WDM IN COURSES OF COMMUNICATION TECHNOLOGIES

M. Filka, M. Bernkopf

Department of Telecommunications, Brno University of Technology
Purkynova 118, Brno 612 00 Czech Republic
mail: filka@feec.vutbr.cz ; xbernk01@stud.feec.vutbr.cz

Summary This conference paper shows and demonstrates how modern technologies (such as WDM – Wavelength Division Multiplex) were introduced to students of Optical Networks lectured at Brno University of Technology, Faculty of Electrical Engineering and Communication, Dept. of Telecommunications.

1. INTRODUCTION

For many years lecturers have tried to integrate this modern technology into laboratory exercises of Optical Networks subject. **WDM**, **CWDM** and **DWDM** transmission technologies are well-known and have been taught for a long time. However, the potential purchase of xWDM equipment is not possible due to very high price which is not affordable.

That is why we have decided to find a cheaper way. We have gradually introduced the measurements on couplers into laboratory exercises and the present goal is to show students some applications of simple WDM principle.

2. THEORETICAL REALIZATION

As part of a practical implementation we have first extended the optical fiber system in our laboratory in order to be able to conduct measurements of various wavelengths and second, **DFB** (Distributed Feedback Lasers) lasers have beening purchased. These lasers work in the 3rd attenuation window and are equipped with 9/125µm pigtail with connector.

The DFB lasers form the basis of our WDM set and the students can clearly understand the main principle of wavelength multiplex.

Spectrum analyzers and other instruments by Safibra have been purchased in order to measure output power. It allows measuring continuous optical radiation power as well as the medium power of modulated radiation. Together with **EDFA** (Erbium-Doped Fiber Amplifier) it enables us to watch and follow a signal (transmission) behaviour in the WDM mode.

3. INTRODUCTION OF DEVICES

DFB Laser

A Distributed Feedback laser is a laser where the whole resonator consists of a periodic structure, which acts as a distributed reflector in the avelength range of laser action, and contains a gain medium.

Fig. 1. DFB fiber laser, containing a fiber Bragg grating with a phase change in the middle

This structure is essentially a direct concatenation of two Bragg gratings with internal optical gain. It has multiple axial resonator modes, but there is typically one mode which is favored in terms of losses. Therefore, single-frequency operation is often easily achieved, despite spatial hole burning due to the standing-wave pattern in the gain medium. Due to the large free spectral range, wavelength tuning without mode hops can be possible in a range of several nanometers. [5]

EDFA Amplifier

This device is an ***amplifier*** rather than a signal regenerator. It directly amplifies optical signals without a need to do the optical-to-electrical conversion.

Fig. 2. Benchtop Erbium-Doped Fiber Amplifier

An **EDFA** contains a short strand of erbium-doped fiber and two signal inputs. One input is the optical signal that needs to be amplified. The other is light from a pump laser that excites the erbium atoms so that they give up photons that amplify incoming optical signal photons.

The optical amplifier consists of a laser pump, erbium-doped fiber, multiplexer, optical insulator, DFB laser, optical coupler, fiber Bragg grating, optical attenuator and detector. Supplied the amplifier is also special software, which allows testting up several modes.

EDFAs are crucial to WDM systems because a single amplifier boosts all the wavelengths simultaneously. With older electrical regenerators, one regenerator is required for each wavelength, meaning that an entire stack of regenerators is needed at each regeneration point. [5],[3]

WDM Multiplexers

For implementation in our laboratory we have used the SFW series of WDM elements produced by OPTOKON Co. Ltd.[4].

These are designed to divide and/or combine different optical wavelengths in optical amplifiers with ultra high isolation.

Fig. 3. WDM Multiplexer

A typical application of WDM multiplexers at 1310/1550nm can be seen in Fig.4.

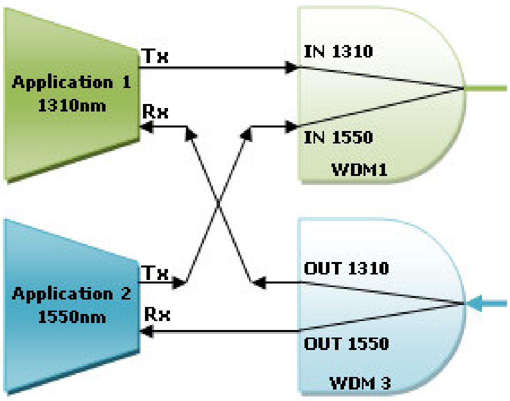

Fig. 4. WDM Multiplexer application

Each application (process) has its own wavelength for transmission and its own fiber connected to the WDM multiplexer. In this case we have only two (the most frequently used) wavelengths. As you can see in Fig. 4, those two wavelengths coming out of Tx output go together to WDM1 multiplexer, where they are combined up into one optical fiber. On the opposite side of this transmission chain there is a similar configuration but in reverse.

