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Self-Seeded RSOAs WDM PON field trial for business and mobile fronthaul applications

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Abstract: GEth, CPRI and 10 Gbit/s transmissions are experimented using amplified and standard self-seeded RSOA WDM PON systems. A field trial setup was exploited to test the system performance in terms of reach and optical budget.
OCIS codes: (060.4510) Optical communications; (060.4264) Networks, wavelength assignment

1. Introduction

Wavelength division multiplexing passive optical networks (WDM PON) has been extensively studied with several technological options [1]. The FP7 ERMES project (Embedded Resonant and ModulablE Self-Tuning Laser Cavity for Next Generation Access Network Transmitter) focused on the realization of a colorless WDM PON transmitter based on self-seeded reflective semiconductor optical amplifiers (RSOAs). ERMES approach has the advantage to provide an automatic and passive mechanism for the wavelength assignment, as the transmitter self-tunes on the channel of the WDM filter which is connected to the RSOA via the drop fiber. So far, results proved the capabilities of this system with 10 Gbit/s transmission over tens of kilometers of standard single mode fiber (SSMF) and very long self-seeded laser cavities [2]. In this paper we demonstrate, within a field trial setup, the successful exploitation of the proposed WDM PON system based on amplified self-seeded and regular self-seeded with Gigabit-Ethernet and common public radio interface (CPRI) traffics, respectively for business users and mobile fronthaul [3], as well as the possibility to obtain error free transmission at 10 Gbit/s.

2. Field trial setup

The field trial consists in the experimentation of the proposed WDM PON system over the city of Lannion (France) fiber rings. Each loop of the ring has a length of 18600 m and insertion losses around 12 dB, mainly due to the high number of connectors in the ring.

The experimental setup is depicted in Figure 1 for an amplified self-seeded architecture [4]. The WDM PON optical distribution network (ODN) has a classical configuration with simply one multiplexer (MUX) at the remote node (RN) and one demultiplexer (DMUX) at the central office (CO) respectively placed at the terminations of the field trial fiber ring. The two multiplexers are flat-top with 200 GHz spacing and 4 channels. At the user premises (RRH or Business access point), the transmitter consists of a packaged high polarization dependant gain (PDG) RSOA (more than 25 dB small signal gain) with a 45° Faraday Rotator (FR45) at its output. The RSOA is directly modulated with a bias current optimized between 125 mA and 145 mA according to the desired cavity length to achieve. At the CO, which can be either the base band unit (BBU) hotel or an Edge Node Router (respectively for mobile fronthaul or business networks), the receiver is based on an avalanche photodiode (APD)

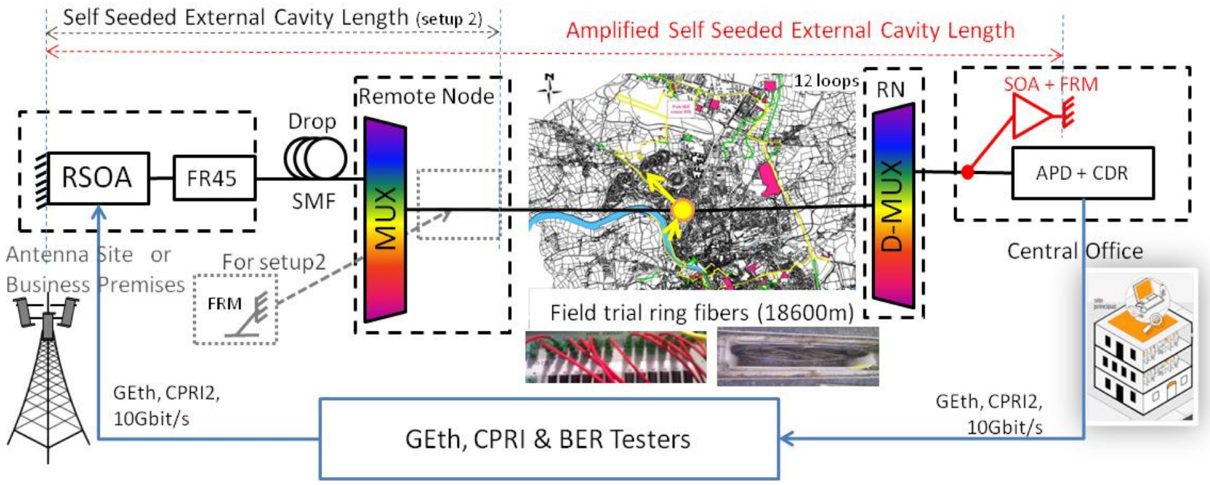

Fig. 1: Experimental setup: amplified self-seeded field trial setup and self-seeded setup using a partial mirror at RN (setup 2)

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followed by a commercially available clock and data recovery (CDR), providing also electronic dispersion compensation (EDC) for the 10 Gbit/s transmissions. To realize an amplified self-seeded architecture, a low-PDG SOA is associated to a Faraday rotator mirror (FRM) and inserted close to the receiver with a 80/20 coupler. Thus, an external cavity laser is created along the entire network: from the RSOA to the FRM. The RSOA outputs a wide band O-Band amplified spontaneous emission which is then spectrally sliced by the MUX, according to the connected channel (here 1325.8 nm). This signal propagates through the network fiber and is amplified and back reflected by the SOA and the FRM. After several round trips in the cavity, an amplified self-seeded laser reaches its steady state condition [4].

