FIBER BASED ONE-WAY TIME TRANSFER WITH ENHANCED ACCURACY

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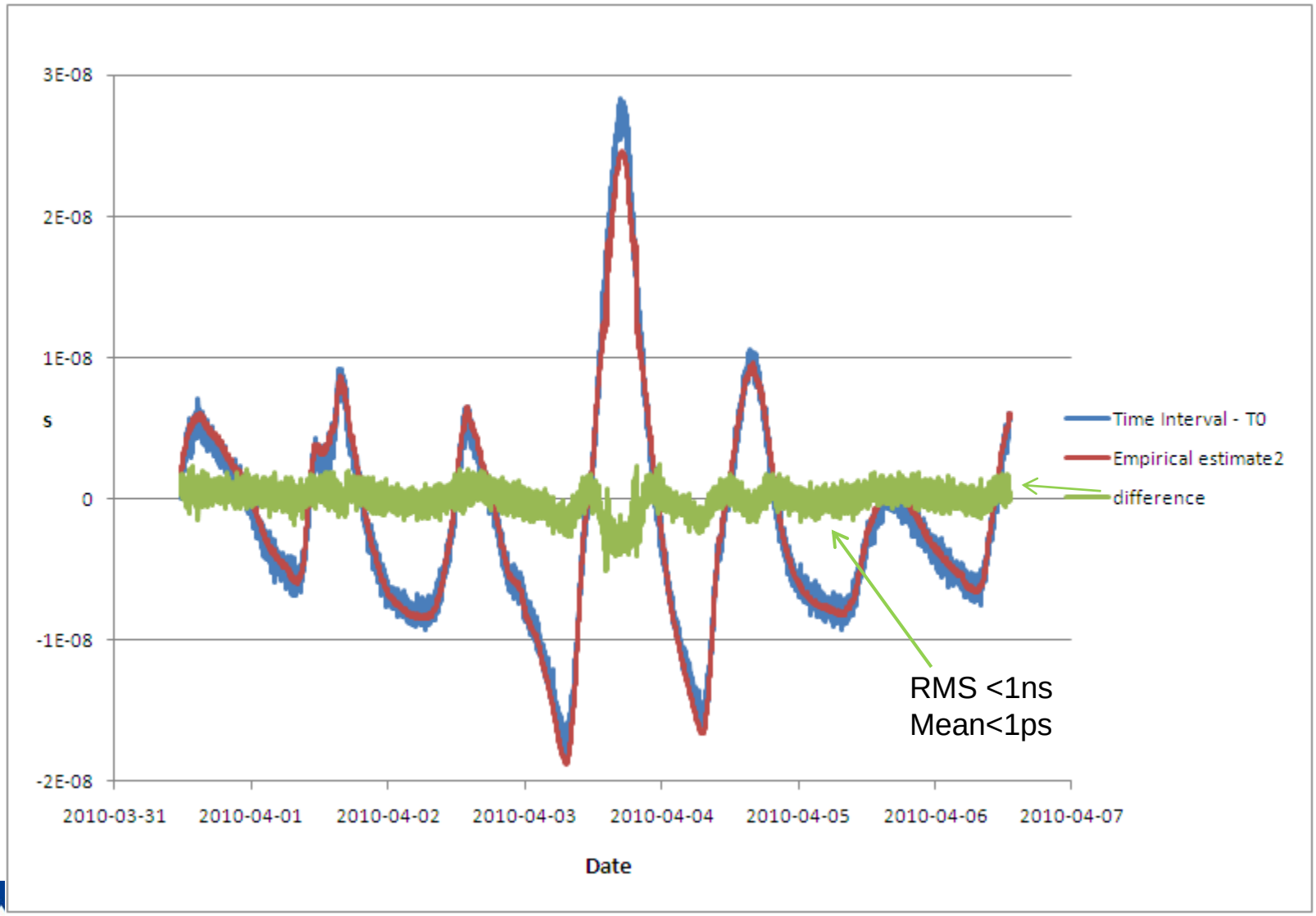
Outline

- Background and goal
- Classic two-way time transfer
- one-way time transfer
- Equipment and experimental setup
- Results
- Conclusion

Results


3E-08
2E-08
1E-08
s
0
-1E-08
-2E-08
2010-03-31
2010-04-01
2010-04-02
2010-04-03
2010-04-04
2010-04-05
2010-04-06
2010-04-07
Date
Time Interval - T0
Empirical estimate2
difference
RMS <1ns
Mean<1ps

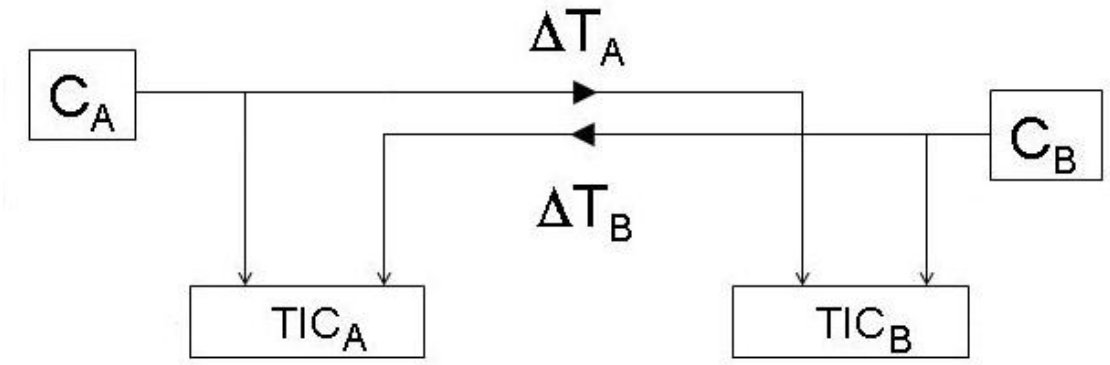
Background

- Asymmetry in some regular two-way methods
- Use of two different paths, one for each direction
- Less equipment

Goal

- Development of a stable one-way transfer method comparable with well established two-way methods
- Operate within the C-band with commercial DWDM networks for distances >100km

