Adição e remoção de canais em sistemas DWDM

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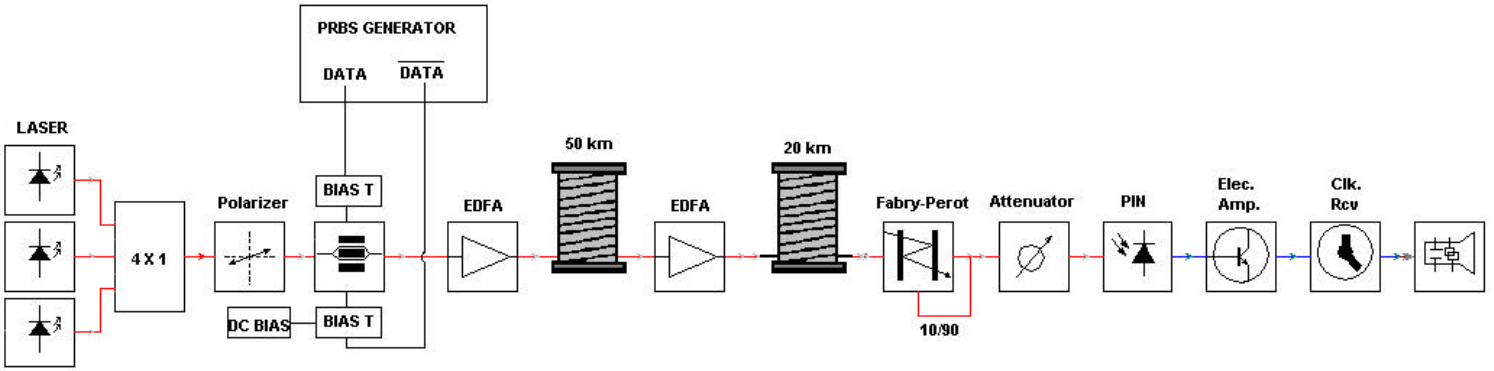
* Bolseiro de doutoramento da FCT (PRAXIS XXI/BD/17227/98), projecto DAWN.

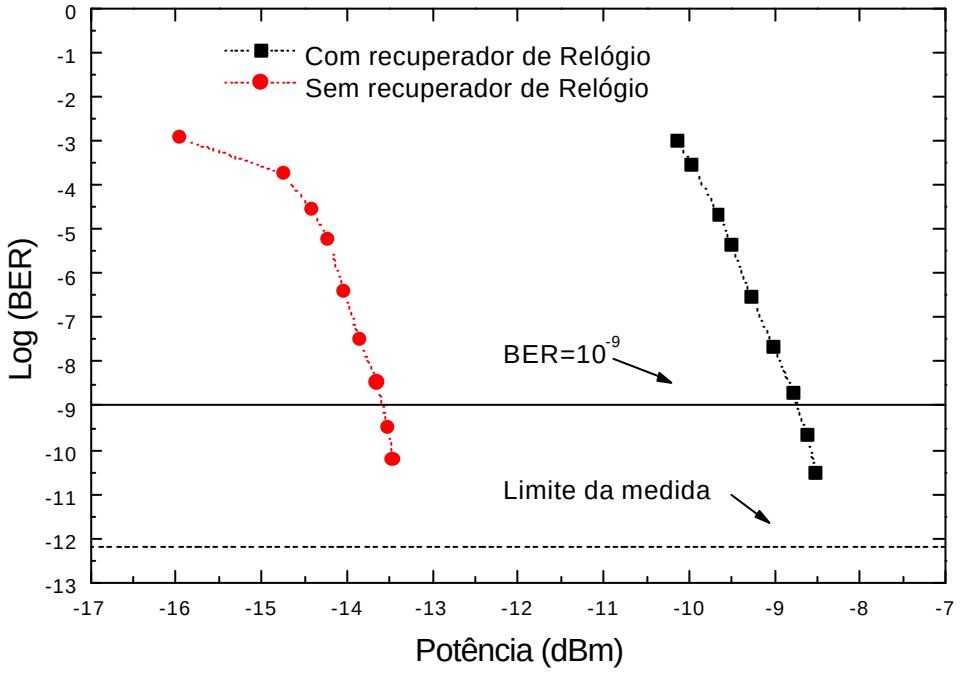
Outline

- 70 km Point-to-point WDM system, with 3 channels 200 GHz spaced, modulated at 2.48832 Gbit/s.
- Crosstalk Study.
- Fibre Bragg Gratings (FBG).
- Optical Add - Drop Multiplexer (OADM) based on Fibre Bragg Gratings (FBG)
- Tuning of FBG
- Tunable OADM

