SIMPLE TECHNIQUES FOR BANDWIDTH MEASUREMENTS OF OPTICAL GUIDED-WAVE MODULATORS

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Abstract: this paper presents two techniques for guided-wave modulators bandwidth measurements using only low-frequency instrumentation. This is made possible through an adequate optical signal processing which translates the information in the low-frequency domain.

Introduction

The increasing data rate capabilities of optical links require modulation devices with ultra-broad bandwidth. For this purpose, optical guided-wave modulators are, to-date, the most suitable devices due to their flat frequency response extending over several gigahertz and their low drive voltage requirement. Bandwidth characterization of these devices is therefore of prime importance when considering their key-function in the transmission link.

In most available measuring systems the frequency response of the optical devices is directly measured electrically, using a microwave measurement apparatus after the detection of the light signal using an ultra-broad band detector [1] [2]. For accuracy purposes and full frequency coverage high standard instrumentation has to be used and requires the according investments .

In this paper we report two techniques for bandwidth measurements which involve instrumentation and devices that most laboratories can afford. In these methods, the electrical part of the measuring system is greatly simplified and has the further advantage to use only *low-frequency* detection and measurement apparatus, resulting in drastic cost reduction, a very uniform response and an improved dynamic range. This was achieved by taking advantage as much as possible of the optical nature of the signal by processing the lightwave directly, using either a sampling technique with a narrow optical pulse as a probe signal or direct optical spectrum measurement.

The optical sampling technique

The sampling technique, which relies upon the well-known stroboscopic effect, provides a replication of a high-speed periodic continious-time signal in an arbitrary enlarged time scale. This can be used to shift an arbitrary periodic optical signal modulated by a guided-wave device down to the low-frequency range. It was achived using short optical pulses as a sampling signal, with a repetition rate close to the optical signal frequency, yielding a replicated optical signal with a frequency equal to the difference between the pulse repetition rate and the initial optical signal freqency, as shown in Fig.1.

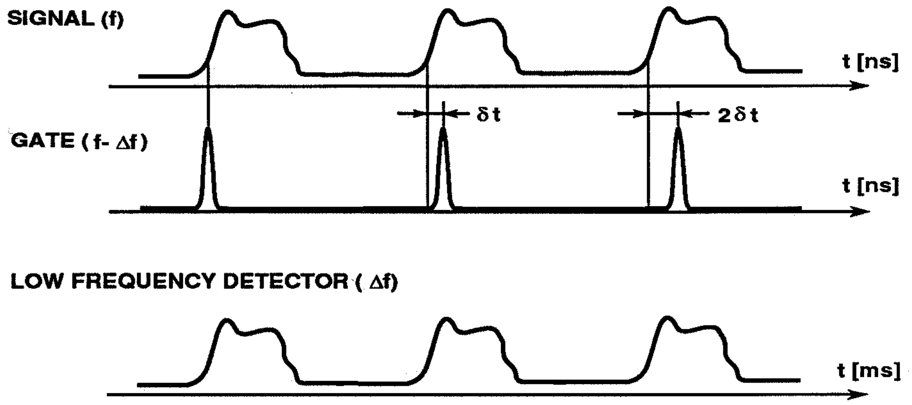

Fig.1 *A short optical gate is used sample a arbitrary optical waveform and reproduce it in the low-frequency domain.*

When using two impulse train signals, this technique can be used to carry out the frequency response of optical guided-wave modulators. Short optical pulses act as an optical probe to analyze an optical gate constituted by an intensity modulator drived with an electrical impulse train signal. The processed signal is then detected by a low-frequency detector. Both optical and electrical signals must have a close repetition rate so that all harmonics of the beat signal in the low-frequency domain are within the bandwidth of the low-frequency detector. Therefore the detected signal is bandlimited only by the modulator.

