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Measuring In-Band OSNR on Polarization-Multiplexed Signals

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In-Band OSNR Measurement

- **In-Band OSNR measurement**
  - Measure the optical noise within the spectrum of a transmitted optical signal = **in-band noise**
  - Use the polarization nulling technique to suppress the signal and get access to the noise
- **Assumptions**
  - Optical ASE noise from optical amplifiers is **un-polarized** light
  - Laser-based optical transmitters emit **highly polarized** light
    - Conventional 10-Gb/s transmitters generate single polarized signals
    - Signals remain highly polarized during transmission
  - Signal and noise may be distinguished by simple polarization analysis
- **Polarization nulling method**
  - The polarized optical signal is suppressed by an **adjustable pol-filter**
  - Unpolarized ASE noise is not suppressed by polarization filter
  - Spectrum of ASE noise can be measured by polarization filter and OSA
  - In-band OSNR can be determined from the total signal power and the in-band noise spectral density

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Principle of In-Band OSNR Measurement

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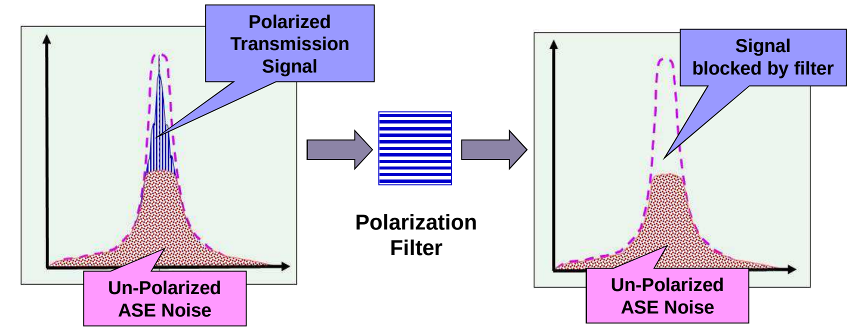
Background: - **ASE noise** from the EDFAs is **un-polarized light**.
- **Transmitted signal** is **highly polarized light**.



Polarization nulling method:
A polarization filter is used to suppress the polarized optical transmission signal allowing measurement of the un-polarized ASE noise.
➔ This is called in-band noise / in-band OSNR measurement

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JDSU's Polarization-Nulling Technique

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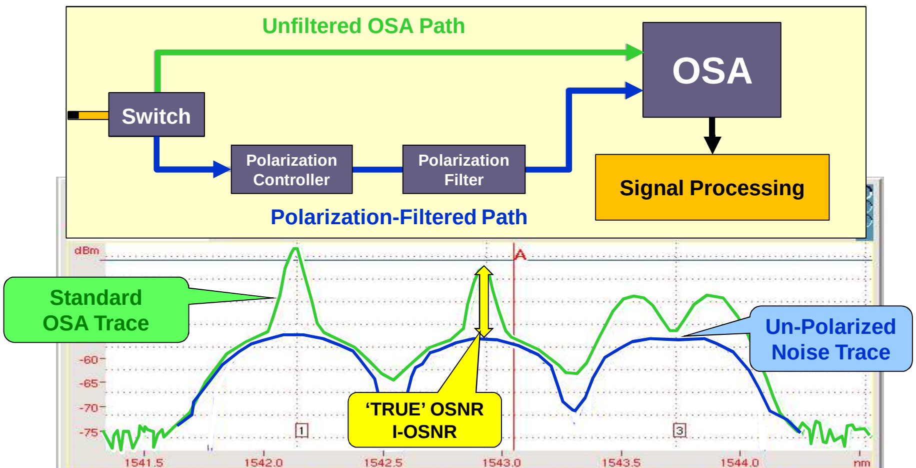

Detect.: Permanent Splitter: No Nb: 003/003 Pcomp: -33.51 dBm/ 445.9 nW

Channel	Wavelen.(nm)	Spacing(nm)	Level(dBm)	Noise(dBm)	I-OSNR(dB)	P/Pcomp(%)
001	1542.137	-----	-36.62	-52.92	16.30	48.77
002	1542.930	0.792	-40.34	-53.75	13.40	20.66
003	1543.725	0.795	-40.15	-54.16	14.01	21.62

