Multiuser Asynchronous OCDMA System with Different Types of FBG based En/Decoders

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Abstract - Asynchronous OCDMA systems are demonstrated using 511 chip, 640 Gchip/s and 31 chip, 40Gchip/s with different types of fiber Bragg grating encoders/decoders. Error-free transmission has been achieved with up to five OCDMA users.

Introduction
Optical code division multiple access (OCDMA) is considered as one of the promising technologies for the future broadband optical access networks for its all-optical operation, full asynchronous and potential security, etc. Several OCDMA schemes have been proposed since the 1980s, which can be classified to incoherent or coherent systems [1]–[4]. Recently, coherent OCDMA using ultrashort optical pulse attracts much attention due to the advances in reliable and compact en/decoder devices and detection schemes [5]–[7]. Optical encoder and decoder are important devices to generate and recognize the optical code signal in coherent OCDMA system. Many different kinds of en/decoder have been demonstrated, such as PLC, AWGs, FBGs and so on. Among these, the superstructured FBG (SSFBG) is particularly attractive because it has provided the most complicated code to 511 chips, 640Gchip/s [8]. This advantage makes SSFBGs more interesting since a longer code sequence provides more available codes. Furthermore, ultra-long codes with high chip rate confirm better autocorrelation and cross-correlation properties. And this is also the most effective way to suppress mitigate beat noise, which is the dominant noise source in multi-user OCDMA systems [9].

Normally, high-precision (nanometer-order) phase control along the grating length is required for fabricating the SSFBG based en/decoders [8], [10]. Using the reconstruction equivalent chirp (REC) technique, the encoder/decoders could be fabricated with sub-micrometer precision and no actual phase jumps are inserted in the gratings [11], [12]. In this Letter, we report the performance of three pairs of 511 chip, 640Gchip/s en/decoders based on REC method with different optical codes and demonstrate asynchronous OCDMA multi-user system with REC-FBG and SSFBG en/decoders where the supercontinuum (SC) based optical thresholder is used after 50km transmission link.

Principle and Experiment
The high-chip-rate en/decoders used in our experiment are mainly based on the REC method which can help to get high-performance filters with complex functions. Based on the REC method, the desired en/decoding function can be obtained in the -1st order channel of a sampled Bragg grating if the sampling function is properly designed. The REC-FBGs are fabricated to generate 511 chip binary phase-shift keying optical pulses in the designed different three Gold-code patterns. The chip length is 0.156mm and the grating length is 79.716mm, which corresponds to the chip rate of 640Gchip/s. The duty cycle of REC-FBG is about 0.4. The center wavelength of grating phase mask is 1549nm which is corresponds to the 0-order channel of REC-FBG. The -1st-order channel is the designed en/decoder spectra with the center frequency about 1554nm. The 31-chip SSFBG has chip rate of 40Gchip/s and the central wavelength is about 1554.5nm which is close to the REC-FBG central wavelength.

Figure 1 shows the experimental setup of multi-user OCDMA experiment. An optical pulse train with pulse width of about 2.2ps is generated by a mode-locked laser diode (MLLD). The center wavelength is 1554 nm and the repetition rate is 10 GHz. The pulse train from pulse pattern generator 1 (PPG1) is electrical signal is fixed pattern “1000 0000” (one “1” every 8 bits) with bit rate of 10GHz. Thus, the repetition rate of pulse train is changed to 1.25GHz after modulator1. After modulator2, the train was converted to a 2^{31}-1 pseudorandom bit sequence (PRBS) at 1.25Gb /s by PPG2. Two electrical tunable delay lines (ETL) are used to confirm the synchronization. Then the signal is amplified and fed into a coupler and encoded by different FBG encoders.
The signals are fed into a single mode fiber (SMF) and a reverse dispersion fiber (RDF) which has total length of 50km. The signal is decoded by corresponding decoders and is detected by a 30GHz bandwidth photo-detector. The electrical low-pass filter (ELPF) with bandwidth of 2.6GHz is placed after the PD and the signal is measured by the bit error tester (BERT), oscilloscope and second-harmonic-generation (SHG) autocorrelator. The en/decoders are set to be three pairs of REC-FBGs firstly and then set to be three pairs of REC-FBGs and four pairs of SSFBGs.

In multiuser system, we use an optical thresholder based on SC generation in dispersion flattened fiber (DFF) to suppress the multiple-access-interference (MAI) noise. It consists of 2-km dispersion flatten fiber (DFF) and a 5-nm optical bandpass filter (OBPF). The dispersion in DFF is kept a low value in the range of 1523.1-1575.2 nm. The operating principle is that the EDFA amplifies the decoded signal to a proper level, with a ~ 2-ps pulsewidth. Then the signal with high peak power can generate SC in the DFF. At the same time, the incorrectly decoded signals (MAI noise) with low peak power are spread over a long time span and unable to generate SC. The OBPF only filters out SC signals and rejects the original signal. Therefore, after the OBPF, the correctly decoded signal can be recovered with the MAI noise greatly suppressed.

**Results**

The BER curves of multi-user with REC-FBGs are shown in Fig.2 and eyediagrams are inserted. Up to three users, the power penalty is about 5.5dBm. In Fig.3, we test different codes in three-user experiment and there is little difference between these codes with REC-FBG en/decoders. And at the first time, we test REC-FBG and SSFBG hybrid multi-user OCDMA system performance. Figure 4 shows the BER curves and eyediagrams are inserted. Seven-user system includes three pairs of REC-FBG en/decoders and four pairs of SSFBG en/decoders. And five-user system includes three pairs of REC-FBG en/decoders and two pairs of SSFBG en/decoders. One can see that the 511-chip REC-FBGs perform better than the 31-chip SSFBGs. In seven-user experiment, the REC-FBG en/decoder can get error-free transmission with power penalty about 2dBm compared with Fig.3.

**Conclusions**

Novel 511chip, 640Gchip/s OCDMA en/decoders are fabricated with REC method in different Gold-codes. Only sub-micrometer precision is required and no actual phase jumps are needed which is much simpler than the SSFBGs. Error-free transmission has been achieved with up to three OCDMA users verifying the performance of REC-FBG encoder/decoders in the asynchronous OCDMA environment. And at the first time, we test the performance of REC-FBG and SSFBG hybrid multi-user OCDMA system. The transmission experiment results show that the distortions between different types of en/decoders have less impairment to high-chip-rate REC-FBGs than the low-chip-rate SSFBGs.

**References**