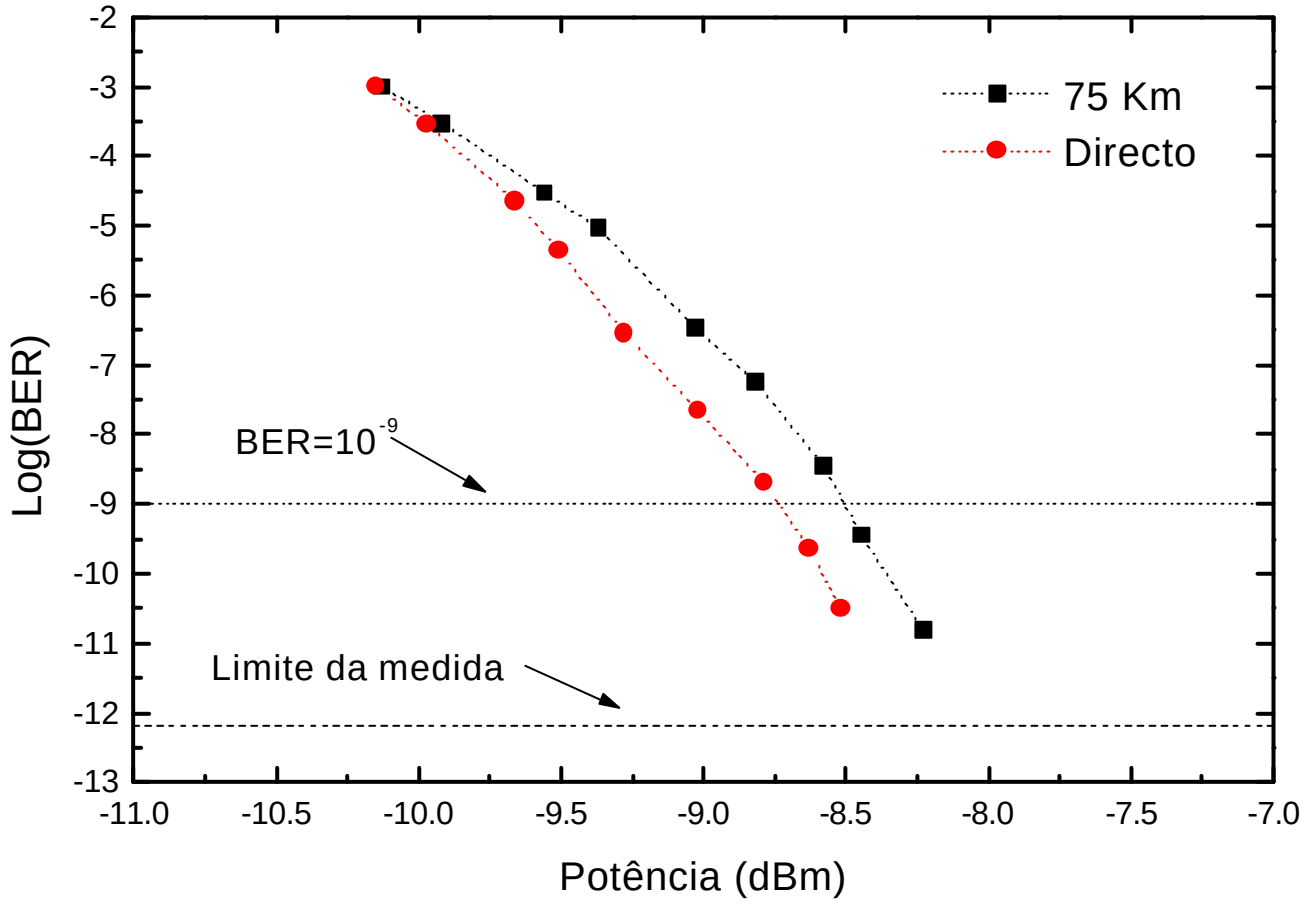
WDM System

1549.32 nm
1550.92 nm
1552.52 nm

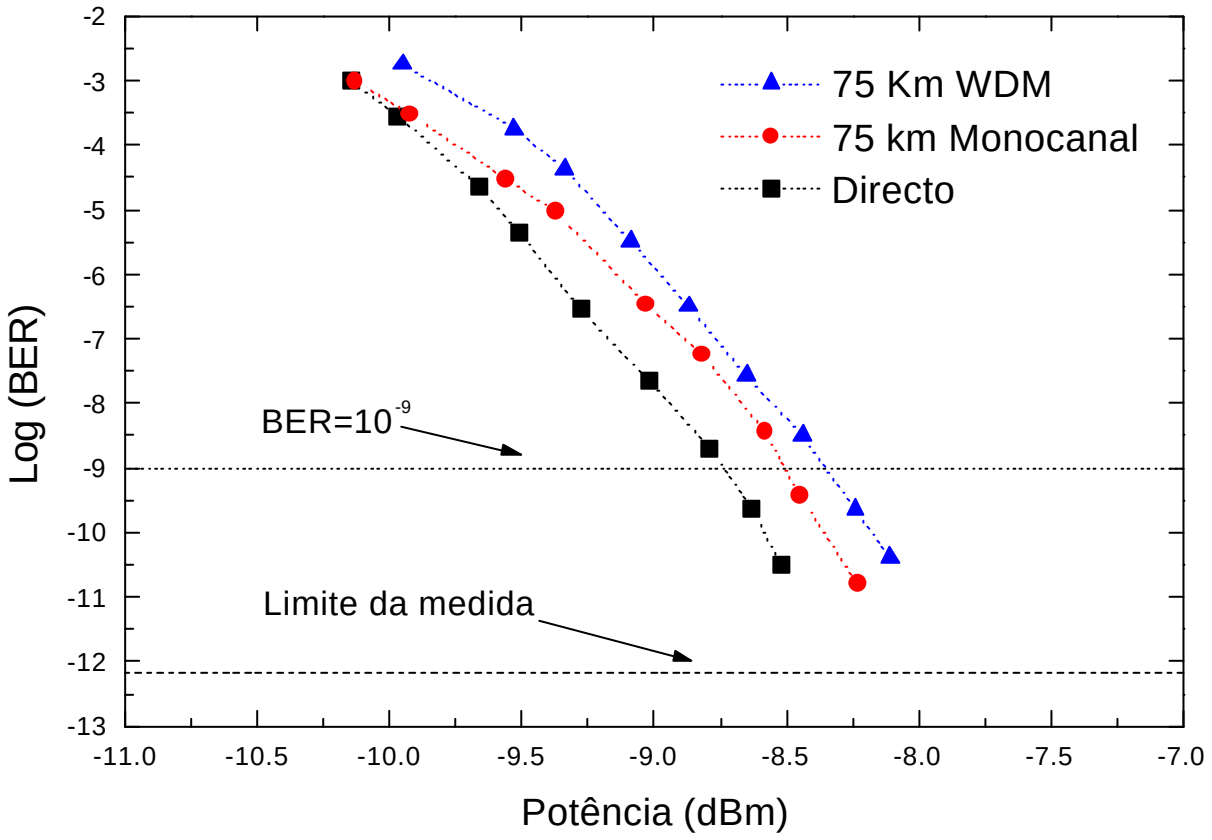




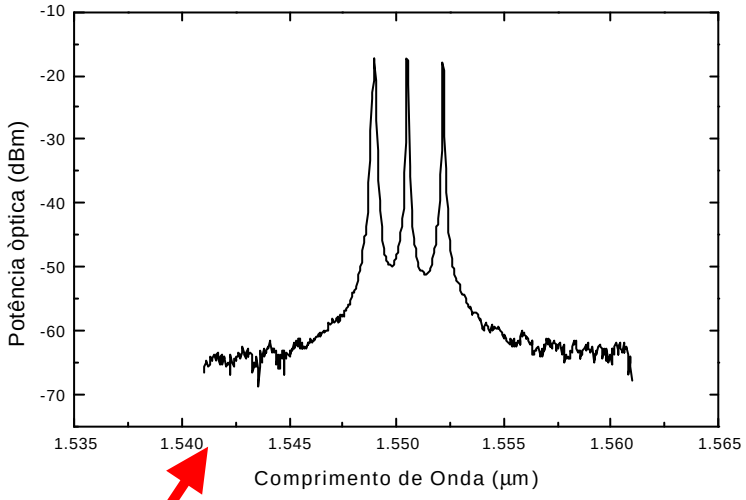
Single Channel

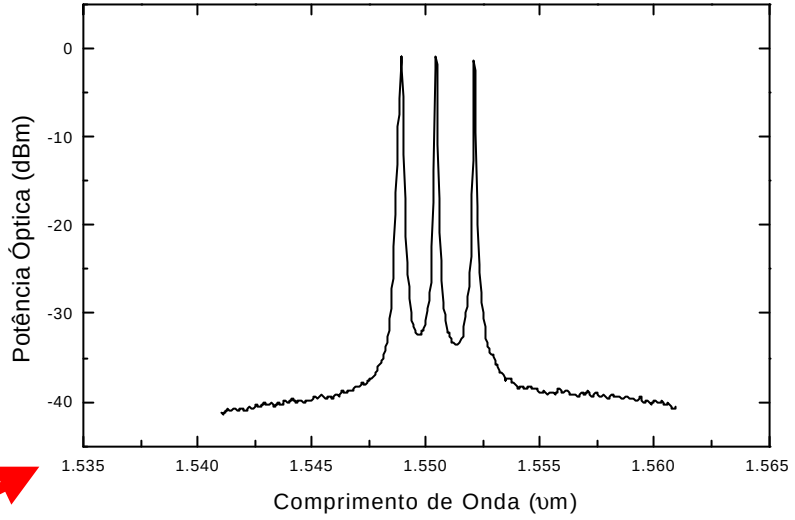


Multi-Channel, Central wavelength



Optical Spectra on the system

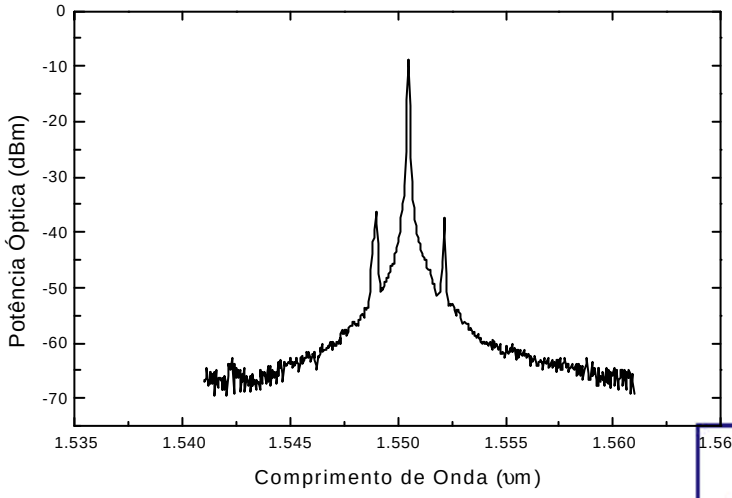




After MUX

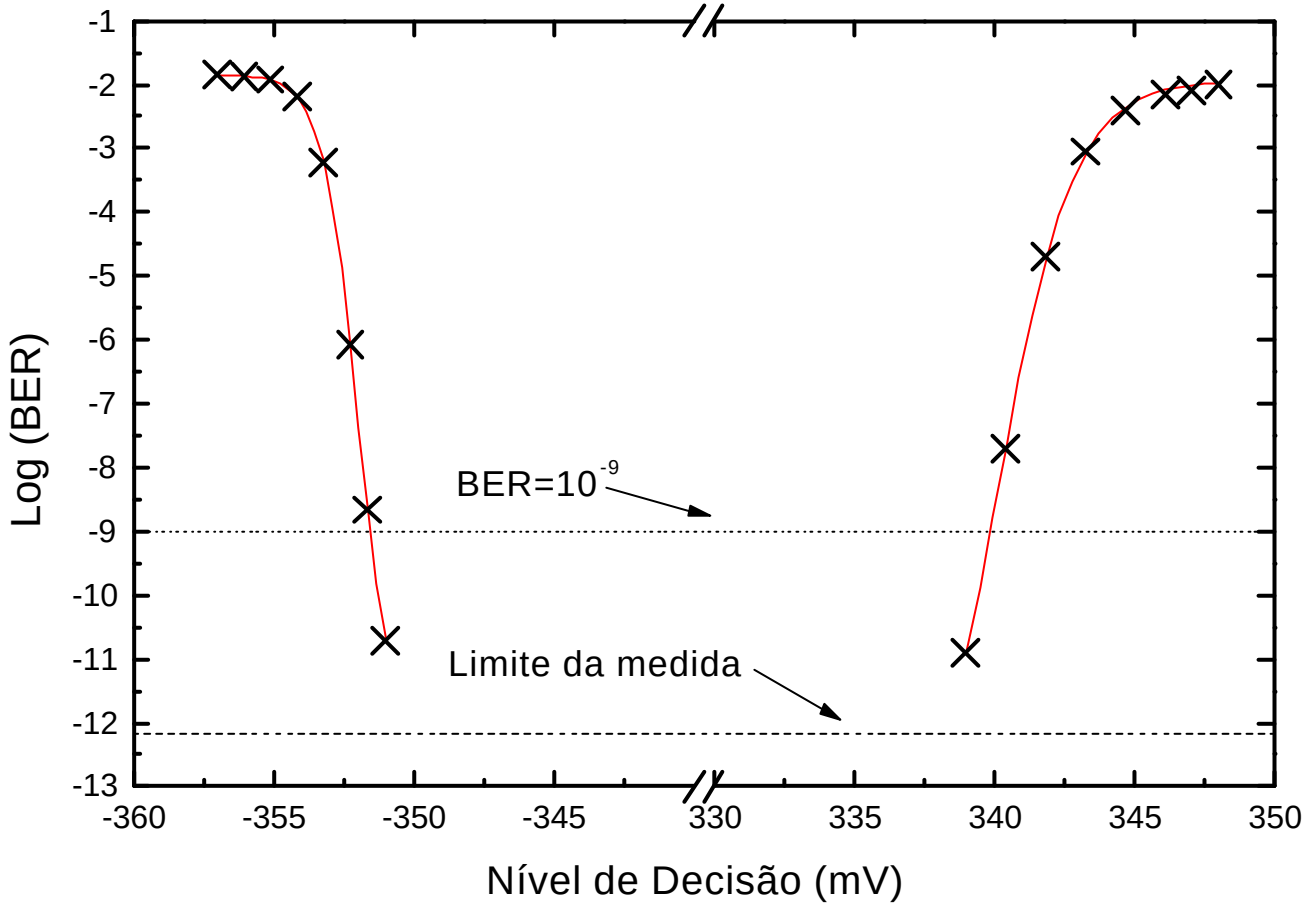
After 2 EDFA

After DEMUX



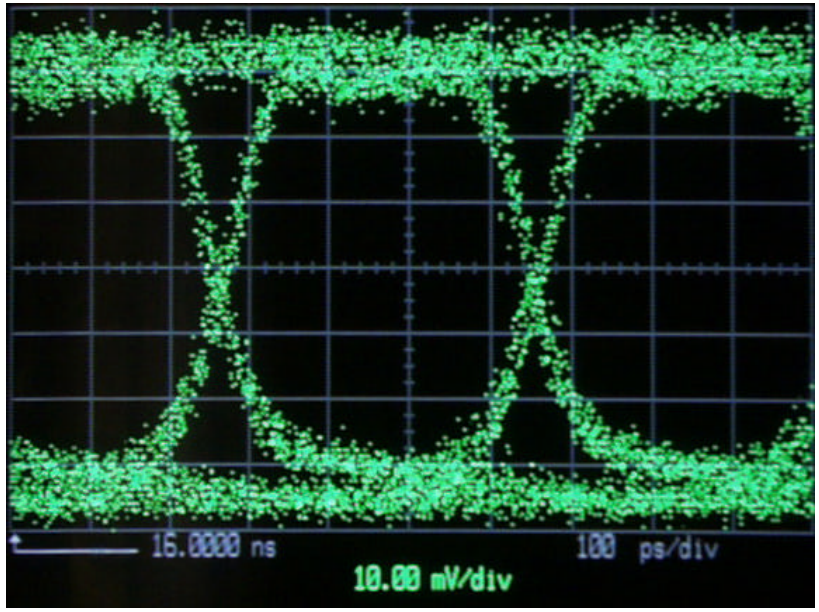
- 28 dB XT

Bit Error Rate as function of the decision level

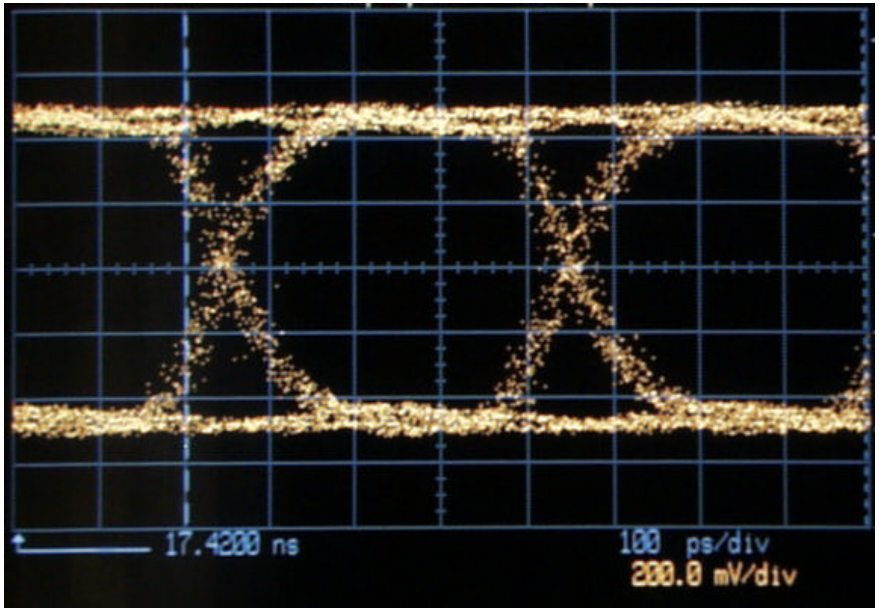


Data after propagation on 70 km of fiber

