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Programmable Fiber-based in-band OSNR Monitoring for Flexgrid Coherent Optical Communication System

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Abstract— With the rapid development of ultra-dense large capacity coherent WDM optical communication networks, the monitoring of in-band optical signal-to-noise ratio (OSNR) plays an essential role to ensure signal qualities. Different from the classic polarization-nulling method, we proposed and experimentally demonstrated a novel fiber-based programmable in-band OSNR monitoring method for flexgrid coherent transmission system, the OSNR monitor is based on linearly chirped fiber Bragg grating (LCFBG) and commercial thermal print head (TPH). For the coherent communication system, when the output power of the pre-amplifier at the receiving terminal is constant, degraded OSNR leads to decreased signal power and elevated ASE noise. Therefore, if the central spectrum (signal and in-band noise) is filtered by an ultra-narrow bandwidth optical filter, the output optical power is in proportional to the OSNR value, the influence of the filtered in-band ASE noise will be negligible with relatively high OSNR and the ultra-narrow bandpass filter is the key element for this technique. Based on the thermo-optic effect of the LCFBG, we used the in-house developed driver circuits and a LabVIEW based software to implement a programmable ultra-narrow passband optical filter for OSNR monitoring. Linear monitoring range of 9–27 dB OSNR values with wavelength ranging from 1530.6 to 1538 nm is achieved. The OSNR monitor has advantages of low cost, low insertion loss, large wavelength tunability and compatible with current optical fiber communication system.

1. INTRODUCTION

With the rapid development of ultra-dense large capacity coherent WDM optical communication networks, the monitoring of in-band optical signal-to-noise ratio (OSNR) plays an essential role to ensure signal qualities [1]. Except the classic polarization-nulling method [2], a novel method based on the integrated silicon microring/microdisk resonator based narrow passband optical filter was proposed [3] to monitor the OSNR recently [1, 4]. However, this method suffers from pretty large insertion loss due to the coupling difficulty between chips and fibers, and the operating wavelength range is limited.

In this work, we proposed and experimentally demonstrated an OSNR monitoring technology based on an all-fiber structured programmable ultra-narrow bandpass optical filter [5]. When the output power of the pre-amplifier at the receiving terminal is constant, degraded OSNR leads to decreased signal power and elevated ASE noise. Therefore, if the central spectrum (signal and in-band noise) is filtered by an ultra-narrow bandwidth optical filter, the output optical power is in proportional to the OSNR value, the influence of the filtered in-band ASE noise will be negligible with relatively high OSNR and the ultra-narrow bandpass filter is the key element for this technique.

2. SYSTEM CONFIGURATION AND EXPERIMENTAL RESULTS

The experimental setup is shown as Figure 1. A tunable laser is set as the optical source, the 16 QAM OFDM signal was generated from an offline DSP and fed into the I/Q modulator through the AWG (Arbitrary Waveform Generator, 10 GSam/s) to generate 16 QAM-OFDM optical signal with 20 Gb/s bit rate. A variable optical attenuator (VOA1) is used to adjust the optical signal power and an ASE noise after 1nm bandwidth tunable optical filter (TOF) is coupled with the signal by a 50 : 50 coupler for accurately setting the OSNR level. After transmission through 100 km single mode fibers (SMFs), the optical signal with ASE noise are amplified by an EDFA operating under constant power mode thus the received optical power (ROP) is constant. After the