Media Converter CS-120 (Optokon)

The CS-120 series are Fast Ethernet-Fiber Converters designed to be media interfaces between 10/100Base-TX Ethernet copper pair cable and 100Base-FX fiber optics cable. They feature an RJ-45 connector, and a single or a pair of fiber optic connectors. The CS120-W31(55) utilizes 1310 nm/1550 nm high performance WDM technology to provide Tx and Rx over a single fiber cable for distance of 20 - 40 km. [4]

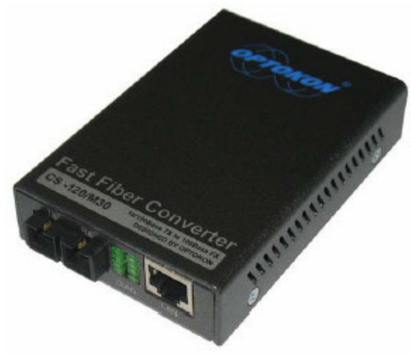

Fig. 5. Media converter - coupler

4. LABORATORY MEASUREMENTS

For practical measuring and for studying the WDM technology we have created a laboratory exercise, which includes all of the devices mentioned above.

The main task of the exercise is to measure the passive elements measuring (in optical networks).Students first begin by cleaning all optical devices since this is a very important point due to attenuation and other losses during the transmission.

Students then perform measurements of each channels on different wavelengths (1310,1550nm), record and compute insertion loss, "Directivity" (near-end crosstalk) and "Wavelength isolation" (far-end crosstalk) according to the following equations [1], [2]:

Excess Loss:

$$-10\log_{10}\left(\frac{P_3+P_4}{P_1}\right)\text{dB} \tag{1}$$

Coupling Ratio:

$$\left(\frac{P_4}{P_3+P_4}\right)\text{x } 100\% \tag{2}$$

Insertion Loss:

$$-10\log_{10}\left(\frac{P_4}{P_1}\right)\text{dB} \tag{3}$$

Directivity:

$$10\log_{10}\left(\frac{P_2}{P_1}\right)\text{dB} \tag{4}$$

Return Loss:

$$-10\log_{10}\left(\frac{P_5}{P_1}\right)\text{dB} \qquad (5)$$

Isolation:

$$10\log_{10}\left(\frac{P_{2/5}}{P_4}\right)\text{dB} \qquad (6)$$

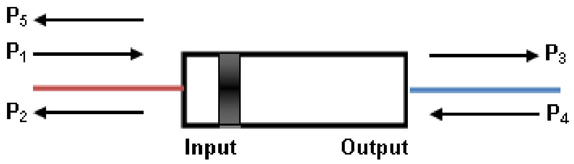

Fig. 6. Coupler scheme

5. MEASUREMENTS AND RESULTS

For educational purposes we have used a WDM training kit. The WDM kit coupled with erbium doped fiber amplifier, allows an experimental study of the EDFA amplifier, working in the multiwavelength mode.[6]

Components included in the WDM kit:

- 4× DFB laser (1535, 1543, 1550 a 1560 nm), 1 mW, CW or analog modulation (100 kHz)
- 1× Optical isolator
- 1× Fiber optic coupler 1×4
- 6× Patchcord E2000/APC Diamond connectors

Thank to WDM kit students can conduct following experiments:

- Laser diode characterization
- Fiber optic coupler characterization
- Four wavelength multiplexing (Fig. 7)
- ADD&DROP assembling (Fig. 8)

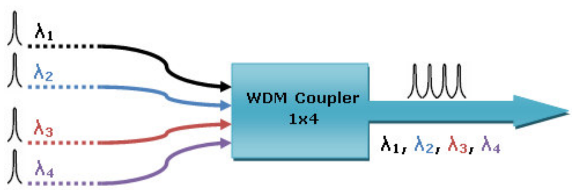

Fig. 7. Four wavelength multiplexing

In the figure below you can see an optical ADD&DROP multiplexer, which may be formed using ring resonators. One or more wavelengths may be added or dropped or a band pass of wavelengths may be added or dropped in a wavelength division multiplexed system.

