Tunable UDWDM Transmitter with Optical Comb Source

Andrzej Dobrogowski, Jan Lamperski and Piotr Stępczak

Abstract — **In the presented paper we show a concept of the tunable UDWDM transmitter for the access networks using multifrequency optical source with an acoustooptic frequency shifter as a key module. Original simulation results of transmitters for systems with 3.125 and 6.25 GHz channel separation with precisely preset standard wavelengths are presented.**

Keywords — **Optical comb source, wavelength multiplexing, tunable transmitter.**

I. Introduction

In fiber optical communications, high capacity transmission is one of the main challenges. Wavelength division multiplexing (WDM) is a key technology for effective utilization of fiber bandwidth and it is used in the realization of all optical multi-access networks. Two approaches are observed in the development of WDM systems: one presents the concept of the highest channel bit rate, the other, preferred for a subscriber loop, focuses on a relatively low channel transmission rate and a small wavelength separation.

The number of channels and channel separation depends on the progress of the optical source technology and the lowest channel spacing implemented currently in systems is 25 GHz. Ultra dense WDM (UDWDM) technology required an array of discrete lasers or multifrequency sources with extreme wavelength stability [1]-[8]. Wavelength tunability is an attractive property for active and passive WDM components. The most flexible networks can be obtained when transmitters, receivers and passive components are made tunable as well as by implementing wavelength conversion. Optical WDM sources can be tuned continuously to operate at different wavelengths but the most valuable lasers are preset to emit accurately at standard wavelengths.

The investigated tunable transmitter with a fixed set of frequencies is based on the active fiber optical carrier frequency comb generator implementing acousto optic frequency shifters (AOFS), Fig.1, and was described by the authors in previous papers [9]-[10].

As the bulk acoustic wave AOFS operating frequency is limited to the value of 1.5 GHz, to obtain higher channel distances it is necessary to use a double frequency shifter configuration.

The double shifter generator consists of two acousto-optic frequency shifters (AOFS), a single master laser (ML), erbium doped fiber amplifiers (EDFA) and a band limiting filter (BLF).

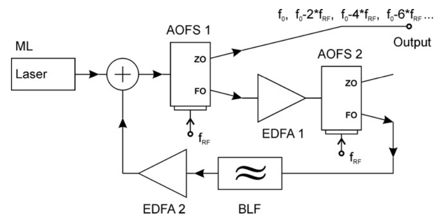

Fig. 1. The configuration of a double shifter multifrequency optical source.

Every loop round-trip AOFS1 splits the optical beam into two and after the amplification, frequency translation (AOFS2) and filtration of the frequency shifted ray is feedback to the AOFS1 input. Multiplication of this process results in a generation of an optical frequency comb. The AOFSs controlled by RF generators determines a frequency comb interval and the BLF limits the number of frequency lines.

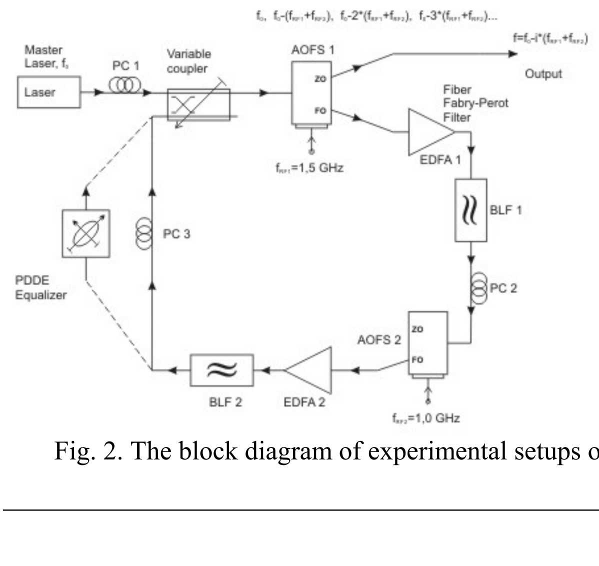

Fig. 2. The block diagram of experimental setups of

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double shifter multifrequency optical source.

In the experimental setups (Fig. 2) we used a narrow linewidth tunable laser as a master laser, double stage erbium-doped fiber amplifiers (EDFA), band limiting filters (BLF) with 0.1 or 1.2 nm transmission width and acoustooptic frequency shifters (AOFS) of 1.5 and 1.0 GHz.