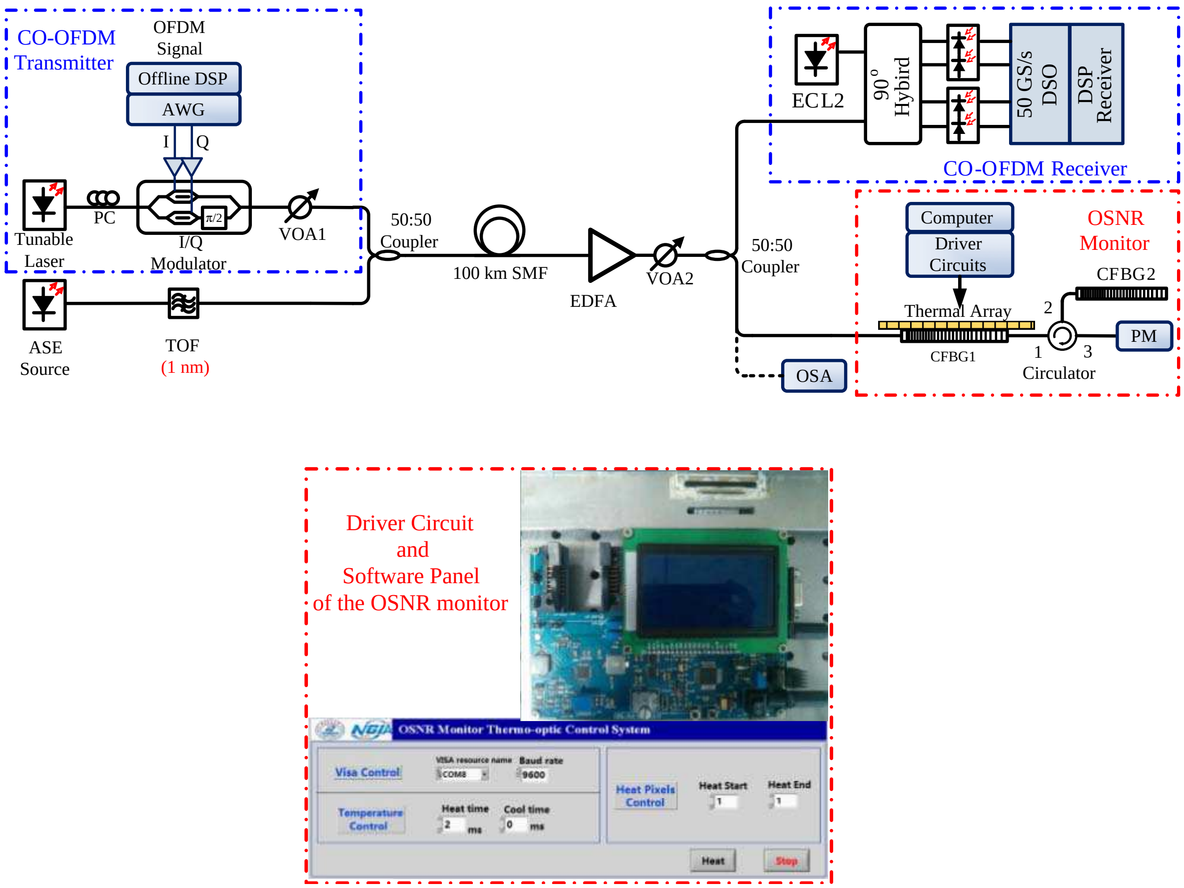
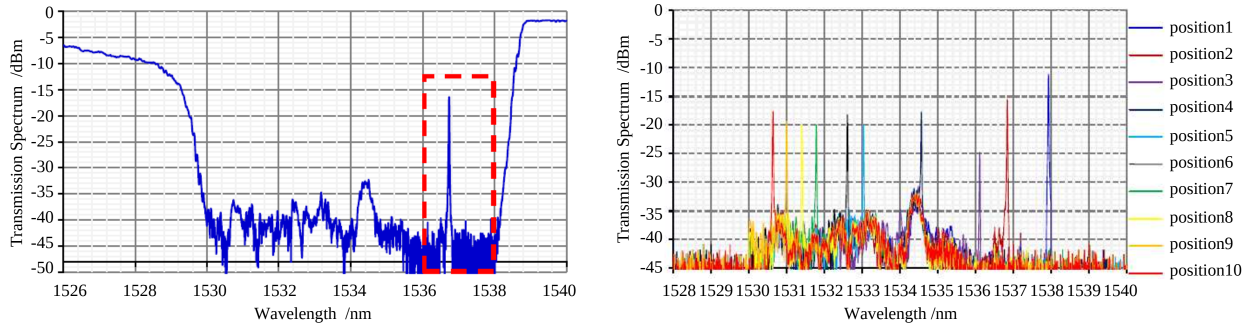


Figure 1: Experimental setup, driver circuits and computer software of the OSNR monitor.