Classic two-way time transfer

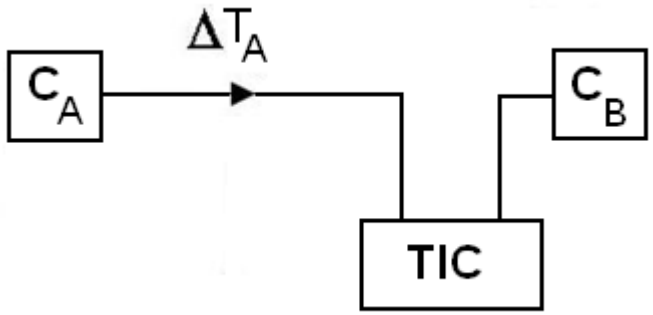


$$TIC_A = C_A - (C_B + \Delta T_B)$$

$$TIC_B = C_B - (C_A + \Delta T_A)$$

$$C_A - C_B = \frac{TIC_A - TIC_B - F(t)}{2}$$

One-way time transfer

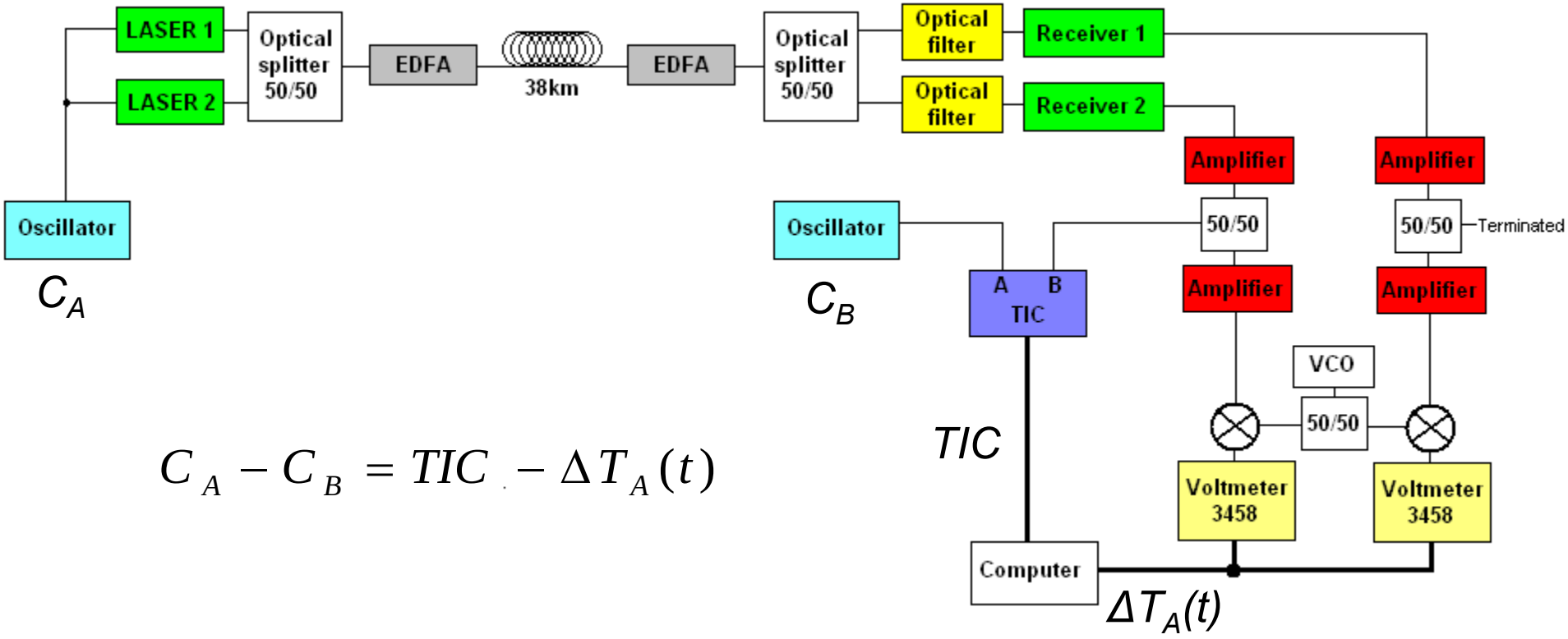


$$TIC = C_B - (C_A + \Delta T_A(t))$$

$$C_A - C_B = TIC - \Delta T_A(t)$$

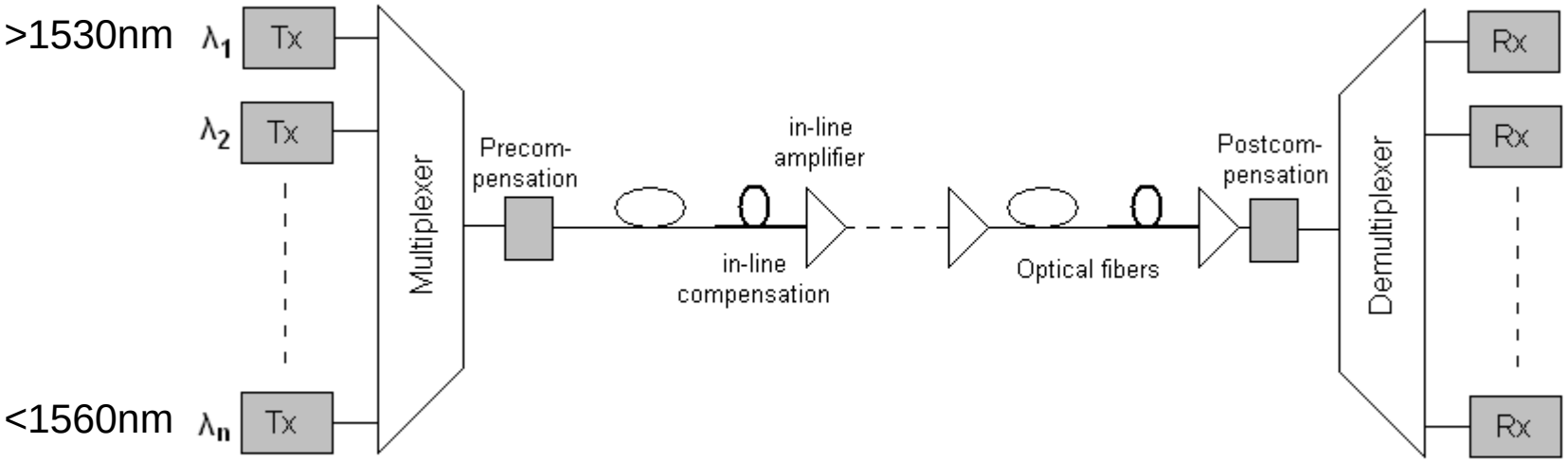
One solution to solve for varying ΔT_A are transmitting two wavelength in the same cable and solve for propagation differences between the wavelengths

One-way time transfer method using two wavelengths

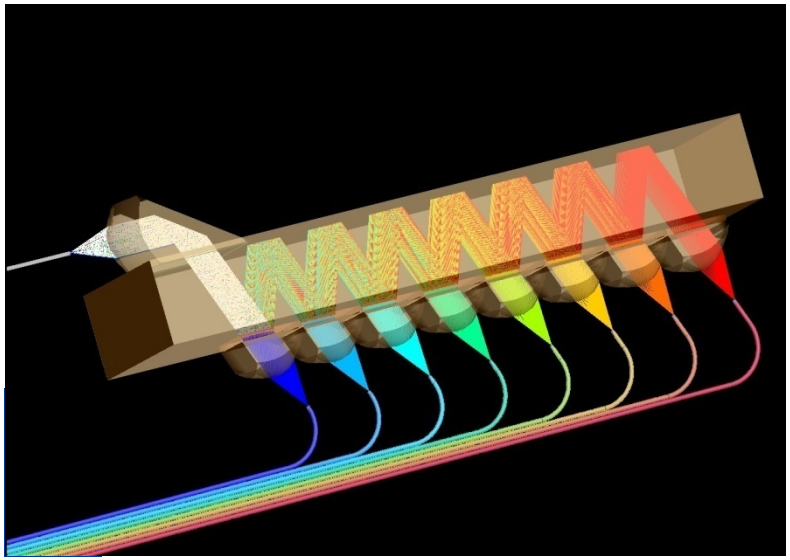


$$C_A - C_B = TIC - \Delta T_A(t)$$

Wavelength-Division Multiplexing (WDM)



