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# Coherent Detection of Wavelength Division Multiplexed Phase-Modulated Radio-over-Fibre Signals

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## Abstract

A WDM phase-modulated Radio-over-Fibre link using digital coherent detection is experimentally demonstrated. 3x50Mb/s WDM transmission of a BPSK modulated 5GHz RF carrier is achieved over 25km.

## Introduction

Radio-over-Fibre systems employing Wavelength-Division-Multiplexing (WDM) are very attractive since they can support a large number of antenna base stations connected to a central station [1]. It is believed that WDM RoF technology can potentially enable increased overall capacity, low-cost antenna base station implementation, increased wireless access coverage and easier network maintenance [1,2]. Recently, phase-modulated RoF optical links have attracted large attention due to their advantages compared to intensity modulation [3,4]. However, phase-modulated optical links require a linear coherent receiver. The advantage of linear coherent receivers is not only that they can provide linear RF signal transport, but can also act like ultra-narrow tunable WDM filters. A combination of WDM and phase-modulation could therefore potentially provide large capacity linear RF systems. In this paper, we report on the successful demonstration of 3x50 Mb/s BPSK WDM phase-modulated RoF link (5 GHz RF carrier) over 25 km of SMF, using digital coherent detection. We demonstrate signal demodulation and subsequent data recovery for WDM channel spacings of 25 GHz and 12.5 GHz. To the best of our knowledge, this is the first transmission experiment of a WDM phase-modulated RoF link, with BPSK modulation format, and using a digital coherent receiver for simultaneous detection and demultiplexing.

## Experimental set-up

The experimental set-up for the WDM phase modulated radio-over-fibre optical link is shown in Fig. 1. The transmitter consists of 3 tunable DFB lasers with ~2 MHz linewidth and wavelengths in the range between 1550.20 and 1550.60 nm. The output of the transmitter is amplified by a high-power EDFA. A Vector Signal Generator (VSG) is used to generate a RF carrier (5 GHz) which is modulated by a 50 Mb/s BPSK data signal. The RF data signal is then used to drive a conventional lithium-niobate optical phase modulator. The phase modulated optical data signal is sent through 25 km of SMF and split in two polarizations using a PBS. Only one polarization is sent to the receiver. At the receiver, a 90° optical

hybrid is used to mix the received data signal with the tunable external cavity LO laser (~100 kHz linewidth). The in-phase ( $I_i$ ) and quadrature ( $I_q$ ) optical signal components are detected with two pairs of balanced photodiodes (BW 7.5 GHz).

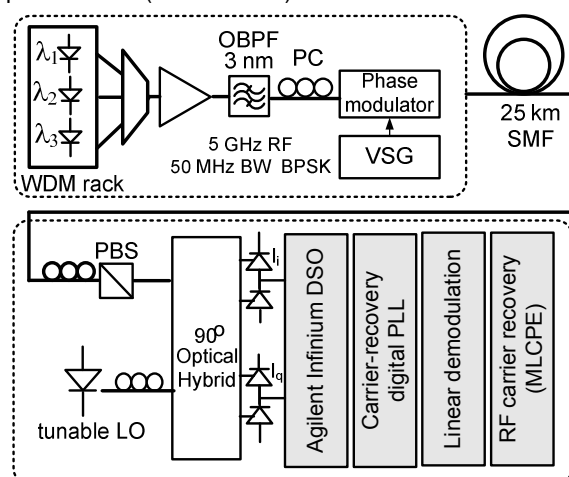


Figure 1. Experimental set-up for the demonstration of WDM phase-modulated RoF optical link.

The wavelength of the LO laser is tunable in order to demultiplex different WDM channels. The detected photocurrents are digitalized at a sample rate of 40 Gs/s using a high-bandwidth real time oscilloscope (Agilent Infinium DSO80000B with 13 GHz analog bandwidth). The sampled photocurrent is later used for offline signal demodulation and data recovery. The frequency difference between the transmitter and LO laser is measured to be in the range between 20 MHz and 400 MHz, depending on the received channel. The post-processing of the digitized data consist of a carrier-recovery digital PLL, linear signal demodulation and an RF carrier phase recovery stage, (see [4] for more details). The carrier-recovery digital PLL is used to remove the frequency and phase offset from the sampled data signal. RF carrier phase recovery is based on the maximum-likelihood approach and the recovered RF carrier is used to demodulate and thereby recover the data.

## Experimental results

Fig 2 shows the optical spectra of the WDM phase-modulated RoF optical signal when the WDM channel

spacing is 25GHz and 12.5GHz, respectively. As the WDM channel spacing is reduced to 12.5 GHz, significant overlap among channels is observed, making the signal recovery very challenging.

