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# 10 GBIT/S 2-PSK TRANSMISSION AND HOMODYNE COHERENT DETECTION USING COMMERCIAL OPTICAL COMPONENTS

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**Abstract:** We present a demonstration of coherent homodyne transmission using 2-PSK at 10Gbit/s, with commercial optical components, which leads to new compact integrated receivers and new transmission formats, thus opening new possibilities for future optical systems.

## Introduction

In most telecommunication fields outside the optical scenario, transmission systems are based on coherent detection, i.e., on a receiver where a Phase-Locked Loop (PLL) tracks the frequency and phase of the received signal. The local oscillator signal is then mixed to the received signal to obtain homodyne or heterodyne detection. Coherent systems have several advantages, mainly related to:

- Increase of receiver sensitivity
- Compatibility with complex modulation formats, such as  $M$ -PSK,  $M$ -QAM, etc.

Coherent systems were investigated in the field of optical transmission in the years around 1990 [1], mainly for sensitivity issues, but they never found commercial application firstly because of their complexity and cost, secondly, because RX sensitivity issues were solved by the introduction of EDFA's.

Today, we believe that there is again a rationale for optical coherent systems, as it has been recently addressed in several research projects [2]-[4], and as it will be outlined later. The goal of this paper is the demonstration that coherent homodyne optical systems are feasible today using advanced but commercially available optical components.

## New Rationale for Coherent Optical Transmission

Even though sensitivity is not anymore a major issue, thanks to EDFA-preamplified receivers, coherent optical detection may have a fundamental role in future optical transmission systems. In fact:

- Coherent (homodyne) detection would open the way to those modulation formats that are largely and successfully used in other telecommunication fields, such as  $M$ -PSK,  $M$ -QAM and others. All these formats allows a much higher spectral efficiency than conventional Intensity Modulation (IM), by a factor  $\log_2(M)$ . For example, 8-PSK bandwidth is 3 times narrower than standard IM-DD, given the same bit rate. Most important, this also allows the use of narrower band electronic and optoelectronic components in the TX and RX, by the same factor.

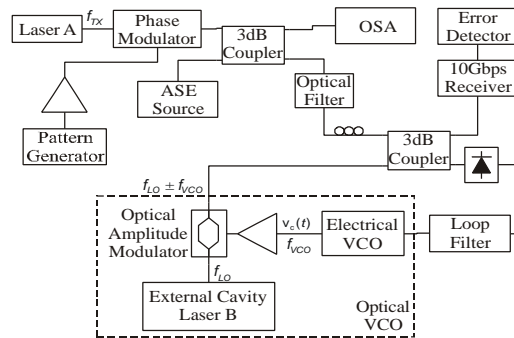


Fig. 1. Experimental setup

- Beside amplitude, coherent detection allows also phase information recovery at the RX, a feature that opens totally new possibilities in receiver equalization for dispersion and PMD compensation. Consequently, all techniques used in equalization of RF receivers, such as multipath fading equalization, could in principle be applied to optics.
- Coherent detection allows separating closely spaced DWDM channels without requiring narrow optical filters, since channel selection is obtained directly at baseband by electrical filtering. This feature is at the basis of several advanced optical networks proposals, such as the ACTS-SONATA [2], where coherent detection was basically used as a way to obtain ultra-fine (and relatively fast) DWDM tunability at the receiver (6.25 GHz channel spacing, 622 Mbit/s)

## Experimental Setup

In Fig.1 we show the setup used to carry out our coherent 2-PSK transmission experiment at 10Gb/s. The transmitter is based on a Corning-OTI LiNbO<sub>3</sub> 10 Gbit/s phase modulator, driven by an NRZ signal whose amplitude has been set to a slightly lower value than the modulator  $V_p$  voltage, in order to obtain a residual carrier 2-PSK modulation [1]. The receiver is based on a novel Optical PLL (SC-OPLL<sup>®</sup>) concept based on Sub-Carrier modulation.

<sup>®</sup> Patent Pending

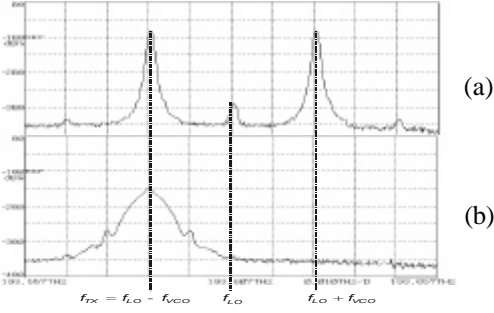


Fig2: Output OPLL optical power spectrum (a) and RX optical signal power spectrum (b).

