APPLICATION NOTE

CWDM and LWDM Components

Wavelength and Polarization Test

O-Band WDM

Increased demand for fiberoptic transmission bandwidth over distances that do not require optical amplification repeaters, such as within and among data centers or within about 10 km, are driving the use of wavelength domain multiplexing (WDM) over the full wavelength range of single-mode fiber and especially in the range 1260 – 1360 nm, known as O-band.

CWDM

One convention, coarse wavelength domain multiplexing (CWDM), was developed to support many wavelength channels over unamplified links, by spreading the channels over the full usable range of SSMF with wide passbands so that the wavelengths of the transmitters do not need to be set and stabilized to a narrow tolerance. CWDM uses a grid based on 20 nm spacing, using channels centered between 1271 nm and 1611 nm. Not every link uses the full wavelength range. For example, CWDM4 transceivers use 4 channels at 1271, 1291, 1311 and 1331 nm. The transceivers include wavelength filter components to multiplex the outgoing channels onto one fiber and to demultiplex the incoming signals to separate photodetectors.

LAN-WDM

With the need for 100 Gb/s links in data communication, the IEEE 802.3 Ethernet Working Group included implementations for reach up to 10 km (100GBASE-LR4) or, with tighter tolerances, 30 km (100GBASE-ER4) by using four wavelength channels in single mode fiber. The wavelengths are assigned to a frequency-based grid, like the dense WDM (DWDM) grid used for telecommunications, but with a wider spacing of 800 GHz, which is roughly 4.5 nm. This is wider and more tolerant than the 50 GHz or 100 GHz grid usually used for DWDM, but narrower than CWDM, and is also called LAN-WDM. Spacing the wavelengths closer reduces skew between the wavelength channels that results from chromatic dispersion. With this spacing, it is also conceivable to use more than 4 wavelengths in the future. The channels, or lanes, are centered at: 231.4 THz (1295.56 nm), 230.6 THz (1300.05 nm), 229.8 THz (1304.58 nm), 229.0 THz (1309.14 nm). Advance to 400GBASE uses 8 wavelengths, adding channels at 232.2 THz, 240.0 THz, 240.8 THz, and 241.6 THz, down to about 1273 nm, for LR8 or FR8.

N7700 Photonic Application Suite

The PAS provides application software for integrated test and measurement solutions. The PAS Lambda Scan engine uses tunable laser sources and other instruments to measure wavelength and polarization dependence of optical components with both GUI and API control.

KEYSIGHT TECHNOLOGIES

Spectral Measurements for Passive Components

The spectral response of components used in WDM links is a key factor in determining link performance at the physical level. The insertion loss (IL) of passive components influence the signal power budget. The wavelength selectivity of filters used for multiplexing and especially demultiplexing, characterized from traces of IL vs. wavelength with parameters like ripple or flatness in the passband and isolation of wavelength outside the passband, is important for signal stability and avoiding crosstalk. Reflections, parametrized as return loss (RL), can also degrade link performance and should be controlled. Low dependence of these response parameters on the polarization of the optical signal is also needed to avoid fluctuations in power, because the polarization state can change randomly along fiber links. So passive WDM components are typically tested and verified by measuring IL, PDL and often RL across the applicable wavelength range. Using a tunable laser source at the common side of an LR4 multiplexer, for example, allows all four lane ports to be measured simultaneously with synchronized power meters. A block diagram for such measurements is shown in Figure 1, implemented using the N7700 Lambda Scan (LS) application software package. For adding RL measurements, a return loss unit like the 81610A can also be included between the N7786C and the DUT. Details for the instrumentation are given farther below. Further details for the LS software are available at www.keysight.com/find/n7700.

