Colourless Self-Seeded Source for CPRI3 Mobile Fronthaul over 70 km Reach

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Abstract *We demonstrate field trial CPRI3 error-free transmission over field fibre at 2.5 Gbit/s with DWDM self-seeded RSOAs in the O-band. The use of FEC in transponders enables to achieve 30 dB optical budget and up to 70 km reach.*

Introduction

Next generation passive optical network (NGPON2) ITU-T standard G989.x has been finalized in 2015 with time and wavelength division multiplexing (TWDM) PON being more likely to target residential market following Gigabit-PON and 10G XG(S)-PONs. Also within the NGPON2 standard, an optional point-to-point (PtP) WDM topology has been defined in 2016. PtP WDM is foreseen to suit requirements of mobile fronthaul to reduce the footprint (less radio access network (RAN) equipment on the antenna site with a shared fibre) with a point-to-point logical connectivity offering low latency and symmetrical bit rates[1].

Among dense WDM technologies suitable for the access, the use of self-seeded reflective semiconductor optical amplifiers (RSOAs) is particularly attractive since no wavelength control is required[2]. This technology already produced high performance laboratory experiments results with bit rates up to 10 Gbit/s and long reach transmissions[3, 4].

In this work, we introduce a forward error correcting (FEC) Reed Solomon 240/218 code in a common public radio interface (CPRI) frame mapping of a new transponder in order to ensure error free transmission (i.e. with bit-error rate (BER) less than 10^{-12}), as required for CPRI3 (2.4576 Gbit/s). The transponder also has the function of converting the signal from the remote radio head (RRH) to a colourless DWDM source based on a self-seeded RSOA in the O-band. We demonstrate the use of the self-seeded RSOA technology for the mobile fronthaul of a 3G/4G antenna with CPRI3 with the possibility to achieve long reach (70 km) and an optical budget higher than 30 dB in a laboratory experiment. Moreover, the system is assessed for the first time using CPRI3 signals in a field trial showing error-free transmission over 36 km.

Principle and experimental setup

Self-seeded RSOA sources enable the implementation of DWDM network without the need for external wavelength management. Their use thus constitutes a strong alternative to NGPON2 point-to-point WDM, which would requires additional auxiliary management and control channels (AMCCs). The principle is as follow: the cavity is formed by an RSOA playing the role of the gain medium and of one mirror of the cavity; a wavelength multiplexer (MUX) slices the spectral bandwidth of the channel, thus enabling colourless operation. Part of the filtered signal is reflected back to the RSOA after a second mirror enabling the establishment of a steady state regime. The full cavity can be

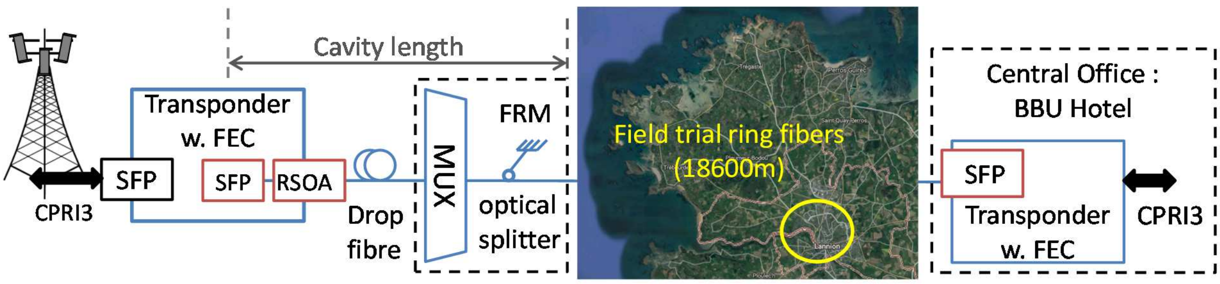

Fig. 1: Experimental setup of the field trial with CPRI3 over self-seeded RSOAs.

several kilometres long when a drop fibre is considered between the RSOA at the antenna site and the MUX at a distant passive street cabinet or remote node.

Fig. 1 depicts the experimental setup of the field trial that took place in the city of Lannion (France) over a deployed fibre ring network composed of 12 fibres of 18600 m of standard single mode fibre (SSMF) that can be connected to increase the total reach.

