

Experiences of sending a reference signal through DWDM multiplexer and 550 km fibre system

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All measurements were done at Chalmers Technical University Photonics Laboratory.

Abstract

The total of nine channels, one the reference signal (in CW mode) and eight channels with a data stream of 2,4 Gbit/s, were multiplexed into one fibre and amplified before sending through a length of 550 km fibre system. The optical wavelengths were monitored over several days. The overall uncertainty reached for monitoring of the reference signal was $\pm 0,02$ nm step size 0,015 nm. No influence of either the multiplexer and/or the fibre system could be noted within the measurement uncertainty.

Introduction

The aim of this report is to verify that a reference signal could be sent in an active DWDM system and over long fibre lengths with several amplifications without change in wavelength. Aims of the original project were to, verify methods for wavelength calibration for DWDM systems and also to verify the function of an “Optical Layer Monitor” developed by a SME.

DWDM involves the combination of a set of traffic-bearing optical signals onto a single fibre pair. These signals must not interact with each other during transmission and they must be capable of being separated for reception at the far end. This is achieved by accommodating each optical signal on a separate wavelength. They must be carefully defined and maintained in order to pass through the DWDM system. The data stream is sending optically into the system, one for each channel, and converted to well defined internationally defined wavelengths in transponder units. The transponder is a detector-to-wavelength source-transforming unit. The transponder unit is fed by a slave source with arbitrary wavelength. Two methods of wavelength referencing have been implemented. One for the reference signal and one for referencing the monitoring instrument. In the result reported here the reference signal was referenced by HCN gas referencing over the total spectral range for the DWDM system although it can be viewed as a reference by itself.

Methods

An absorption line at 1550,866 nm in acetylene $H_2^{13}C$, was stabilised with a tuneable laser in a feedback loop with a detector guaranteeing the laser to be at referenced wavelength. The reference signal was launched into the ERION multiplexer, channel 6, with ITU central value 1550,92 nm. Deviation between reference and MUX centre was 0,05 nm (5-6 GHz). In selecting the fitting reference wavelength, here at 1550,866 nm, this had to be considered. The reference signal, and eight ITU channels, was recorded at two locations. After multiplexer and one EDFA amplification was first monitoring, Port 1. After the fibre system the signal was recorded again, Port 2. A switch altered the signal from before and to after the fibre system for the reference instrument. The same referenced Ando OSA (Optical Spectrum Analyser) was used in both at all measurements. In Figure 1, two Optical Layer Monitor instruments named WISTOM can be viewed.

