10 Gb/s Chirped Duobinary Transmission (CDBT) over 277 km of Uncompensated Standard Single Mode Fibre

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ABSTRACT
We have performed the first experimental demonstration of chirped duobinary transmission (CDBT). The enlarged transmission distance of this modulation format compared to conventional chirp-free duobinary transmission has only been shown by simulation previously. Thus we enlarge the maximum transmission distance of chirp-free duobinary transmission up to the new record distance of 277 km of standard single mode fibre without dispersion compensation.
Keywords: Chirped Duobinary Transmission, CDBT, Duobinary Transmission, Chirped Transmission, Modulation.

1. INTRODUCTION

The benefits of optical duobinary transmission are well known. Due to the reduced bandwidth of the duobinary signal the dispersion tolerance is increased resulting in larger chromatic dispersion limited transmission distance [1, 2].
However these improvements are significantly reduced in the nonlinear regime by the self-phase modulation (SPM) limitations [3]. Beyond the so-called nonlinear duobinary limit at approximately 8 dBm optical input power, there is a threshold-like decrease of the dispersion tolerance resulting in merely slight improvement compared to binary transmission.
The chirp-free optical duobinary signal is generated by a Mach-Zehnder modulator (MZM), that is driven in push-pull configuration. Residual chirp due to asymmetries of the MZM decreases the performance of the transmission [4]. The influence of thoroughly adjusted pre-chirp generated by asymmetrical driving signals of the MZM has been investigated earlier. In one approach, a transmitter setup has been reported that reduces the residual chirp due to MZM asymmetries [5]. In [6, 7] the setup complexity is reduced by the proposed transmitter designs.
The new modulation format chirped duobinary transmission (CDBT), that we proposed in [8, 9], is based on a transmitter setup consisting of a conventional duobinary transmitter followed by an additional phase modulation. CDBT reduces the signal degradation and spectral broadening in the nonlinear regime significantly. Thus, the uncompensated transmission distance is enlarged up to 130% compared to chirp-free duobinary transmission in the strong nonlinear regime.
We report the results of the first experimental demonstration of chirped duobinary transmission and show the improvement in the nonlinear regime compared to chirp-free duobinary transmission resulting in enlarged uncompensated transmission distance.

2. EXPERIMENTAL SETUP

The transmitter setup is shown in figure 1. The conventional duobinary transmitter, consisting of a pulse pattern generator to generate a 10 Gb/s NRZ pseudorandom bit sequence, a duobinary precocoder, the realization of which is described in [10], and a MZM driven in

push-pull configuration by a ternary duobinary signal, that is generated by a Gaussian low-pass filter with 2.6 GHz cut-off frequency as encoder, is followed by an additional phase modulator. The phase modulator is driven by the binary data signal *d(t)*, which is proportional to the intensity of the launched optical duobinary signal, resulting in a phase signal $\varphi(t)\sim\Delta\Phi$. The amplitude of the phase shift $\Delta\Phi$ is controlled by an adjustable amplifier with optional inversion to generate an either positive or negative chirped duobinary signal.
The transmission performance in the nonlinear regime is increased by the combined influence of pre-chirp, chromatic dispersion and SPM. The optimum phase shift depends on the launch power and the fiber length [9]. The pre-distortion of the phase of the signal mitigates the distortion due to SPM.

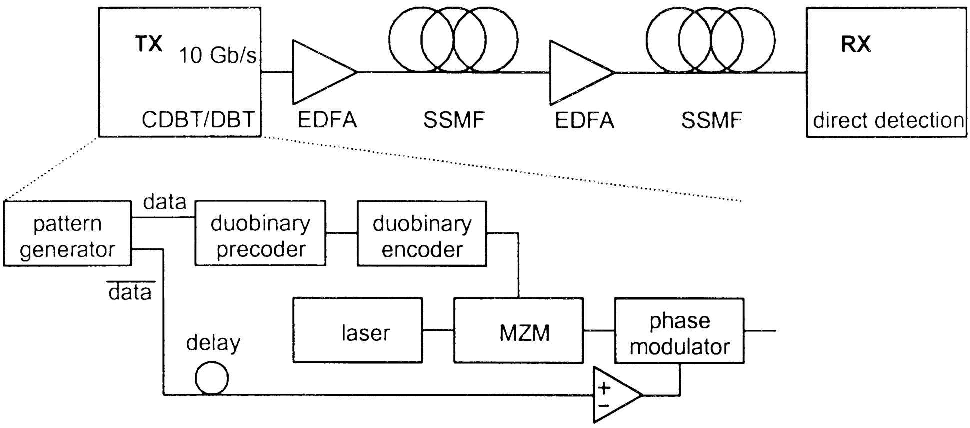

Figure1: Chirped duobinary transmission setup

The performed transmission experiment shows the improved dispersion tolerance of CDBT in the nonlinear regime by the investigation of the maximum uncompensated transmission distance over standard single mode fibre (SSMF) compared to chirp-free duobinary transmission. The system setup, see figure 1, consists of a transmitter followed by a booster erbium-doped fibre amplifier (EDFA), that achieves high launch power for compensating fibre loss, and two spans of SSMF separated by an inline EDFA after 126 km SSMF. Note that no dispersion compensated fibre (DCF) is used in the experiment. A standard binary NRZ optically preamplified receiver is used. The receiver sensitivity is measured by means of a variable optical attenuator in front of the optical preamplifier.