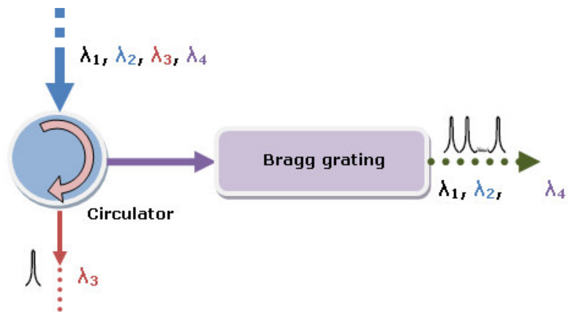

Fig. 8. ADD&DROP multiplexer configuration

In our laboratory we use an optical spectrum analyzer produced by the IDIL company (France), which allows us to analyze the spectrum of optical fiber. For instance, in Fig. 9 you can see the final spectrum of the ADD&DROP configuration. [6]

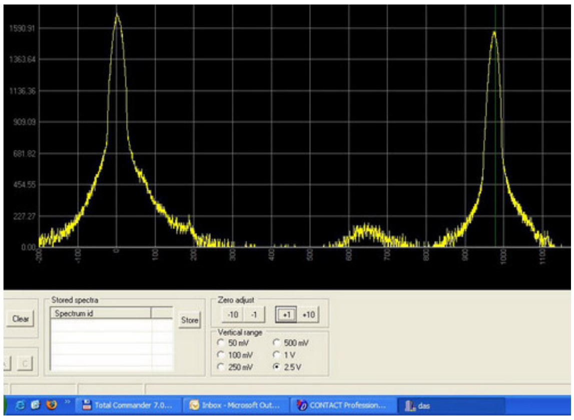

Fig. 9. ADD&DROP spectrum

6. PRACTICAL APPLICATION

All devices mentioned above have been tested in our laboratory and serve an aid for students during lessons where they can „touch“ devices, conduct measurements, carry out tests and transfer theoretical knowledge into practice.

The whole designed configuration can easily be integrated and interconnected with the optical network at Department of Telecommunications. For more information see Fig. 10.

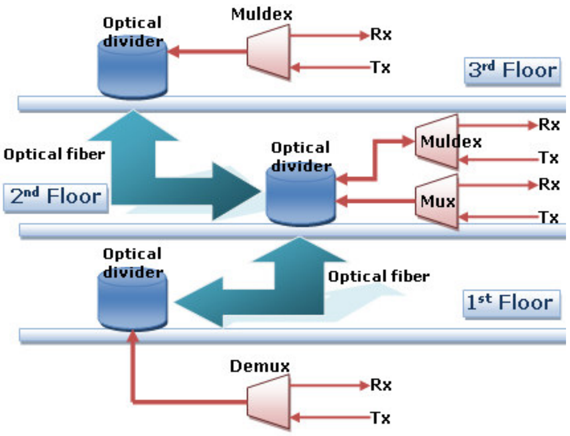

Fig. 10. WDM at Dept. of Telecommunications

7. CONCLUSION

The paper showed how modern fiber optics transmission technologies such as WDM can be integrated into lessons and what the practical configuration and application in laboratories can look like.

Theoretical considerations and instrumentation have been mentioned in the first part of this paper.

Laboratory exercises and measurements are also mentioned too as well as equations needed for a practical understanding of WDM principles.

In another part of the paper the ADD&DROP Metod has been introduced and measurements demonstrated.

A practical application of this technology can be seen in Fig. 10 – application at the Department of Telecomunications of the Faculty of Electrical Engineering.

Even with a limited budget we have reached our goal and we were able to integrate WDM technology demonstration into laboratory lessons so that students can "touch and feel" things they have been studying only theoretically so far.

The most important fact is that all the equipment, configuration and the project as a whole have been funded from non-investment resources and with the support of FRVŠ 1635/2008/F1/a.

Our gratitude also belongs to Optokon Company, Safibra Company and IDIL Company.

REFERENCES

[1] FILKA, M.: *Optické sítě.* TKO 07-081. Brno VUT, 2007
[2] FILKA, M.: *Přenosová média.* Brno VUTium, 2003. ISBN TK000
[3] SALEH, B. E. A., TEICH, M. C.: Základy fotoniky II, Matfyzpress, Praha, 1994, ISBN 80-85863-01-4
[4] http://www.optokon.cz
[5] http://www.safibra.cz
[6] http://www.idil.fr

Assoc. Prof. Miloslav Filka Graduated in Link communication techniques at the Faculty of Electrical Engineering at VUT Brno. Dissertation thesis he write his in 1978, in 1981 he was appointed a assistant professor in telecommunications. In the course of his scientific work, he has studied the problems of transmission and optical communications. Presently he lecture on Telecommunication Lines and Optical Communication. In recent years he has lectured at the Universities of Cairo, Mexico City and Santiago de Cuba.The author and co-author of more than 250 publications. Presently he is the technical representative of the Czech Republic in IEEE Communication Society and a member of the Photonics Committee.

Miroslav BERNKOPF, BSc, (1984) is a student of Master degree study programme at Brno University of Technology, Faculty of Electrical Engineering and Communication. He has been studying Communications and Informatics at the Department of Telecommunications since 2003. Curently, he is working on his diploma thesis dealing with optical fibers, SC/APC connectors and triple-play networks. A part of his work is to measure the characteristics of APC connectors and to determine their suitability frm the viewpoin of transmission quality.