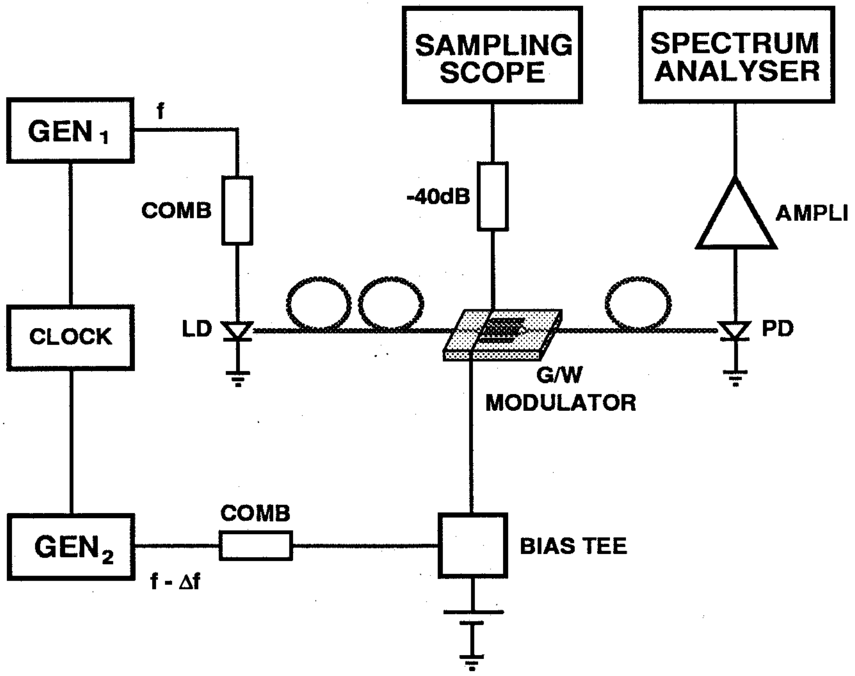

Fig.2 *Schematic diagram of the experimental setup*

The experimental setup is shown schematically in Fig. 2. A 10 MHz master clock is used to drive two RF generators at frequencies *f* and *f-Δf*. The impulse trains are produced electrically by frequency comb generators to drive the laser and the modulator. The resulting comb spectrum, which corresponds to repetitive 130 ps FWHM pulses, consists of discrete lines up to and beyond 18 GHz. The beat frequency Δf is chosen to be 100 Hz, which is 10^6 smaller than the original RF frequency f. A 1.3 µm semiconductor laser operating in gain switched condition delivers 50 ps FWHM optical pulses, which are launched into an electrooptic modulator. The output signal is detected by a InGaAs pin photodiode followed by a high gain operational amplifier fixing the bandwidth of the detection system. By using a low-frequency electrical spectrum analyzer the frequency response of the modulator is obtained by analyzing the spectrum of the output signal and knowing the scale factor. Figure 3 presents a typical frequency response of a $LiNbO_3$ electrooptic modulator measured using this method.

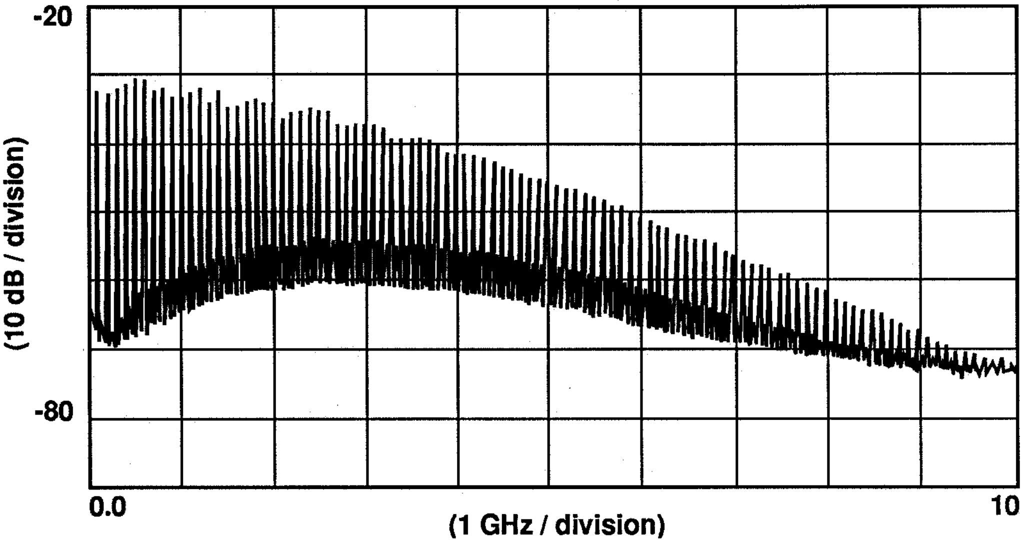

Fig.3 *Frequency response of a $LiNbO_3$ traveling wave modulator measurement using the optical sampling technique.*

Direct optical spectrum analysis

When the optical modulator is driven by a continuous-wave electrical signal, discrete sidebands are created in the optical spectrum, provided that the source is coherent and single mode. The sidebands spacing is equal to the modulation frequency, that is, in the gigahertz range, and can therefore be easily observed using a Fabry-Perot analyzer. Such an analyzing scheme is shown in Fig. 4. The free spectral range of the analyzer was 100 GHz, so that its finesse of 1000 resulted in a 100 MHz resolution, enabling the sidebands to be clearly resolved, as shown in Fig. 5.