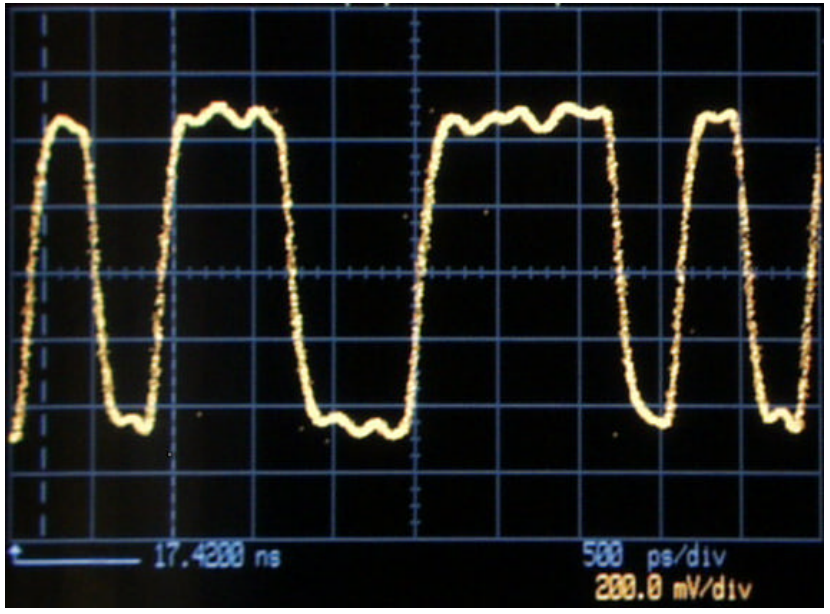
Eye diagram without signal reformatting



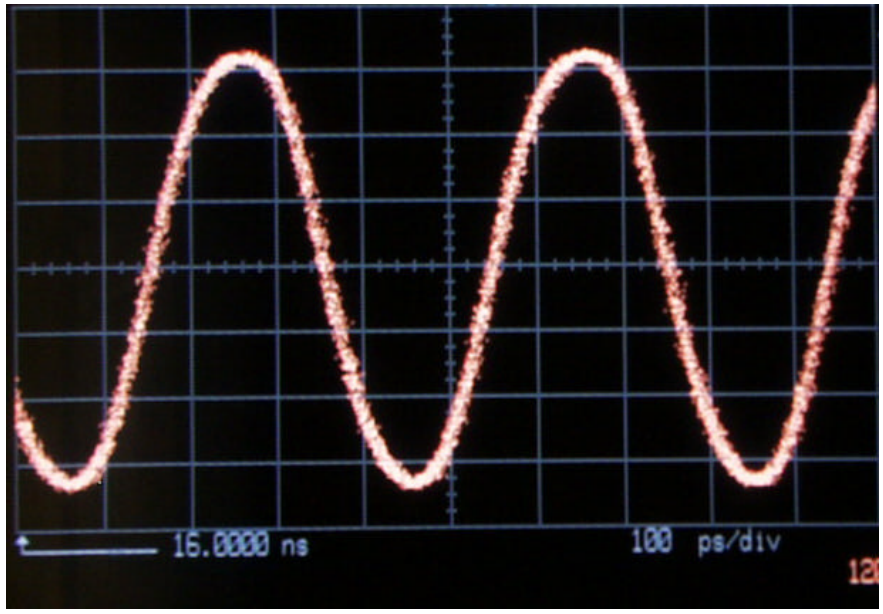
Eye diagram with signal reformatting



Data



Clock



Crosstalk

- Another technical key issue on a wavelength reused OADM network is how to reduce the crosstalk, which severely degrade the system performance.

- Heterodyne Crosstalk, due to low rejection of the FBG between adjacent channels and the central wavelength.

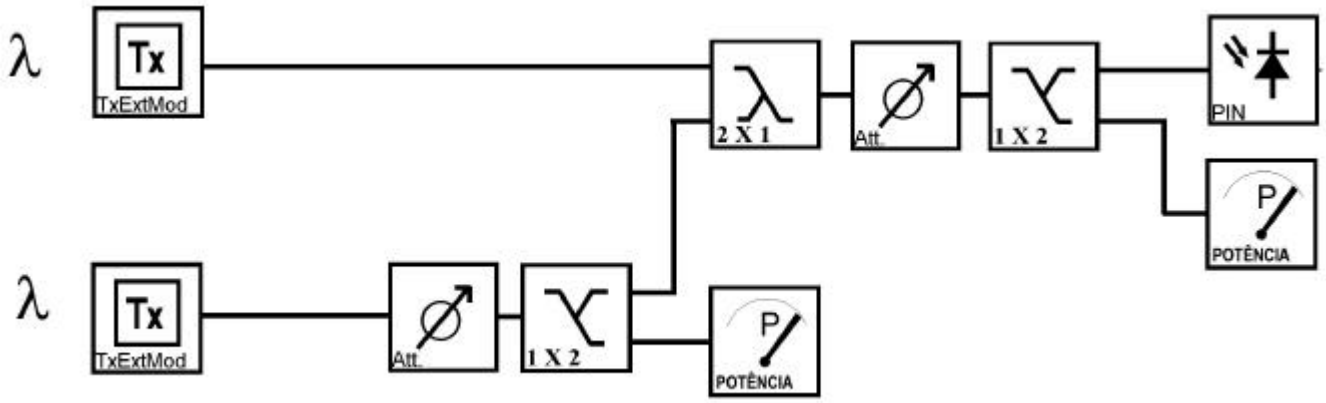
$$P_p = -10 \cdot \log(1 - X)$$

- Homodyne Crosstalk, due to reflectivity of the FBG to the central wavelength (limit the number of nodes of a network).