The polarization controller PC1 allowed to adjust the state of polarization (SOP) of a master laser for the maximum diffraction efficiency, and PC2/3 were used to control the feedback loop polarization. For a large number of spectral lines we implemented polarization dependent diffraction efficiency equalizer (PDDE).

Measured output spectra of optimized optical carrier frequency comb generator are shown in Fig. 3 and Fig. 4.

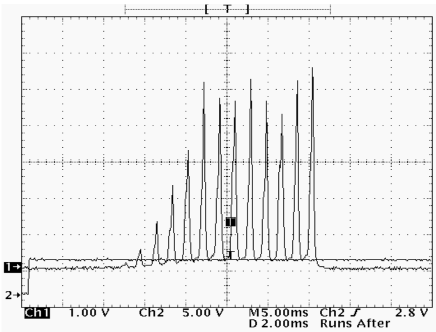

Fig. 3. A generated comb spectrum consisting of 8 optical carrier frequencies, channel separation: 2.5 GHz.

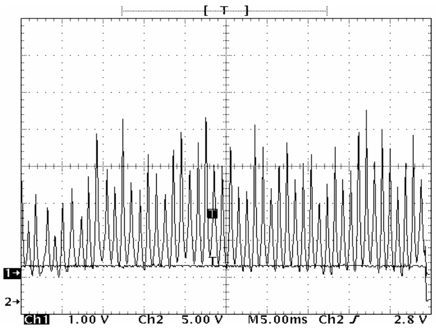

Fig. 4. A generated comb spectrum consisting of 60 optical carrier frequencies, channel separation: 2.5 GHz.

Although in the experiment we use AOFS operating at 1.0 and 1.5 GHz (2.5 GHz channel separation), the obtained results assure us that a proper shifter selection will lead to the generation with standard (3.125 GHz) channel distances and the signal to noise ratio of about 40 dB.

II. Numerical Results

The tunable transmitter operating at the preset standard wavelengths consists of an optical comb generator followed by a tunable fiber Fabry-Perot filter (FPF) and a low chirp integrated Mach-Zehnder modulator (MZM) operating at 1.25 Gbps. The optical channel separation equals 3.125 GHz which corresponds to the 1/32 of 100 GHz standard ITU frequency grid.. The bandwidth of BLF was chosen to compare the simulation results with the experiment (Fig. 3). In the other version we implemented an additional Mach-Zehnder filter (MZF - optical de-interleaver) to separate odd and even carrier frequencies and, thus, increasing the channel separation to 6.25 GHz.

The simulation was performed using a rate equation model of EDFA and mathematical models of other optical components (AOFS, ML, BLF, MZM, MZF). The simulations allowed a full spectral and time analysis. The results of calculations of an optimised configuration with the interchannel distance of 3.125 GHz and 9 spectral lines is shown in Fig. 5.

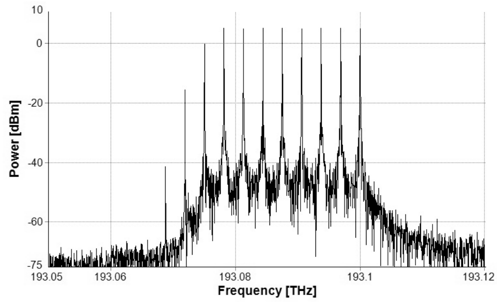

Fig. 5.The output spectrum of comb generator consisting of 9 optical carrier frequencies, channel separation: 3.125 GHz.

The output spectrum of a comb generator with 6.25 GHz channel spacing (multiwavelength source with interleaver) is shown in Fig. 6.

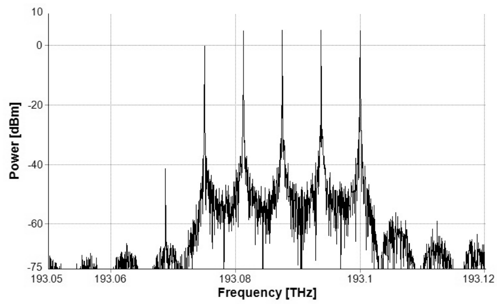

Fig. 6. The output spectrum of the comb generator followed by the interleaver consisting of 5 optical carrier frequencies, channel separation: 6.25 GHz.

The output spectrum of a modulated signal and the eye diagram for 3.125 GHz channel separation are shown in Fig. 7 and Fig. 8.