In our experiment, the RSOA is based on a multi-quantum well active medium with a small signal gain of 35 dB at 1330 nm, a high polarization dependent gain and a 2 GHz electro-optical bandwidth at 100 mA bias. The RSOA emitting in the O-band is directly modulated by the signal to be transmitted as described later. The SSMF-based drop fibre length varies from 9 m to 15 km in our experiment and the flat-top multiplexer has a 100 GHz channel spacing. It is followed by an optical splitter to extract part of the signal and close the cavity using a 90 % reflectivity Faraday rotator mirror (FRM). The association of a 45° Faraday rotator (FR) at the output of the RSOA with a 90° FRM was indeed shown to guarantee a stable polarization state in the RSOA at its maximum gain[5]. In this work the RSOA is modulated by a CPRI3 signal transposed from a commercial SFP module (electrical-optical-electrical transposition) that can be placed directly in the network equipment (RRH or transponder). We use the field fibre to assess an upstream fronthaul link with a CPRI3 tester generating a 2^{31} pseudo-random binary signal (PRBS) in the payload of 2.4 Gbit/s frames generated at the antenna site and received at the base band unit (BBU) hotel. For this field trial, a transponder, allowing the interfacing between point-to-point single- or multi-mode links from RRHs/BBUs and coloured DWDM links, was developed and used at both sides of the network. A FEC encoder was implemented in the transponder to enhance the CPRI transmission performance while keeping the system end-to-end latency below 5 µs. We implement a hard-decision (240,218) Reed Solomon code whose

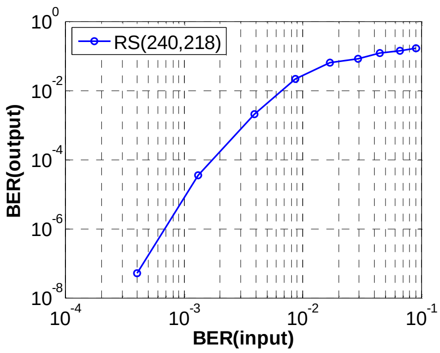

Fig. 2: Simulated RS (240,218) FEC performance.

simulated performance is shown in Fig. 2. For a pre-FEC BER of 10^{-4}, a BER of 10^{-12} is expected after correction.

Results

The self-seeded source carrying CPRI3 traffic including FEC was first assessed after propagation through laboratory fibres. Values of the optical budget (from the output of the source to the input of the receiver) allowing transmission with a BER better than 3.10^{-12} for different cavity lengths and transmission reaches are summarized in Table 1. For a cavity length of 5 km, error free transmission was obtained after up to 65 km transmission (total length of 70 km) with an optical budget of 30.5 dB. For a cavity length of 15 km, error free transmission was obtained after up to 50 km (total length of 65 km) with an optical budget of 18.9 dB. It is to notice that the performance was optimized for each cavity length by adjusting the coupling ratio at the output of the cavity in order to find the best compromise between the optical budget (output power of the source) and the total cavity losses (80/20 splitter for the 15 km long cavity and 50/50 splitter for the 5 km long cavity). The receiver sensitivity being similar for both cavity lengths (-28 and -29.6 dBm), the optical budget difference mainly comes from the lower source power of the longer cavity (+2.5 dBm and -7 dBm output power for the 5 km and 15 km long cavity, respectively).

Table 1. Optical budget at BER < 3.10^{-12} for different cavity lengths and transmission distances.

		Transmission distance			
		B2B	40 km	50 km	65 km
Cavity length	5 km	> 31 dB	> 31 dB	> 31dB	30.5 dB
	15 km	22.6 dB	22.5 dB	18.9 dB	

The implemented FEC was then assessed in a back-to-back (B2B) experiment. Fig.3 (a) shows the results of BER measurements as a function of optical budget in B2B configuration for 2 different cavity lengths including FEC or not. Without FEC (full symbols), the optical budget decreases with longer cavities because the relative intensity noise of the source, dominated by mode beating, also increases with cavity length[4]. The eye diagrams for the two cavity lengths are presented in Fig. 3 (b) and (c). The increase of amplitude noise with longer cavity is clear in the 2 km cavity case.