DWDM system and fibre system Set-up

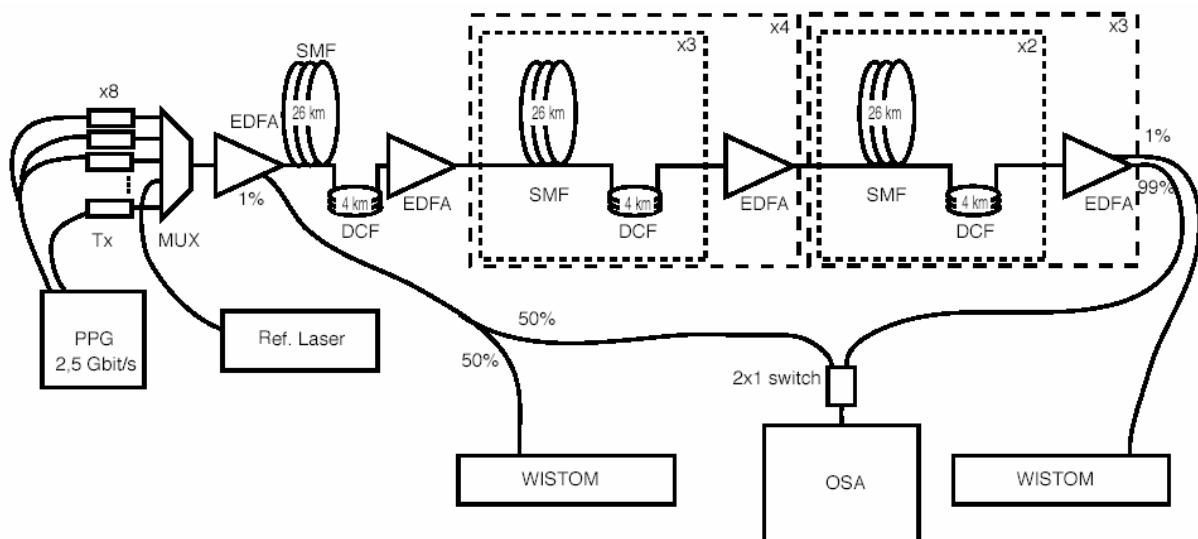


Figure 1: Measurement set-up for verification of reference signal and supervision of DWDM system including 550 km of fibres. One amplification before fibre system and seven within the fibre system.

Wavelength calibration of the referencing OSA was done several times every day during the tests using a broadband source method and $H^{13}CN$ absorption lines between 1545 nm and 1560 nm.

The fibre transmission system, developed at CTH Photonics Laboratory, consisted of 19 units of 25 km length of standard single mode fibre plus 4 km length of dispersion compensating fibre, DCP. Total fibre length was approximately 550 km. The signals were EDFA-amplified seven times in the fibre system.

A DWDM system named ERION, installed at CTH, is an optical transmission system with 16 channels working from 1546,92 nm to 1558,98 nm with a spacing of 100 GHz (approx 0,8 nm). ERION was used with 2,4 Gb/s at the measurements.

The total of eight channels with a data stream of 2,4 Gb/s and one reference signal in CW mode, were multiplexed into one fibre and amplified before sending through a length of 550 km fibre system.

Results

Eight channels plus reference channel measured with an OSA before and after fibre system. Reference channel 1550,866 nm was launched into the ERION multiplexer with ITU central value 1550,92 nm, a deviation of 0,05 nm.

The measurements in this report verify that the reference signal is the same in both transmitter-end and receiver end with no influence of either other channels, multiplexer and/or 550 km length of fibre including eight amplifications.

All results from referencing the eight channels were found within tolerance for the ERION multiplexer i.e. ± 20 GHz = $\pm 0,16$ nm.

Wavelength calibration uncertainty for channel referencing was estimated to be 0,025 nm with $k=2$ i.e. 95 % confidence.

An OSNR out from ERION launched into 550 km fibre system was estimated to approximately 35 dB. An OSNR after fibre system and seven Erbium Doped Fibre Amplifiers, EDFAs, was estimated to approximately 5 dB in this example. The small maximum wavelength deviations observed between before and after fibre system in all the measurements (0,015 nm) falls within measurement uncertainty (0,025 nm). Also the reference channel deviation measured before and after system was 0,01 nm at largest which also falls within measurement uncertainty of the reference channel (0,01 nm). I.e. no wavelength deviation could be noted caused by the long fibres and several amplifications. The OSA was calibrated in power and power linearity from -5 dBm to -65 dBm at 5 nm intervals from 1545 nm to 1560 nm. The correction was 0,84 dB ($\sigma = \pm 0,11$ dB) over the whole interval. Studying the height of the peaks we can note the equal height but also see some shape from the amplifiers in the noise floor and OSNR changes spectrally in the measurements after fibres and amplifications.

