Demonstration of the improvement of apodized 127-chip SSFBG in coherent time-spreading OCDMA network

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Abstract: We for the first time report the apodized SSFBG en/decoder for coherent time-spreading OCDMA. The performance improvement of the apodized SSFBG with 127-chip, 160-Gchip/s, bipolar Gold code is demonstrated experimentally.

OCIS codes: (060.2330) Fiber optics communications; (060.2340) Fiber optics components

1. Introduction

The last mile is the most critical segment in the telecommunication network as it provides broadband connections to the business and residential customers that can generate the revenues. For now, the existing infrastructures are not fast enough to deliver the next generation broadband access service. There is a wide consensus that only the optical techniques, especially, the passive optical networks (or PON) can provide sufficient bandwidth for this requirement. Optical code division multiple access (OCDMA) is one of the promising candidates for the next-generation broadband access network. It has unique features of *all optical processing* which performs the en/decoding operations in optical domain, *full asynchronous transmission* without complex protocols and expensive electronic equipments, *low delay access* which is desirable for the bursty traffic environment, *soft capacity on demand*, potentially *excellent security*, etc [1-3].

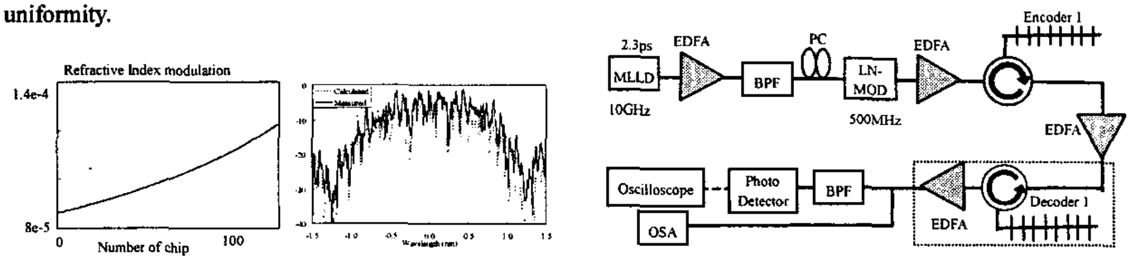
The key component in an OCDMA system is the en/decoder that perform the code generation and recognition functions all optically. Fiber optic delay lines, planar lightwave circuits (PLC), spatial light modulators (SLM), arrayed-waveguide-grating (AWG) and fiber-Bragg-gratings (FBG) have been used for this purpose. Particularly, for the coherent time-spreading OCDMA (TS-OCDMA), the en/decoding operation is not easy to implement because it requires controlling of the optical path of the en/decoder in an optical wavelength dimension. Recently, superstructured fiber Bragg grating (SSFBG) with phase shift has been proposed for coherent OCDMA [4]. It has advantages of good correlation property, high compactness, compatibility with fibre-optic system, and potentially low cost.

But the SSFBG has to be with a relatively low reflectivity to guarantee the simple Fourier transform relationship between the spatial profile of superstructure refractive index modulation and the impulse response will take effect [4,5]. There is a tradeoff between the coding performance of the SSFBG and the increase of its reflectivity [5]. It will be a very severe issue for the application in an access network, especially for passive optical networks (PON), in which the power budget is very tight. In [5], we have theoretically proposed a possible solution to this issue for 15-chip SSFBG by applying apodization alone the whole grating to improve the coding performance in high reflectivity region. In this paper, we will report for the first time the experimental performance of apodized 127-chip, 160Gchip/s, bipolar SSFBG with Gold code and the demonstration of the coding performance improvement by a comparative study of it and the uniform SSFBG with different reflectivities.

2. Experiments and results

The apodization profile of the prepared 127-chip SSFBG is shown in Fig.1(a). The SSFBG is written using 8.3cm long phase masks that contain 127 grating segments. The phase shifts between segments are arranged to be either "0" or "π/2" according to 127-chip Gold code pattern. The length of each segment is 0.65331mm, which corresponds to the chip rate of about 160Gchip/s. The center wavelength of the grating is about 1548.8nm at 25°C. The apodization of the SSFBG is realized by dithering the phase mask during the writing progress. A group of the apodized samples with different Gold code patterns (code1 & code2) are fabricated using this method. Figure1(b) shows one of the measured reflection spectra as well as the calculated result by simulator. They have good agreement with each other.

We have also prepared another two groups of uniform SSFBG with different reflectivities (HR and LR) for the reference. The peak reflectivities of the different samples are listed in Table 1. The uniformity of the sample's peak reflectivity in the AP (~0.1 dB) is improved from 3 dB of the LR and 0.2 dB of the HR group. This is due to the fact *that with the minimum controllable illuminance, the UV induced index change is smaller in the high index change* region [6], and thus the precision of controlling the index change is higher than that in the low index change region. This improvement is crucial in practice because the coding performance of the SSFBG is very sensitive to this uniformity.