We use a CW laser at frequency  $f_{LO}$  followed by a high bandwidth Corning-OTI LiNbO<sub>3</sub> Mach-Zehnder (MZ) amplitude modulator, driven by the output of a Voltage Controlled Oscillator (VCO) at frequency  $f_{VCO}$ . By biasing the MZ at a null of its transfer function, a sinusoidal carrier-suppressed modulation is obtained. In our experiment, we use a low jitter silicon-bipolar based 20 GHz VCO from Agilent Technologies [5]. The resulting optical spectrum at the output of the MZ (which is also the output of our OPLL) is shown in Fig. 2a, and contains two subcarriers at frequencies  $f_{LO} \pm f_{VCO}$  plus other spurious lines. Using the subcarrier at  $f_{LO} - f_{VCO}$ , we obtained an optical frequency controlled by the electrical input of the VCO, i.e., the basic building block of an OPLL. It may be noted that this OPLL setup does not require advanced optical components, such as solid-state lasers that were used in previous coherent experiments [1].

Using our novel SC-OPLL<sup>®</sup>, we developed a coherent receiver that mixes the received optical signal to the OPLL output. The OPLL loop filter, when properly set, generates a VCO control signal that locks the subcarrier frequency (say  $f_{LO} - f_{VCO}$ ) to the received signal frequency (see Fig. 2b). Moreover, the OPLL tracks the phase of the 2-PSK residual carrier, thus allowing coherent homodyne detection. We performed Q measurements in a back-to-back configuration, adding ASE noise to the received signal in order to change the received OSNR. In Fig. 3, we show the resulting eye diagrams with ASE noise (Q=16 dB) and without, while in Fig. 4 we show the resulting Q curve vs. OSNR (measured on a 0.1 nm bandwidth).

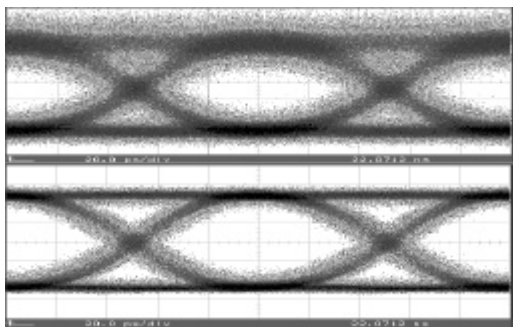


Fig3: Eye diagram measurements with ASE noise (top, Q=16 dB), and without ASE noise (bottom)

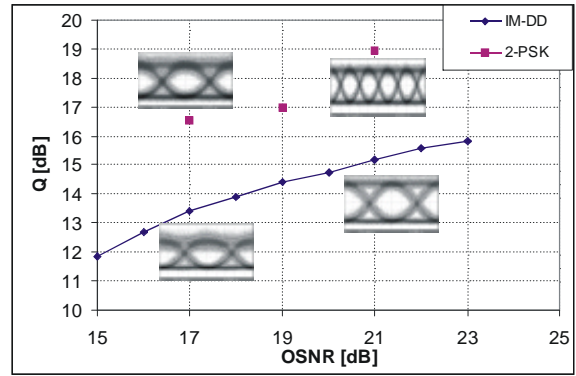


Fig4: Q factor measurements versus OSNR for 2-PSK and IMDD modulation formats.

By comparison, we show on the same graph the performance of a standard 10 Gbit/s IM-DD system. Furthermore, a compact integrated device including all commercial components grouped in the dashed line of Fig.1 is feasible and is currently under design. As demonstrated in the experiment, and as we have verified by simulation, the VCO central frequency should be greater or equal to twice the bit rate. At 10 Gbit/s, this means using a VCO having  $f_{VCO} \geq 20$  GHz. At this frequency, the commercially available driver and external modulators developed for STM-256 systems are more than adequate. The other receiver elements are a tunable laser, for  $f_{LO}$  coarse tuning, and a polarization controller.

## Conclusions

The proposed coherent setup key element is the sub-carrier modulation driven by the VCO output that permits the SC-OPLL<sup>®</sup> realization. All the SC-OPLL<sup>®</sup> components are commercially available today, thus demonstrating the *technical* feasibility of coherent homodyne detection by means of compact integrated receivers. Even though the economical feasibility of this system still remains to be proved, we believe that coherent systems could be a potential candidate for future high-capacity optical transmission systems.

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