EXTREMELY NARROW CHANNEL SPACING 10GB/S-DWDM TRANSMISSON FOR ADVANCED SUBMARINE CABLE SYSTEM

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Abstract: This paper describes the technologies developed for 10Gb/s WDM transmission systems covering trans-Pacific distance with Tb/s capacity. We have also confirmed by experiments that transmission over 11,833km with 25GHz-spaced RZ-DPSK signal is feasible with a performance comparable with that of 33GHz channel spacing.

1. INTRODUCTION

The 10 Gb/s DWDM systems have been implemented in the last several years as infrastructure for international communication and global network. To cope with the increasing future capacity requirements, two types of approaches have been mainly investigated in order to increase the capacity. One is to increase the number of 10Gb/s channels by reducing the channel spacing[1-3] and the other is to increase the channel bit rate to 40Gb/s [4-5]. To date, we have already deployed 33GHz spaced 10Gb/s DWDM submarine cable systems.

This paper describes our recent development of 10Gb/s DWDM transmission technologies with extremely narrow channel spacing for submarine cable systems to achieve over Tb/s capacity. It has been confirmed by experiments that it is feasible for 25GHz-spaced RZ-DPSK (Differential Phase Shift Keying) signal to achieve the trans-Pacific transmission distances.

2. RECEIVER SENSITIVITY OF 25GHZ-SPACED RZ-DPSK SIGNALS

The receiver sensitivity is one of the key design factors for the submarine cable systems with a long transmission distance over several thousands kilometers. It is well known that RZ-DPSK modulation signal has better receiver sensitivity by approximately 3dB than the conventional RZ modulation signal [6]. In order to confirm that the advantage of receiver sensitivity is kept even for narrow channel spacing, we compared the difference of receiver sensitivity between the RZ-DPSK signal and the RZ signal for various channel spacing. Figure 1 shows the Q value performance as a function of the received OSNR for both the RZ-DPSK signal and the RZ signal.

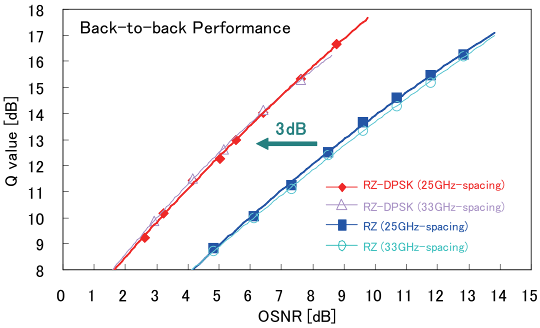


Fig. 1: Q value dependencies on the OSNR for RZ-DPSK and RZ with various channel spacing

The open triangle and the open circle show the measured Q value for the RZ-DPSK and the RZ signals with a 33GHz channel spacing respectively. The RZ-DPSK signal improves the required OSNR by approximately 3dB compared to the RZ signal for a 33GHz channel spacing. The closed diamond and the closed square show the measured Q value for the RZ-DPSK and the RZ with a narrower channel spacing of 25GHz respectively. As shown in this measurement result, no degradation was observed even for 25GHz channel spacing compared to 33GHz channel spacing which is widely used in the commercial submarine cable systems today. This result indicates that the 25GHz-spaced RZ-DPSK signal keeps its excellent receiver sensitivity for the extremely dense WDM system.

3. LONG DISTANCE TRANSMISSION PERFORMANCE WITH 25GHZ-SPACED RZ-DPSK SIGNALS

In general, a narrow channel spacing enhances the nonlinear effects, such as the cross-phase modulation (XPM) and the four-wave-mixing (FWM), in the optical fiber transmission, and it degrades the transmission performances. To make an assessment of the transmission performance with a narrow channel spacing, we compared the Q values between 25GHz and 33GHz channel spacing after long distance transmission over the dispersion managed fiber (DMF).