(a) (b) (c)

Fig.1. (a) The apodization profile of the 127 chip SSFBG (b) Measured and calculated optical spectral reflectivity of the SSFBG (c)Experimental setup to measure the pulse response of the apodized SSFBG

Table 1. Peak reflectivity of the SSFBG samples

Group	Apodizaed (AP)			Reference (uniform)					
				High reflectivity (HR)			Low Reflectivity (LR)		
Sample	Encoder 1	Decoder 1	Encoder 2	Encoder 1	Decoder 1	Encoder 2	Encoder 1	Decoder 1	Encoder 2
Peak Reflectivity	-1.03 dB	-0.92 dB	-0.91 dB	-2.05 dB	-2.11 dB	-1.8 dB	-10.19	-8.05 dB	-7.13 dB

In Fig.1(c) the experimental set up to measure the pulse response of the SSFBG en/decoder is shown. The 2.3ps optical pulse train with 10GHz repetition rate is generated from the mode-locked laser diode ((MLLD) at ~1548nm, it is modulated into the repetition rate of 500MHz (2000ps pulse interval) for measuring the en/decoded waveforms. The spectra and waveforms of the encoded signals from the LR, HR and AP encoders are measured first, Fig.2(a) and (b) show the results. The peak optical power of the encoded signals from these samples are measured to be –31.9dBm, –24.8 dBm and –22.4dBm respectively. In Fig.2(b), the signal from the LR encoder has a uniform waveform. The uniformity of the waveform gets worse with the HR sample as predicted [5]. The waveform from the AP sample shows an improved uniformity compared with the HR, although the reflectivity is even higher. Then, by adding the decoder in the system, the auto-correlation waveforms are also measured and shown in Fig.2(c). Compared to LR and AP samples, the sidelobe grows with HR.

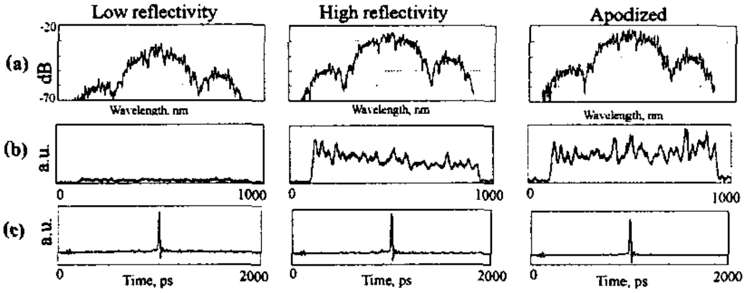


Fig.2. Comparison of the measured results for the three samples

(a) Spectra of the power reflectivity. (b) Encoded waveforms. (c) Decoded waveforms

Compared to LR and AP samples, the sidelobe grows with HR.

The transmission experiment has also been carried out to evaluate the overall BER performance of the apodized SSFBG en/decoder. Fig.3(a) is the experimental set up. The fiber laser and the first electro-absorption modulator (EAM) generate the 2.8ps pulse train with repetition rate of 1.25GHz at ~1549nm, it is then modulated by 2^{23}-1 PRBS at the second EAM. The data signal is encoded with Encoders 1 and 2 by splitting into two arms with a different time delay and multiplexed. At the receiver the multiplexed signal will be decoded by Decoder 1 and finally measured by the BER tester. In Fig.3 (b) the measured BER results for the three groups of samples are shown. In the case of single user transmission (filled marks in the figure), the AP samples give 1.7 dB improvement to the LR samples for error-free transmission (BER<10^{-9}) and 3 dB improvement to the HR samples. In the case of two users multiplexing (open marks), only the AP samples can achieve the error-free transmission. The power penalty to the single user case is 3.8dB. This penalty is presumably due to the beat noise rising from the coherent fact of the signal [7].

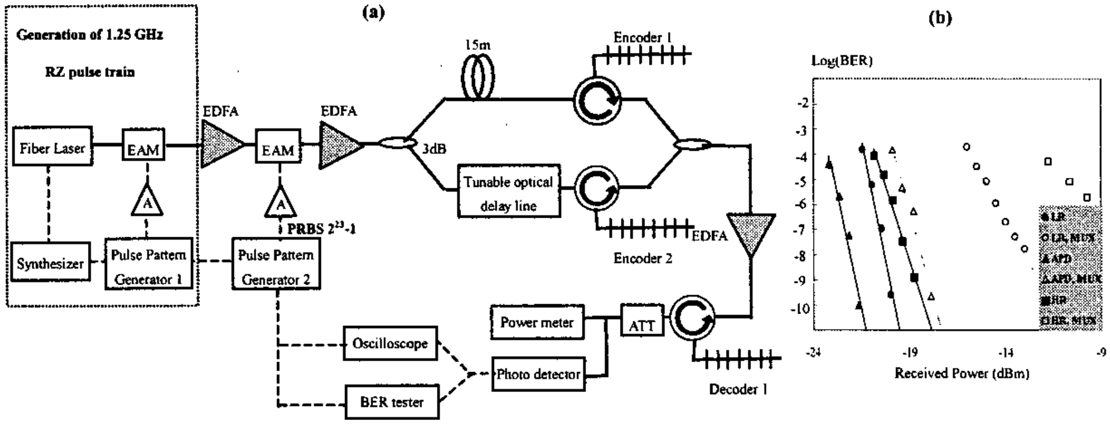


Fig.3. (a) The setup of the transmission experiment with 2 MUX users. (b)BER performance against received optical power for the three groups with & without MUX

3. Conclusions

We have demonstrated the coding performance of the apodized 127-chip, 160Gchip/s bipolar SSFBG for coherent TS-OCDMA. In the comparative experimental study of the apodized samples and the uniform samples with low and high reflectivity, the apodized samples is showed to have simultaneously improvements in obtaining high reflectivity, good reflectivity uniformity, and better BER performance. Error-free transmission with multiplexing of two active users has also been achieved. In conclusion, the apodization technique is an effective solution to the low reflectivity issue with the SSFBG en/decoder. The next step will be the optimization of apodiazation profile.

4. References

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