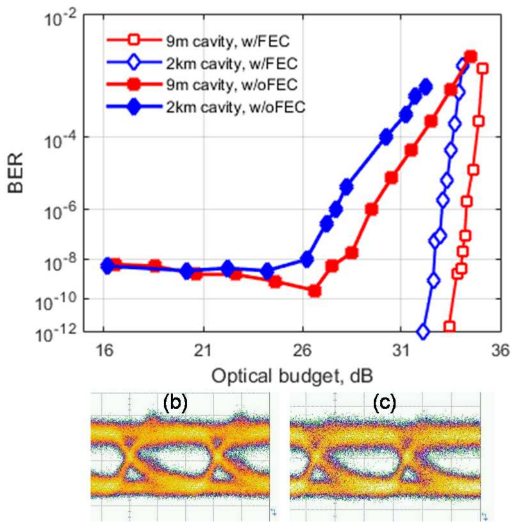

Fig. 3: (a) BER versus optical budget for 9 m and 2 km long cavities with or without FEC in B2B; B2B eye diagrams for (b) 9 m and (c) 2 km long cavities without FEC for a power on the photodiode of 2 dBm.

The optical spectra (normalized to 1 mW) of the source are represented in Fig. 4 for 9 m, 2 km and 5 km long cavities respectively. The 3-dB bandwidth of the source increases with the cavity length (from 60 pm at 9 m to 146 pm at 5 km) as a consequence of the increase of the number of modes in longer cavities which in turn leads to higher mode beating intensity noise at detection.

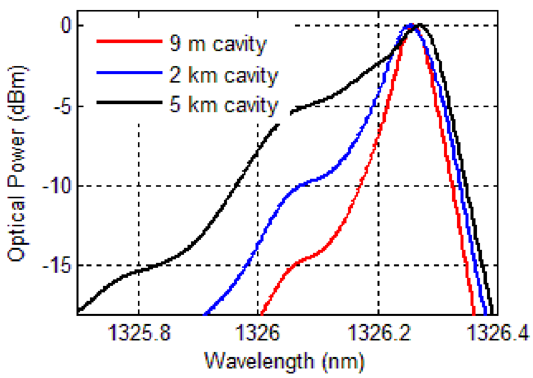

Fig. 4: Optical spectra at the output of the cavity (resolution bandwidth 60 pm).

When FEC is implemented, error floors are removed (empty symbols in Fig. 3 (a)) and the only influence of cavity length is the small decrease of the source output power directly impacting the optical budget. These tests validate the operation of the developed transponder.

Signals provided by the cavity and carrying CPRI3 traffic were then transmitted through the field fibre. The three cavity lengths were again assessed. Fig. 5 shows the results of BER measurement after two round trips in the local fibre resulting in a propagation distance of 36 km. Lower loss field fibre would be required for longer transmission (here 11 dB losses per round trip).

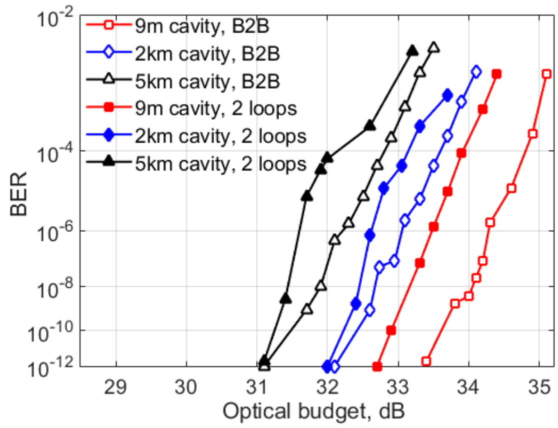

Fig. 5: BER versus optical budget for a 9 m, a 2 km and a 5 km long cavity with FEC in B2B and after 36 km in the field fibre.

After 36 km, a low penalty (less than 1 dB at a BER of 10^{-12}) with respect to B2B is measured for the three cavity lengths, still leading to an optical budget higher than 31 dB.

Conclusions

We have demonstrated a colourless system for mobile fronthaul architectures carrying CPRI3. Using self-seeded RSOA sources in transponders with FEC, we performed error free transmission over up to 70 km with optical budget higher than 30 dB. We also showed the capabilities of such system in a field trial setup, with error free transmission over 36 km of field fibre with cavity lengths up to 5 km.

Acknowledgements

This work was supported by the French National Research Agency LAMPION project (ANR-13-INFR-0002). The authors would also like to thank “Pôle Images et Réseaux” for making the field fibre available.

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