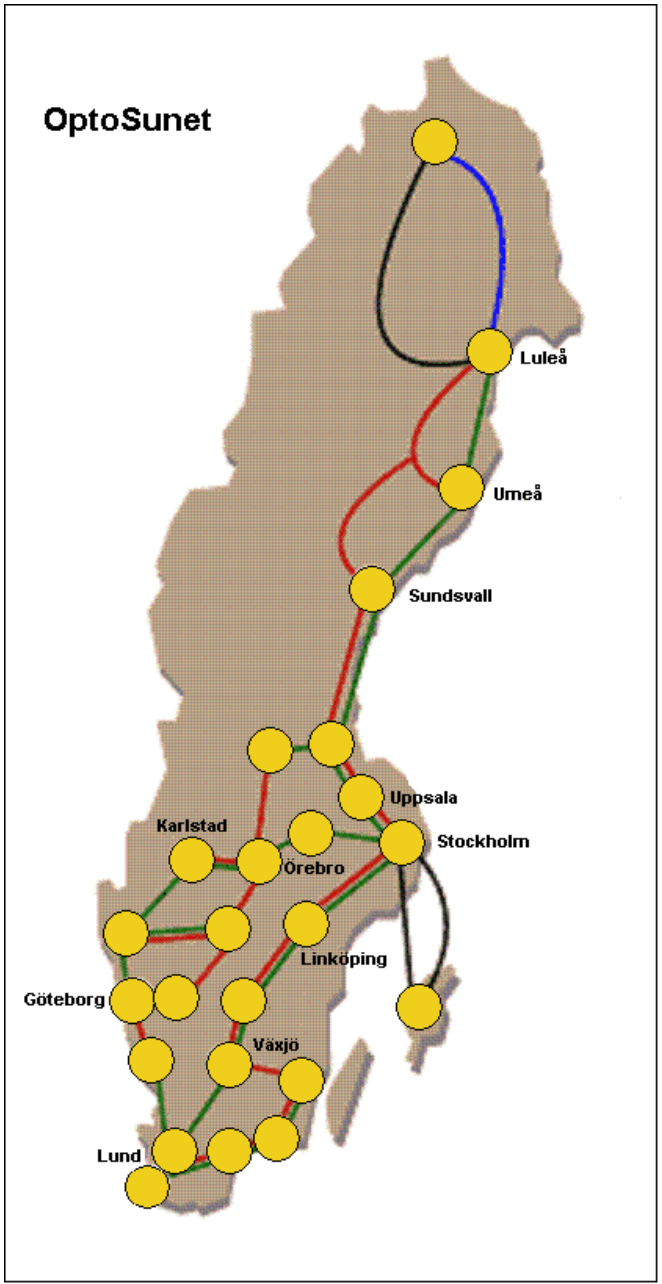
C-band is of use and efficient amplifiers for the whole band are available



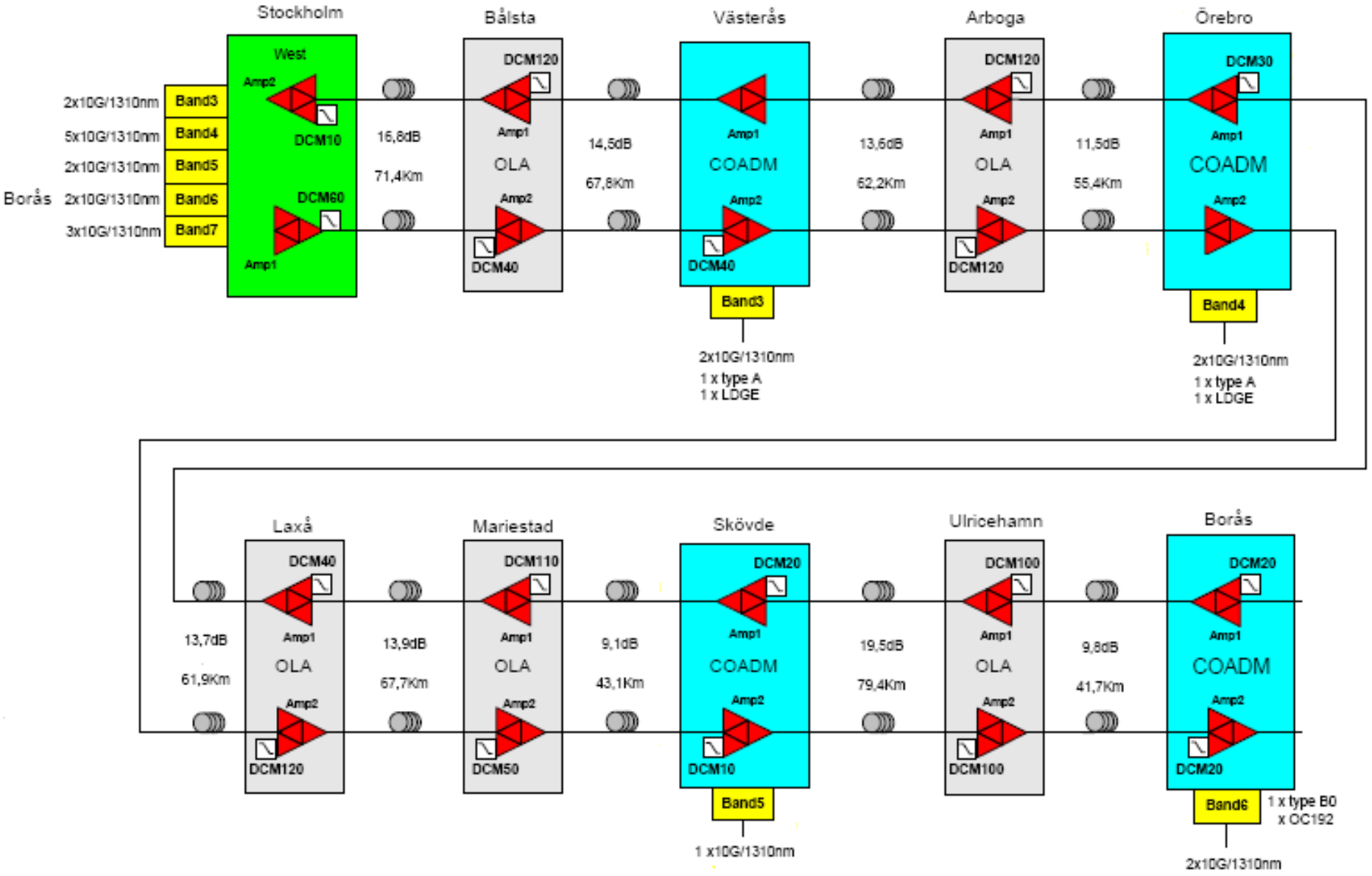
Swedish University Computer Network (OptoSUNET)

SUNET is an abbreviation for Swedish University Computer Network.

