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Bidirectional uncompressed HD video distribution over fiber employing VCSELs

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Abstract—**We report on a bidirectional system in which VCSELs are simultaneously modulated with two uncompressed HD video signals. The results show a large power budget and a negligible penalty over 10 km long transmission links.**

Keywords-high-definition (HD); VCSEL; bidirectional

INTRODUCTION

Video distribution is one of the main drivers of the current bandwidth demand hike [1]. Video is usually transmitted employing network services [1], yet current demand of high definition (HD) channels and availability of ready-to-use HD receivers and transmitters lead to think that this distribution will be pushed down to the physical layer. Access networks are however very cost sensitive, and hence, cost-effective solutions for such distribution need to be engineered. Among the technologies that are clearly find a niche in this segment; vertical-cavity surface emitting lasers (VCSELs) are considered a viable solution to optical laser sources, because they provide a substantial operational bandwidth while having high integrability, low driving voltage and power dissipation requirements [2]. Figure 1 shows a network topology in which HD video signals are distributed directly over the physical layer.

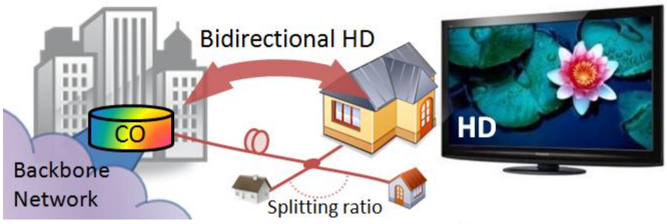

Figure 1 Network topology. Central office (CO).

In this paper we present a two HD-channel bidirectional system employing low-driving voltage VCSELs operating at the L-band for the downstream and the O-band for the upstream. This band splitting prevents the system from crosstalk. The overall performance of the system demonstrates that VCSELs can be employed to simultaneously generate a plurality of uncompressed HD channels, enjoying a large power margin.

EXPERIMENTAL SETUP

Figure 3 shows the experimental setup and a superimposed picture of the transmitted optical spectrum. In order to emulate a high-definition serial digital interface (HD-SDI) and accounting for 7% margin for forward error correcting (FEC) coding implementation, we generated a 1.6Gbps with a 2^{15}-1 pseudorandom bit sequence (PRBS) word length from a pulse pattern generator (PPG).The signal is divided into two through an active radio frequency (RF) splitter and decorrelated by using tunable electrical delay-lines. One of the branches is upconverted to 5 GHz with an RF-mixer. The power of the local oscillator (LO) is tuned to optimize the eye diagram, and the mixer's insertion loss is compensated with an amplification stage. Baseband and the upconverted signals are added up with a 6-dB power combiner and subsequently amplified. The resulting signal is subdivided into two with another 6-dB electrical splitter and decorrelated via a mechanical delay line. The signals are adjusted to be around 1 Vpp at the second power combiner's output.

The signals are used to modulate an L-band and an O-band VCSEL to generate the downstream and the upstream link, respectively. Both lasers exhibit 10 GHz 3-dB modulation bandwidth at ambience temperature and the unmodulated emitting center wavelengths are 1578.6 nm and 1281.9 nm – almost overlapping the 10G-EPON transmission bands. The output power was set to be 2 dBm (downstream) and -1.2dBm (upstream). O/C passive band splitters filters are used at each end of a 10 Km long standard single-mode fiber (SSMF) spool for coupling and splitting the corresponding wavelengths.

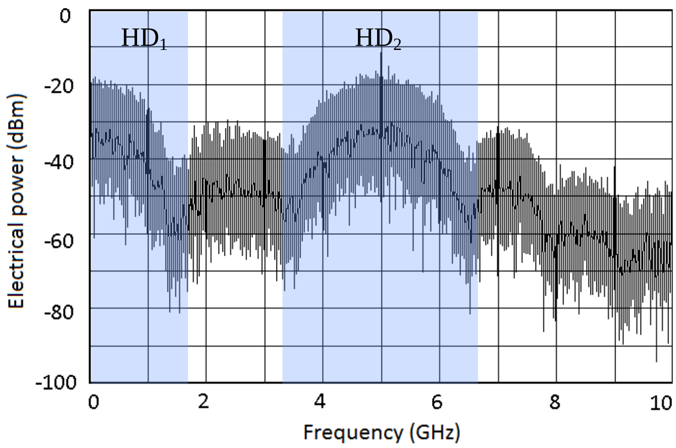

Figure 2 Transmitted electrical spectrum with HD_1 and HD_2 channels.

