Flexible 10 Gbps, 8-user DPSK-OCDMA System with 16×16 Ports Encoder and 16-level Phase-shifted SSFBG Decoders

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Abstract: 16-chip, 16-level phase-shifted superstructured fiber Bragg grating (SSFBG) encoder/decoder is reported for the first time. 10 Gbps, 8-user optical code-division-multiple-access system has been demonstrated using hybrid 16×16 ports encoder/SSFBG decoder.

OCIS codes: (060.2330) Fiber optics communication; (060.5060) Phase modulation; (060.4230) Multiplexing

Introduction Optical code division multiple access (OCDMA) is one promising technique for next-generation broadband access network with unique features of full asynchronous transmission, low latency access, soft capacity on demand as well as optical layer security. By combining OCDMA with wavelength division multiplexing (WDM) technique, high capacity in access networks can be achieved, which in prospective can enable gigabit-symmetric fiber-to-the-home (FTTH) [1-2].

There are many different kinds of OCDMA encoder/decoders. For coherent time-spreading (TS) OCDMA, multi-port arrayed-waveguide-grating (AWG) OCDMA encoder/decoder has the unique capability of simultaneously processing multiple time-spreading optical codes (OCs) with single device [3], which makes it a potential cost-effective device to be used in the central office of OCDMA network to reduce the number of encoder/decoders [2]. The multi-port AWG-based encoder/decoder also has very high power contrast ratio (PCR) (15~20 dB) between auto- and cross-correlation signals, which means the interference value could be significantly reduced (up to 20 dB) with the short OC [2].

Meanwhile, phase-shifted superstructured fiber Bragg grating (SSFBG) encoder/decoder is another attractive TS-OCDMA encoder/decoder, which has the ability to process ultra-long TS-OC with polarization independent performance, low and code-length independent insertion loss, inherent compatibility with fiber-optic system, high compactness as well as low cost for mass producing [4-6].

Hybrid using different types of the encoder/decoder in an OCDMA network is expected to significantly improve the system flexibility and performance [2]. As an example, figure 1 shows the architecture of a flexible and cost-effective hybrid WDM/OCDMA network, a multi-port encoder with periodic spectral response can be used in the central office to process multiple OCs in multiple wavelength bands with a single device, whose cost can be shared by all the subscribers; while at the ONU, the WDM demultiplexing and OCDMA decoding could be carried out by employing a low cost SSFBG decoder.

In this paper, we prepare 16-chip, 16-level phase-shifted SSFBG encoder/decoders and demonstrate 10 Gbps multi-user OCDMA system using hybrid multi-port encoder/SSFBG decoder for the first time.

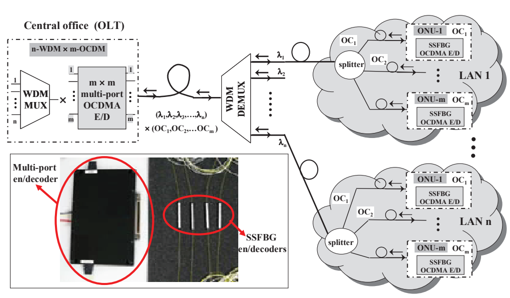

Fig. 1. Cost-effective WDM/OCDMA network architecture

Performance of the 16-level phase shifted SSFBG encoder/decoders The fabrication techniques for the phase-shifted SSFBG encoder/decodes enable us to fabricate a wide range of gratings with different code length and/or multiple phase levels [4, 6]. In this experiment, we prepared four uniform index change 16-chip SSFBG decoders (FBGs 1-4), the center wavelength is 1551 nm, chip length is ~0.52 mm, total length of grating is 8.32 mm, and the 16 phase levels are generated by shifting the chip grating by a step of +/- λ/8. Two 16-level phase shift patterns were used for these gratings: the pattern for FBGs 1 and 2 is OC-1 and for FBGs 3 and 4 is OC-2; OC-1 and OC-2 correspond to the OCs generated from the multi-port encoder with input port 8, output ports 3 and 7, respectively [3]. The gratings were simply packaged that is unable to compensate the temperature drift. Figure 2(a) shows input pulse