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Principle of Polarization Multiplexing

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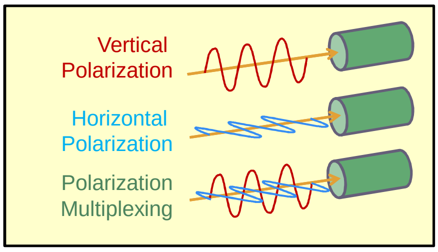
- **Polarization Multiplexing**



  – Transmitter emits 2 data streams at the same wavelength but in orthogonal polarization states
  – Polarization multiplexing or polarization-division multiplexing (**PDM**) doubles the spectral efficiency of signal transmission by combining **two orthogonally polarized signals** of the same bit rate into the same wavelength channel.
  – **PDM** is widely used for long-haul 100 Gb/s DWDM transmission (usually in combination with coherent detection).

Polarization Nulling of PDM Signals

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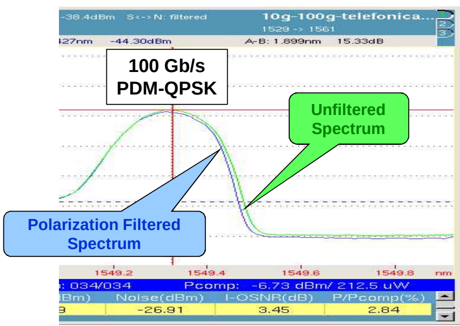
- Transmitter emits 2 data streams at the same wavelength but in orthogonal polarization states
  – Polarization multiplexed signals are **not highly polarized**
  – They appear to be un-polarized when measured with a polarization analyzer
- Polarization filter cannot suppress polarization multiplexed signals
- **Un-polarized ASE noise cannot be separated from signal**

Polarization nulling technique does not work with polarization-multiplexed (PDM) signals



Single-Polarization vs. Polarization-Multiplexed Signals

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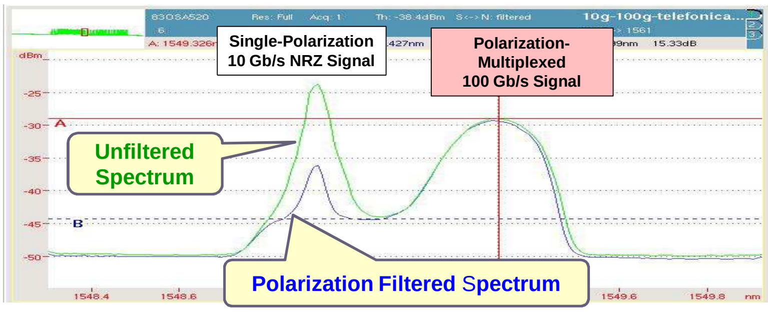

- **Polarization nulling works with single-polarization signals**
  - In-band noise can be extracted from conventional 10 Gb/s NRZ-OOK signal
- **Polarization nulling does not work on polarization-multiplexed signals**
  - In-band noise **cannot** be extracted from 100 Gb/s PM QPSK signal
- **Power, wavelength, and out-of-band OSNR measurements can be performed on polarization-multiplexed signals with conventional OSAs**
  - **JDSU OSA-110M/180/500/500R**

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Testing 40/100G with an OSA (line side)

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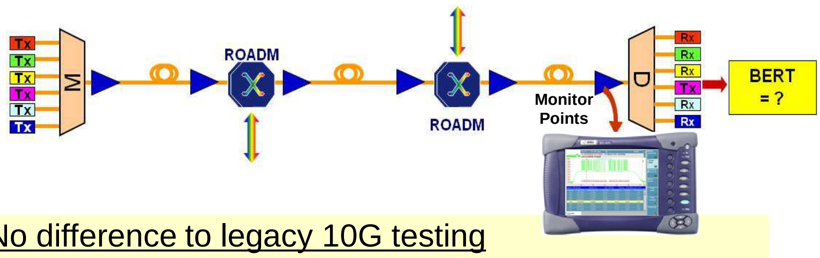