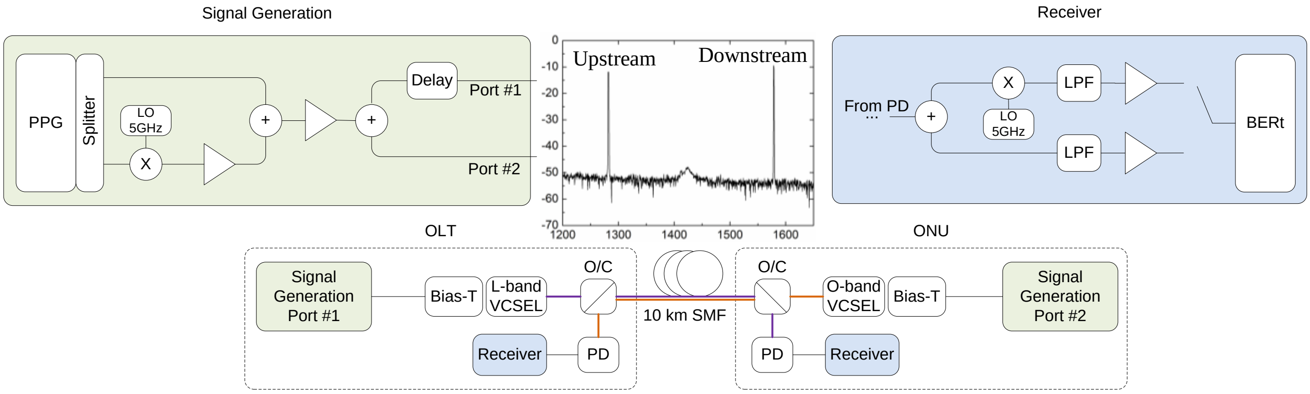

Figure 3 Experimental setup. Pulse pattern generator (PPG), local oscillator (LO), optical line termination (OLT), optical network unit (ONU), low-pass filter (LPF), photodiode (PD).

At the receiver side, a variable attenuator and a 20-dB coupler are used to control and monitor the incoming optical power. A high sensitivity 10-GHz PIN photodiode is used to detect the signal. After a passive electrical splitter, an RF-mixer is inserted in one of the branches for downconverting the 5 GHz channel. An independent and synchronized LO is utilized. Low-pass filters with 1.8 GHz cut-off frequency are used cancel off the harmonics and reduce the out-of-band (OOB) noise. Two individual low-noise high-linear amplification stages are applied after filtering. Finally, the outgoing stream is analyzed with a bit error rate (BER) tester.

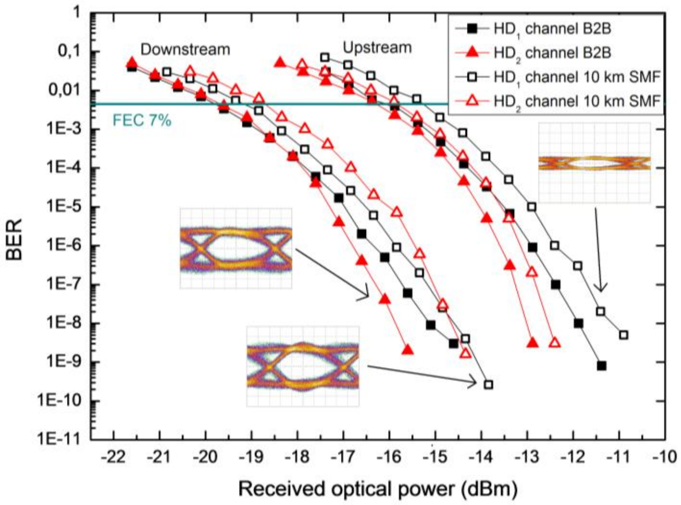

Figure 4 BER versus received optical power

At the receiver, a variable attenuator and a 20-dB coupler are used to control and monitor the incoming optical power. A high sensitivity 10-GHz PIN photodiode is used for sensing the signal. After a passive electrical splitter, an RF-mixer is inserted in one of the branches for downconverting the 5 GHz channel. An independent and synchronized LO is utilized. The LO power had to be slightly adjusted to compensate for the band-dependent photodiode's responsivity. Low-pass filters with 1.8 GHz cut-off frequency are used cancel off the harmonics and reduce the out-of-band (OOB) noise. Two individual low-noise high-linear amplification stages are applied after filtering. Finally, the outgoing stream is analyzed with a bit error rate (BER) tester.

RESULTS AND DISCUSSION

The BER curves for each optical source are shown in Figure 4. The O-band upstream performance shows a negligible average power penalty for both HD1 and HD2 of 0.5 dB with a maximum of around 1 dB. The L-band downstream performance exhibits an indiscernible power penalty for both channels of less than 0.5 dB. Concerning the transmission penalty, less than 0.5 dB is held in both lasers diodes for the two HD channels with the exception of the downstream HD_2 case, for which a slightly increased deviation is observed. Figure 4 also shows some eye diagrams at different points.
No error floors are observed within the tested received power interval and the 7%-FEC threshold is clearly exceeded for received power levels higher than -16 dBm for O-band and -19 dBm for the L-band. This grants error free transmission (BER~10^{-15}) under considerably relaxed power budget conditions. Such power margins allow a loss allocation (including transmission) of 15 dB and 21 dB in the upstream and downstream respectively, permitting diverse splitting ratio configurations (e.g. Class A optics in combination with 10 km link) and/or the consideration of additional safety margins.

CONCLUSION

Uncompressed HD video distribution needs to be addressed employing already deployed PON systems. We assessed how VCSELs can be used efficiently for such purpose and experimentally demonstrated two-channel bidirectional system over 10 km of SMF employing the L- and O-bands. During the presentation, we will show an interactive video describing the experimental setup and how HD video signals are recovered.

REFERENCES

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[2] R. Rodes et al.,"100 Gb/s single VCSEL data transmission link," OFC'12, Postdeadline paper PDP5D.I0 (2012).