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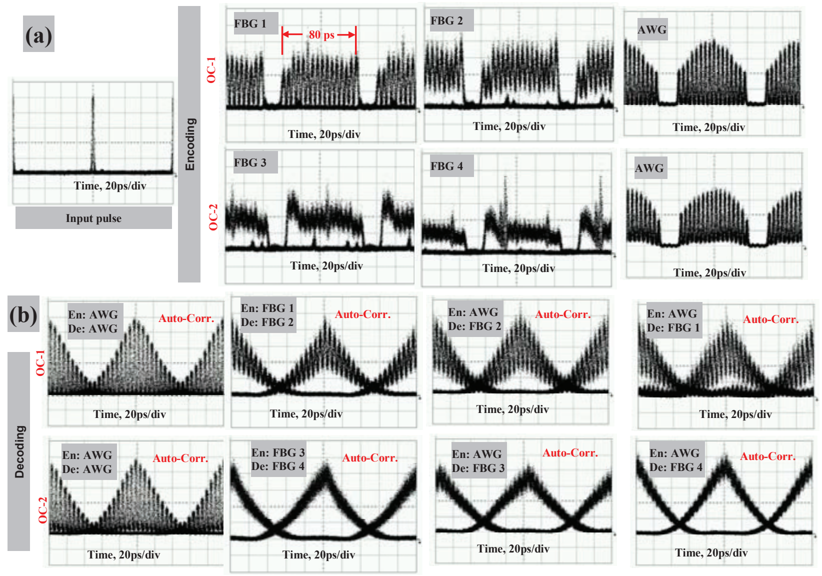

Fig. 2. Waveforms of (a) encoded and (b) decoded signals with AWG-type and FBG en/decoders

and the generated OCs with these gratings compared with those with the AWG-based encoder. The duration of the generated OCs is ~80 ps, chip-rate 200 Gchip/s. The temporal waveforms of the encoded signals from SSFBGs are different as those from AWGs mainly because that we focused on phase shift pattern here and used uniform gratings. The temporal waveform of the generated signal could be further tailored by carefully design the index-change along the whole grating [7]. The peaks of each individual chips of OC-2 generated from SSFBGs are not as clear as OC-1 and that from the AWG. This is probably due to the non-ideal fabrication condition for these gratings. Figure 2(b) shows the waveforms of the auto-correlation with different combinations of AWG and SSFBG encoder/decoders. They are quit similar showing that the AWG and SSFBG encoder/decoder can work with each other. Figure 3 shows the comparison of power contrast ratios of auto- to cross-correlation (PCRs) for AWG and SSFBG decoders. Comparing to a pair of AWG-based encoder/decoder, the PCRs of AWG encoder/SSFBG decoders have the similar performance but generally 1~5 dB lower. Considering that the gratings are uniform and there was obvious imperfectness in the fabrication, these results are reasonably good. Moreover, SSFBG decoder is very robust to the temperature change. In the experiment, with 2~2.5°C temperature change of the AWG encoder, the changes of PCR are within 1 dB. These performances verify the feasibility of hybrid using multi-port AWG-type encoder and multi-phase-level phase-shifted SSFBG decoder to enable flexible and cost-effective OCDMA network. Performance is expected to be further improved by using non-uniform SSFBGs.

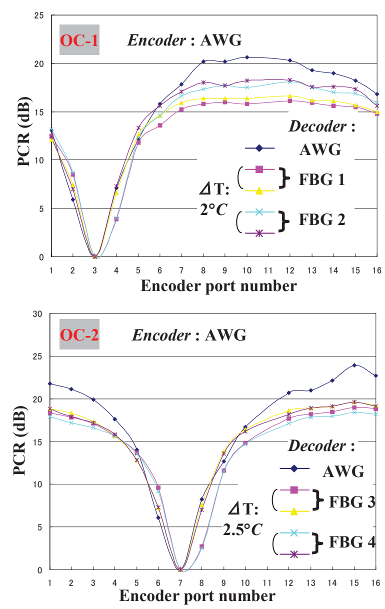

Fig. 3 PCR for AWG/FBG decoders

Multi-user OCDMA experiment Figure 4(a) shows the experimental setup to demonstrate 10 Gbps, 8-user DPSK-OCDMA using hybrid multi-port AWG encoder/SSFBG decoder. Figure 4 (b) shows the waveforms, spectra and eye diagrams measured at different points in the experiment. The mode-lock laser diode (MLLD) generated ~1.8 ps optical pulses at repetition rate of 9.95328 GHz (OC192) with central wavelengths of 1550.8 nm. The signal was modulated with differential-phase-shift-keying (DPSK) format by Lithium Niobate phase modulator (LN-PM) (point α in the figure). The data were 2^{23}-1 pseudo random bit sequence (PRBS). The signal went to the port #8 of the