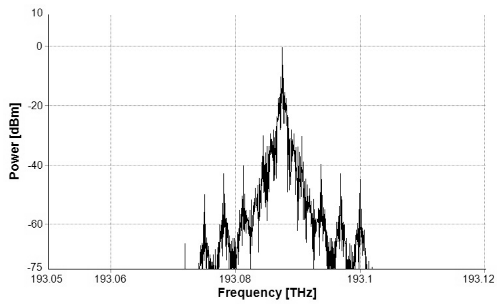

Fig. 7. The spectrum of transmitter output, channel separation: 3.125 GHz.

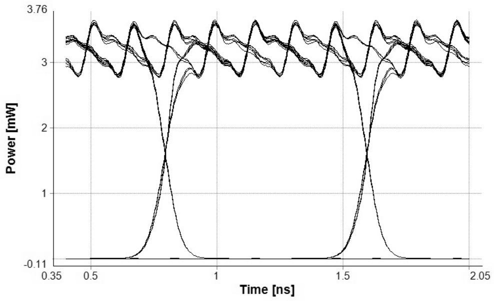

Fig. 8. The eye diagram, system without LPF, channel separation: 3.125 GHz.

Oscillations seen on the eye diagram (Fig.8) result from inter channel differential frequencies and can be filtered by a low pass filter (LPF), Fig. 9.

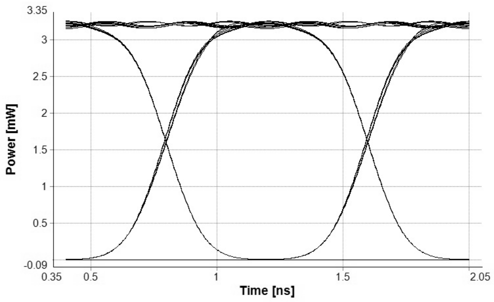

Fig. 9. Eye diagram, LPF: 1.25 GHz, channel separation: 3.125 GHz.

Fig. 10 – Fig. 12 show similar characteristics of a transmitter in which the interleaver was used.

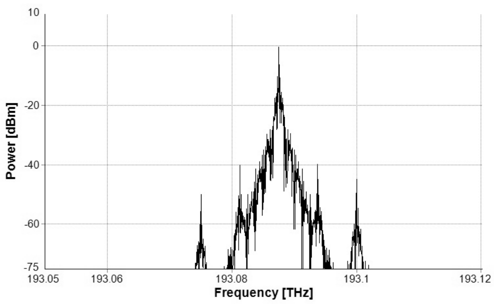

Fig. 10. The spectrum of the transmitter output, channel separation: 6.25 GHz.

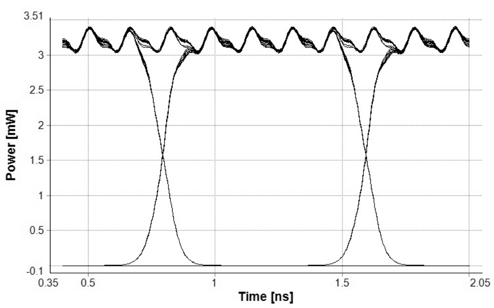

Fig. 11. The eye diagram, system without LPF, channel separation: 6.25 GHz.

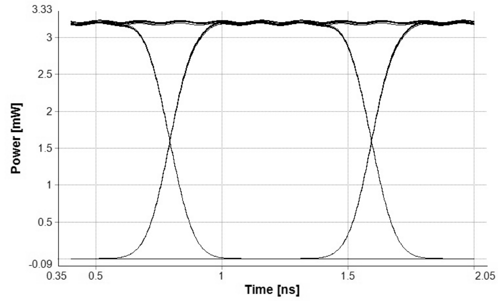

Fig.12. The eye diagram, LPF: 2.5 GHz, channel separation: 6.25 GHz.

By implementing two cascaded M-Z interleavers it was possible to obtain 12.5 GHz channel distances.

III. Conclusion

In the presented paper we showed the concept of the discretely tunable transmitter for UDWDM fiber systems.

We show original results of the simulation of tunable transmitters with a fixed set of carrier frequencies with the standard channel separations of 3.125 and 6.25 GHz. The systems with precisely preset standard wavelengths are preferred over continuously tuned solutions.

Our approach allows to realize the systems with all standard frequency grid separations lower than 25 GHz, what posed a problem in earlier solutions.

The simulation results confirmed the possibility for using the module for a subscriber loop with a Gbps bit rate.

Using the described method it is possible to obtain extremely stable channel separations. Absolute comb frequency stabilization requires a stable operation of only one master laser.

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