3.1. EXPERIMENT SETUP

Figure 2 shows our experimental setup for long distance transmission with the re-circulating technique.

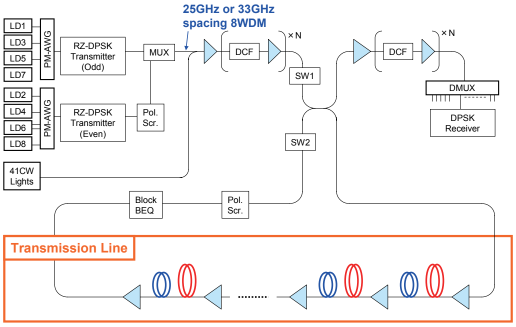


Fig. 2: Experimental Setup

In the transmitter side, we prepared two sets of RZ-DPSK transmitters and one set of 41 CW light sources. Four odd channels and four even channels of the RZ-DPSK signals were separately modulated by different transmitters respectively. The RZ-DPSK signals had a line rate of 10.7Gb/s with a 2^{23}-1 PRBS. A low speed polarization scrambler was applied in the even channel transmitter side to intentionally randomize the polarization state between the adjacent channels in the WDM signal. The odd and even channels were multiplexed into the 25GHz-sapced WDM signals or 33GHz-spaced WDM signals. The 41 channels of CW lights were allocated from 1530nm to 1566nm except the wavelength band of 8 RZ-DPSK signals. The appropriate pre-dispersion compensation fiber was adapted after coupling 8 RZ-DPSK signals and 41 CW light sources. In the receiver side, the 25GHz-spaced or 33GHz-spaced WDM signals were demultiplexed into one 10.7Gb/s RZ-DPSK signal by the demultiplexer after the appropriate chromatic dispersion compensation. The RZ-DPSK signal was demodulated into a 10.7Gb/s electrical signal with using the 1bit delay demodulator followed by the balanced photo-detector. Figure 3 shows the DMF transmission line, which was composed of thirteen 73km DMF spans and sixteen 980nm-pumped-EDFAs with +16.5dBm output power. Two DCF spans were added to adjust the residual dispersion. The loop length was 1,076km. A low speed polarization scrambler was also adopted in the transmission line to simulate the fluctuation of the polarization status.

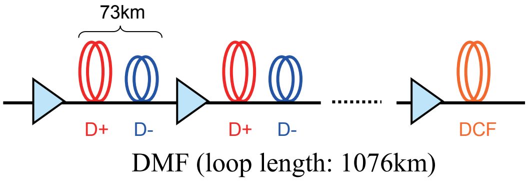


Fig. 3: Transmission Line Configurations

3.2. ASSESMENT OF TRANSMISSION PERFORMANCE

We measured the Q value performance dependency on the transmission distance for both channel spacing of 25GHz and 33GHz in order to make an assessment of narrowing channel spacing impact on the transmission performance.

The channel power of RZ-DPSK signal was set to -5.1dBm/ch by adjusting the 41 CW light sources power level. Figure 4 shows the measured Q value performance for various transmission distances from 5,379km to 13,984km. The measured Q value for 33GHz spacing and the one for 25GHz spacing was 12.2dB and 11.9dB on an average after 11,833km transmission, respectively. Both the Q values for 33GHz and 25GHz channel spacing exceeds our FEC detection limit of 8.8dB. The Q value difference between 33GHz spacing and 25GHz spacing was only 0.3dB even after 11,833km transmission, and no difference between them was observed in the received waveforms shown in Figure 5. With narrowing channel spacing, the inter-channel interaction of both the linear cross talk and the non-linear cross talk may increase and may make the Q value fluctuation larger. To evaluate the influence of the inter-channel interaction, we compared the Q time variations between 33GHz spacing and 25GHz spacing after 11,833km transmission. The Q time variation was measured with changing the polarization states by the slow speed polarization scramblers adopted in the transmitter side and the transmission line. Figure 6 shows the measured Q time variations. The standard deviation for 33GHz spacing and the one for 25GHz was 0.17dB and 0.22dB, respectively. Although the Q time variation of 25GHz spacing is slightly larger than the one of the 33GHz spacing, the difference is small enough to be managed in the power budget design of the commercial submarine cable systems.