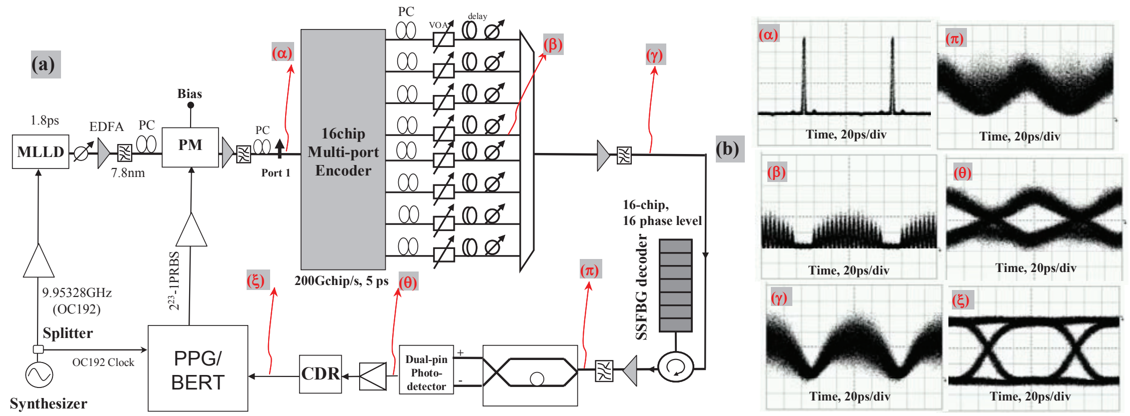

Fig. 4 (a) Multi-user experimental setup; (b) waveforms, spectra and eye diagrams in the 10 Gbps, 8-user DPSK-OCDMA experiment

16×16 ports AWG encoder and generated eight different OCs (point β). These 8 signals were mixed in a truly-asynchronous manner with equal power, random delay, random bit phase and random polarization states emulating 8×10 Gbps asynchronous OCDMA network (point γ). The measurements were done under one of the worst-case scenario, which is bit synchronous and polarization aligned. At the receiver, the 16-chip, 16-level phase-shifted SSFBG decoder decoded the received multiplexed OCDMA signal for a target OC (point π). A fiber based interferometer and balanced detector performed the DPSK detection (point θ). The data were recovered by the clock-data-recovery (CDR) circuit (point ξ) and measured by bit-error-rate tester (BERT). For 8-user OCDMA, very clear eye opening can be observed from θ and ξ.

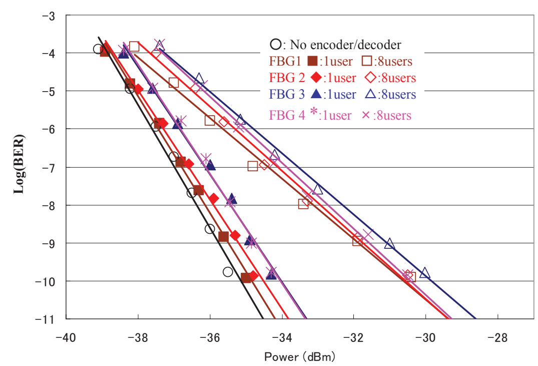

Fig. 5. BER performance

Figure 5 shows the measured BER performances for single- (K=1) and eight-user (K=8) with different SSFBG decoder. Error free has been achieved for all the four decoders in both cases. About 4 dB power penalty has been observed at BER=10^{-9} for K=8 OCDMA compared to K=1.

Conclusion 16-chip, 16-level SSFBG, whose coding performances are similar to 16×16 multi-port AWG-based encoder/decoder, has been reported in this paper. 10 Gbps, 8-user DPSK-OCDMA system has been demonstrated using hybrid multi-port encoder/SSFBG decoder. Performance could be further improved by using non-uniform SSFBG. Hybrid using multi-port AWG-type encoder and multi-phase-level phase-shifted SSFBG decoder could enable flexible and cost-effective OCDMA network.

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