Alleviation of Four-wave Mixing Effect on O-band WDM Optical Links via Polarization Interleaving

Gyeong Cheol Park[1], Miran Park[1], Geonwon Lee[2], Namje Kim[1], Seungchul Lee[1], Jun-Hwan Shin[1], Suho Park[1], Mihee Hwang[2], Soonwon Hong[2], Jongmin Lee[3] and O-Kyun Kwon[1,*]

[1] *Photonic/Wireless Devices Research Division, Electronics and Telecommunications Research Institute, 218 Gajeong-ro, Yuseong-gu, Daejeon, 34129, Republic of Korea*
[2] *OE Solutions,52, Cheomdannyeonsin-ro 30beon-gil Buk-Gu, Gwangju, 61080, Republic of Korea*
[3] *HFR, C-dong, 40 Geumto-ro 80beon-gil, Sujeong-gu, Seongnam-si, Gyeonggi-do, 13453, Republic of Korea*
[*] *okyun@etri.re.kr*

Abstract: Four-wave mixing (FWM) severely constrains O-band WDM optical links by limiting power and channel density. We experimentally demonstrate substantial FWM mitigation in a six-channel optical link via optimized polarization tailoring, enhancing nonlinear tolerance.

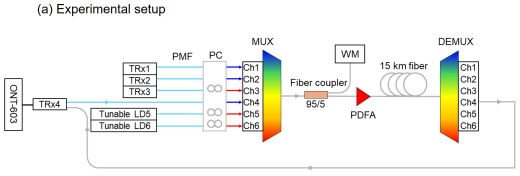
1. Introduction

The continuously increasing data usage is urging the transition from fifth-generation (5G) to sixth-generation (6G) optical links. The O-band has emerged as the optimal spectral window for high-capacity links in that it contains the zero-dispersion wavelength (ZDW) window of standard single-mode fiber (SSMF), which minimizes chromatic dispersion [1]. As a result, simple intensity-modulation and direct-detection (IM/DD) can be adopted for O-band optical links. However, the lack of chromatic dispersion in the O-band causes a rather severe nonlinear effect of FWM, which generates parasitic optical tones ($f_{fwm} = f_i + f_j + f_k$), resulting in in-band crosstalk [2,3]. Although unequal channel spacing effectively mitigates Four-Wave Mixing (FWM) impairments, it requires a significant compromise in spectral efficiency [3].

In here, we experimentally demonstrate FWM mitigation in a 6-channel optical link via polarization interleaving with a channel interval of 200 GHz. Firstly, three channels with the same polarization are assigned unequally in the channel space, which can mitigate the FWM impairment. Secondly, the other three channels, also unequally spaced, are assigned to a different polarization from the first group, and the FWM interaction is mitigated. All 6 channels are allocated to the consecutive spectral grid. By adjusting the polarization of the three channels following the proposed alignment, it is experimentally proven that the bit-error-rate (BER) penalty is relaxed and merges toward the BER curve of the single channel.

2. Experimental results and discussion

To validate the effect of the polarization interleaving of the 6-channel optical link with the equal channel spacing of 200GHz, we configure the experimental setup as shown Fig. 1(a). The center frequency and polarization alignment are shown in Fig. 1(b). The 4th channel is modulated with 100Gb/s PAM4 and transmitted over a 15 km SSMF, and then the BER is analyzed using an optical network analyzer (ONT-603).



(b) Frequency and polarization arrangement in the experiment

WDM index	Center frequency (THz)	Center wavelength (nm)	polarization
Ch1	231.4	1295.55	X
Ch2	231.2	1296.68	X
Ch3	231.0	1297.80	Y
Ch4	230.8	1298.92	X
Ch5	230.6	1300.53	Y
Ch6	230.4	1301.18	Y

Fig. 1. (a) Schematic diagram of an experimental setup for a six-channel optical link and (b) frequency and polarization arrangement of the experiment.

To verify the FWM effect, the optical spectrum is measured as shown in Fig. 2. Fig. 2(a) shows the spectra of the 6-channel optical link with the black-solid line and the spectra for the case where the 4th channel is off with the red-

dotted line when the parasitic optical tones in the out-band are maximized by adjusting the polarization alignment. Even though the 4th channel is off, the FWM interaction generates the parasitic channel at the same frequency as the 4th channel. Fig. 2(b) shows the spectra of the 6-channel optical link; one spectrum is for the parasitic optical tones at maximum ('polarization condition1'), and the other at minimum ('polarization condition2').

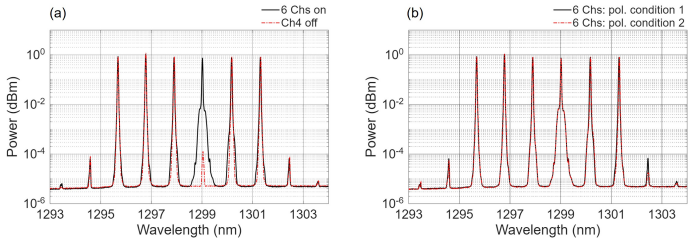


Fig. 2. Measured optical spectra of (a) all six channels on-state and only the fourth channel off-state with the same polarization condition, and (b) all six channels on-state with two different polarization conditions.

To confirm the FWM impairment, the BER curves are obtained as shown in Fig.3 for the two polarization alignments. All 6-channel optical signals are transmitted over the 15 km SSMF, and the BER of the 4th channel is measured at each received power. To eliminate the FWM effect, only the 4^{th} channel is on, and the signal is transmitted. To match the optical power level between the two cases, the optical power at the output of DEMUX is adjusted by controlling the PDFA. Fig. 3(a) shows the BER curves when the polarization alignment is set to maximizing the parasitic optical tones for the two different input power levels: 'H' and 'L', respectively. The FWM effect impairs the BER even when the input power is increased. When the polarization arrangement is set to minimize the out-band parasitic tones, the BER curves merge toward the BER curve of the 4^{th} single channel.

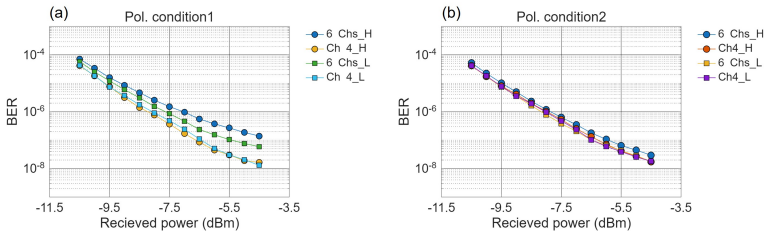


Fig. 3. Measured BER curves at two different input power conditions for an on-state of all six channels, and only the fourth channel on-state, with (a) a 'polarization condition1' and (b) a 'polarization condition2'.

3. Conclusion

We have experimentally shown that the FWM effect is mitigated by adjusting polarization interleaving for the 6-channel O-band optical link. By adjusting the polarization state, the BER curve of the 6-channel optical link converged to the BER curve of the optical link operating as a single channel.

4. Acknowledgment

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