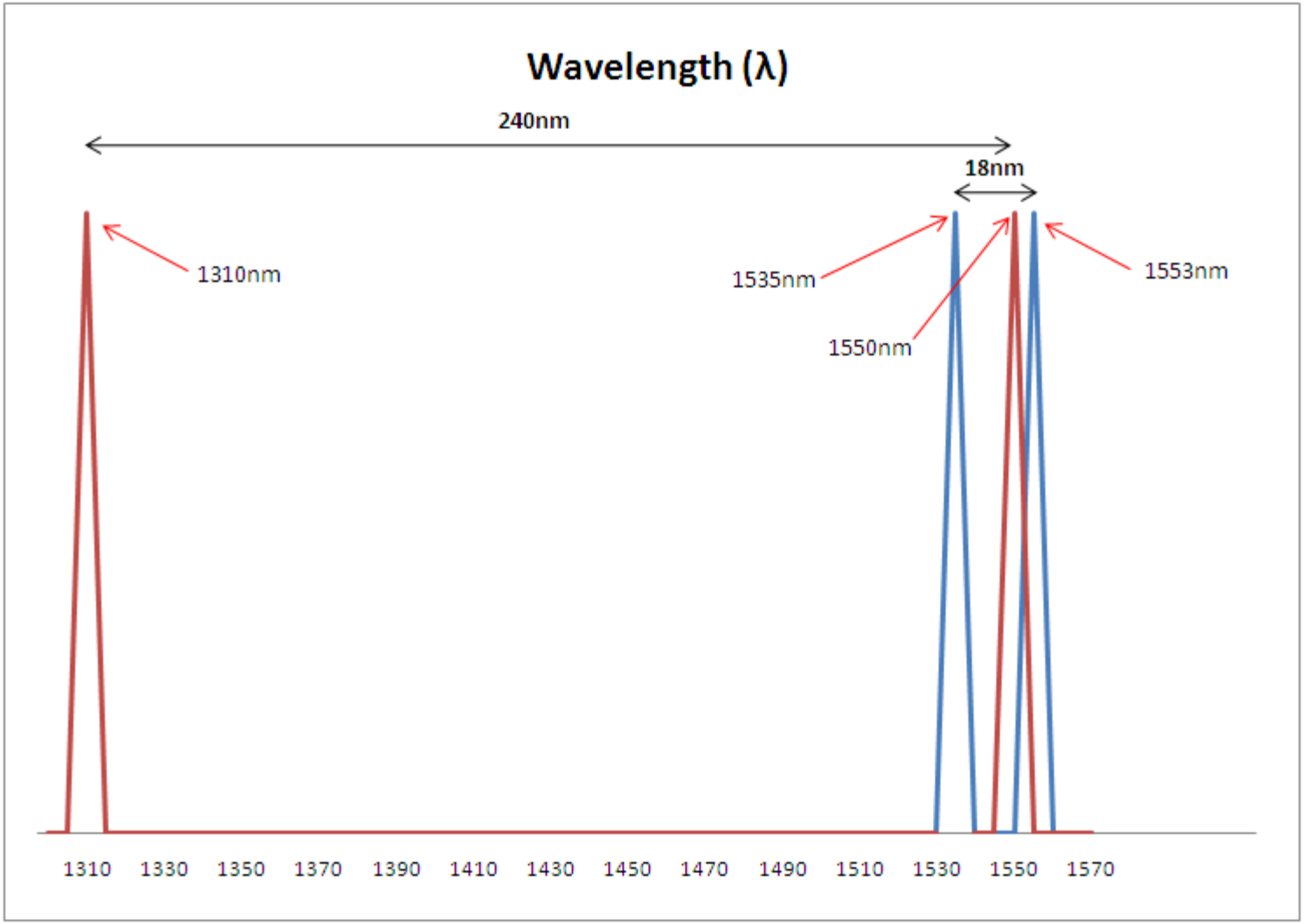
The network is configured as a star topology with a hub in Stockholm.



Dissemination of one path in OptoSUNET

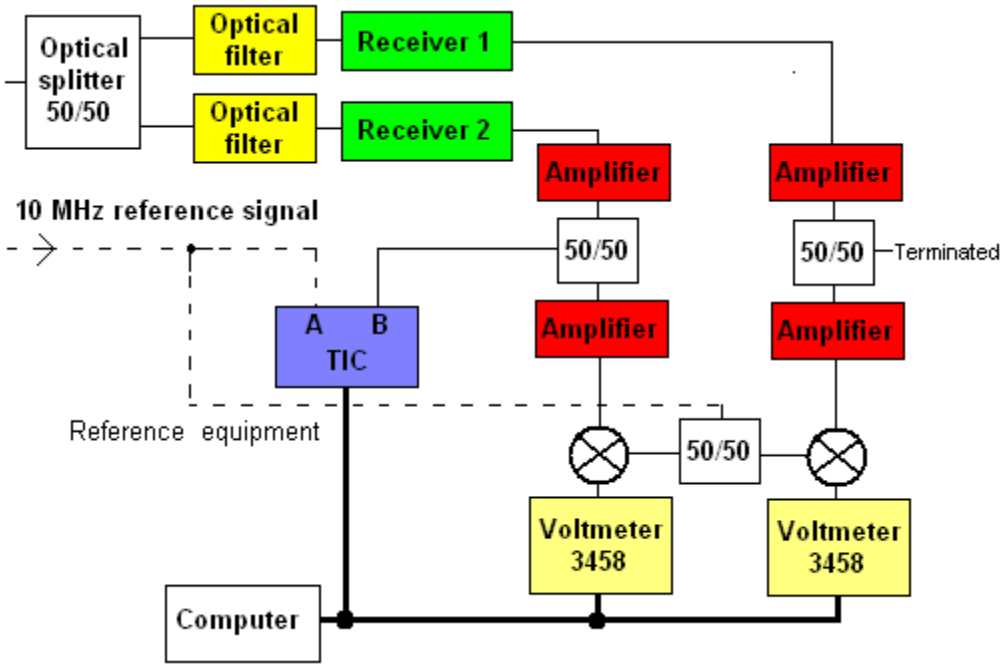


Experimental Wavelengths



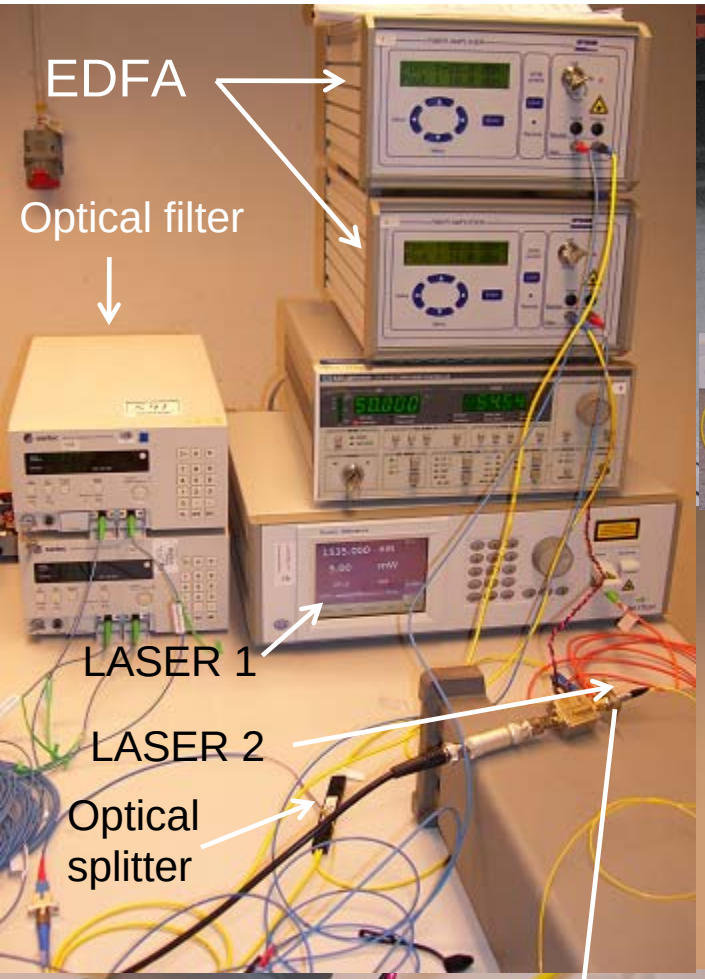
Previous study with wavelength 240nm (red peaks) apart was presented at PTTI09.
This study present results from wavelengths 18nm (blue peaks)apart.

