Serial 107Gbit/s ETDM NRZ Transmission over 320km SSMF

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Abstract: We report on a complete serial 107 Gbit/s ETDM NRZ transmission system and assess system performance in an error free transmission experiment over 320 km SSMF with 3.5 dB OSNR margin.

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1. Introduction

During recent years a growing trend towards Ethernet transport technologies can be observed, and it is a common understanding that Ethernet will be the dominant transport technology of next generation metro/core networks. The expected strong growth of traffic in data/IP networks combined with high pressure on transport costs will lead to a strong demand for the next generation of Ethernet technology. 100 Gigabit Ethernet (100 GbE) is considered to be the next logical evolution step and according standardisation activities are already under discussion [1]. 100 Gbit/s serial transmission might offer a cost efficient option for 100GbE transport networks. But progressing towards 100 Gbit/s serial transmission rates represents an enormous technical challenge due to the associated strong transmission impairments and due to the speed limitations of current electronics and opto/electronic components. Up to now the only realised 100 Gbit/s ETDM systems are based on DQPSK [2,3,4]. For serial transmission systems independently a 107 Gbit/s transmitter [5] and an integrated 107 Gbit/s [6] receiver were reported. In [7] we reported on a 100 Gbit/s ETDM transmitter and electrical demultiplexing at the receiver side. We report here for the first time a true serial 107 Gbit/s (100 Gbit/s +7% FEC overhead) ETDM transmission system with ETDM transmitter and ETDM receiver including electronic clock recovery. In a 107 Gbit/s NRZ transmission experiment error free operation is achieved after transmission over 320 km standard single-mode fiber (SSMF).

2. 107 Gbit/s ETDM Transmission System

The schematic setup of our 107 Gbit/s ETDM transmission system is depicted in Fig. 1. Eight 13.39 Gbit/s electrical data streams each with a PRBS word length of 2^{31}-1 are fed to two parallel 4x13.39:53.5 Gbit/s multiplexers. The resulting data streams are used as input signals for the 2x53.5 Gbit/s selector, which aggregates the data to the line rate of 107 Gbit/s. The 107 Gbit/s data signal is amplified by an electrical broadband driver amplifier, having a bandwidth of 70 GHz (provided by SHF Communication Technologies), and is modulated onto the 1554.9 nm cw light of a DFB laser using a single-drive $LiNbO_3$ Mach-Zehnder modulator. Each of the eight electrical 13.39 Gbit/s input channels was individually delayed for decorrelation.

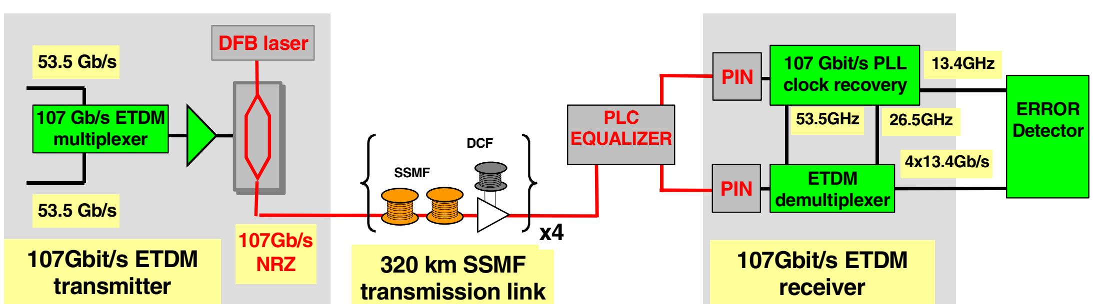

Fig. 1: Schematic setup of the 107 Gbit/s ETDM transmission experiment

In front of the 107 Gbit/s ETDM receiver we placed an optical attenuator together with an EDFA to vary the OSNR, which was monitored by an optical spectrum analyzer. The signal is amplified and passes an optical bandpass filter with 1.3 nm bandwidth.
After another amplification we apply a tuneable planar lightwave circuit based lattice filter (PLC Equalizer). It consists of 7-cascaded Mach-Zehnder interferometers, see Fig. 2, four asymmetrical and three symmetrical ones and has an FSR of 200 GHz. Each branch can be individually tuned with a heater. We placed the PLC equalizer in front of our receiver to take advantage of its features as a tuneable dispersion compensator [8].

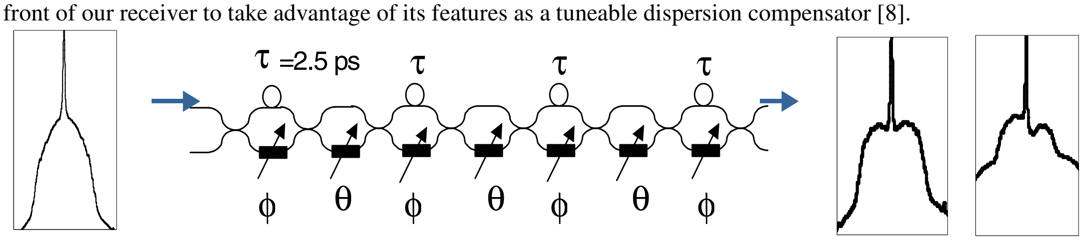

Fig. 2: Schematic of the PLC Equalizer together with optical input and output spectra

A high speed photodiode feeds the electrical 107 Gbit/s data signal to an integrated Clock-data-recovery (CDR), originally designed for 86 Gbit/s operation, which is used as phase detector within our PLL based clock recovery circuit in conjunction with an external VCO and a control circuit. The sensitivity of the specific CDR device we had for this experiment was not sufficient for error free operation at 107 Gbit/s NRZ. Therefore we used a second photodiode and a fast SiGe DFFs for demultiplexing the data signal to 53.5 Gbit/s and to 4x13.39 Gbit/s with the following 1:4 demultiplexer. One of the resulting 13.39 Gbit/s data signals is then fed to the bit error rate tester.

