All-optical demultiplexing using an electroabsorption modulator

Højfeldt, Sune; Bischoff, Svend; Mørk, Jesper

Published in:
Proceedings of Lasers and Electro-Optics

Link to article, DOI:
10.1109/CLEO.2000.907091

Publication date:
2000

Document Version
Publisher's PDF, also known as Version of record

Link back to DTU Orbit

Citation (APA):
for case (b). Also, no obvious correlation between the FWM crosstalk variations and Q fluctuations was observed. Fig. 2 gives the standard deviations (STI) of measured Q as a function of the average FWM crosstalk. It shows that the magnitudes of fluctuations of Q values increase as FWM crosstalk increases, while the standard deviation of FWM crosstalk decreases slowly with the increase of the average FWM crosstalk. Therefore, the fluctuations of Q values are not correlated to the variations of FWM crosstalk level.

To further evaluate the Q variations, we measured Q values for different OSNR in Fig. 3. Measured Q values in about 1.7 hours for two OSNRs, 19.7 dB and 28.0 dB. The average FWM crosstalk level was unchanged for these two cases. From Fig. 3, we observe that increasing amplified spontaneous emission (decreasing OSNR) reduces not only the magnitude of Q, but also the fluctuation of Q. This is contrary to the FWM effect which reduces the magnitude of Q, but increase its fluctuations, as shown in Fig. 2.

From our measurement results, we believe that the Q fluctuations were related to FWM, but not induced by the variations of FWM crosstalk level. The causes of the Q fluctuation can be tracked in two directions. First, part of fluctuations may simply come from the accuracy reduction of the Q measurement method due to the non-Gaussian statistics of FWM crosstalk, which increases the difficulty to get a good fitting curve from the measured points and induces large fluctuations among different measurements even though the system performance might be quite stable. This can be justified by the fact that decreasing OSNR reduces the Q fluctuations, as shown in Fig. 3.

The second reason of the Q variations goes to the real system performance fluctuations. Though the FWM crosstalk varies little, its phase may vary due to the laser frequency drifts and the variations of fiber characteristics. Thus the FWM degradation on the channel signals may vary since the interference effect of FWM on the channel signal depends on the phase. We would expect the same results, since the interference effect of FWM also depends on the polarizations states of the channel signals and the FWM signals.

However, we know that polarization variations should also induce fluctuations on FWM crosstalk, as shown in Fig. 2 and Fig. 3, no large fluctuations were observed on FWM crosstalk. Therefore, there should be no large polarization effect on the variations of system performance. The phase fluctuation is the main factor for the system performance fluctuations. This can be partly justified by the fact that measured Q values drifted from time to time and also the magnitudes of the drifts are highly related to the levels of average FWM crosstalk.

In summary, we have investigated FWM induced Q fluctuations in WDM systems. Our measured results show that FWM can induce large variations on system Q-factor. The magnitudes of the fluctuation on Q have little correlation to the magnitudes of fluctuations of FWM power, but strongly depend on the average FWM crosstalk level. We believe that these fluctuations mainly result from FWM induced non-Gaussian characteristics of the noise in channel signals and also from the variations of the phase coherence between the FWM signals and the channel signals. Thus, these fluctuations may have great impacts on the performance of forward-error correction (FEC) that will be implemented widely in next generation WDM systems.


**Cultural Significance**

The document discusses the investigation of four-wave mixing (FWM) induced Q fluctuations in WDM systems. The authors measured Q values for different OSNRs and observed fluctuations that were not correlated to FWM crosstalk levels. They observed that the Q fluctuations were primarily due to phase fluctuations, which affected the system performance. The authors concluded that phase fluctuations were the main factor affecting system performance fluctuations. They recommended that forward-error correction (FEC) be implemented in future WDM systems to mitigate these effects.

CWK70 Fig. 2. Eye diagrams of all 8 OTDM channels at the output as a function of delay length. At the input, all channels are equal, but into the device, other channels than the demultiplexed are rejected. The time window is 100 ps. The control pulse energy was 14 dBm, and the average OTDM pulse power was 7 dBm.

CWK70 Fig. 3. Level of rejection as a function of delay length with average control pulse power as parameter. The level of rejection, determined by one of the rejected channels or by the gated space (whichever gives the worst eye), levels out when the control pulses become too weak to saturate the device, but the signal levels keep decreasing. Bit patterns were chosen to obtain the greatest possible impairment.

CWK71 Long-haul soliton transmission in a standard fiber at 1.3 μm with distributed Raman amplification

A. Oldrichuk, G. Onischukow, F. Lederer, Inst für Angewandte Physik, Friedrich-Schiller Univ. Jena, Max-Wien Platz 1, D-07743 Jena, Germany; e-mail: skelin@iap.uni-jena.de, photonics@iap.uni-jena.de

The desired increase of transmission capacity demands to develop optical amplifiers for the expanded optical communication window 1.3–1.6 μm. Raman fiber amplifiers are among the most promising candidates to achieve this goal because of their flexibility regarding the operation wavelength, i.e., only a pump source with an appropriate wavelength is necessary. Broadband Raman amplifiers and Raman amplifiers as supplement to EDFA have attracted a considerable deal of interest in recent years,1,2 but beyond 1.5–1.6 μm communication window the long-haul transmission with Raman amplification are not investigated yet. In this work we report on transmission experiments over 10,000 km with distributed Raman amplification in 1.3 μm region.

We have investigated 10 Gb/s soliton propagation in the 1.3 μm wavelength region using a re-circulating fiber loop set up. Distributed Raman amplification in a standard communication fiber was used to compensate for losses in the 24 km fiber and 6 dB losses in additional elements (3.1 m optical bandpass filter, acousto-optical switch, 20% coupler, isolators). The counter-propagating pump scheme was chosen. The pump source was a 1244 nm cascaded fiber Raman laser pumped by an 1.06 μm Yb-doped fiber laser. In order to stabilize the Raman gain, the laser diode current in the Yb laser was controlled by the 1.24 μm output of the Raman laser through electro-optical feedback. An intensity modulator governed by a random pulse generator was used to convert the optical pulses from an external cavity mode-locked semiconductor laser to the PRBS format.

We have obtained error-free propagation (Q > 6) up to 10,000 km at 1307–1311 nm wavelengths in a fiber with zero dispersion at 1305.3 nm. No stable propagation has been achieved at zero dispersion wavelength and in normal dispersion domain. For anomalous group velocity dispersion it has been found that the Q-factor strongly depends on the pulse energy and the optimum energy is found to be the fundamental soliton energy. This optimum pulse energy is proportional to the fiber dispersion in the 1305.3–1306 nm range as for solitons with a fixed duration. The propagation near zero dispersion wavelength was poor because of low soliton energy and consequently low signal to noise ratio. The best results were obtained near 1308 nm. Non-transform limited 20 Gb/s input pulses are narrowed down to 5 ps as a result of transformation into solitons during a few hundred km. The dependence of the Q-factor on the distance near the optimum wavelength and a typical eye diagram are shown in Fig. 1.

We have found that timing jitter and not the signal to noise ratio degradation is the main limiting factor for long distance transmission in such a system. The measured dependence of