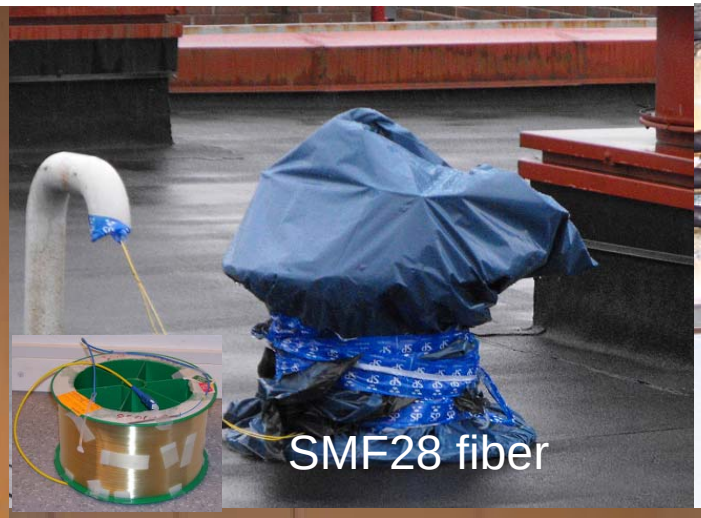
Test setup for evaluation of the wavelengths