$$P_p = -10 \cdot \log(1 - Q^2 \cdot X)$$ Q - SNR

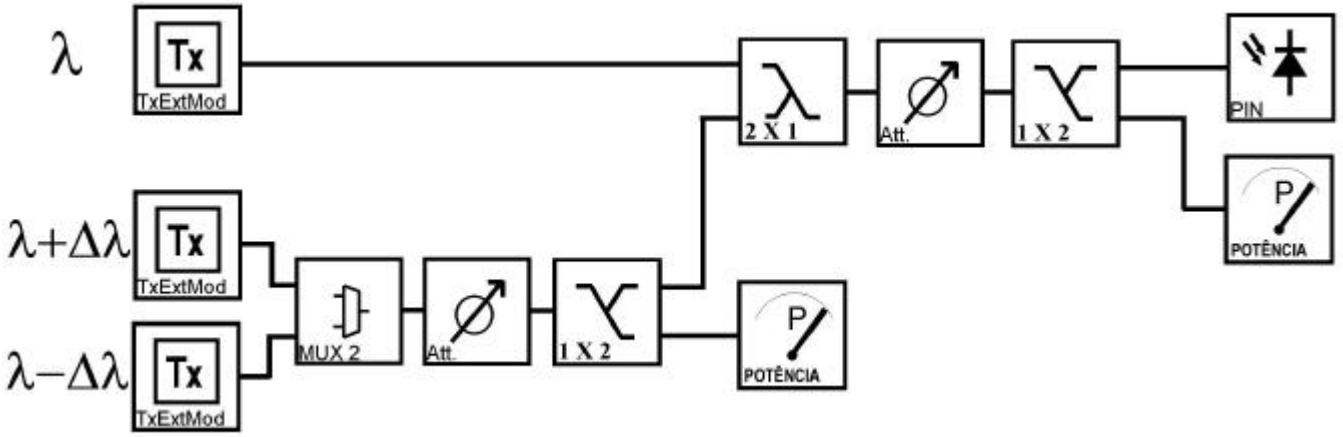
Homodyne

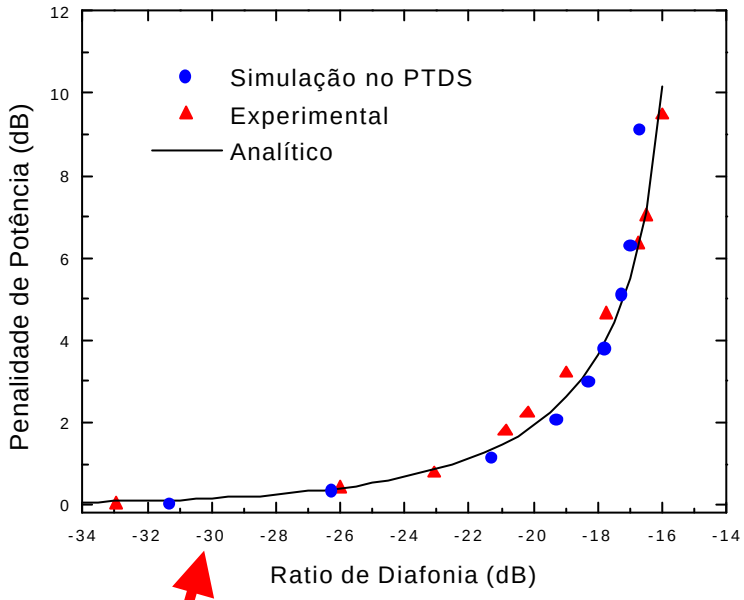
Crosstalk

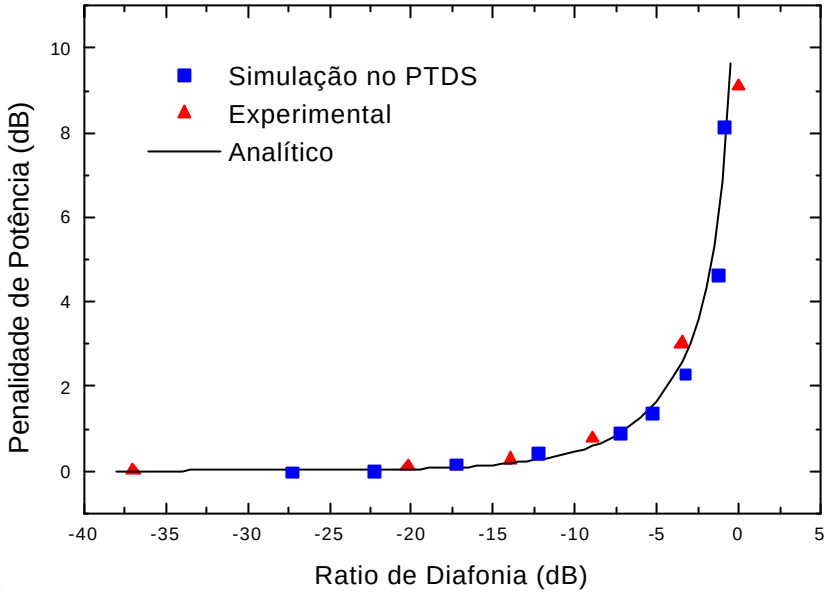


Heterodyne

Crosstalk



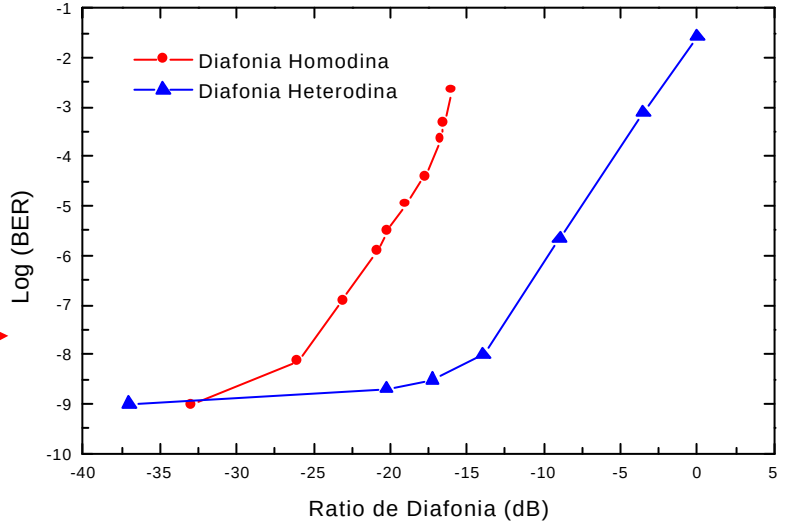




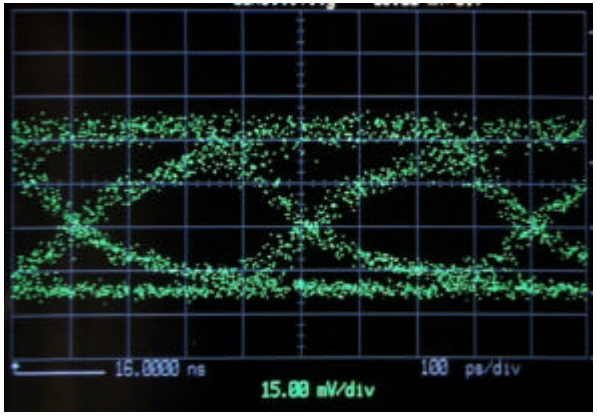
Homodyne Crosstalk

Heterodyne Crosstalk

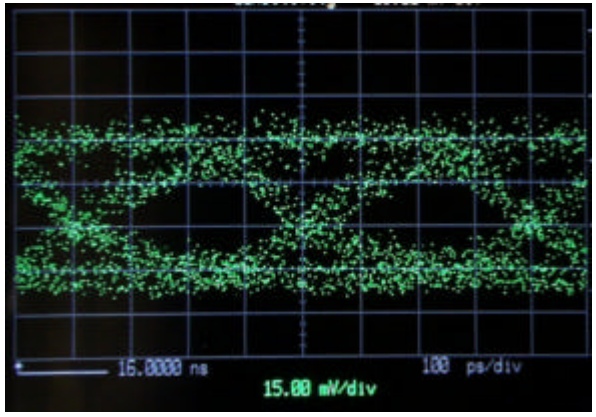
BER



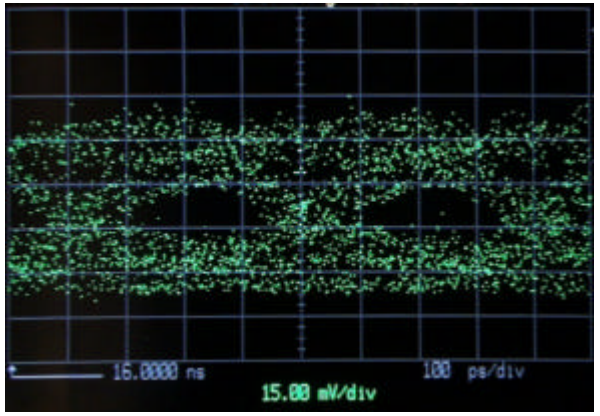
Heterodyne Crosstalk



- 40 dB

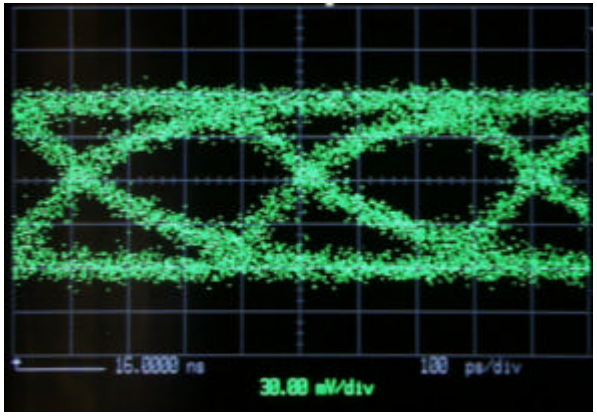


- 4 dB

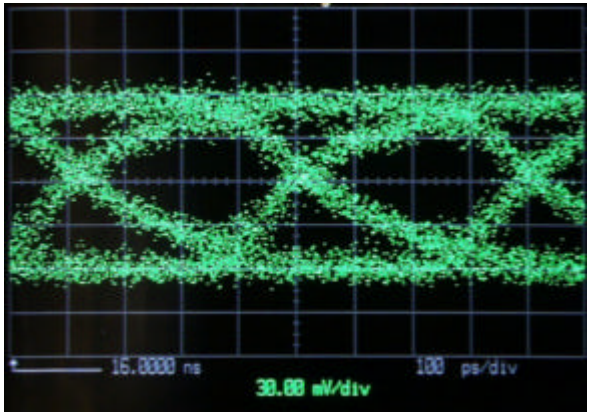


0 dB

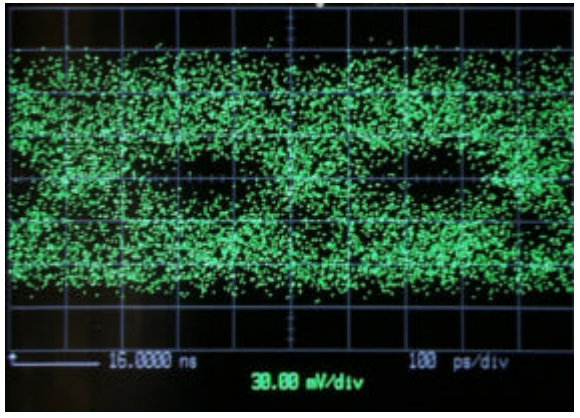
Diafonia Homodina



- 40 dB

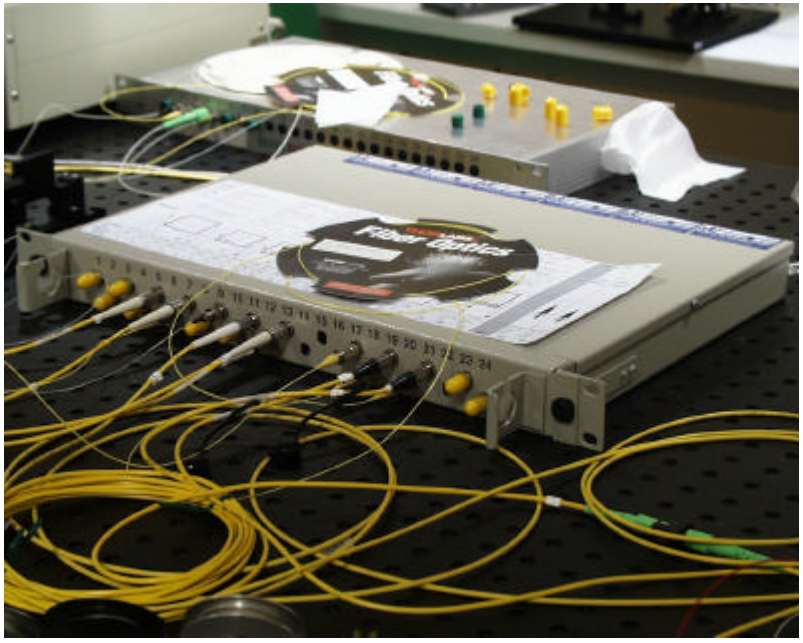


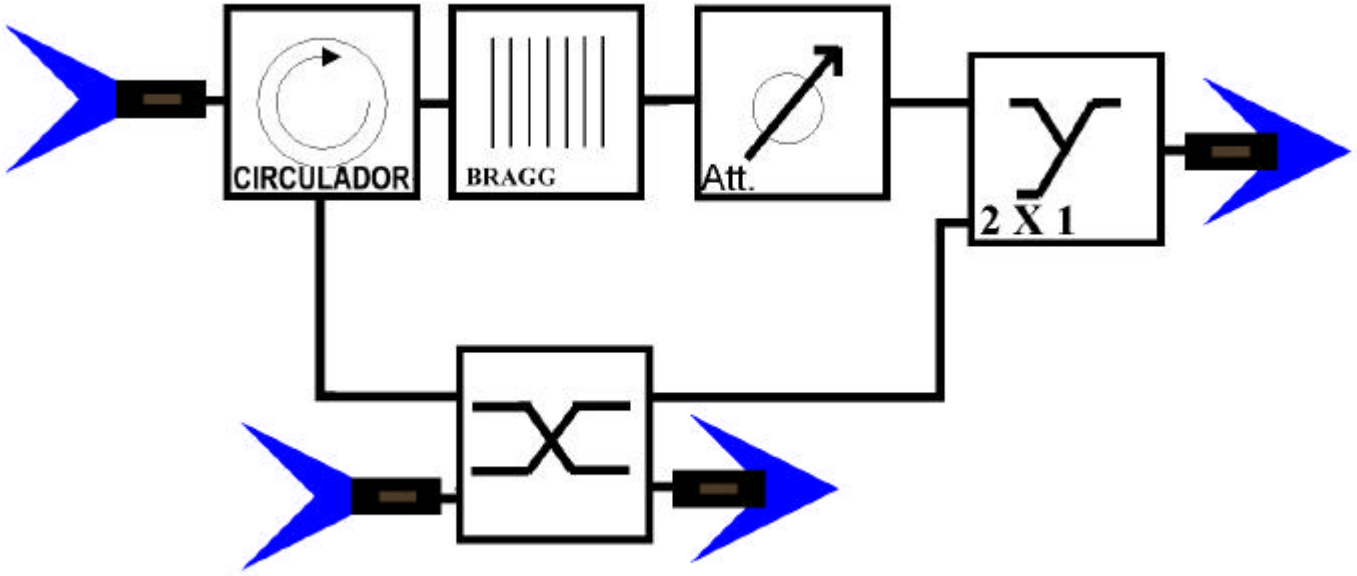
- 15 dB



-8 dB

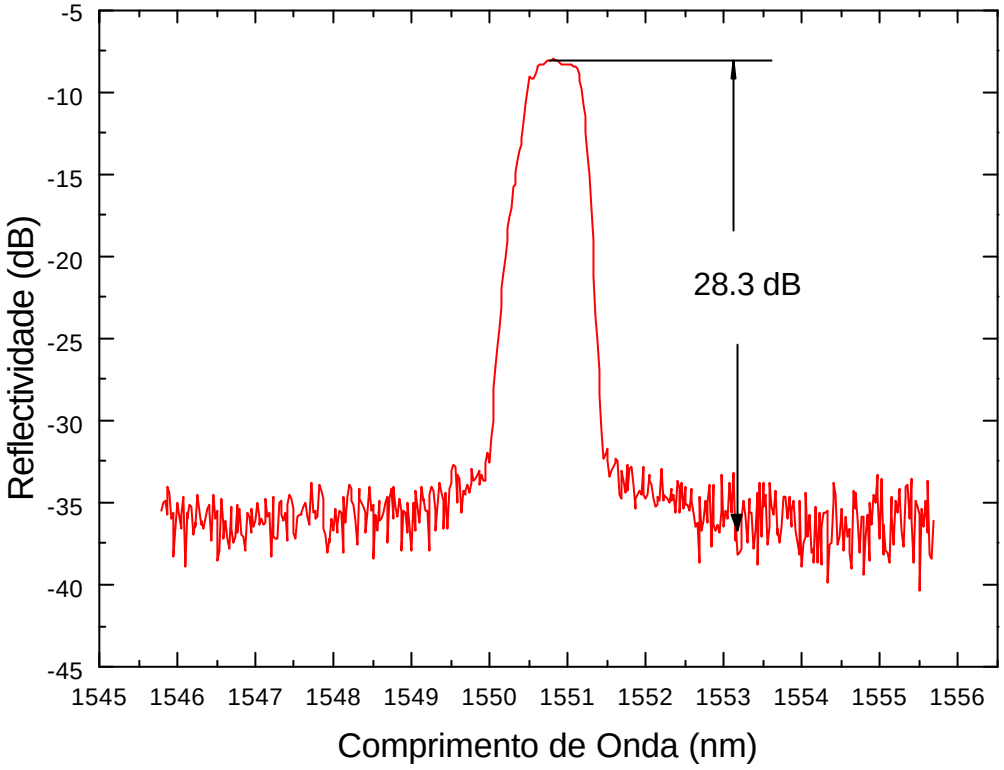