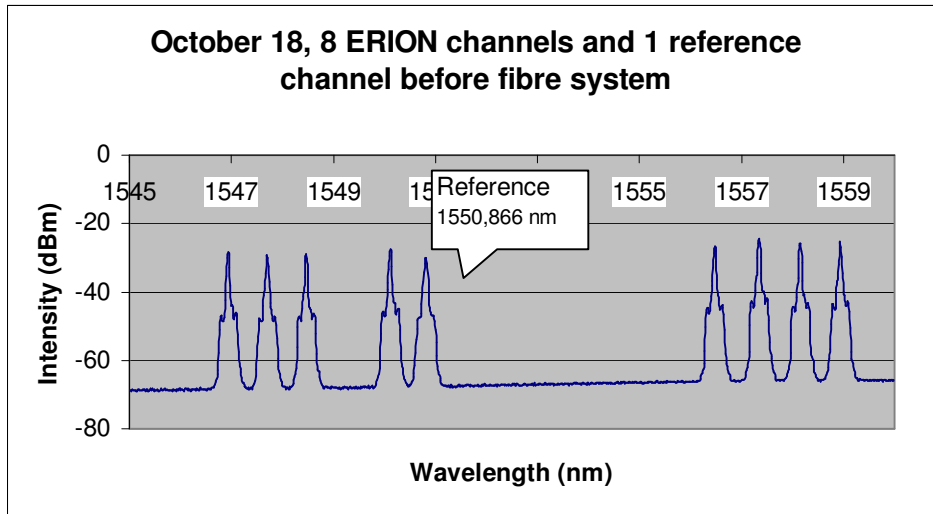


Diagram 1: Eight ERION DWDM channels and one reference channel (H2C2-1550,866 nm) measured before fibre system. The presented data is not corrected in wavelength.

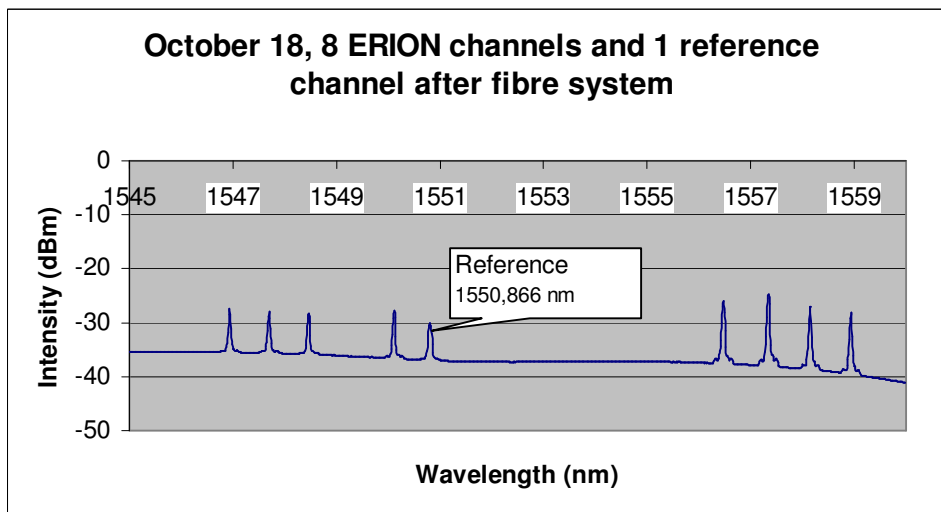


Diagram 2: Eight ERION DWDM channels and one reference channel (H2C2-1550,866 nm) measured after fibre system. The presented data is not corrected.

The registration was for all channels were done over 120 hours. First 48 hours the method for the reference channel was not stabilised. Last 70 hours the reference channel was stable within 0,01 nm. No influence from either MUX or fibre system could be noted. This is probably due to the step in the OSA measurement.

Diagram 3 shows results from Port1, before fibre system, monitored over 120 hours.