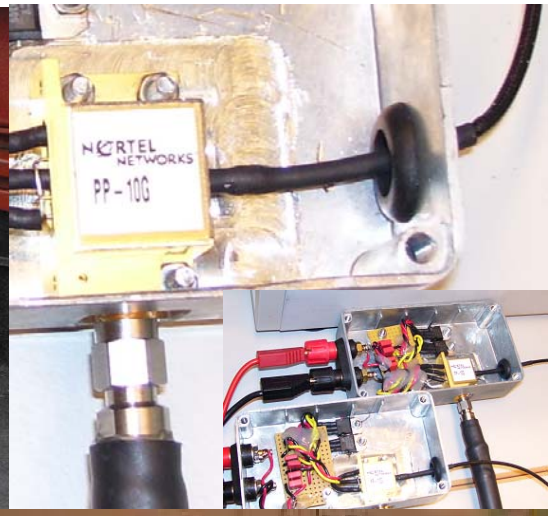


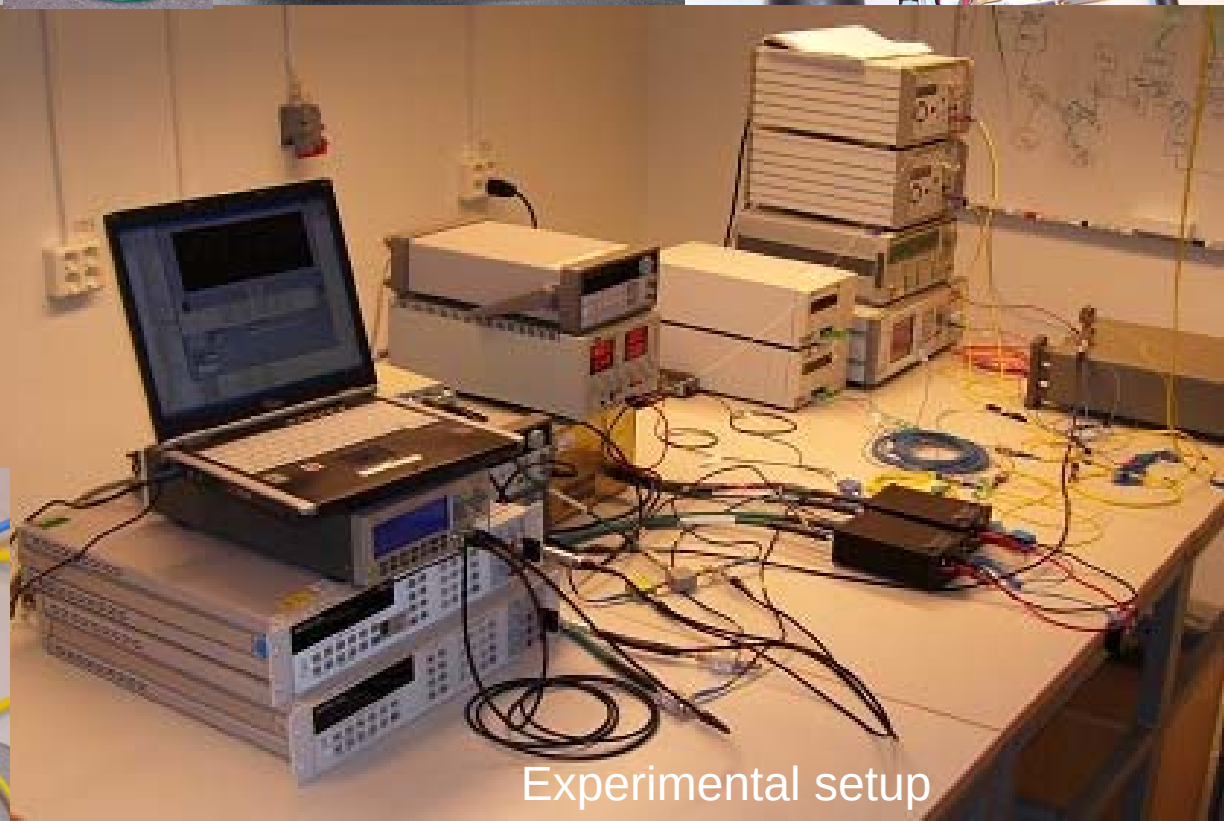
Covered fiber spools placed outdoors

p-i-n Photodiode

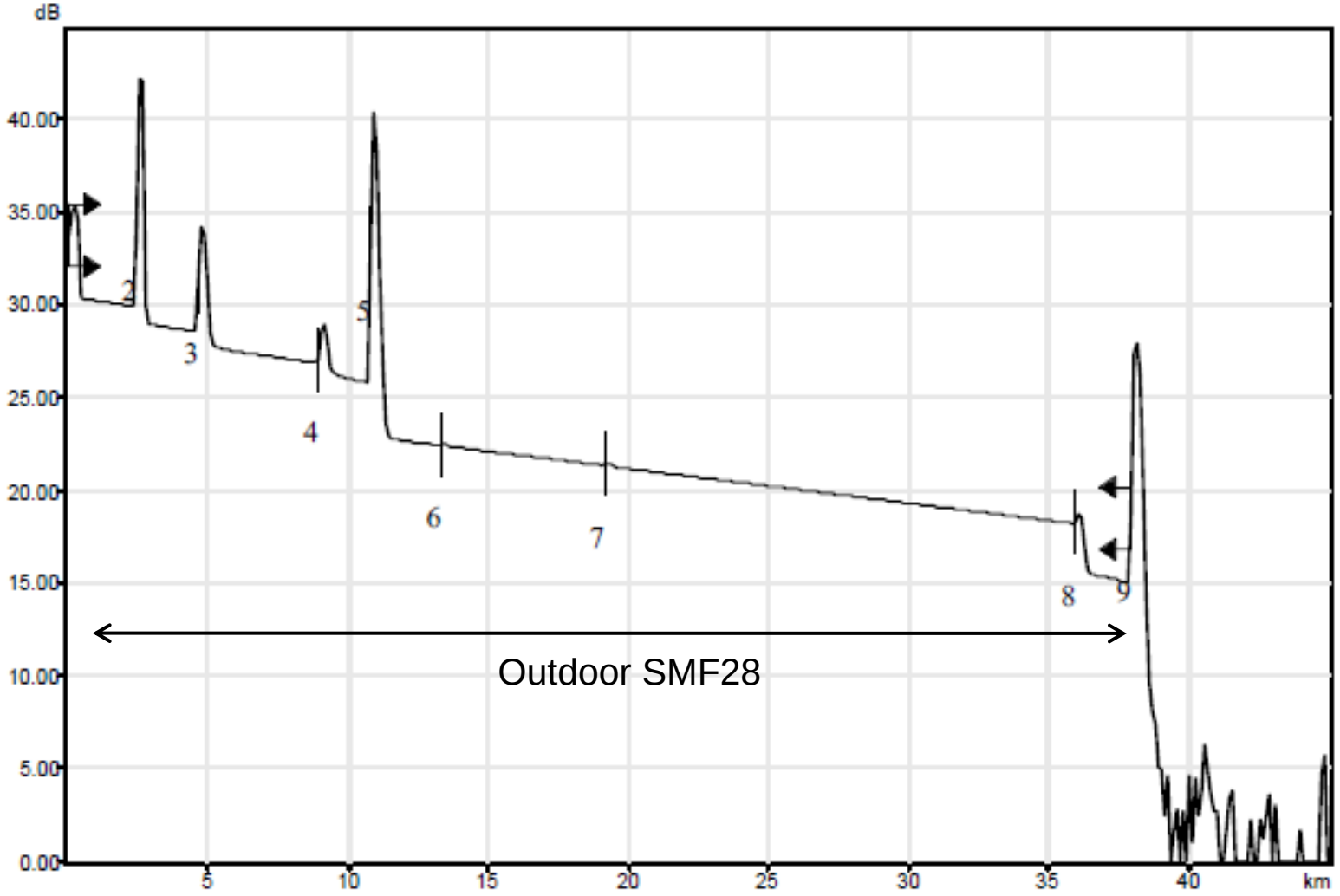






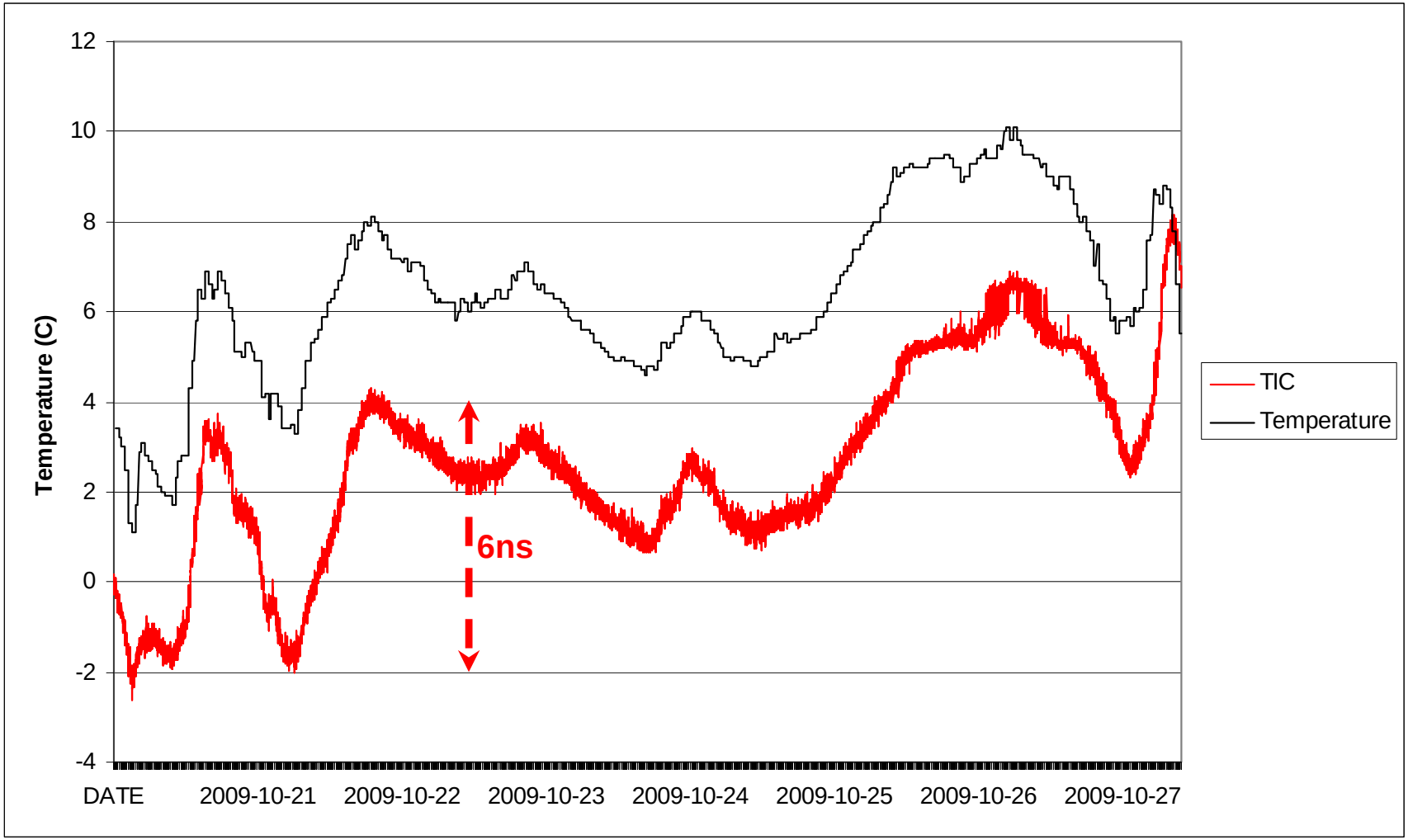


Optical Time-Domain Reflectometer (OTDR) measurements of the fiber



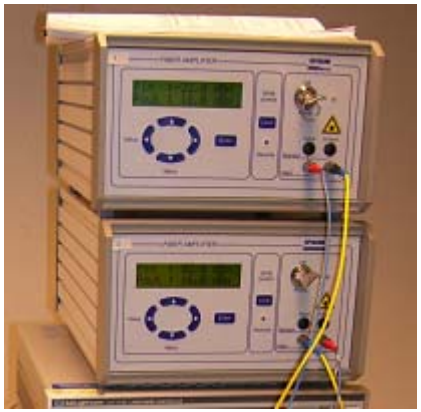
Total length is 38km.