No difference to legacy 10G testing

- Final acceptance tests during I&M and trouble shooting
- Use system monitor points (Mon) at amplifiers
- Measure power, wavelength and OSNR of each DWDM-channel

Challenges for spectral testing

- New modulation formats create different optical spectra and require new analysis for accurate measurements
- Need for in-band OSNR testing in ROADM networks

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Questions and Answers

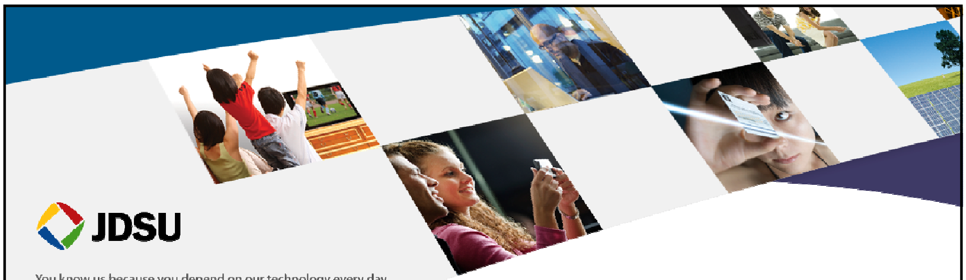
- **What are the basic OSA measurements in WDM systems ?**
  - Measure ch-power, ch-wavelength and OSNR (=> OSA-110M, OSA-180/OSA-500)
- **What are the measurement challenges in ROADM networks ?**
  - Standard out-of-band measurements provide wrong OSNR results due to filtered noise distribution induced from ROADM network elements
  - Requires in-band OSNR measurement (use of pol-nulling technique => OSA-500R)
- **What are the measurement challenges in 40G networks ?**
  - Using 40G data transmission at 50GHz channel spacing will create overlapping spectra. Standard out-of-band OSA measurements provide wrong OSNR results.
  - Requires in-band OSNR measurement (use of pol-nulling technique => OSA-500R)
- **What are the measurement challenges in 100G networks ?**
  - 100G networks are using coherent transmission techniques with **polarization multiplexed** (PDM) modulation formats
  - **PDM** signals cannot be analyzed using polarization nulling techniques.
  - It is not possible to perform **in-service in-band** OSNR measurements !
  - **In-band** OSNR measurements can be performed **out-of-service** in a 2 step method:
    1. Perform WDM measurement with all channels activated
    2. Perform WDM channels with 100G PDM channels switched-off
    3. Measure the noise power inside switched-off channels and calculate in-band OSNR
- **What about standard OSA measurements in 100G networks ?**
  - All standard measurements like ch-power, ch-wavelength and **out-of-band** OSNR can be measured with a standard OSA (=> OSA-110M, OSA-180/OSA-500)

Conclusion

- High Speed Networking (e.g. 43G) is based on new modulation formats creating different spectra than legacy 10G signals
- OSA requires advanced analysis SW to accurately measure the optical channel power, channel wavelength and number of channels.
- Conventional spectrum analyzers do NOT provide accurate results
- All JDSU OSAs (**OSA-110M/180/500/500R**) have advanced analysis-SW to measure systems at 40G, 100G and above

- **ROADM** network topology and the use of high data rates at tig channel spacing (40G@50GHz ch-spg) require new methods to measure the 'TRUE' in-band OSNR.
- **JDSU OSA-500R** provides in-band noise measurement capability to measure the 'TRUE' OSNR in high speed networks with ROADMs or with 40/43G@50GHz ch-spcg

- In-band OSNR measurements in 100G networks using polarization multiplexing can only be performed by measuring the noise power when the 100G channel is switched-off



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JDSU's On/Off-OSNR Method

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Challenge:

- As it is not possible to use the polarization nulling technique to measure the in-band OSNR in polarization-division multiplexed (PDM) systems,
  JDSU is using the On/Off-OSNR method

Principle of „On/Off-OSNR Measurement“:

- The On/Off-OSNR method is based on measuring the noise power when the transmission channel is switched-off. This is a 2 step method:
  1. Switch-on all channels and perform a standard WDM measurement
     - Take a note of all channel power levels P_{on}
  2. Switch-off the channel carrying PDM signals and perform a second measurement
     - The channel power measured at the deactivated channel wavelength will indicate the in-band noise P_{off} = noise power
     - In-band OSNR: I-OSNR = $P_{on} – P_{off}$ (in dB)

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Prepare OSA for First Measurement

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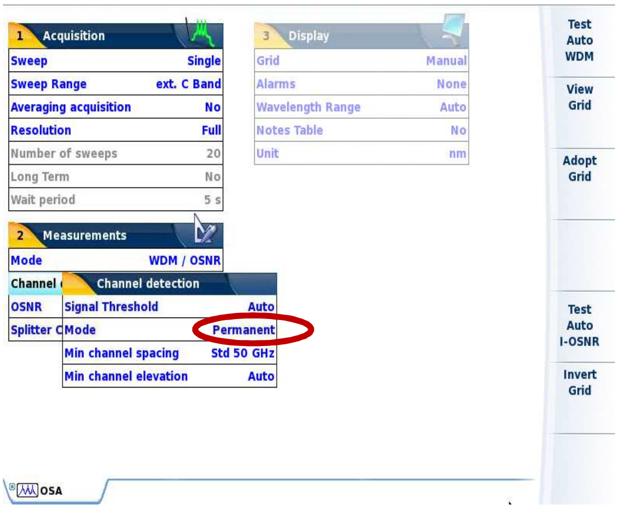
Setup: sweep range: ext. C-band
resolution full
channel detection mode permanent



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Perform First Measurement

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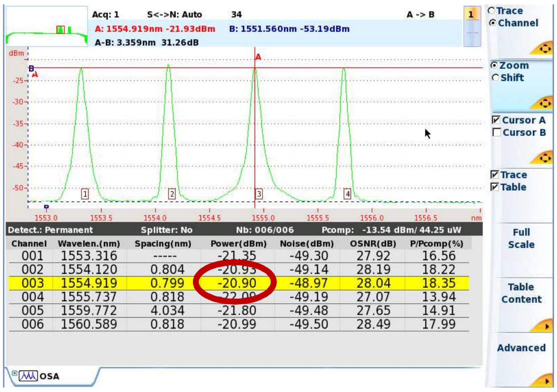
Result: WDM table shows all relevant measurement results
NOTE: Channel power is shown in the table as the total channel power
= integrated channel power

Example for CH3 (switched on)

P_{3on}: **-20.90 dBm**

But:
OSNR = 28.04 dB



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Prepare OSA for Second Measurement

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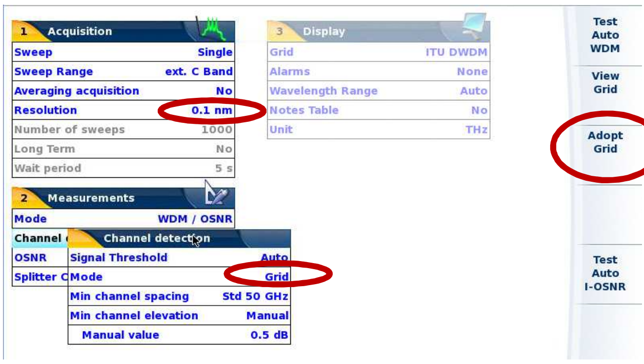
Pre-setup:

- Press “Adopt Grid” presets channel grid to identified channels from test 1
- Set channel detection mode to “Grid” will force the instrument to measure at same channels like test 1
- Set resolution to “0.1nm” = noise measurement bandwidth for OSNR calculation
  Note: OSNR is defined as: [total channel power] / [noise power in 0.1nm bandwidth]



Preset multi trace

Goto “Result” screen

- Selecet “Advanced” => “Overlay” “Set New Trace” a new empty trace will be generated