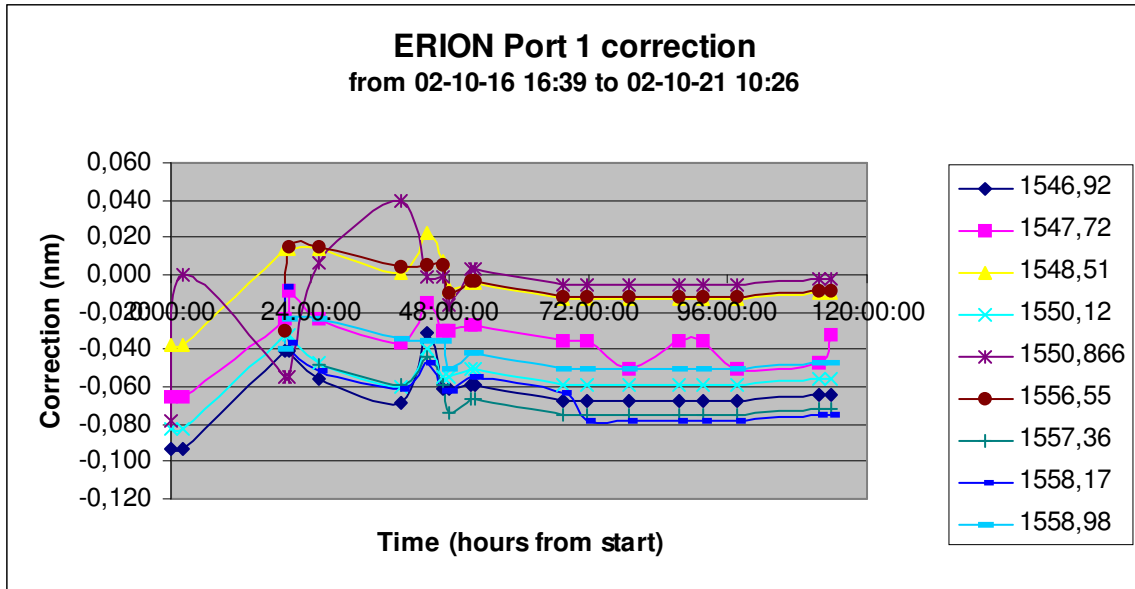


Diagram 3 shows results from Port1, before fibre system, monitored over 120 hours.

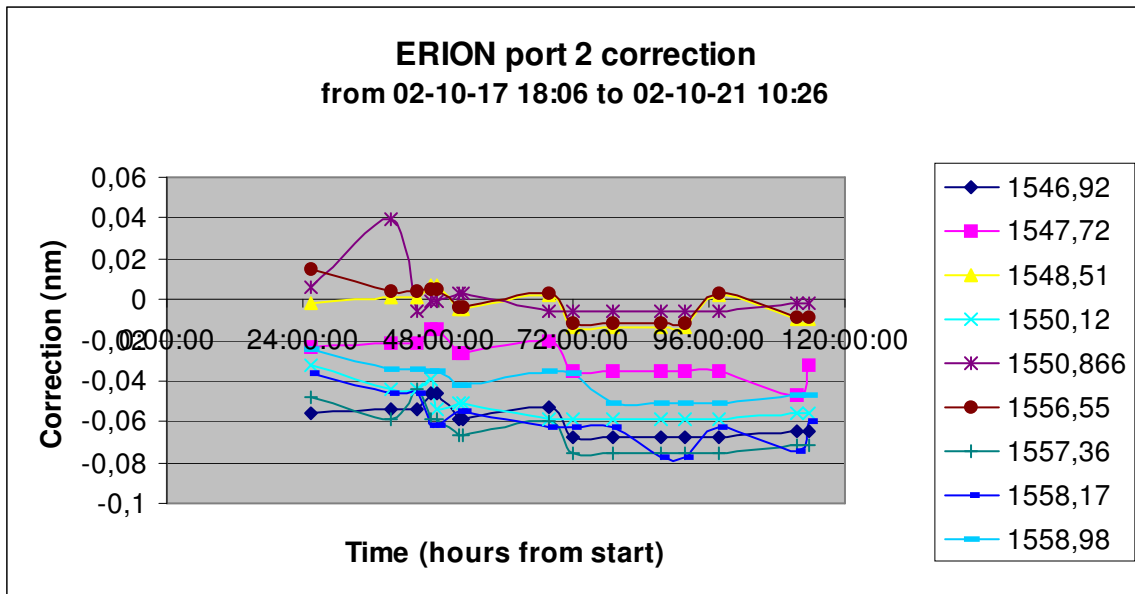


Diagram 4: The diagram shows results from Port2, after fibre system, monitored over 120 hours. Still the reference channel is within 0,01nm after first days.