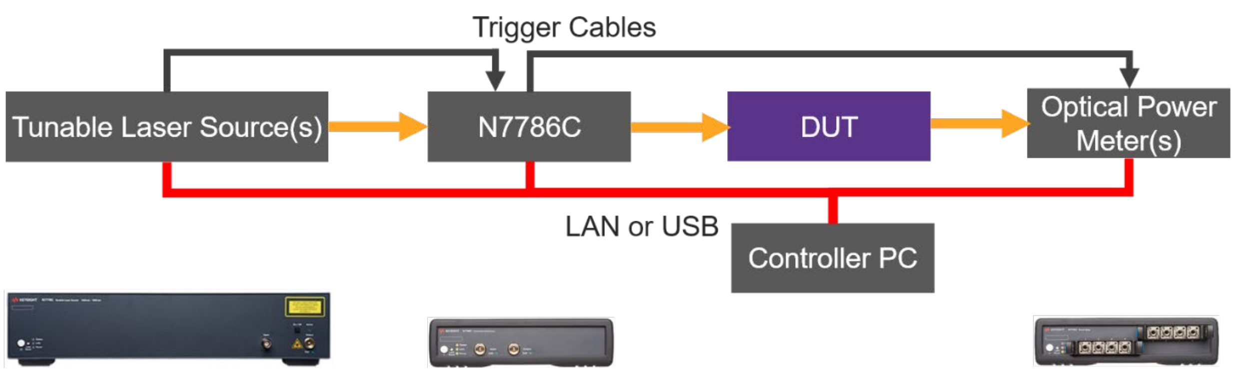

Figure 1. Schematic setup for measuring wavelength and polarization dependence of an optical multiplexer device, IL and PDL.

As shown in Figure 2, the measurement results show the insertion loss spectrum for each output port, averaged over all states of polarization, here with 80 dB dynamic range. That would be the IL for unpolarized input signal. Spectra of the polarization dependent loss are shown in the middle graph. This dependence can also be shown as 2 IL spectra for each port, corresponding to the IL for the principal polarization axes of the DUT, as in the lower graph. For planar devices like wafer chips, this usually corresponds to polarization parallel or perpendicular to the chip surface (TE or TM). Or for optical filters used at non-normal incidence angle, these can be s-polarization and p-polarization.

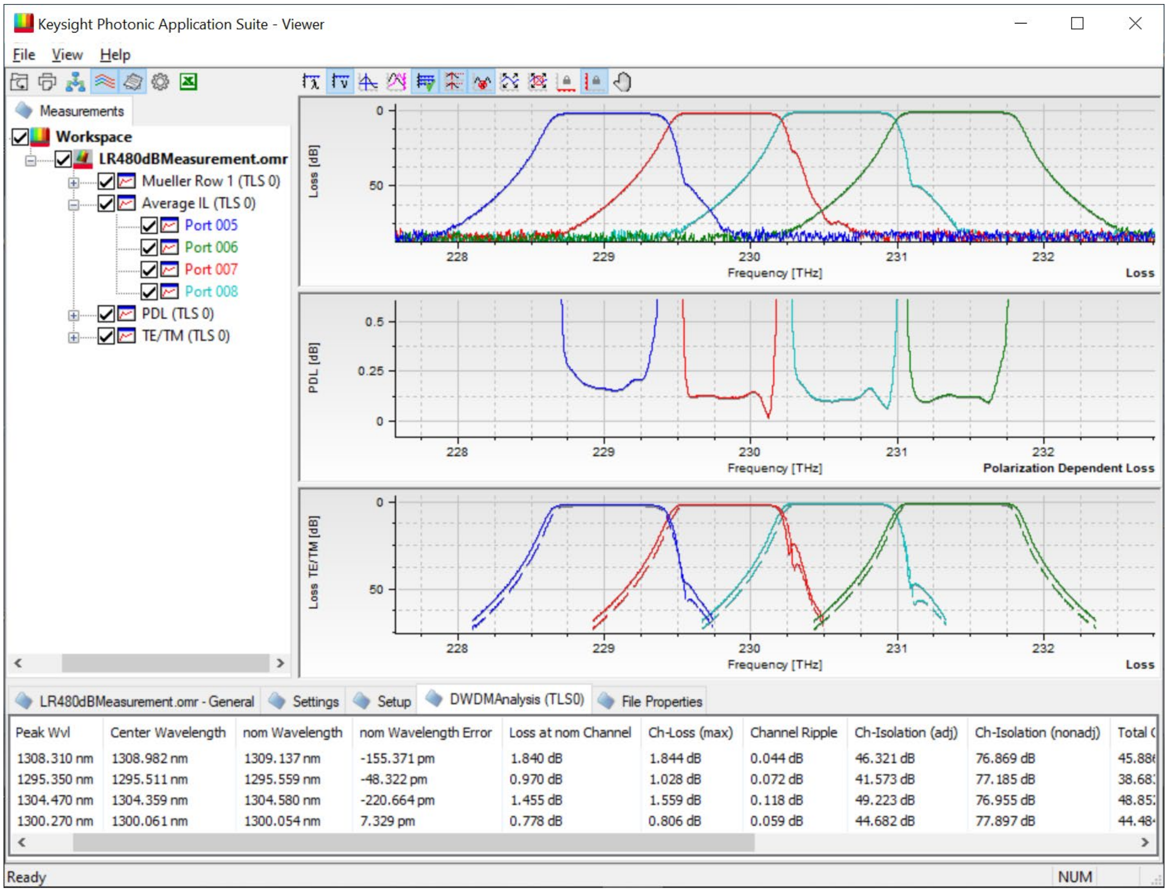

Figure 2. Measurement result for a 4-port multiplexer, including data analysis

The N7700 software also provides for calculation of key analysis parameters for the LAN-WDM passbands, like wavelength offset, bandwidth, isolation, ripple and maximum in-channel IL and PDL.

