# USING OF THE PHOTONIC COMPONENTS FOR MULTICHANNEL OPTICAL TRANSMISSIONS

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## ABSTRACT

This article treats of the basic aspects of wavelength division multiplexors utilization. Description of designing such systems is included.

## 1 INTRODUCTION

Nowadays requirements for a data transfer rate are increasing rapidly. To fulfil these claims new technical solutions are explored. It is commonly known that optical fibres provide a broad electrical bandwidth. One of the most effective method how to enhance the bandwidth in such systems is using of a wavelength division multiplexing (WDM). Simply said, with the WDM the individual transmission channels are carried on separated optical wavelengths and combined into one fibre directly at the optical domain.

The main purpose of this article is to describe systems with WDM, to compile a method of designing such systems and to design two-channel WDM system. Demanded wavelengths are 1480 and 1550 nm. This system will be used to find out the practical aspects of wavelength division multiplexors using.

## 2 IDEA OF THE SYSTEM WITH WDM

The general chart of the system with the wavelength multiplexing is shown in Figure 1. The blocks $\mathsf{EO}_x$ are electro-optical converters, for example laser diodes with drivers. Transmission channels are distinguished according to the operating wavelength $\lambda_1, \ldots, \lambda_n$ (optical carrier). The block WDMX is the wavelength division multiplexor that realizes combining of all optical carriers into one optical fibre. Combined channels are transmitted over this fibre to the input of the wavelength division demultiplexor, the block WDDX, which realizes splitting of the optical carriers into the particular fibres. The blocks marked as $\mathsf{OE}_x$ are opto-electrical converters, for example PIN photodiodes or other optical receivers.

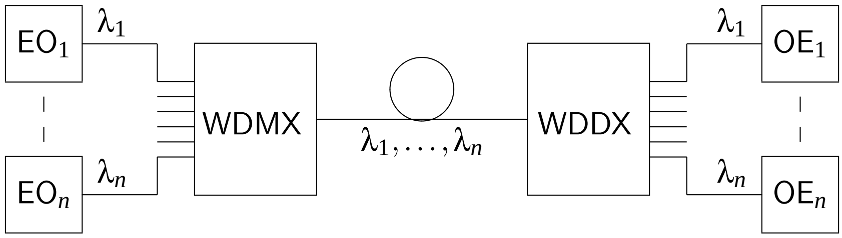


Figure 1: General WDM system structure.

## 3 WAVELENGTH DIVISION MULTIPLEXOR AND DEMULTIPLEXOR

The block of a WDMX and a WDDX is shown in Figure 2. In the WDMX optical filters are applied on inputs and similarly in the WDDX optical filters are applied on outputs. The main difference between WDDX and classical coupler is that WDM demultiplexor divides the signal by the wavelength while classical coupler divides signal into fibres that are of equal power.

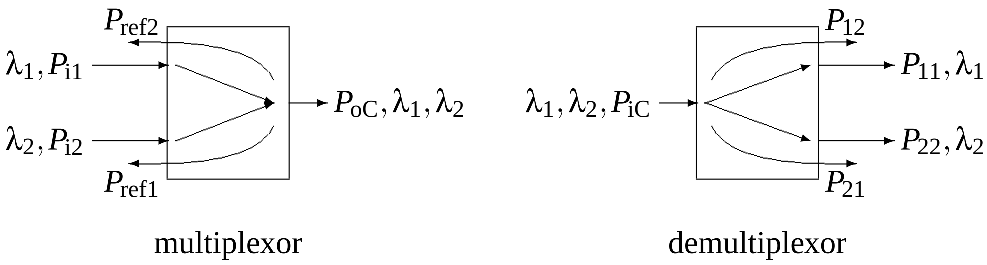


Figure 2: Two channels WDM multiplexor and demultiplexor.

To the main parameters of the WDMX and WDDX belong: bandpass $B_s$ for each input, insertion loss $L_{cx}$, isolation $I_{xy}$ and directivity $D_x$.