3. EXPERIMENTAL RESULTS AND DISCUSSION

We have investigated the maximum transmission distance in the nonlinear regime comparing chirp-free and chirped duobinary transmission. The record transmission distance for chirp-free duobinary transmission is 252 km of SSMF [10]. The input power into both spans is chosen to be 8 dBm avoiding the SPM limitations [3]. Increasing the optical input power above the nonlinear duobinary limit to overcome the noise limitations of the system results in signal degradation and reduced performance. The receiver sensitivity is decreased by 2 dB if we increase the launch power from 8 dBm up to 13 dBm, see figure 2. Thus, for conventional duobinary transmission the launched power should not exceed the SPM limit of 8 dBm.
However, the receiver sensitivity of chirped duobinary transmission with the optimised launch power of 13 dBm is reduced by 3 dBm up to –32 dBm at BER of 10^{-9} after 252 km of SSMF compared to chirp-free duobinary transmission with the optimised launch power of 8 dBm. The CDBT signal is less distorted due to the combined influence of pre-chirp, chromatic dispersion and SPM indicated by the eye diagrams shown in figure 3. A good agreement

between measurement and simulation can be observed. This effect can be used to enlarge the maximum error-free transmission distance up to 277 km. The receiver sensitivity is –27 dBm at a BER of 10^{-9}.

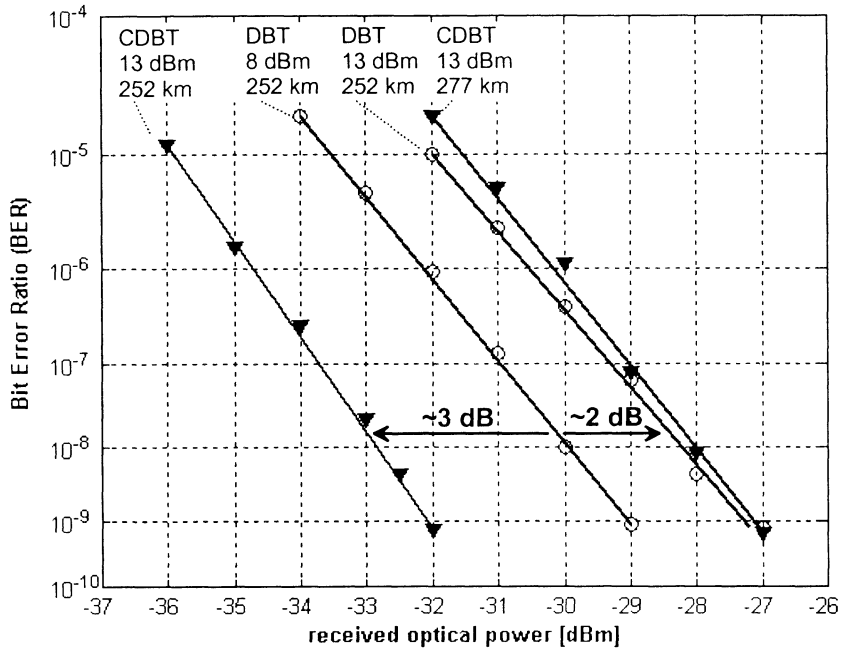

Figure 2: Measured BER versus receiver input power for the conventional chirp-free duobinary transmission (DBT) and the chirped duobinary transmission (CDBT) over uncompensated SSMF

DBT, launch power 8dBm DBT, launch power 13 dBm CDBT, launch power 13 dBm

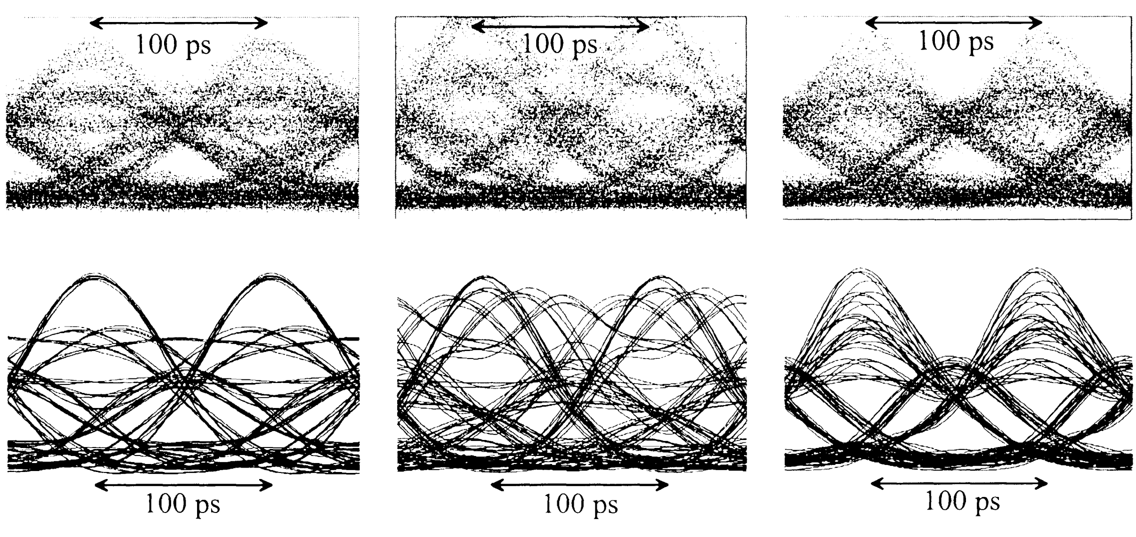

Figure 3: Eye diagrams of conventional chirp-free duobinary transmission (DBT) and the new chirped duobinary transmission (CDBT) after 252 km uncompensated SSMF, upper trace measurement, lower trace simulation