Temperature and time interval measurements of fiber



Intermediate Component such as EDFA

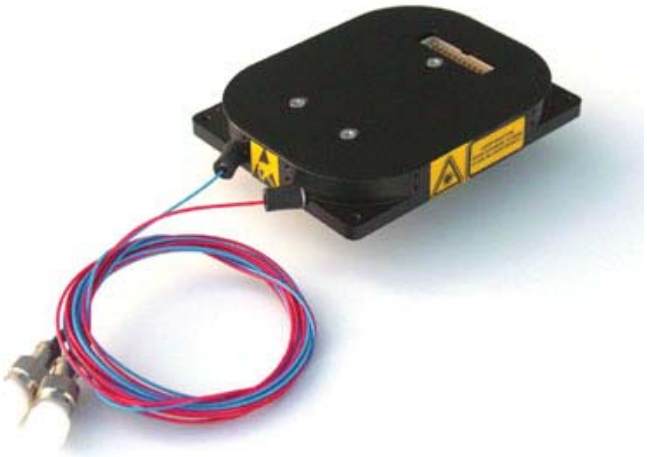
Erbium Doped Fiber Amplifier (EDFA)

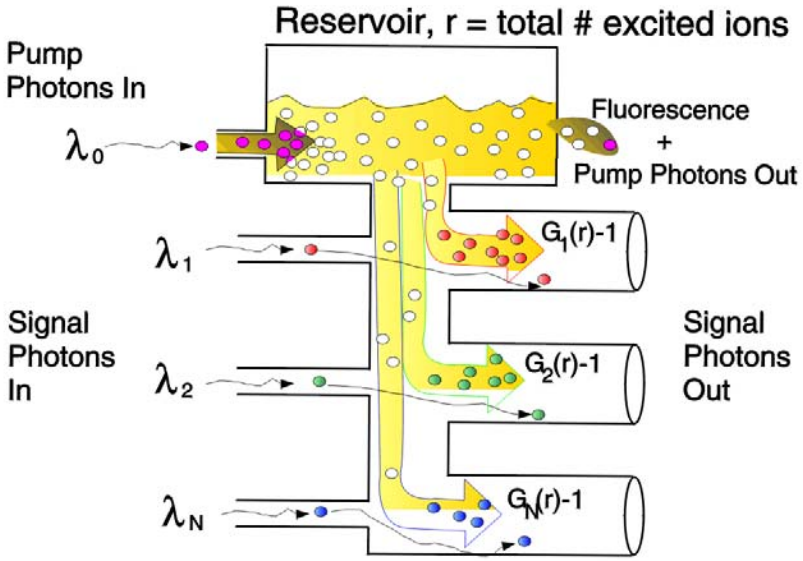


Broad spectrum 30nm in silica, typically. The broad gain-bandwidth of fiber amplifiers make them particularly useful in wavelength –division multiplexed communications systems as a single amplifier can be utilized to amplify all signals being carried on a fiber and whose wavelengths fall within the gain. It is only working for one direction

APPLICATIONS

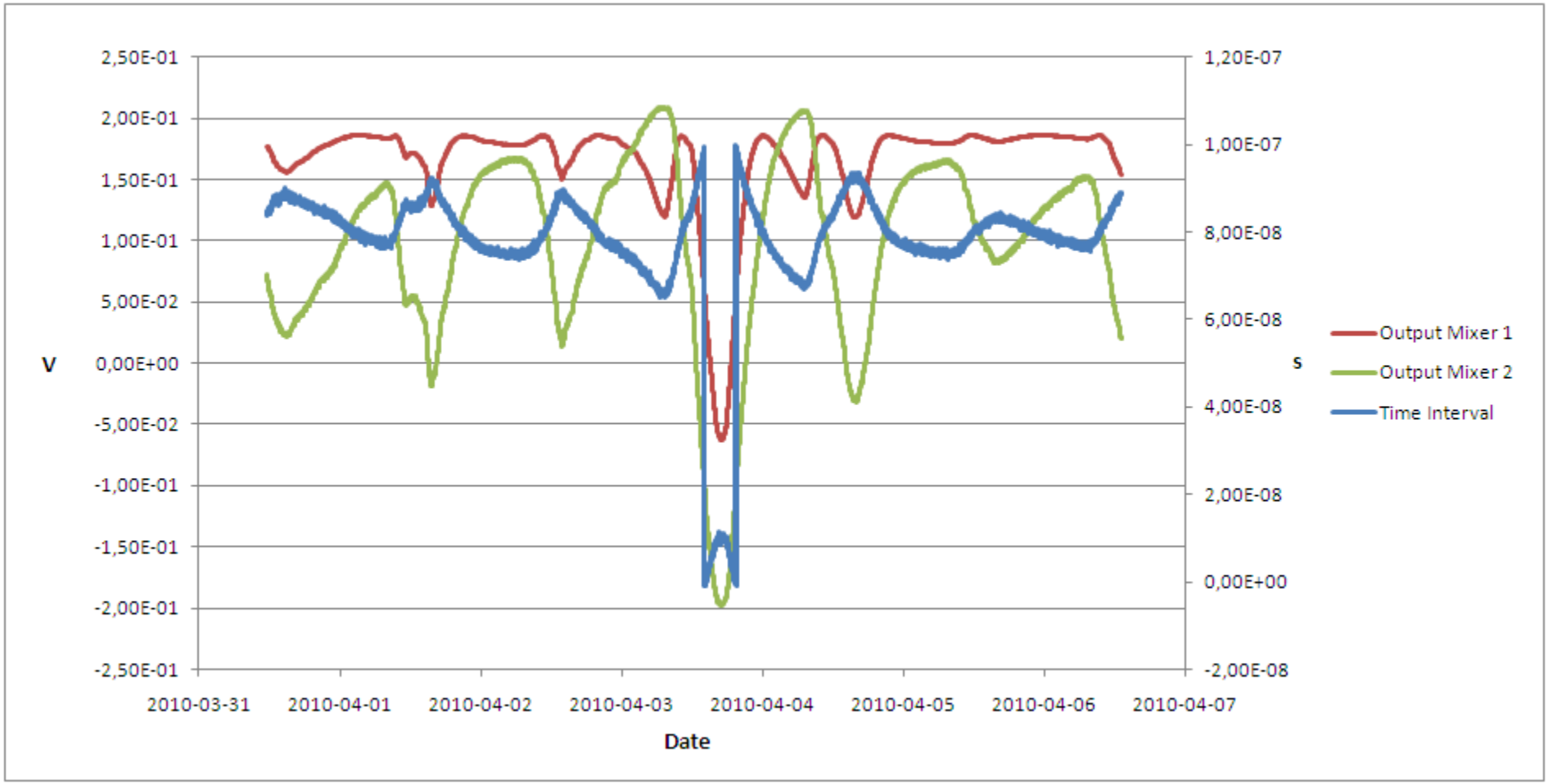
Long Haul and Metro Networks
Transmitter and Receiver Amplification
Single Channel, Narrowband and Wideband DWDM