The insertion loss $L_{cx}$ is depended on channel wavelength and for WDMX can be expressed:

$$L_{cx} = 10 \log \frac{P_{ix}}{P_{oC}}, \quad x = 1,2; \quad [\mathrm{dB}], \tag{1}$$

where $P_{ix}$ is the input power of fibre $x$, $P_{oC}$ is the WDMX output power. The equation is valid when only the channel $x$ is in operation. For WDDX it can be expressed similar from Figure 2.

The WDDX parameter isolation $I_{xy}$ is defined as follows:

$$I_{xy} = 10 \log \frac{P_{iC}}{P_{xy}}, \quad x \neq y, \quad x,y = 1,2; \quad [\mathrm{dB}], \tag{2}$$

where $P_{xy}$ is the crosstalk power from the fibre $y$ channel band to the fibre output $x$, while $P_{iC}$ is the WDDX input power by condition that consists only of the fibre $y$ channel band.

The WDMX parameter directivity $D_x$ is defined:

$$D_x = 10 \log \frac{P_{ix}}{P_{refx}}, \quad x = 1,2; \quad [\text{dB}], \tag{3}$$

where $P_{ix}$ is the optical power at the input $x$ and $P_{refx}$ is the fraction of $P_{ix}$, which is reflected back into other inputs.

## 4 WDM SYSTEM DESIGN

The designing rules of the WDM system can be obtained by generalizing of the one-fibre system design [1]. It is necessary to take into account the new aspects which have appeared from wavelength multiplexors using. The proper design consists of the following steps:

1. System parameters definition and the selection of the system configuration.
2. Power condition analysis and the effect of fibre dispersion analysis (the dispersion limitation) [1].
3. Crosstalk analysis [2].

All steps have to be performed once at the least. If all steps don't correspond, the system reconfiguration and the whole analysis must be performed again.

For the purpose of design must be known the desired electrical bandwidth $B$ or data rate $B_0$, desired signal to noise ratio SNR or minimum bit error ratio BER at the inputs of the photodetectors and the distance $L$ between the transmitters and the receivers.

The middle operational wavelengths are chosen according to number of the optical carriers. The situation shows Figure 3, where $B_s$ is the wavelength spectrum of the particular optical transmitter, $S$ is all signals spectral function, $B_f$ is the bandwidth of the optical filter in the WDMX and WDDX, $H_f$ is the optical filter spectral function and $f_d$ is the optical carriers spacing.

In the power analysis must be taken into account the mentioned insertion loss $L_{cx}$ of the WDMX and WDDX. The dispersion analysis is practised as described in [1]. Every

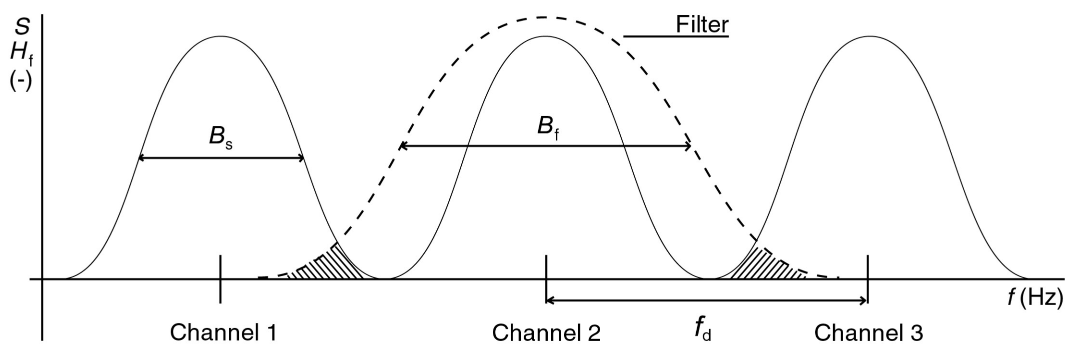


Figure 3: Multiplexed optical spectrum.

channel have to comply with these analyses. In the case of disagreement, the system must be reconfigured.