Static OADM





Fibre Bragg Grating

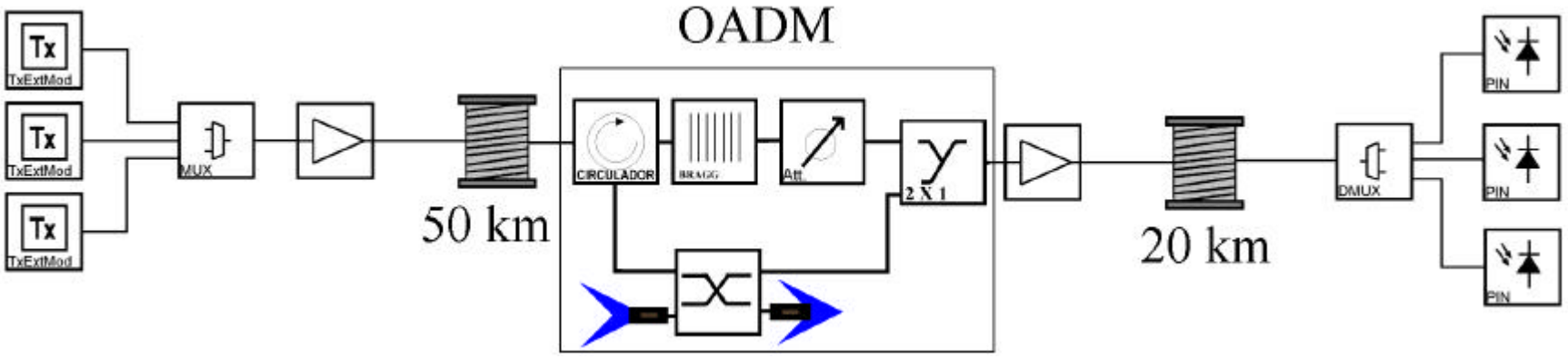
Central Wavelength	1550.92 nm
- 0.5 dB Bandwidth	0.256 nm
- 1 dB Bandwidth	0.532 nm
- 3 dB Bandwidth	0.748 nm
- 20 dB Bandwidth	1.388 nm
Insertion Loss at λ_C	30.7 dB
Reflectivity for adjacent Channels	28.3 dB
Reflectivity at λ_C	99.99 %

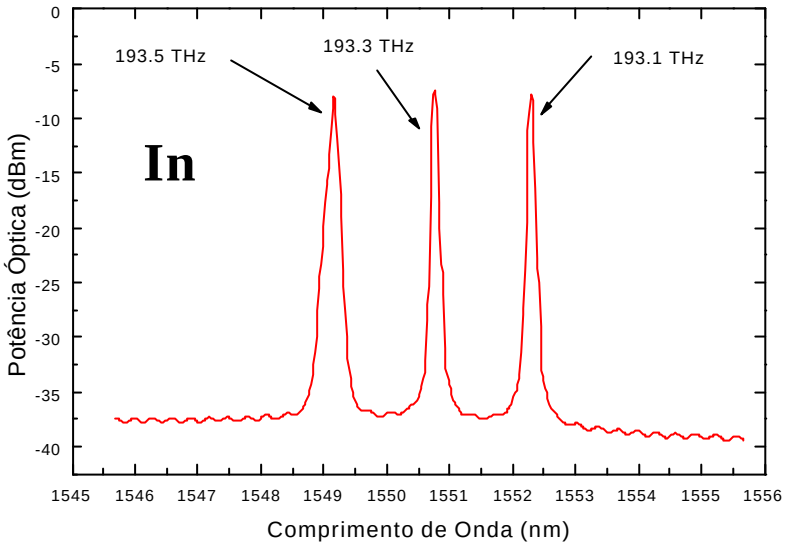


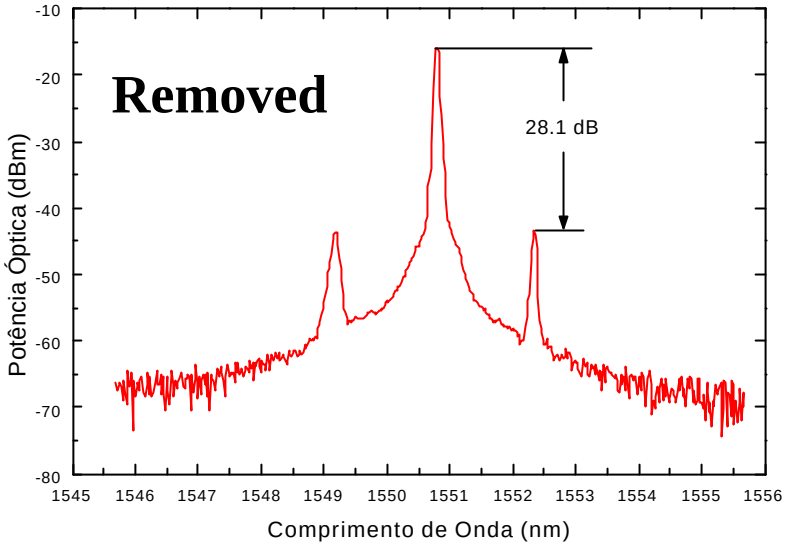
Optimised for the ITU 200 GHz frequency grid, λ_c = 193.3 THz

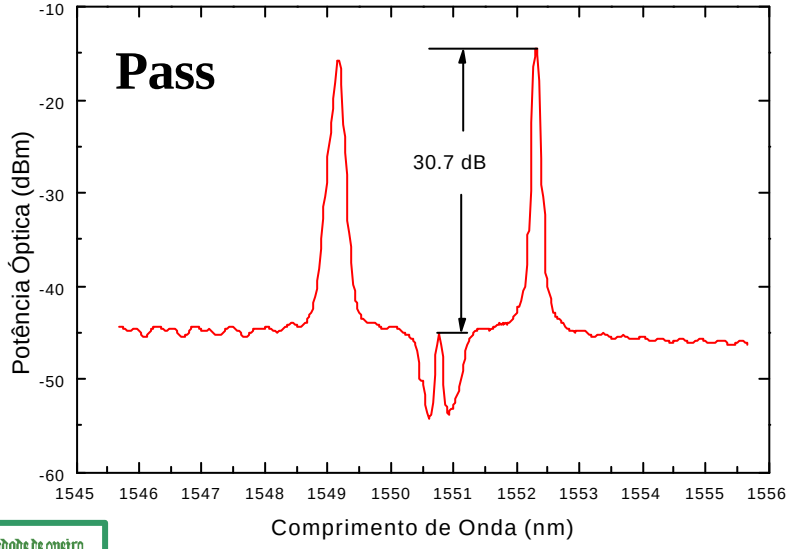
WDM System with a Static OADM

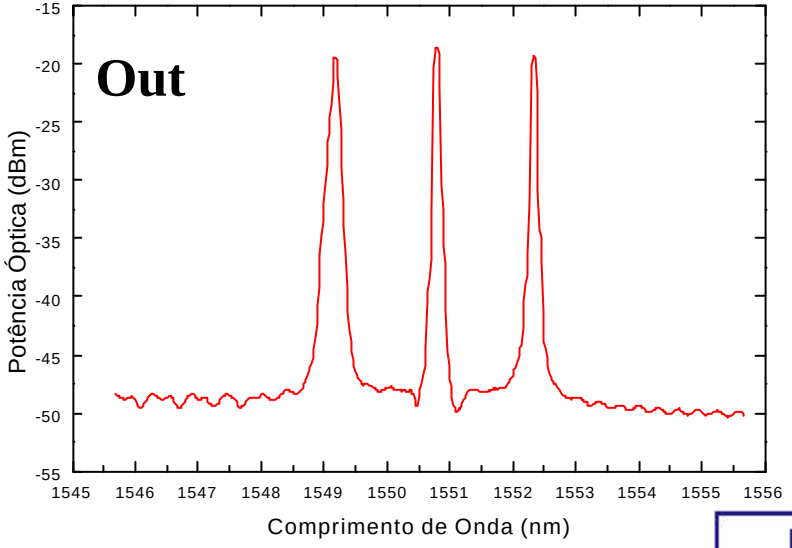
- 3 channels at 193.1, 193.3 and 193.5 THz
- Externally modulated at 2.48832 Gbit/s (STM -16)
- Transmission over 70 km of fibre G.652




In
193.5 THz
193.3 THz
193.1 THz
Potência Óptica (dBm)
Comprimento de Onda (nm)