Start Second Measurement

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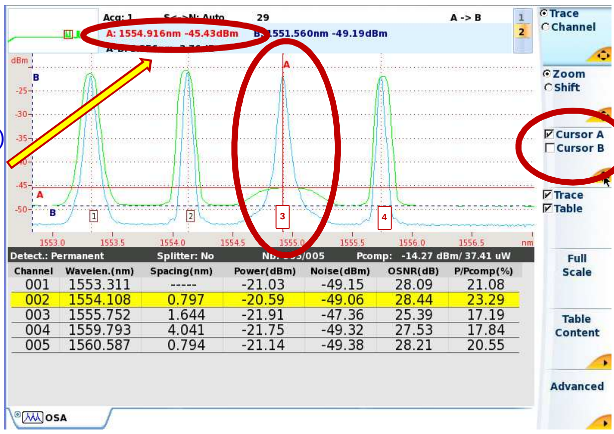
- Switch-off the channel to be measured in in-band OSNR mode (= PDM channel)
- Start measurement: a second trace will be displayed
- Place cursor A to the center of the channel which is switched-off
- On top of the screen the power level at marker A will be shown
  This power level = noise power measured with 0.1nm res bandwidth = noise

- Example: CH3 (switched off)
  P_{3off} = Noise = -45.43 dBm



Calculate In-band OSNR

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1. Take power from measurement 1 = P_{3on}
2. Subtract power P_{3off} from measurement 2

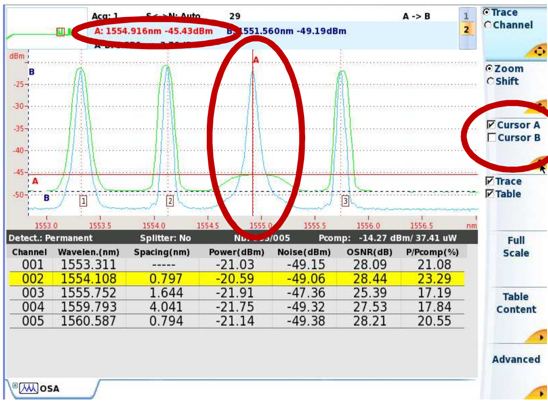
   In-band OSNR = $P_{3on} - P_{3off}$

Example:

I-OSNR = $P_{3on} - P_{3off}$

= -20.90 – (-45.43) dB

= 24.53 dB



Verification with I-OSNR Measurement

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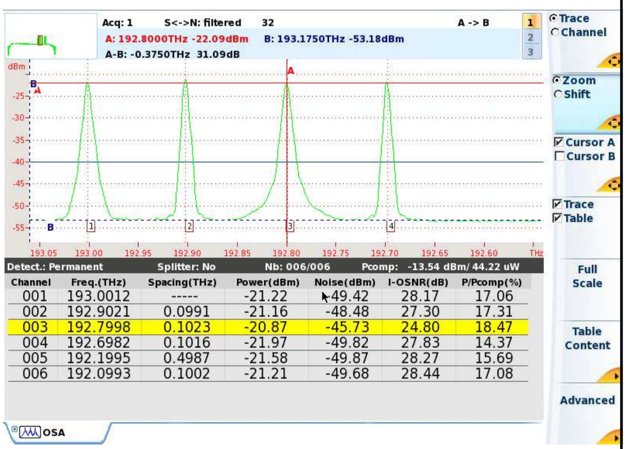
For transmission signals **NOT being modulated with polarization division multiplexing** a verification of the measurement using the OSA-500R in the I-OSNR mode can be used

Example:

Ch3 analyzed with OSA-500R

I-OSNR = 24.80 dB



Conclusion

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- Using the On/Off-OSNR method it is possible to measure the in-band OSNR of all kind of signals including 100G with polarization-division multiplexing (PDM)
- The On/Off-OSNR method is applicable with all kind of JDSU OSAs: OSA-110M/180/500/500R
(It is NOT necessary to use the in-band OSA 500R)

- The On/Off-OSNR method requires an intervention into the system as the PDM channel needs to be deactivated
- JDSU is working on an automation to support easy instrument setup and auto calculation of in-band OSNR at 100G systems using polarization-division multiplexing

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