Generation of 100+++ Gbit/s signals using multilevel modulation formats

Tokle, Torger; Serbay, M.; Jensen, Jesper Bevensee; Rosenkranz, W.; Jeppesen, Palle

Published in:
LEOS Summer Topical Meetings, 2007 Digest of the IEEE

Link to article, DOI:
10.1109/LEOSST.2007.4288431

Publication date:
2007

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

Link back to DTU Orbit

Citation (APA):
Generation of 100+++ Gbit/s signals using multilevel modulation formats

Torger Tokle, Murat Serbay, Jesper Bevensee Jensen, Werner Rosenkranz and Palle Jeppesen.

Abstract — Multilevel modulation formats are used as the enabling technology to obtain 120 Gbit/s per channel bit rates, and 240 Gbit/s when polarization multiplexing is added. Using OTDM, this can be extended even further.

I. INTRODUCTION

The use of multilevel modulation formats is an effective way to increase the bit rate of optical communication systems. Many experiments in the recent years have demonstrated that multilevel modulation formats offer many benefits compared to binary modulation at the same bit rate. The benefits include the use of low-bandwidth electrical generation and reception equipment, enhanced tolerance towards chromatic dispersion and polarisation mode dispersion, and enhanced spectral efficiency in wavelength division multiplexing (WDM) systems.

By combining phase and amplitude modulation, even higher bit rates can be obtained. Already in 2003, Liu, et al. demonstrated the combination of differential binary phase shift keying (DBPSK) and amplitude shift keying (ASK) at 10 Gbaud [1]. Since then, a number of experiments at higher symbol rates have extended the maximum per channel bit rate. Furthermore, the bit rate per wavelength can be doubled by transmitting two modulated signals with orthogonal polarisations (PolMUX).

In this article, we present several experiments on multilevel modulation formats to obtain bit rates above what is obtainable by using binary transmitters. We present a demonstration of 240 Gbit/s per channel bit rate obtained by combining differential quadrature phase shift keying (DQPSK), ASK and PolMUX. It is clearly demonstrated that multilevel modulation is an efficient method to increase the bit rate of optical communication systems.

II. MULTILEVEL MODULATION FORMATS

Multi-level modulation formats allow realisation of transmission links at higher bit rates than available from binary formats. Even when using state of the art electronics the bit rate can be doubled or even tripled by using quaternary or 8-ary modulation formats operating at the same symbol rate.

Several experiments using DQPSK have demonstrated bit rates of 80 Gbit/s to 100 Gbit/s [2, 3]. We further applied an additional ASK modulation to the DQPSK in order to create an 8-ary modulation at a symbol rate of 40 Gbaud, and thus generate a 120 Gbit/s signal using only commercially available electronics.

As illustrated in Figure 1, the signal was generated by a concatenation of four modulators, one Mach-Zehnder modulator (MZM) for pulse carving, one MZM for ASK modulation, one MZM for DBPSK modulation and finally one phase modulator for DQPSK modulation [4]. With three bits per symbol, the resulting bit rate of the RZ-DQPSK-ASK signal was then 120 Gbit/s. By further applying PolMUX, the bit rate was doubled to 240 Gbit/s.

When combining amplitude modulation and phase modulation, the amplitude extinction ratio is a trade-off between good eye opening for the amplitude signal and good eye opening for the demodulated phase signal. We found that an extinction ratio of 4.5 dB resulted in optimum performance for the system as a whole, significantly lower than the theoretical value due to amplitude jitter on the driving signals [4].

In the pre-amplified receiver, the signal was split into two branches, one for detection of the phase modulation and one for ASK detection. The ASK signal was directly received by a 50 GHz photodetector, while the phase information was demodulated using a one-symbol delay interferometer followed by a 45 GHz balanced photodetector.

As seen in Figure 3(a) the width of the optical power spectrum is exactly the same for 120 Gbit/s RZ-DQPSK-ASK and for 40 Gbit/s DBPSK. Thus we can increase the bit rate by a factor of three (six with PolMUX) without increasing the spectral width.

The receiver sensitivity is illustrated in Figure 3(b). Compared to the sensitivity of the pure 80 Gbit/s RZ-DQPSK, the additional amplitude modulation caused a power penalty of 10 dB, which is primarily caused by the low extinction ratio of the ASK signal, and the resulting distortions on the demodulated DQPSK eye.

Next we transmitted the signal over a 50 km fibre span,
Authorized licensed use limited to: Danmarks Tekniske Informationscenter. Downloaded on November 13, 2009 at 10:07 from IEEE Xplore. Restrictions apply.