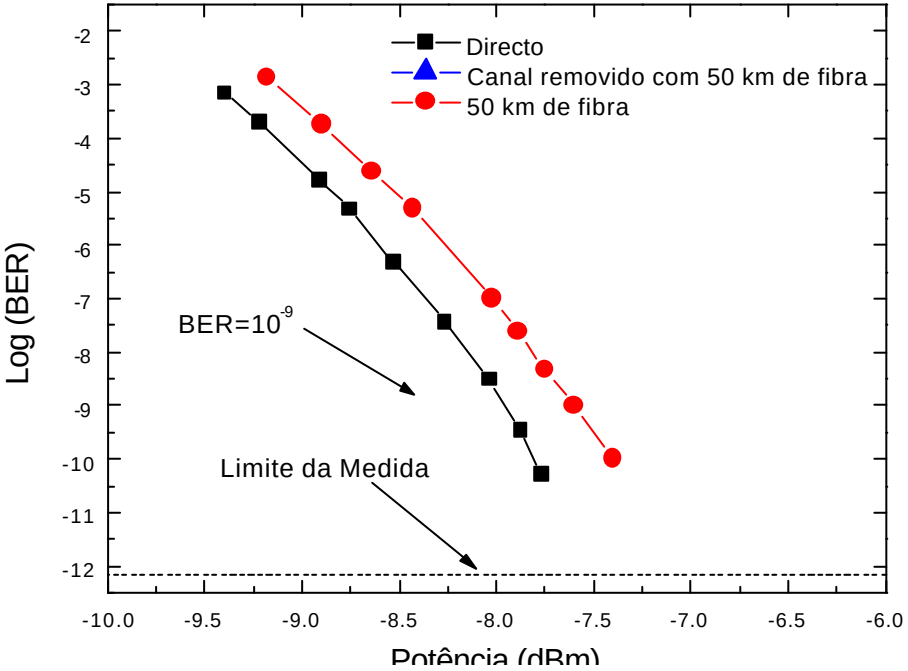

Removed
28.1 dB
Potência Óptica (dBm)
Comprimento de Onda (nm)


Pass
30.7 dB
Potência Óptica (dBm)
Comprimento de Onda (nm)


Out
Potência Óptica (dBm)
Comprimento de Onda (nm)

BER of the removed and added channel

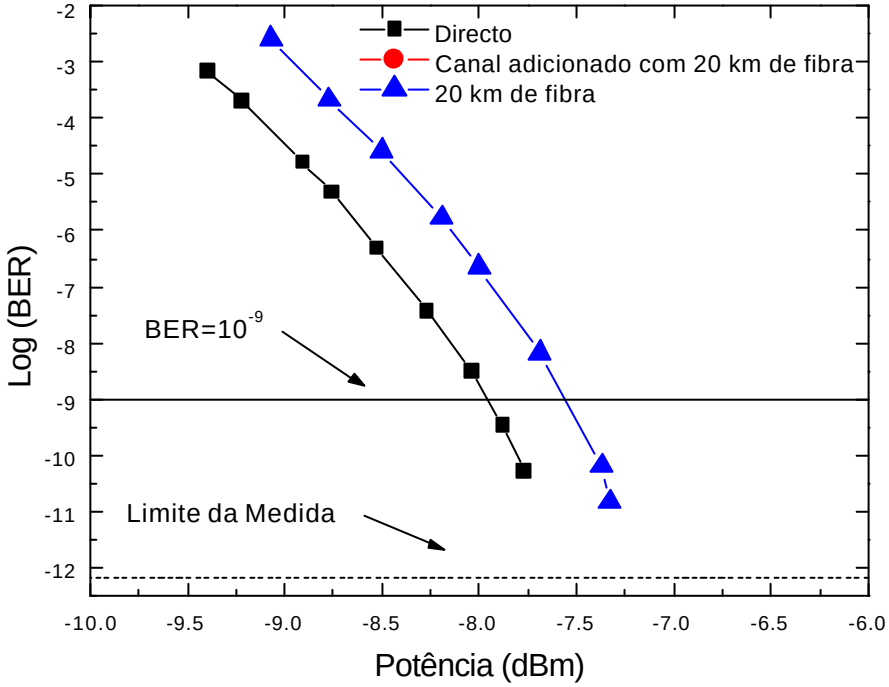
Removed Channel



P_p=0.08 dB

P_{pt}=0.01 dB

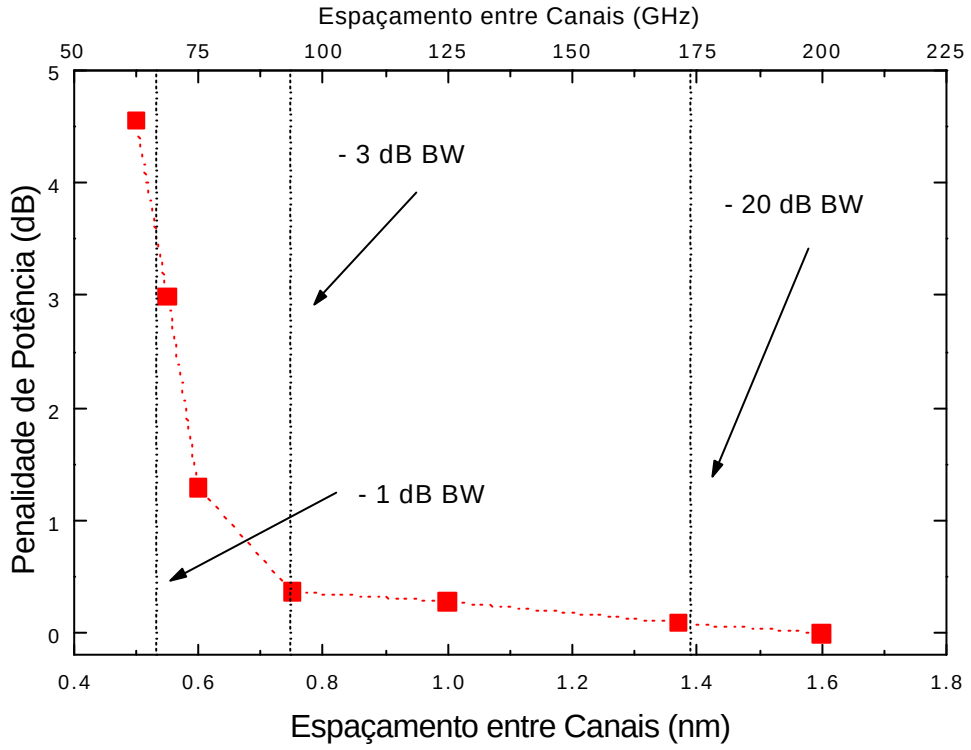
Added Channel

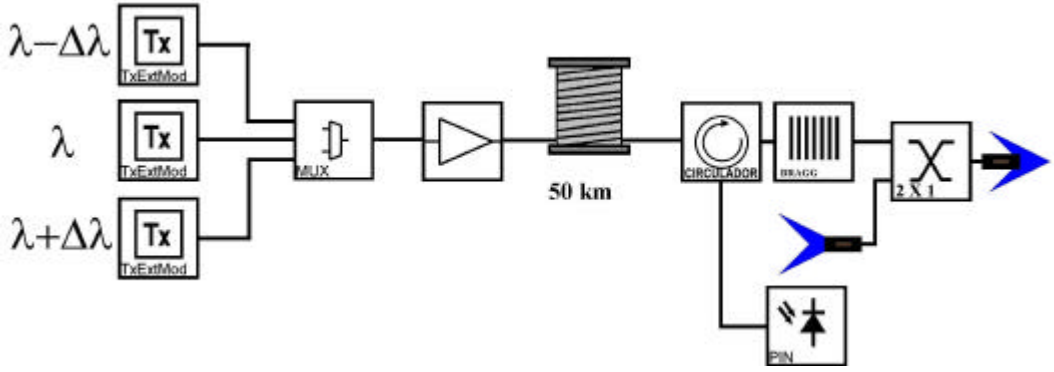


P_p=0.18 dB

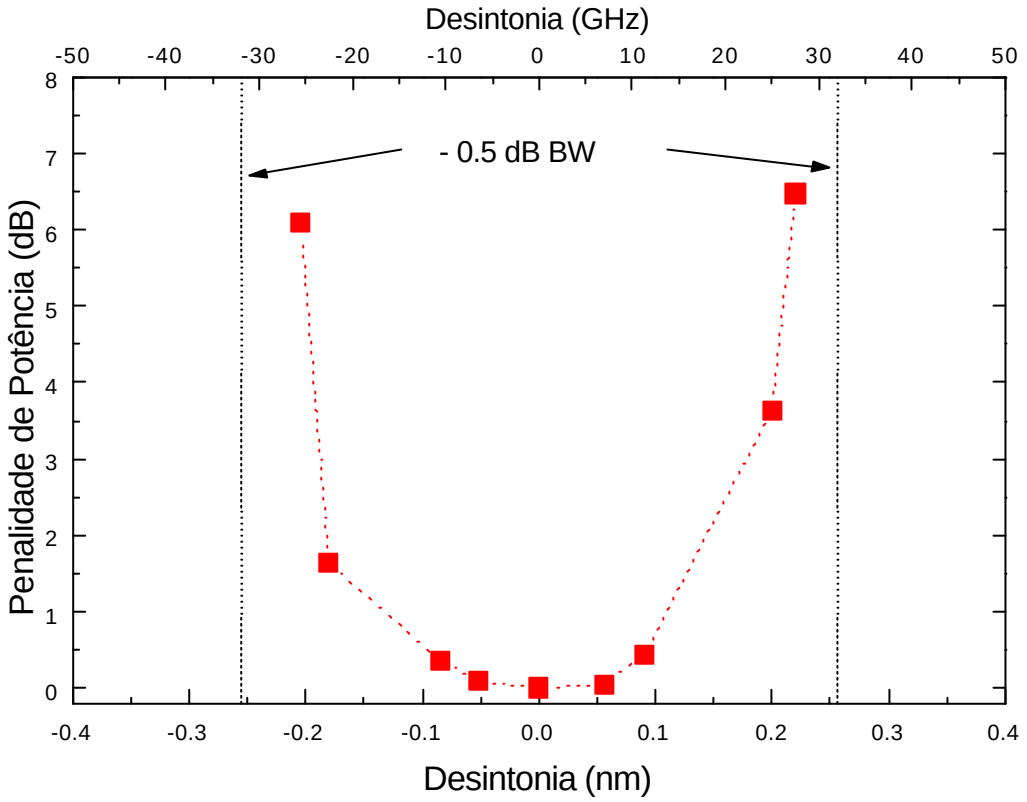
P_{pt}=0.14 dB

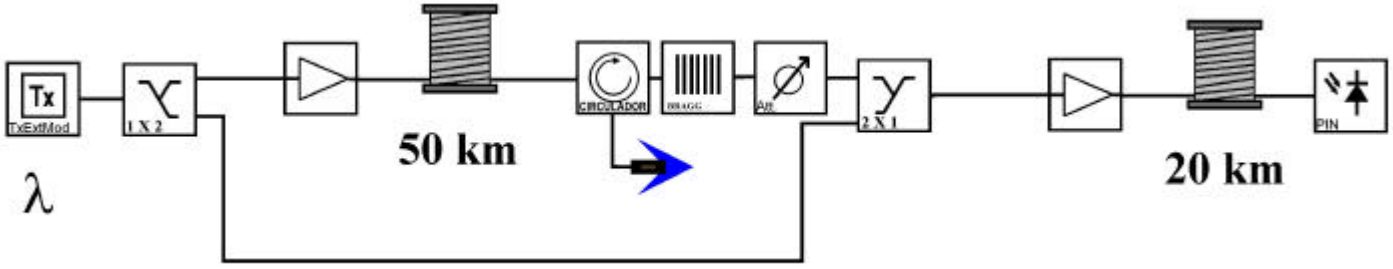
Torelance to Channel Spacing





Torelance to Detuning





Tunable OADM

- A wavelength tunable OADM, giving access to all the wavelengths of the WDM signals provides more flexibility to satisfy reconfiguration requirements and to enhance network protection.

