128 × 2 Gb/s WDM PON System with a Single TDM Time Lens Source using an AlGaAs-On-Insulator Waveguide

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Abstract: We demonstrate a WDM-PON transmitter based on optical Fourier transformation of a single-source TDM-PON. Using a single AlGaAs-on-insulator waveguide, 128 WDM-PON signals at 2 Gb/s are generated and transmitted over a 100-km unamplified link.

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1. Introduction

Access networks, linking the nearest backbone to the end subscribers, need new technologies that can support a few Gb/s bandwidth for every office and home energy and cost effectively [1]. The current dominant technology for access networks is passive optical networks (PONs), which are based on a point-to-multipoint time-division multiplexed (TDM) structure [2]. Increasing the TDM bit rates is challenging due to the low dispersion tolerance and declining signal to noise ratio, limiting the dispersion uncompensated reach to 24 km for 25 Gb/s TDM-PON [3]. As all subscribers share the same total capacity, the available bandwidth per subscriber at busy hours would be 25 Gb/s/N (e.g. 780 Mb/s. for $N = 32$ splitting). Point-to-point (P2P) wavelength division multiplexed (WDM)-PON, using a wavelength-based optical distribution network, is attractive with features such as long reach, high bandwidth, high service level guarantees, easy network management and simple upgrade. However, a major disadvantage of P2P WDM-PON is the large port count for transmitters and terminations at the central office requiring more space and increased operational costs [3]. Recently, we proposed a new highly flexible and scalable optical line terminal (OLT) structure for WDM-PON based on time lenses, which allows for a bit-rate scalable and spectrally efficient optical Fourier transformation (OFT) of a high-speed TDM signal to a dense WDM format. 64 WDM channels, each at 2 Gb/s, were generated and transmitted over a 100 km unamplified fiber, and the time lens was implemented using a highly nonlinear fiber (HNLF) [4].

In this paper, we extend our original proposal and investigate its scalability. We demonstrate 128×2 Gb/s WDM PON downstream transmission over a 100-km unamplified SMF-plant using a 200 m HNLF. Although all 128 generated WDM channels achieve BERs below the forward error-correction (FEC) limit 10^{-3} after transmission, a bandwidth limitation of the HNLF is observed, and this will limit the scalability of the proposed scheme. To overcome this issue, we investigate the use of AlGaAs-on-insulator (AlGaAsOI) nonlinear waveguides [5,6] for implementing the time lens. We demonstrate the same 128×2 Gb/s WDM PON system using an AlGaAs device, which achieves similar performance as HNLF, but without showing indications of having reached a bandwidth limitation.

2. Principle and experiment

The principle is shown in Fig. 1a. In the OLT, a single TDM transmitter generates a high-speed TDM signal, which is then converted to a number of lower-speed WDM channels using a time-lens based OFT signal processor, composed of a dispersive medium followed by a quadratic phase modulation [7]. The generated WDM signals are transmitted through a wavelength-splitting *outside plant* using e.g. an arrayed waveguide grating (AWG). Then, each ONU receives its own specific wavelength channel using low-speed components. To demonstrate the scalability, we constructed a TDM transmitter able to deliver very high TDM rates, but for more practical systems addressing 40-60 Gb/s total rates, a standard commercial e/o-TDM transmitter can be used.

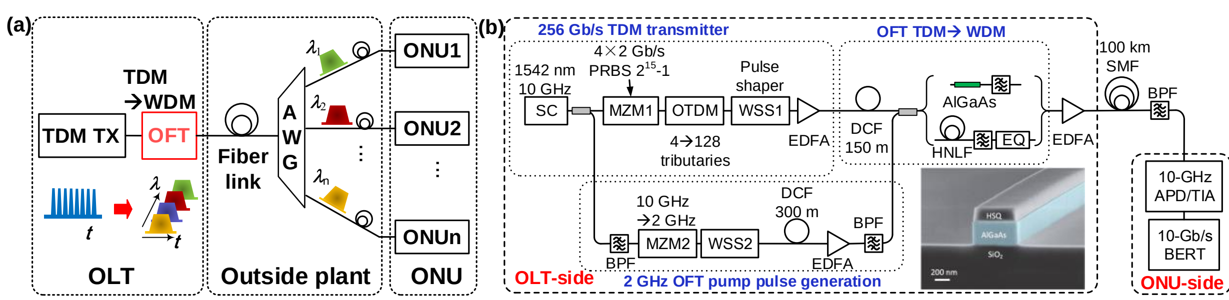

Fig. 1. (a) Principle of the proposed PON structure. (b) Experimental setup of 128 × 2 Gb/s WDM PON over 100km unamplified fiber-plant. Inset: picture of an AlGaAsOI nano-waveguide (highlighted in blue)