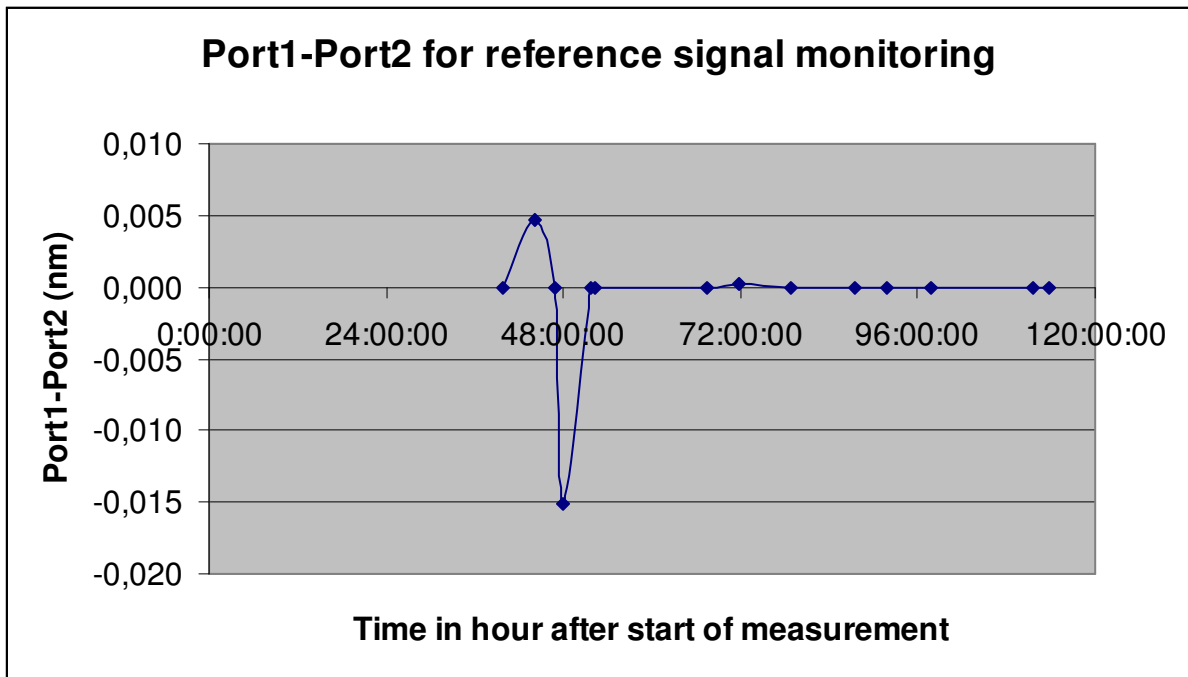


Diagram 5: Port1-Port2; deviation in reference channel monitoring between before and after fibre system.

Table 1: Uncertainty budget for reference channel H₂¹³C₂ at 1550,866 nm

Uncertainty budget for measurements on reference channel	Factor	s	(s) ²	
on Ando AQ-6315B SP502749				
Uncertainty of H2C2 line 1550,866 nm	0,001	1	0,001	0,00000
Absorption max stability in feed-back	0,002	0,289	0,001	0,00000
Step length of OSA meas.	0,015	0,289	0,004	0,00002
Switch influence	0,010	0,289	0,003	0,00001
			k=1	k=2
All values in nm	uncert		0,005	0,011

Conclusion

Two methods of wavelength referencing have been implemented. One for the reference signal and one for referencing the monitoring instrument. In the result reported here the reference signal was referenced by HCN gas referencing over the total spectral range for the DWDM system although it can be viewed as a reference by itself.

The total of nine channels, one the reference signal (in CW mode) and eight channels with a data stream of 2,4 Gbit/s, were multiplexed into one fibre and amplified before sending through a length of 550 km fibre system. The optical wavelengths were monitored over several days. The overall uncertainty reached for monitoring of the reference signal was ± 0,02 nm step size 0,015 nm. No influence of either the multiplexer and/or the fibre system could be noted within the measurement uncertainty.

Discussion

The measurement uncertainties would have been improved using a wavelength meter instead of the reference, monochromator based, OSA. The switch somewhat altered the spectral properties and made the signals broader which also increased measurement uncertainty.