- The wavelength tuning capacities of the OADM are related with the FBG capacities to shift their central reflection wavelength.

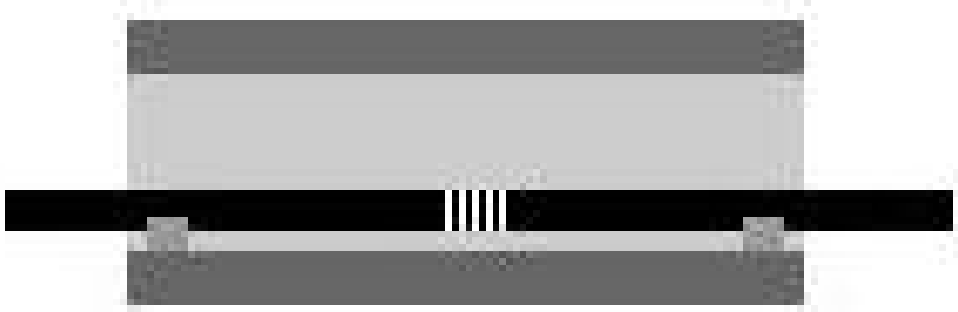
- To shift the Bragg grating central wavelength peak there are two main methods: by modifying the fibre refractive index or by changing the grating period. These variations can be induced thermally or/and by mechanical stress.

$$\lambda_B = 2 \cdot n_{eff} \cdot \Lambda$$

- Mechanical stress: Large tuning range (> 36 nm), high tuning speed (< 10 ms/nm), low reproducibility and reversibility.

- Thermal: High reproducibility and reversibility, built-in temperature compensation, low tuning range (< 1 nm) and low tuning speed (> 10 s/nm).

- We present a hybrid method based on a thermal-stress thermally enhanced actuation on a FBG .



$$\Delta\lambda_B = 2\cdot\left(\Lambda\cdot\frac{dn_{eff}}{dl}+n_{eff}\frac{d\Lambda}{dl}\right)\cdot\Delta l + 2\cdot\left(\Lambda\cdot\frac{dn_{eff}}{dT}+n_{eff}\frac{d\Lambda}{dT}\right)\cdot\Delta T$$

$$\Delta\lambda_{BT} = \lambda_B \cdot (1 - p_e) \cdot \varepsilon_z \qquad \Delta\lambda_{BT} = \lambda_B \cdot (\alpha_\Lambda + \alpha_n) \cdot \Delta T$$

$$\varepsilon_Z = \alpha_{CTE} \cdot \Delta T$$ Deformação axial (stress)

$$\Delta\lambda = \lambda_B \cdot [(1 - p_e) \cdot \alpha_{CTE} + (\alpha_\Lambda + \alpha_n)] \cdot \Delta T \approx \lambda_B \cdot 26.31 \cdot 10^{-6} \cdot \Delta T$$

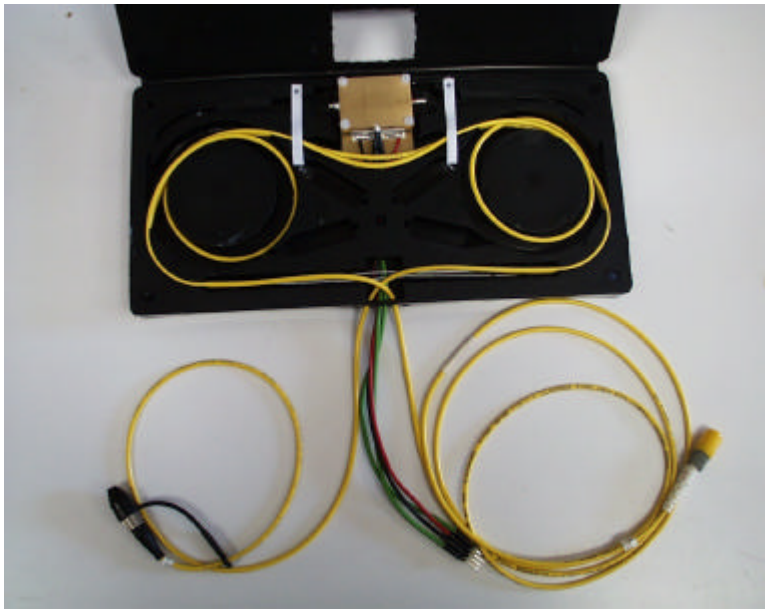
KTS = 41.1 pm / ºC

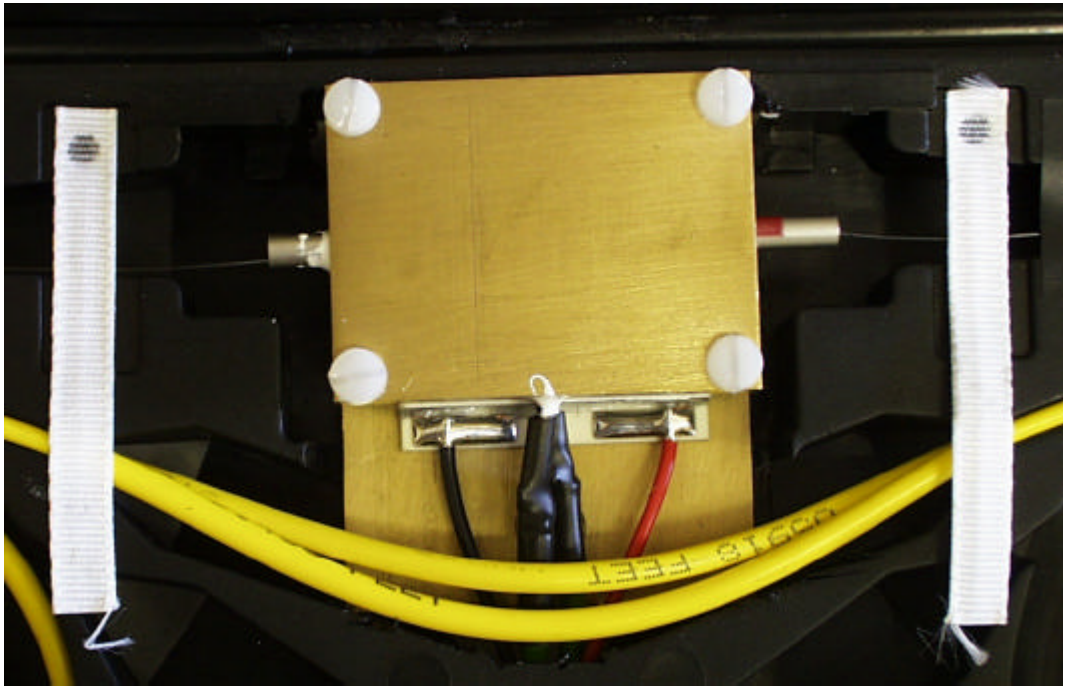
Aluminium Coefficient of thermal expansion $\mathbf{a_{CTE}} = 22.0 \times 10^{-6}\ ºC^{-1}$

Silica Photo elastic coefficient $\mathbf{p_e} = 0.22$

Sílica Thermal expansion coefficient $\mathbf{a_L} = 0.55 \times 10^{-6}$

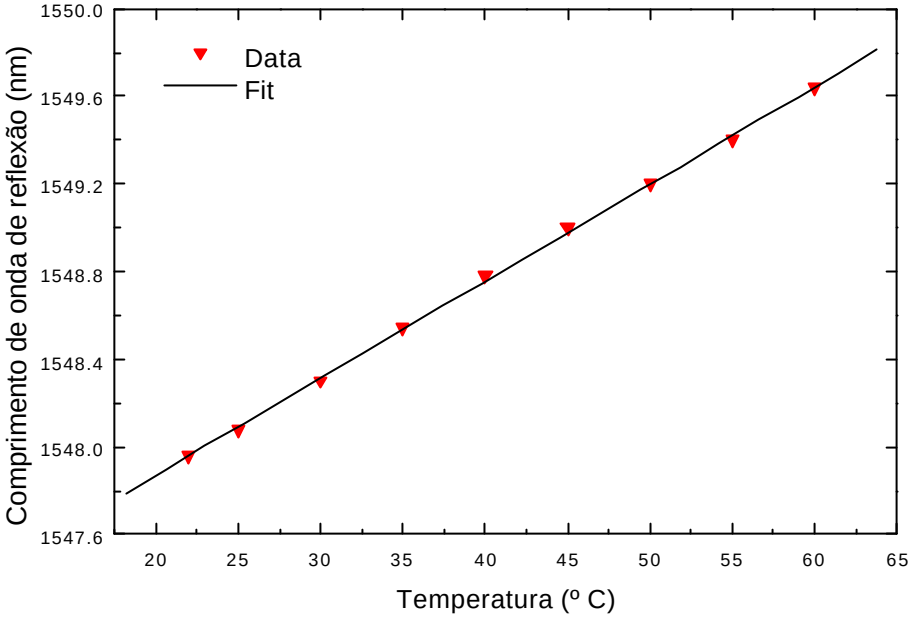
Sílica Thermal optic coefficient $\mathbf{a_n} = 8.6 \times 10^{-6}$