Tab. 1: GEth and CPRI2 test results vs fiber reach

Cavity Length	1 Field Trial Loop	25 km	35 km	50 km
GEth	Error Free	Error Free	Error Free	5.10^{-9}
CPRI2	Error Free	Error Free	Error Free	1.10^{-4}

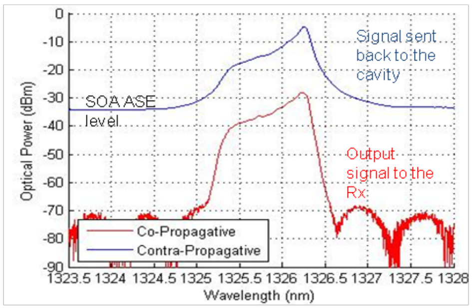

Fig. 2: Amplified Self-seeded optical spectra copropagating (red) and counterpropagating (blue), meas. at the DMUX output.

During the field trial, Giga Ethernet (GEth) (1518 bytes frame including pseudo random bit sequence (PRBS) 2^7-1 test sequence) and CPRI2 (1.228 Gbit/s, equivalent to PRBS 2^{31}-1) traffics was generated by GEth and CPRI testers. Results of the transmission performance are summarized in Table 1, showing that error free transmissions were realized for up to 35 km of SSMF. The maximum reached transmission length was 50 km, due to optical budget (OB) limitations. Moreover only 1 field trial loop of 18,6 km was achievable because of its high insertion losses.

Figure 3 and Figure 4 present 2.5 Gbit/s results from a BER test bed respectively obtained with 2^7-1 and 2^{31}-1 PRBS sequences. With 25 km and 1 field trial loop of fiber, error free (BER $<10^{-9}$) transmissions were realized for a short PRBS sequence (2^7-1) at 2.5 Gbit/s. However to achieve higher reach or longer pattern sequences (2^{31}-1) as recommended for CPRI3, the BER was limited to 4.10^{-9} at best (25 km curve, gray squares). Thus, the use of a proper forward error correction (FEC) code is recommended. Furthermore, for a 10 Gbit/s transmission with a 2^7-1 PRBS, the BER was limited to 4.10^{-4} with 10 km of fiber cavity. Thanks to the presence of a second gain element, amplified self-seeded allows for very long cavity lengths, which obviously present a very high number of modes and consequently a high relative intensity noise (RIN) with respect to shorter cavities. Comparing 2^7-1 PRBS and 2^{31}-1 PRBS results, a patterning effect has also to be noticed and can be related to the combined effect of RSOA bandwidth limitations and the cancellation-remodulation condition at the RSOA.

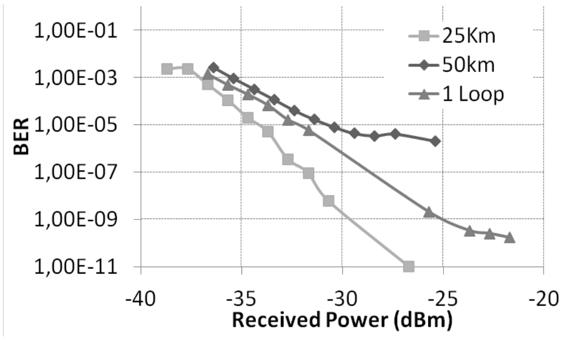

Fig. 3: 2.5 Gb/s BER results vs. received power with 25 km (gray squares), 50 km (black diamonds) SSMF and 1 field trial loop (18600 m, gray triangles) for a 27-1 PRBS

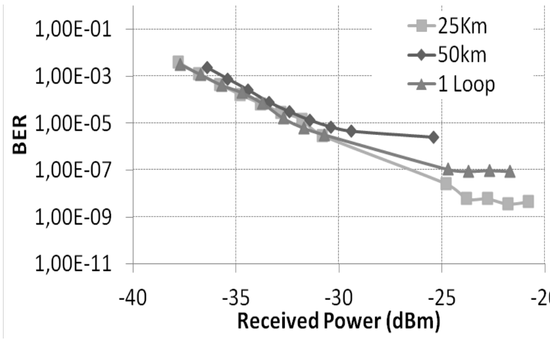

Fig. 4: 2.5Gb/s BER results vs received power with 25 km (gray squares), 50 km (black diamonds) SSMF and 1 field trial loop (18600m, gray triangles) for a 2^{31}-1 PRBS

In order to avoid the ASE noise of the SOA in amplified self-seeded configuration and bridging long fiber distance while relying on shorter fiber cavities, a regular self-seeded architecture was also experimented, the cavity length in fact is defined by the drop fiber only. Here, the SOA is removed and the partial mirror (a 90/10 splitter with a FRM) is placed at the RN, on the common port of the Multiplexer (setup 2 of Figure 1). For this architecture, a 32 channels, 100 GHz spacing Gaussian shaped AWG has been exploited, which previously allowed 10 Gb/s transmission [2]. No DMUX was implemented in this experimental setup.