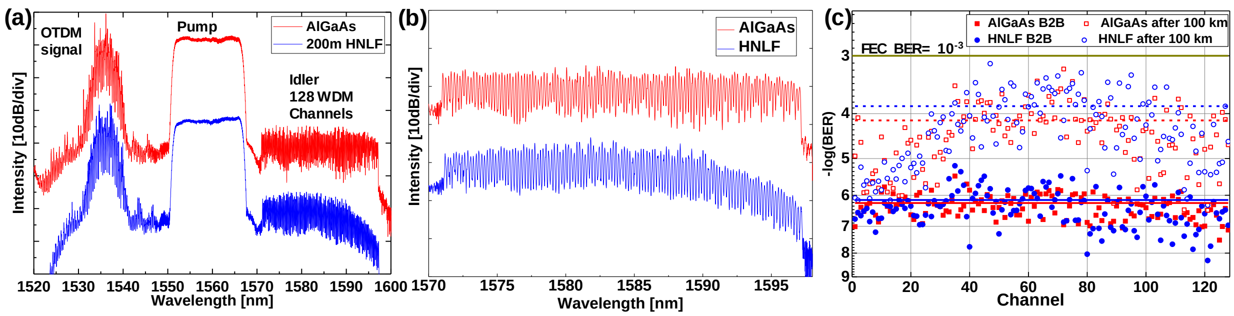

Fig. 2. Experimental results, AlGaAsOI in red and HNLF in blue. (a) Spectrum of the OFT output, (b) a zoom-in on the idler, (c) BER performance with AlGaAs and HNLF of all 128 WDM channels at a fixed received power of −27 dBm for both B2B and 100 km transmission.

The experimental setup is shown in Fig. 1b. The output of a 10 GHz supercontinuum (SC) source is on-off keying modulated (MZM1) with 4×2-Gb/s 2^{15}-1 PRBS TDM tributaries. The output is further optical time-division multiplexed (OTDM) to 128×2-Gb/s using a fiber based OTDM multiplexer. A 100-ps guard interval is added between every 128 TDM tributaries for OFT operation. A wavelength selective switch (WSS1) carves the signal into a 1.2 ps Gaussian shape with a 38% duty cycle. This signal is directly converted to individual WDM channels using OFT, based on four-wave mixing in a highly nonlinear device using linearly chirped rectangular pump pulses [7]. The AlGaAs nanowire is a dispersion engineered straight 4 mm long AlGaAsOI waveguide, which includes tapering sections for low loss interfacing with tapered optical fibers. The main waveguide section is ~3 mm long and the total insertion loss is 6 dB. The HNLF has a length of 200 m, non-linear coefficient γ~10 $W^{-1}km^{-1}$, zero-dispersion wavelength ~1560 nm and dispersion slope 0.005 ps/(nm^2·km) [8]. The pump pulses are generated from the same SC source followed by MZM2, which is used to decrease the repetition rate to 2 GHz for OFT operation. The OFT pump is obtained by filtering in WSS2 followed by 300 m DCF propagation for mapping the 3.125 ps TDM tributary spacing to a 25 GHz frequency grid. The optimized input power to the AlGaAs waveguide is 22.0 dBm for the pump and 13.4 dBm for the OTDM signal, and the optimized input power to the HNLF is 19.5 dBm and 11 dBm, respectively. After OFT, the generated 128×2-Gb/s WDM signals are boosted to 21 dBm using an EDFA, and launched into a 100 km unamplified SMF fiber link. After transmission, a tunable bandpass filter (BPF) is used to select the individual WDM channels, one at a time, to be directly detected by an APD/TIA receiver.

The experimental results are shown in Fig. 2. The output spectrum with HNLF is shown in Fig. 2a in blue. The idler is the obtained 128 WDM channels at 2 Gb/s each. A zoom-in on the idler is shown in Fig. 2b, in which the Fourier transformation of the 256 Gb/s Gaussian OTDM signal to 128 individual 25 GHz spaced WDM channels can be observed. However, the power difference between the short and long wavelength channels is more than 15 dB as shown in Fig.2a and 2b. This is due to the limited nonlinear operational bandwidth of the HNLF, requiring additional equalization before transmission. With power equalization using a WSS, all 128 WDM channels after 100 km transmission achieve BERs below the FEC limit at BER = 10^{-3}, as shown in Fig. 2c. The AlGaAs experimental results are shown in Fig.2 in red. The power difference between the individual channels is less than 3 dB as shown in Fig. 2b. After 100 km transmission, all 128 WDM channels achieve BERs < 10^{-3}, as shown in Fig. 2c. The average BER values before (solid line) and after transmission (dashed line) with the AlGaAs waveguide are similar to that with the HNLF. For both HNLF and AlGaAs, we obtain BER < 10^{-3} for all 128 WDM channels after transmission, but it is difficult for HNLF to scale to higher channel counts, due to the limited operational bandwidth. In contrast, the AlGaAs waveguide shows a greater potential for further scaling of the channel count.

3. Conclusion

A 128×2-Gb/s WDM-PON system with 100 km unamplified transmission based on a single TDM time lens source is demonstrated with both an AlGaAs waveguide and a HNLF. All 128 converted WDM channels achieve BERs below FEC limits after transmission for both cases, confirms the high scalability of the proposed scheme. The experimental results show that the AlGaAs waveguide has potential for further scaling the subscriber count and the total capacity of the proposed OLT structure.

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4. References

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