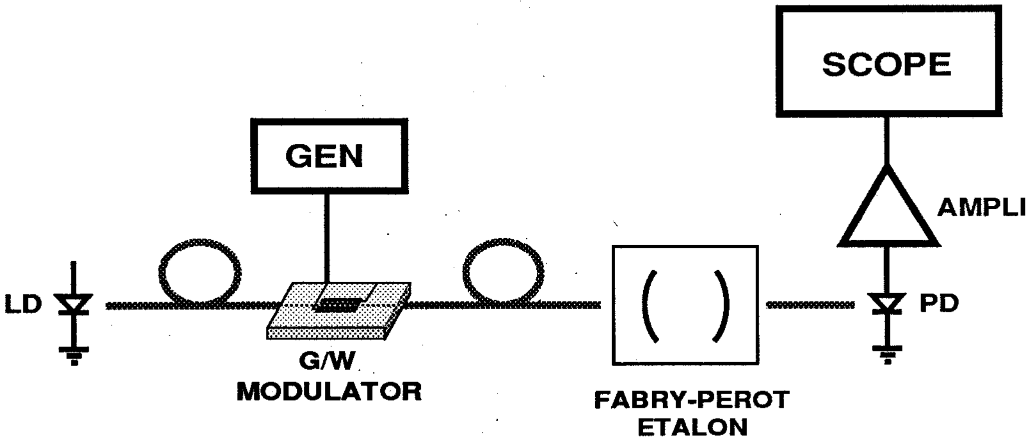

Fig. 4 *Schematic diagram of the experimental setup*

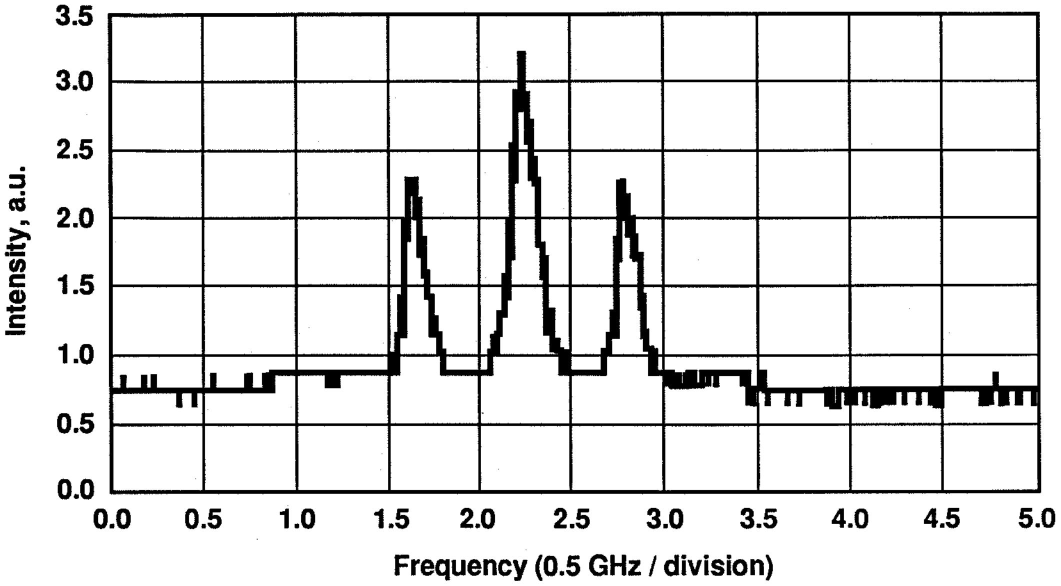

Fig.5 Optical spectrum of the modulated signal measured with the Fabry-Perot analyzer

The bandwidth can then be measured by sweeping the frequency of the signal driving the modulator and by observing the decrease in the sidebands amplitude. Though it is very accurate and gives an unbiased information of the actual affect of the modulator on the lightwave, this technique requires a tunable microwave generator which covers the full investigated frequency range. An alternative way is to drive the device with a frequency comb, using the same modulation scheme presented in the previous section. In this case the Fabry-Perot directly yields the frequency response of the modulator.

Here again the detection bandwidth is not a limiting factor and can be arbitrary reduced. In addition to the actual representation of the lightwave spectrum, this technique has the further advantage to be relevant for any kind of modulator (phase, intensity) without additional optical circuitry. The only requirement is related to the source spectrum,which must be narrow and single -mode. This condition requires the laser source to be isolated.

Conclusions

In this contribution we have demonstrated that bandwidth measurements of guided-wave modulator can be performed over a several gigahertz frequency range without using microwave instrumentation and measuring apparatuses. Furthermore the optical processing translates the relevant information in the low-frequency range, resulting in the use of noiseless and low-cost detection scheme and a standard accurate measuring instrumentation.

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Reference:

1. R. W. Wong, P. Hernday, M. G. Hart, G. A. Conrad, Hewlett-Packard Journal, June 1989,Volume 40, Number 3, pp. 35-51.
2. T. S. Tan, R. L. Jungerman, and S. S. Elliott, IEEE Transaction on Microwave Theory and Techniques, Vol. MTT-2, May 25, 1988, pp. 1067-1070.