EDFA, the VOA2 adjusts the ROP fed into the coherent optical OFDM receiver. A digital signal oscilloscope (DSO) with 50 GS/s sampling rate is used for data acquisition and the received signals are processed offline for data recovering. Meanwhile, 50% of the signal is coupled into our OSNR monitor. An Optical Spectrum Analyzer (OSA) is used for OSNR calibration.

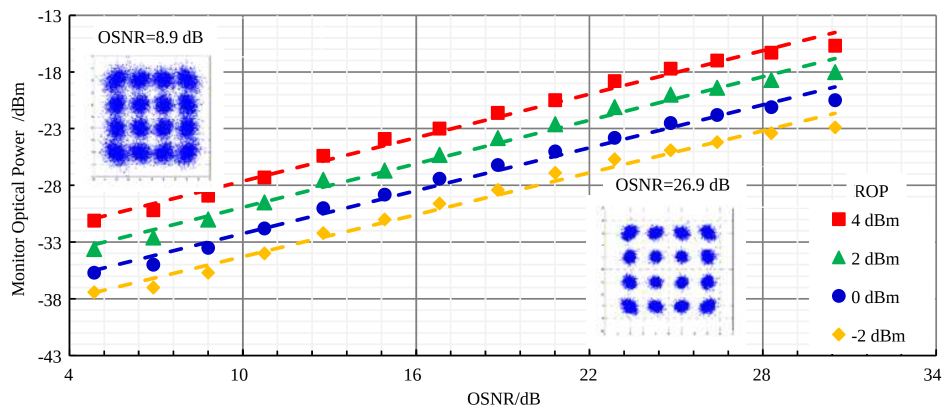
The heart of our OSNR monitoring system is the all-fiber structured wavelength-variable optical filter based on a linearly chirped fiber Bragg grating (LCFBG) and a thermal print head (TPH), as shown in the right corner of Figure 1. TPH consists of 586 independent thermal pixels with spacing of 125 μm and is fixed tightly with CFBG1. We can control the on/off status and heating temperature of each pixel respectively by computer software through in-house developed driver circuits. Utilizing the thermo-optic effect, we can introduce a temporary phase shift into the stopband of the LCFBG's transmission spectrum, thus an ultra-narrow transmission peak will appear at the stopband, as shows in the red box in Figure 2(a). The 3 dB bandwidth is less than 0.02 nm (limited by the OSA). Since the passband of the optical filter is much less than the transmission signal, a linear relationship between filtered optical power and OSNR is anticipated. In order to eliminate the unwanted ASE light beyond the stopband, CFBG2 is used together with the circulator to ensure that only the filtered optical power can reach the powermeter (PM). An advantage of our programmable optical filter is that the central wavelength can be easily reconfigured to meet the OSNR monitoring requirements for coherent communication systems at arbitrary wavelength. Figure 2(b) shows the superimposed transmission spectrum when we heat different position of the TPH. The filter's center wavelength can be accurately adjusted across the stopband of the LCFBG transmission spectrum. Therefore our technique will be ideal for the OSNR monitoring of flex-grid transmission system with the wavelength ranging from 1530.6 nm to 1538 nm. The operating wavelength range can be further increased by using optimized LCFBG and TPH.