Table 2 summarizes the results obtained for the experimentation of GEth and CPRI2 traffics over the field trial fiber rings and for several cavity lengths (10 m, 300 m and 1 km).

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Tab. 2: Self-seeded error free achievements with GEth or CPRI2 for various cavity and feeder fiber lengths

(1 loop = 18600 m)	10m cavity	300m cavity	1km cavity
B2B	GEth CPRI2	GEth CPRI2	GEth
1 loop	GEth	GEth	GEth
2 loops	GEth	GEth	OB limit

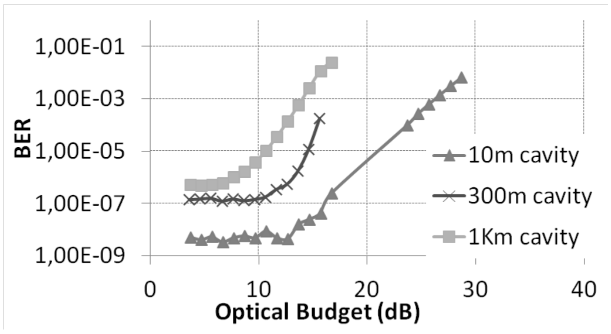

Fig. 5: BER results according to cavity length at 2.5Gbit/s (2^{31}-1 PRBS) for back-to-back transmission.

With the self-seeded architecture, GEth was transmitted successfully for each cavity length and over at least one field trial fiber ring. Transmission errors occurred for 2 loops and 1 km cavity length because of the limitation of the optical budget, due to field trial fiber ring very high losses. CPRI2 transmission reach (i.e. optical budget) was reduced since error free with a 2^{31}-1 PRBS is required and, as alredy stated, patterning effect was observed on measured BER curves.

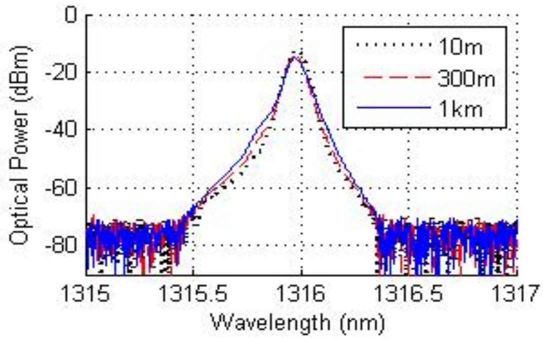

Fig. 6: Self-seeded optical spectra with the Gaussian AWG and several cavity lengths.

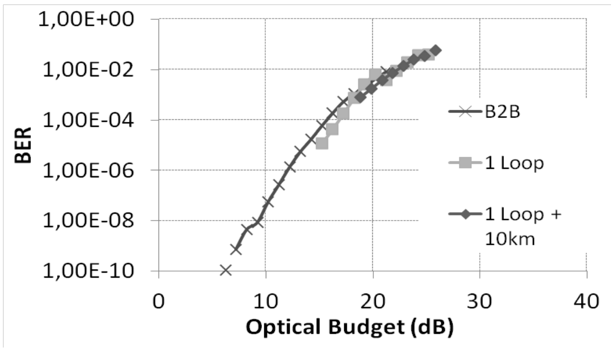

Fig.7: 10-Gbit/s BER results according to the transmission fiber length for a 10-m cavity length (2^7-1 PRBS) vs OB.

Figure 5 shows back-to-back BER results and Figure 6 presents the corresponding optical spectra, at 2.5 Gbit/s with 2^{31}-1 PRBS when varying the cavity length. Penalties due to longer cavity lengths are observed due to the higher RIN associated with the increasingly higher number of cavity modes. Nevertheless the exploitation of a FEC with 10^{-4} BER limit, would allow error free tranmission for OB of 25.7dB, 15.6dB and 13.7dB respectively for 10 m, 300 m and 1 km cavity lengths.

Figure 7 presents the BER results at 10 Gbit/s for a 10 m cavity in back to back, after 1 loop of the field trial fiber ring and 1 loop and 10 km of SSMF. Error free transmission was realized for back to back. Moreover, as expected, with O-band operation, no penalties due to chromatic dispersion were observed. An OB of 18 dB can be achieved using a proper FEC (10^{-4} BER limit).

3. Conclusions

A WDM PON system based on amplified self- seeded RSOAs was experimented in a field trial configuration. Very long external cavity lasers were realized and GEth and CPRI transmissions were demonstrated as well as 2.5 Gbit/s BER error free results. 10 Gbit/s transmissions were realized with a standard self-seeded architecture with 28.6 km reach.

Optical budget, reach, and bit rate achievements showed the great capabilities of the proposed self-tuning DWDM technology for business and mobile fronthaul networks with typical reach of 20 km and a few hundred meters between the network termination and the remote node.

4. Acknowledgements

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5. References

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