Further, the wavelengths and other quantities from Figure 3 must be chosen to eliminate crosstalk. The crosstalk power is marked out as the shaded area there. It is also necessary to find out how stable is the middle wavelength of every optical transmitter. The main parameter of WDMX or WDDX that influences crosstalk is the isolation $I_{xy}$. The crosstalk power $P_{12}$ from the second to the first channel can be obtained as follows:

$$P_{12} = P_{i2} - L_{ca} - I_{12}, \quad [\text{dB}; \text{dB}, \text{dB}, \text{dB}], \tag{4}$$

where $P_{i2}$ is the power at the WDMX input fibre 2 (see Figure 2), in $L_{ca}$ all system losses are included (insertion loss of WDMX, WDDX, optical fibres etc.) and $I_{12}$ is above explained isolation. The crosstalk power $P_{21}$ can be expressed alike.

To eliminate the most of the mentioned influences, it is advantageous to use the results of the crosstalk analysis from [2]:

$$\frac{f_d}{B_s} = 5.61 \cong 6. \tag{5}$$

This equation was derived under the condition $B_f = 2B_s$ and ensures, that the crosstalk power is only 1% of the signal power in one channel.

## 5 DESIGNED TESTING SYSTEM

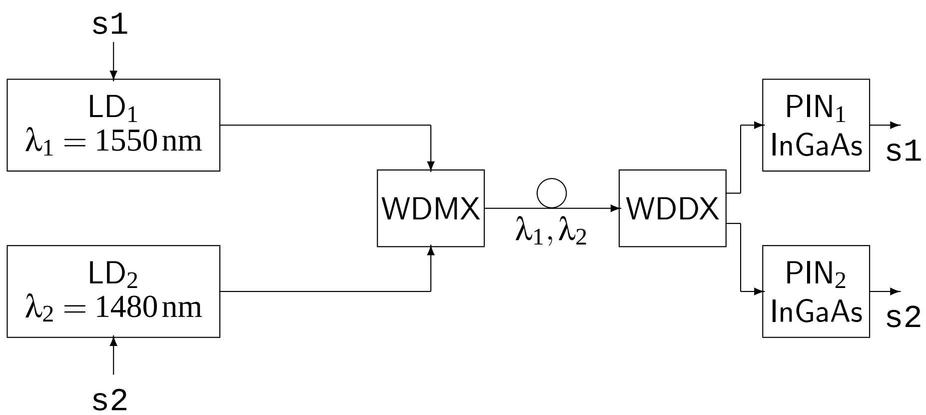


Figure 4: Designed system structure.

The system, which was designed for the testing, is shown on Figure 4. It is simplified version of the general WDM system structure from Figure 1. As $\text{LD}_x$ modulated optical transmitters are used, as $\text{PIN}_x$ functional blocks PIN photodetectors are used. The whole system is designed for single mode operation. Bidirectional multiplexor WD202C-FC by Thorlabs is used as WDXM and WDDX – for its parameters see Table 1. This system is too expensive for realization and so it have been reduced for only one half of the structure from Figure 4 (with only one multiplexor, one optical transmitter and one optical receiver) as follows:

Table 1: WDM Multiplexor WD202C-FC Parameters.

| | |
|---|---|
| Working channel I | 1450 – 1490 nm |
| Working channel II | 1530 – 1580 nm |
| Channel I insertion loss | 0.3 dB |
| Channel II insertion loss | 0.5 dB |

- laboratory laser driver by David Hlavac [4] is used instead of modulated optical transmitter,
- optical power meter Anritsu ML9002A is used instead of PIN photodetector.

Reduced version of the system is convenient for real properties testing of the WDMX and WDDX functional blocks. Proposed measurements are in following list:

- insertion loss in both direction,
- crosstalk – isolation,
- directivity,
- reaction to interchanged wavelength,
- reaction to non-working wavelength,
- mechanical stability – vibration influence,
- background radiation influence,
- power linearity.

## 6 CONCLUSION

In this article the description of a WDM system and basic WDM system design method was done. In next the demanded testing system was designed. Hereafter it is necessary to build this system and to perform the proposed measurements.

## REFERENCES


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