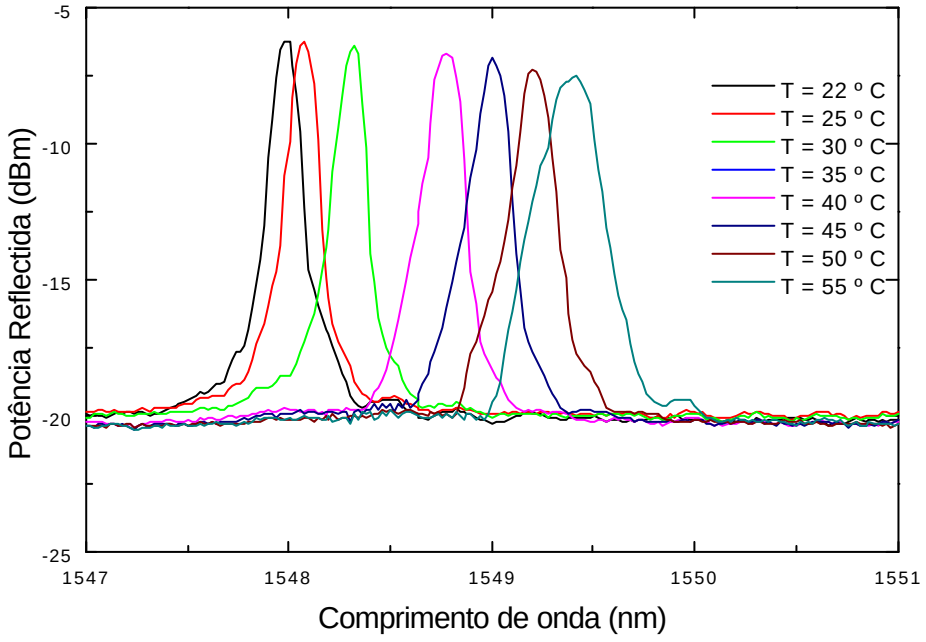




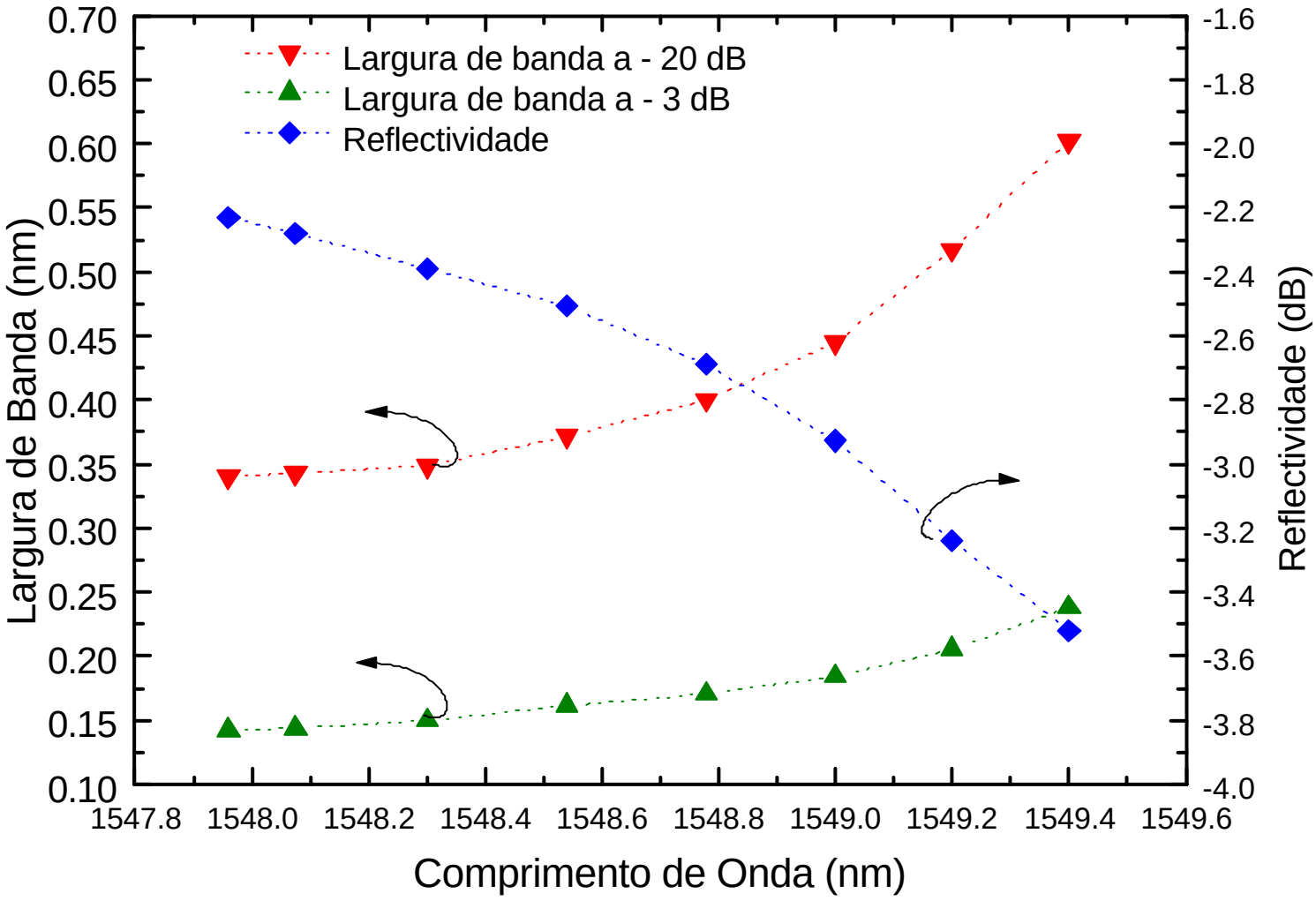
Tuning Capacity

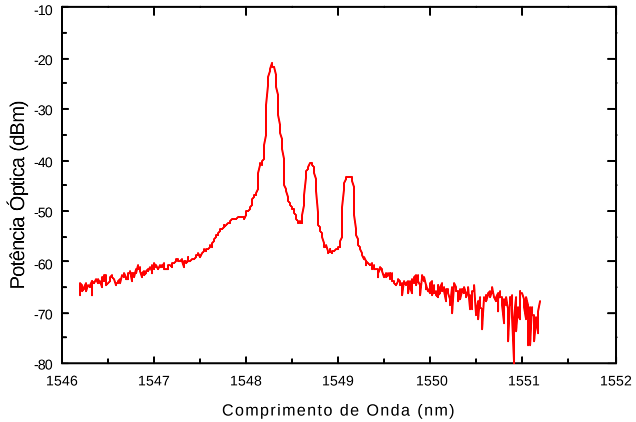
KTS = 44.3 pm / ºC

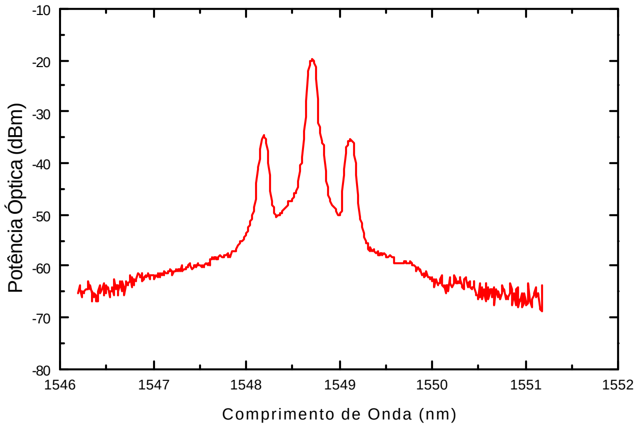


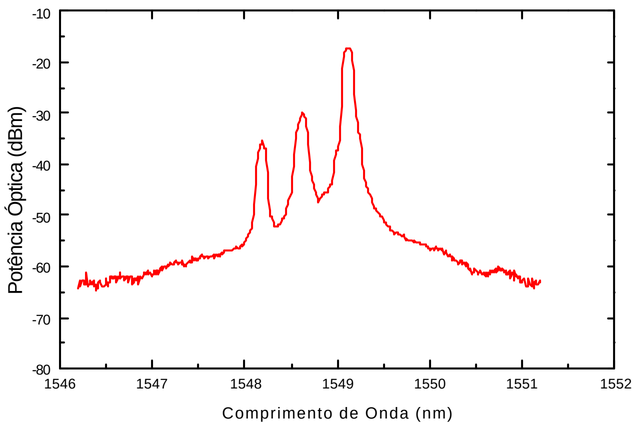


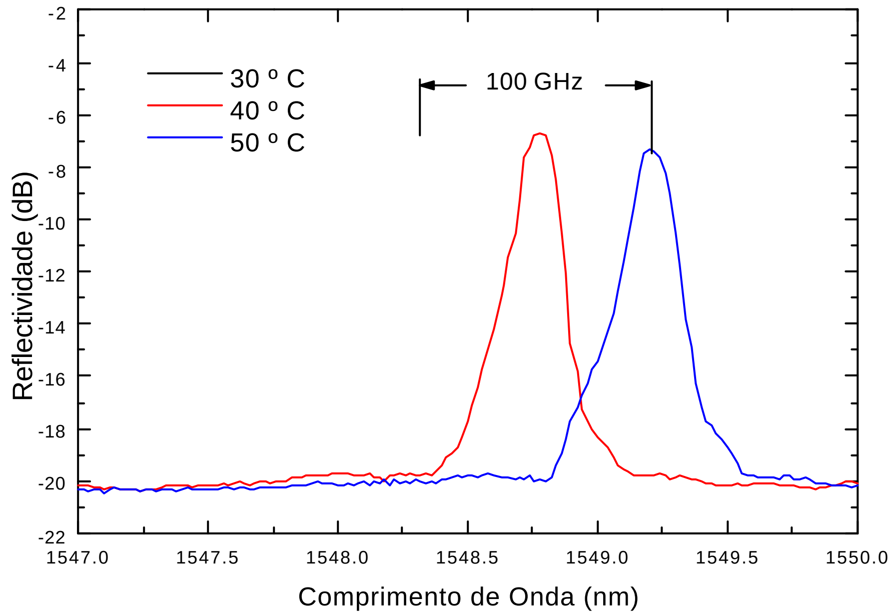
FBG Temperature Performance

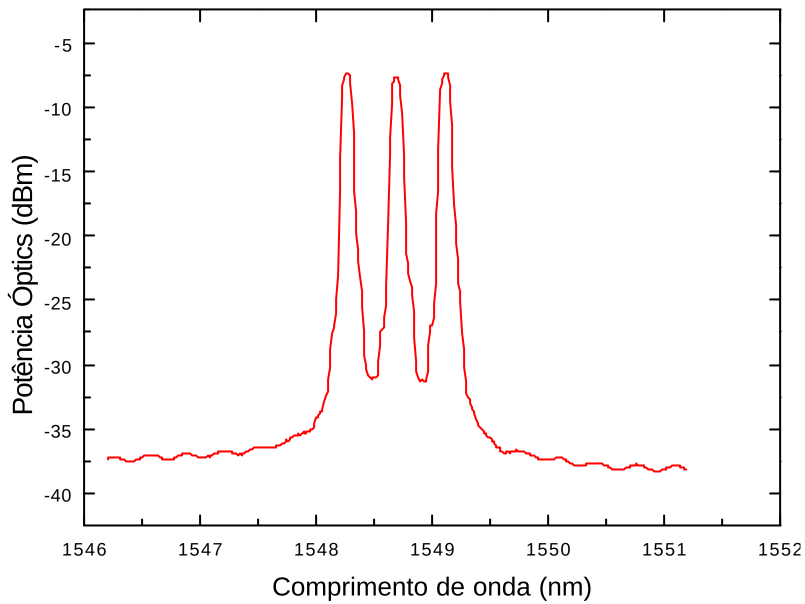












universidade de aveiro

Conclusions

- We have reported an OADM solution for DWDM systems using a FBG.
- The OADM performance was demonstrate in a 200 GHz, 3 channels WDM system, working at STM-16 bitrate.
- The OADM show a good performance with respect to channel spacing and crosstalk.
- We also reported a tunable OADM based on a thermal - stress thermal enhanced tunable FBG.