

Coherent Optical Spectrum Analyzer

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Abstract—In this letter, we demonstrate coherent optical spectrum analysis with ~ 70 -dB dynamic range based on a swept-tuned optical local oscillator and a coherent receiver operating in the 1.5- μm wavelength band. Measurement principles are presented along with high-resolution measurements of distributed feedback laser spectra.

Index Terms—Measurement, optical communications, optical interferometry, optical mixing, spectral analysis.

I. INTRODUCTION

INCREASING BANDWIDTH demands on fiber-optic networks have driven network designs toward more closely spaced optical wavelength channels and also toward higher transmission bit rates. The spectral characteristics of these lightwave systems receive a great deal of scrutiny since optical noise, modulation spectra, and channel balance have important bearing on transmission performance. For closely spaced dense wavelength-division-multiplexed (DWDM) systems, the limited resolution of conventional diffraction grating-based optical spectrum analyzers (OSA) reduces the ability to measure spectral features between DWDM channels. Improved resolution and dynamic range are possible with coherent analysis measurement techniques based on an optical local oscillator [1]–[4]. However, previously reported heterodyne measurements employing balanced coherent receivers [2], [3] were limited to analyzing continuous-wave (CW) signals, or signals with no intensity modulation. This is a consequence of the limited balance achieved with the twin head-to-toe photodetector arrangements used in the experiments. A coherent optical spectrum analyzer (COSA) should, in general, be capable of measuring a broad class of optical signals including PRBS-modulated lasers that exhibit a high level of noise. This “modulation noise” can be characterized by an effective relative intensity noise (RIN), which is approximately equal to the inverse of the modulation bit rate. The spectral portions of the intensity modulation that fall in the photodetection bandwidth can completely mask the desired coherent measurement, and at best, limit measurement dynamic range. In this letter, we demonstrate a method of coherent optical spectrum analysis using a swept-tuned optical local oscillator (LO) and a balanced optical receiver capable of suppressing the high intensity noise levels of pseudorandom bit sequence (PRBS)-modulated lasers. The COSA is shown to offer excellent spectral resolution, and to our knowledge, demonstrates the best reported dynamic range for any optical spectrum analyzer with comparable resolution. Measurements are given for the first time showing

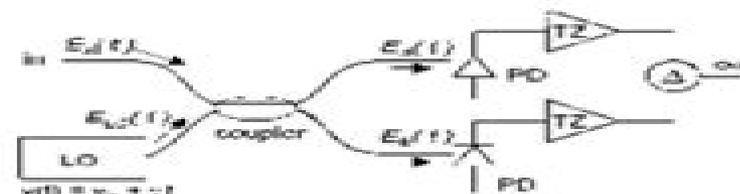


Fig. 1. Simplified block diagram of coherent optical spectrum analyzer. PD: Photodetector; TZ: Transimpedance amplifier; LO: Optical local oscillator.

the close-in spectral features of a PRBS-modulated distributed feedback (DFB) laser. Additionally, we report the observation of the quadratic phase behavior of the detected coherent fringe envelope. Background theory and measurement comparisons with an alternative coherent OSA are presented.

II. COHERENT OPTICAL SPECTRUM ANALYSIS

A simplified block diagram of the COSA is shown in Fig. 1. The input signal is combined with an LO whose frequency is swept across the measurement wavelength range. Optical mixing, due to the nonlinear dependence of the photocurrent on the optical field, allows for measurement of the input field strength. As will be shown, the detected intensity is composed of in-phase direct detection components and antiphase mixing beat terms. By subtracting the currents generated by the balanced photoreceiver, the direct detection is reduced relative to the heterodyne signal. This results in a measurement free of corruption from unwanted direct detection. In Section III, the theoretical basis for the COSA is described.

III. COSA THEORY

We start with an analytical representation for the input signal field representing simple coherent light [1]

$$E_d(t) = |E_d(t)| e^{j2\pi\nu_d t + \phi_d(t)} \quad (1)$$

where ν_d is the mean optical frequency and $\phi_d(t)$ describes laser phase noise. Similarly, the swept local oscillator field is described by

$$E_{LO}(t) = |E_{LO}(t)| e^{j2\pi\nu_{LO} t + \phi_{LO}(t)} \quad (2)$$

with the LO frequency swept according to $\nu_{LO}(t) = \nu_0 + \gamma t$, and γ is the rate of change of frequency with time. The polarization states of the signal and LO fields are aligned for maximum interference at the coupler. The incident fields on the two photodetectors shown in Fig. 1 are

$$E_{\pm}(t) = j\sqrt{k}E_d(t)e^{j\phi_d(t)} + \sqrt{1-k}E_{LO}(t) \quad (3a)$$

Manuscript received September 6, 2001; revised November 6, 2001.
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Publisher Item Identifier S 1041-1135/02/030353-03.

Coherent Spectrum Analyzer Manual

Lingsheng Yao



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