantaneous optical power, as the squared modulus, and the frequency chirp, as the derivative of the instantaneous phase. The TRC calculated from spectral measurements for the SUT is depicted in Fig. 3.

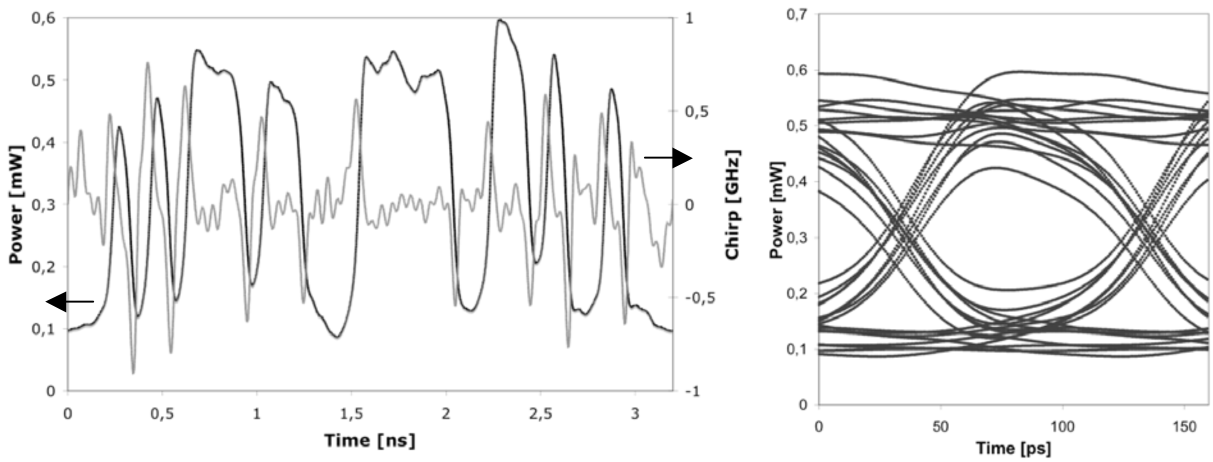

Fig. 3. TRC for the measured signal (left) and recovered eye diagram (right)

We can observe how the time-domain data is recovered by performing a IFFT on the measured complex spectrum data. Uncertainty in the measurements is below 1 dB in power and 10º in phase. However, accumulated errors in the phase difference produce a higher error for high-frequency components that lead to some degree of distortion. There is a compromise between the detail of the retrieved signal, given by the number of measured points and thus by the used pattern length, and the distortion of higher frequency components which has to be optimized for best results.

4. Conclusion

We have presented a new method to measure the phase difference between frequency components, produced when an optical source is modulated with a repetitive pattern, based in SBS filtering and heterodyning. Complemented with optical power spectrum measurements performed with a BOSA-C, time-resolved chirp measurements of a 10 Gbps NRZ modulation from a MZM using a 32 bit pattern have been carried out. This methods takes advantage of the optical high-resolution filtering, that allows a large number of components to be measured, and the amplification effect of SBS to achieve a larger dynamic range than other traditional methods.
We consider this method has a great potential for the analysis of modulation formats due to its capability to measure the instantaneous power and phase of the signal.

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5.References

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