We fixed the monitor's operation wavelength at 1535.82 nm (one of the DWDM channel center wavelength according to the standard of the ITU-T G.692), and adjusting the attenuation of the VOA1, we can alter the received OSNR value. The ROP after VOA2 is adjusted to several values and the relationship between monitor optical power after optical filter and the OSNR is

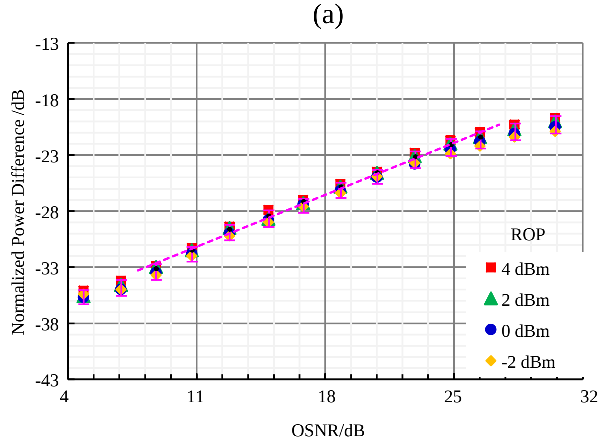


(a) (b)

Figure 2: (a) Transmission spectrum of CFBG1 after heated specific pixels, the red box is the ultra-narrow optical filter introduced by thermal phase shift. (b) The transmission spectrum of the monitor with wavelength tunable range from 1530.6 to 1538 nm.



(a)



(b)

Figure 3: (a) Measured monitor power as a function of OSNR at different ROP. Insert: constellation of the 16 QAM-OFDM at ROP = 0 dBm. (b) Relationship between normalized power difference and OSNR, pink lines: error bars, pink dashed line: linearly working range.

demonstrated in Figure 3(a) at different ROPs. It can be clearly found that at all ROP values, the filtered output optical power shows a linear function of OSNR and the linear fitting curve matches the data very well. The inset diagrams in Figure 3(a) present the constellation of the 16 QAM OFDM signal at the best and worst OSNR situation when the ROP is 0 dBm after offline DSP processing. By comparing the filtered optical power and the ROP, the normalized power difference after the programmable optical ultra-narrow filter versus OSNR is plotted in Figure 3(b). It can be observed that, although the ROP is different, the normalized power difference data converges at the corresponding OSNR level and it can be regarded as a transfer function of OSNR monitoring. The error bars are calculated and are shown in the same figure. It can be seen that the linear working range with negligible error (standard deviation < 0.5 dB) can be achieved when the OSNR varies from 9 to 27 dB, respectively.

3. CONCLUSION

We demonstrated an in-band OSNR monitoring with programmable ultra-narrow passband optical fiber filter for coherent transmission system. Linear monitoring range of 9–27 dB OSNR with wavelength ranging from 1530.6 to 1538 nm is achieved. The programmable ultra-narrow optical filter is based on linearly chirped fiber Bragg grating (LCFBG) and thermal print head (TPH), and we experimentally demonstrated the OSNR monitor for 16 QAM-OFDM transmission system. The scheme can be extended to monitor signal with other modulation formats and this technique is promising for practical deployment because it is fully compatible with the fiber transmission system.

ACKNOWLEDGMENT

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REFERENCES

1. Xu, K., et al., "An ultracompact OSNR monitor based on an integrated silicon microdisk resonator," *IEEE Photo. J.*, Vol. 4, 1365–1371, 2012.
2. Lee, J. H., et al., "OSNR monitoring technique using polarization-nulling method," *IEEE Photonic. Tech. L.*, Vol. 13, 88–90, 2001.
3. Yang, J. Y., et al., "Optical signal-to-noise ratio monitoring of an 80 Gbits/s polarization-multiplexed return-to-zero differential phase-shift keying channel," *Opt. Lett.*, Vol. 34, 1006–1008, 2009.
4. Li, Q., et al., "A fully-integrated in-band OSNR monitor using a wavelength-tunable silicon microring resonator and photodiode," *Optical Fiber Communication Conference*, W3E.5, 2014.
5. Zhang, H., M. Tang, et al., "Programmable all-fiber structured waveshaper based on linearly chirped fiber Bragg grating and digital thermal controller," *Appl Phys B — Lasers O*, Vol. 112, 479–484, 2013.