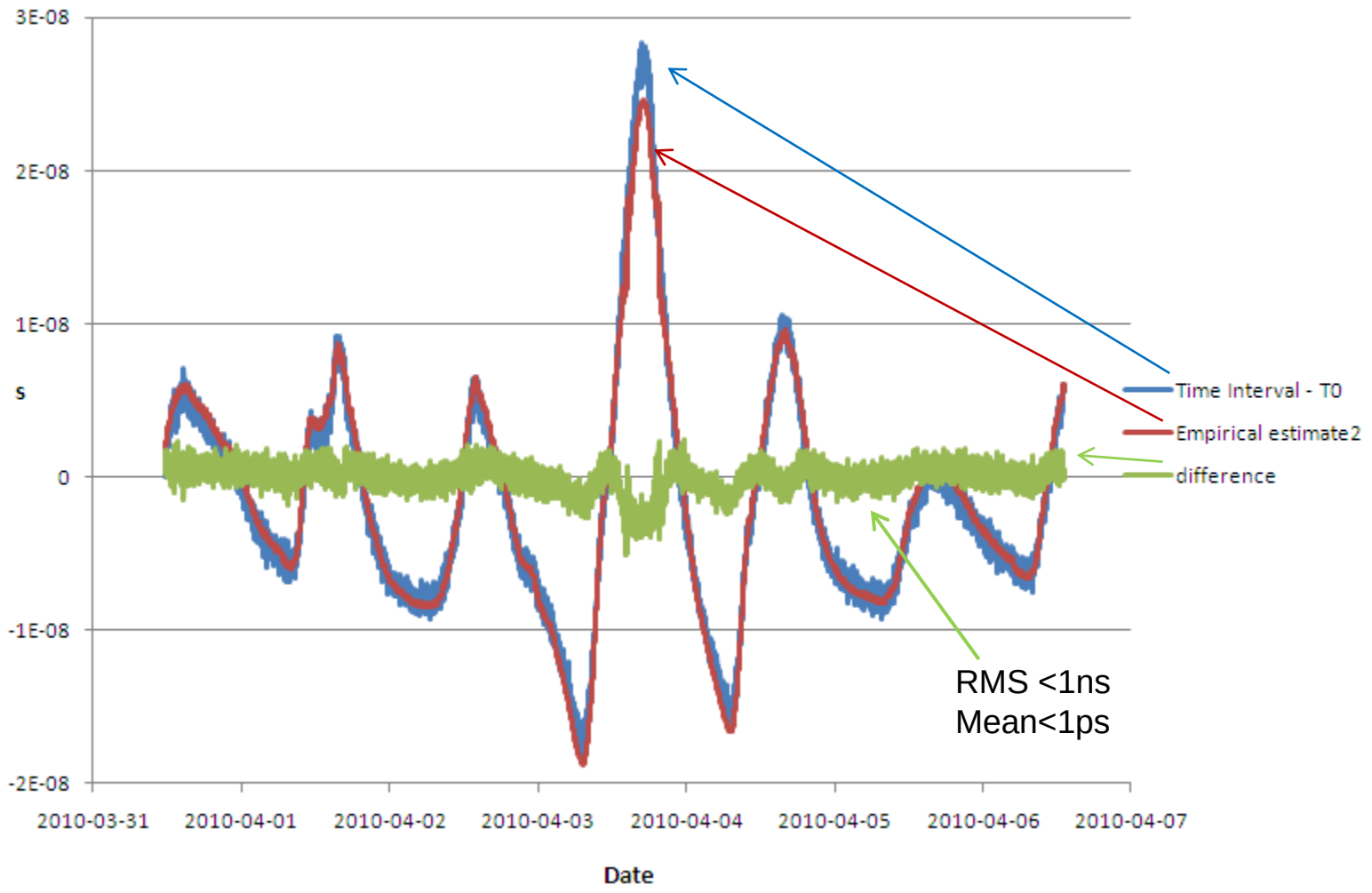
The vision above is derived from paper [BR_jlt_98] A.Bononi , L. A. Rusch, ``Doped fiber amplifier dynamics: a system perspective", IEEE J. Lightw. Technol. , vol. 16, pp. 945-956, May 1998.

Raw data from mixers and TIC

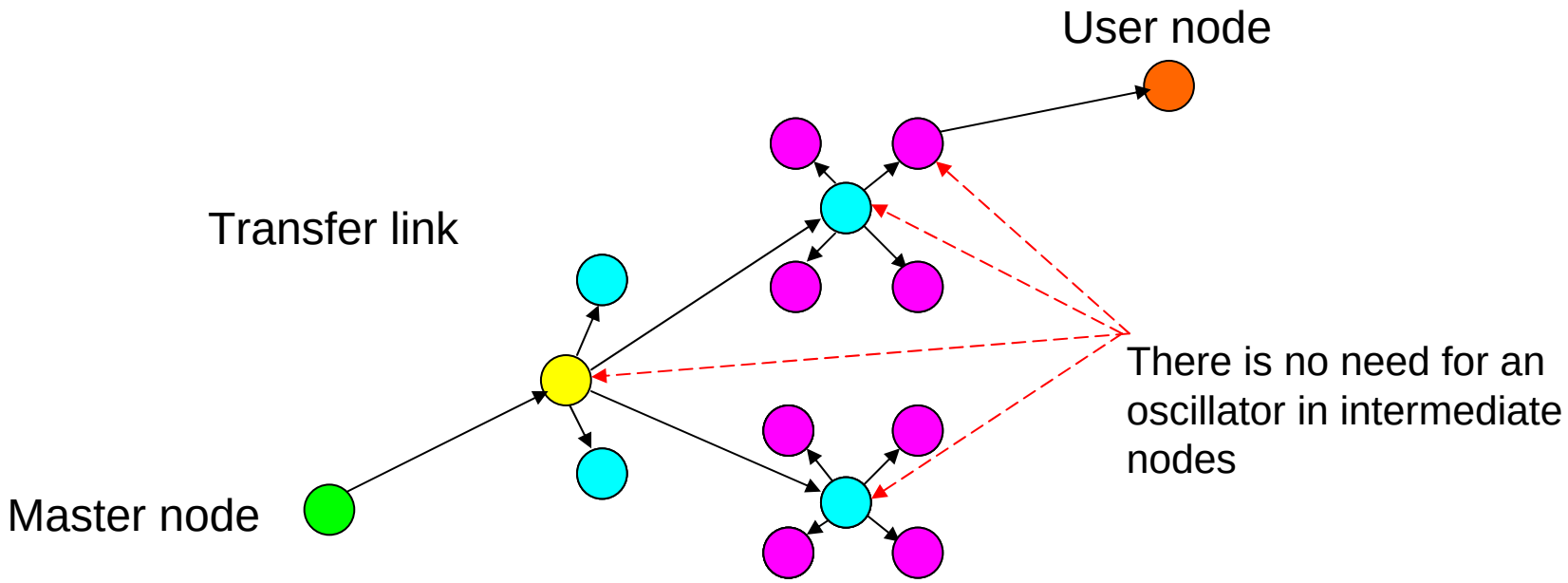


Results

$$Empirical\_estimate = (\arccos((mixer1 - mixer2)/\max\_value(mixer1 - mixer2))) \times 1{,}58 \times 10^{-8} + 1{,}71 \times 10^{-9}$$



Use of method and proposal of transfer network tree



Conclusions

- Proof of concept
- Possible operation within the C-band (30nm)
- The information is to receive from the two wavelengths

- Future work includes
  - Mathematical algorithms
  - Better finesse of the receiver
  - Use of AWG (Arrayed Waveguide Gratings)instead of active optical filter
  - Method needs test with fiber 60km or more
  - Evaluation with wavelengths in C-band and on a commercial WDM-net

Thank you for your attention.