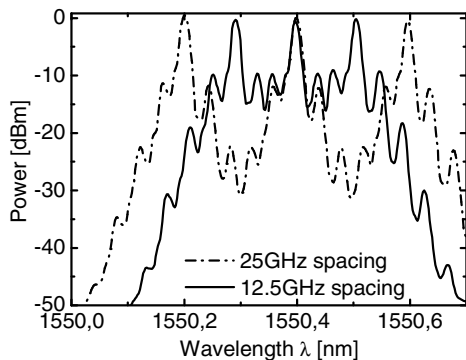


Figure 2. Measured optical spectra of WDM phase-modulated RoF optical signal

To begin with, the WDM channel spacing is set to 12.5 GHz. In Fig 3, the Q-factor of the demodulated WDM channel at  $\lambda_2=1550.40$  nm is shown as a function of average received optical power. Results are only provided for the centre channel at  $\lambda_2$  since it is the one that experiences most crosstalk from the two neighbouring channels. Three different scenarios are considered: 1) two neighbouring WDM channels at  $\lambda_1=1550.20$  nm and  $\lambda_3=1550.60$  nm are present, 2) the WDM channel at  $\lambda_1=1550.20$  nm is removed, and 3) the WDM channels at  $\lambda_1=1550.20$  nm and  $\lambda_3=1550.60$  nm are both removed.

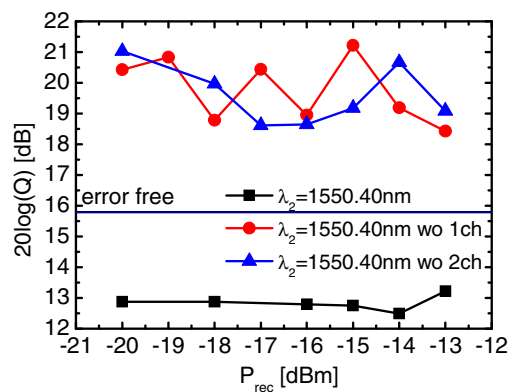


Figure 3. Q-factor of the demodulated WDM channel ( $\lambda_2=1550.40$  nm) for a WDM ch. spacing of 12.5 GHz.

The Q-factor of the demultiplexed and demodulated WDM channel at  $\lambda_2=1550.40$  nm is about 13 dB, when the channels at  $\lambda_1=1550.20$  nm and  $\lambda_3=1550.60$  nm are simultaneously present. This is below 15.6 dB, which corresponds to error free (bit-error-ratio better than  $10^{-9}$ ) signal demodulation and detection. From Fig 3, it is observed that, as the neighbouring channels are removed, the system performance in terms of Q-factor improves, as expected and the measured Q-factors are above 15.6 dB. Next, the WDM channel spacing is increased to

25 GHz. In Fig 4, the Q-factor for the 3 demodulated WDM channels is shown for back-to-back measurement and after 25 km transmission in the case of 25 GHz channel spacing. The measured Q-factors are all above 15.6 dB, which corresponds to error free signal demodulation and detection. We stress that, even though no dispersion compensation algorithm has been used, error free signal demodulation is still obtainable after 25 km.

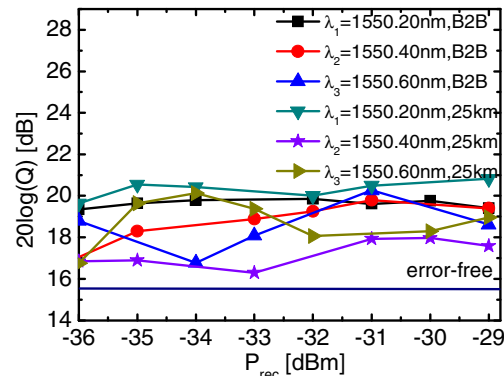


Figure 4. Q-factor of demodulated WDM channels (25 GHz spacing) for back-to-back and after 25 km

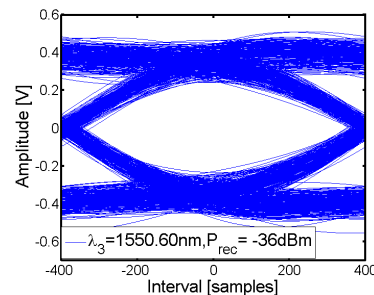


Figure 5. Eye diagram of the demodulated WDM channel

In Fig. 5, an eye diagram of the demultiplexed and demodulated WDM channel ( $\lambda_1=1550.60$  nm,  $P_{rec} = -36$  dBm) is shown after 25 km of transmission. A very clean eye diagram is observed confirming error free signal demodulation.

### Conclusion

We have experimentally demonstrated a novel concept of WDM phase-modulated radio-over-fibre link using digital coherent detection. Successful demultiplexing and signal demodulation for WDM channel spacings of 25 GHz has been demonstrated for BPSK modulation of a 5 GHz RF carrier.

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