3. Experimental results

We characterized the system in a back-to-back experiment. With 2^{31}-1 PRBS we measured the OSNR (@ 0.1 nm) sensitivity for a BER of 2×10^{-3}, corresponding to the correction limit of an enhanced Forward Error Correction circuit, to be 30 dB for all eight 13.39 Gbit/s tributaries. In the back-to-back experiments we used the PLC Equalizer to improve the quality of our optical 107 Gbit/s NRZ signal, see Fig. 2 for the optical spectrum after equalization.
A 107 Gbit/s transmission experiment over 320 km of standard single-mode fibre (SSMF) was conducted. The fiber link consisted of 4 spans with lengths between 77 and 82 km showing losses between 15 and 17 dB, respectively.
In front of the fiber link a dispersion compensating fibre (DCF) with –325 ps/nm for dispersion pre-compensation was placed interstage in the booster EDFA. After each span the signal is amplified by a double-stage EDFA with a DCF module interstage. The dispersion map of the 320 km transmission link is shown in Fig. 3.

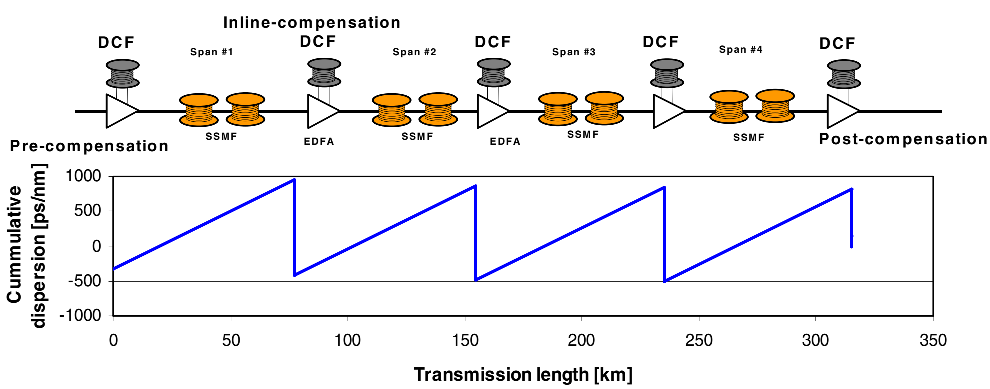

Fig. 3: Dispersion map of the 107 Gbit/s NRZ transmission experiment

The 107 Gbit/s NRZ signal was launched with an optical power of +7.5 dBm into each SSMF span and +0.5 dBm into the DCF modules. The residual chromatic dispersion after the last span was compensated for by short pieces of standard single-mode fiber. Although we used dispersion slope compensating DCF modules the dispersion slope of the link was not fully compensated for, so the heater control voltages of the PLC were adapted manually for best BER. We observed a suppression of the upper sideband, which is often seen when using PLC Equalizer for dispersion or dispersion slope compensation. This is also described in [8] reporting on previous experiments with PLC Equalizers for adaptive dispersion compensation. The optical spectra after transmission over 320 km of SSMF and after the PLC Equalizer are given in Fig. 2.
We applied no PMD compensation and no principle state of polarization launch. Manually varying the input state of polarisation of the transmission link with a polarisation controller resulted only in slight BER changes.

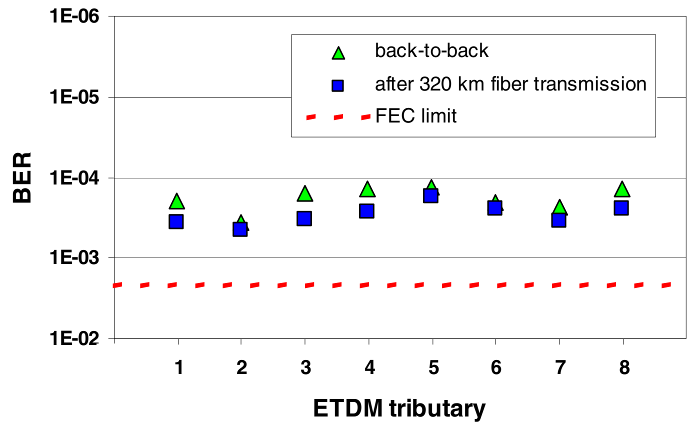

Fig. 4: BER for all tributaries back-to-back (triangles) and after transmission (squares)

After transmission over 320 km SSMF we measured the BER for all 13.39 Gbit/s tributaries at an OSNR of 33.5 dB. The results are given in Fig. 4 together with the BER of the back-to-back experiment measured at the same OSNR. As all tributaries are well below the FEC correction limit of $2x10^{-3}$ (indicated by the dotted line in Fig. 4) we can state an error free transmission without OSNR penalty. We measured the required OSNR where the BER reaches the FEC correction limit to be 30 dB, which means an OSNR margin of 3.5 dB for our transmission experiment.

4. Conclusion

We reported a complete binary 107 Gbit/s ETDM transmission system. The performance of the 107 Gbit/s ETDM NRZ system was assessed in a transmission experiment over 320 km SSMF with error free operation and 3.5 dB OSNR margin.

5. Acknowledgement

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6. References

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