We confirmed that the over 11,833km transmission with 25GHz-spaced 10Gb/s RZ-DPSK signals is feasible with the almost same performance as the case of 33GHz channel spacing.

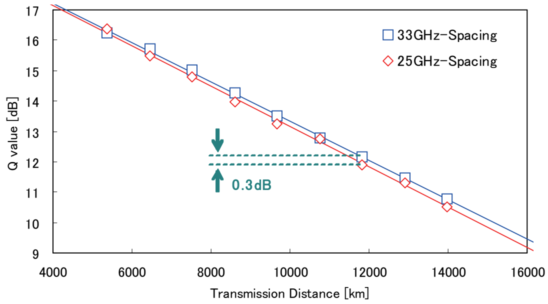
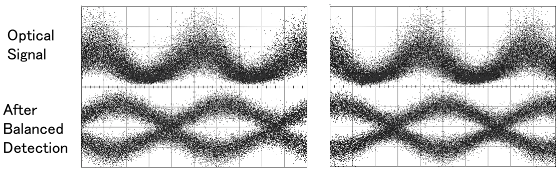


Fig. 4: Performance of RZ-DPSK with 25GHz-spacing over 11,833km Transmission



25GHz-spacing 33GHz-spacing

Fig. 5: Waveform after 11,833km Transmission

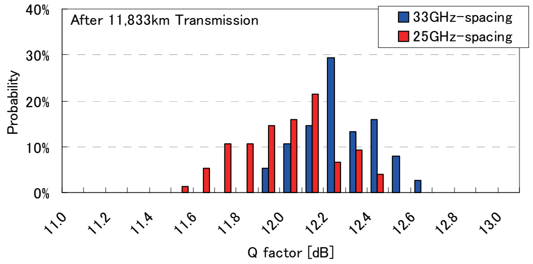


Fig. 6: Q Distribution

3.3. 132x10GB/S- 6,5000km TRANSMISSION

To demonstrate the extremely narrow channel spacing transmission using the fully-engineered 10Gb/s technologies, we conducted 132x10Gb/s-6,500km transmission experiment with adopting the RZ-DPSK modulated 132 signals with a 25GHz channel spacing. The transmission line used in this experiment was same as the configuration shown in Figure 3. Figure 7 shows the measured Q values and optical spectrum after 6,500km transmission. We confirmed that all the 132 channels have large Q margins of more than 6dB against our FEC detection limit of 8.8dB.

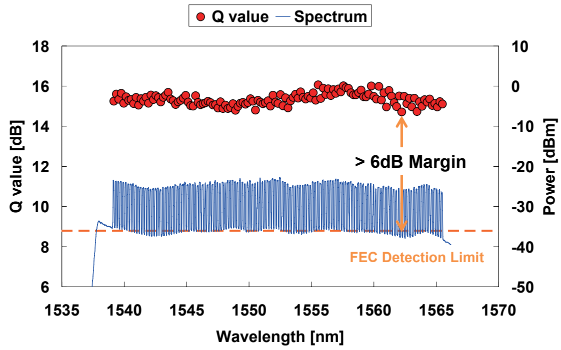


Fig. 7: Transmission performance of 132 x 25GHz-spaced 10Gb/s RZ-DPSK signal over 6,500km transmission

4. CONCLUSION

This paper described our recent development of 10Gb/s DWDM transmission with extremely narrow channel spacing of 25GHz for transoceanic submarine cable systems to achieve over Tb/s capacity. It has been verified that transmission over 11,833km with 25GHz-spaced RZ-DPSK signal is feasible with a performance comparable with that of 33GHz channel spacing.

5. REFERENCES

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