Spectral measurements for Light-detecting Components

Another class of components requiring similar measurements is increasingly important. The optical detectors used in receivers are also characterized for relevant wavelength and polarization dependence, but the response usually doesn’t have strong variation. However, when the detectors are integrated with filters or other passive components, this assembly needs to be characterized in a similar way as for the individual components. An important example is the LR4 receiver optical subassembly (ROSA), which can include the demultiplexer optics, photodiodes for detecting each signal lane, and often some electronics for transimpedance amplification for the RF signal carried on the detected photocurrent. Such a structure is shown schematically in Figure 3.

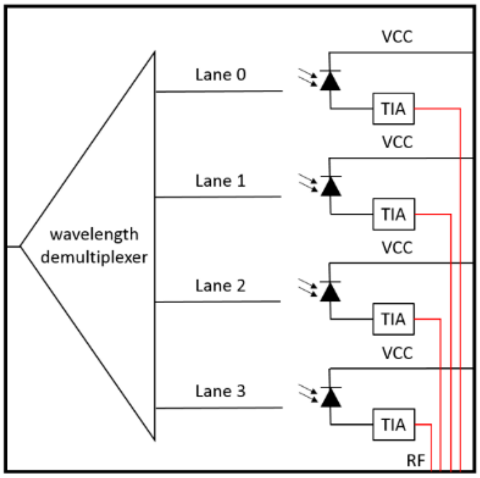

Figure 3. Schematic diagram of a 4-lane ROSA device

The electrical contacts on the ROSA that are used for providing bias voltage to the photodiode detectors can also be used to access the photocurrent while an input optical signal is varied in wavelength and polarization to measure responsivity and related parameters. Such a solution is shown in Figure 4.

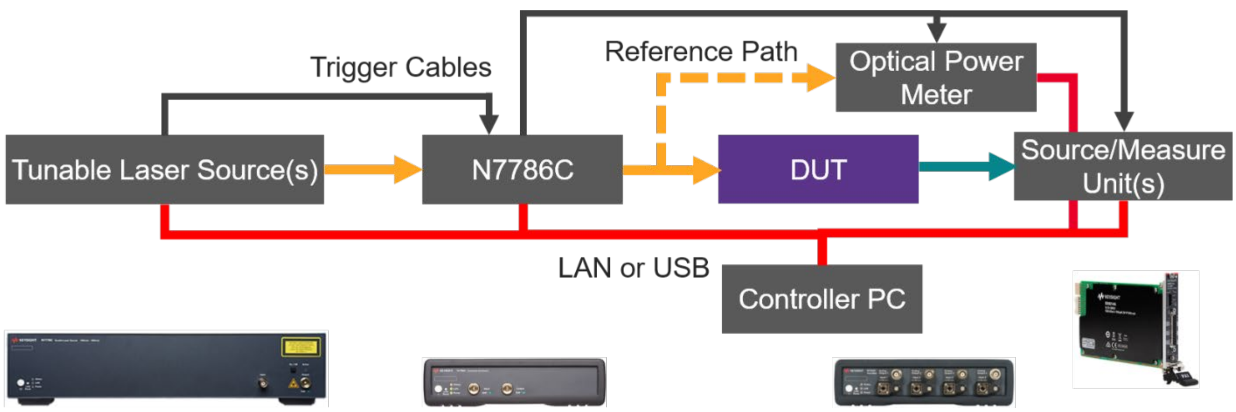

Figure 4. Block diagram for measurements of wavelength and polarization dependent responsivity from an O/E device

This measurement uses source/measure units to apply bias voltage and measure the photocurrent from the integrated detectors of the DUT. The results are then interpreted as responsivity in units of mA current per mW optical input power. The absolute input optical power is measured with an optical power meter and then applied to the DUT. Again, both the polarization-averaged response as well as the minimum and maximum responsivity vs. polarization are determined by the software. An example is shown in Figure 5. In such a measurement it is also important to include the wavelength dependent responsivity of the optical power meter in the results calculation. Here the upper graph shows the responsivity in linear units for the two principal polarization states, while the lower graph uses a logarithmic scale to better show the channel isolation.

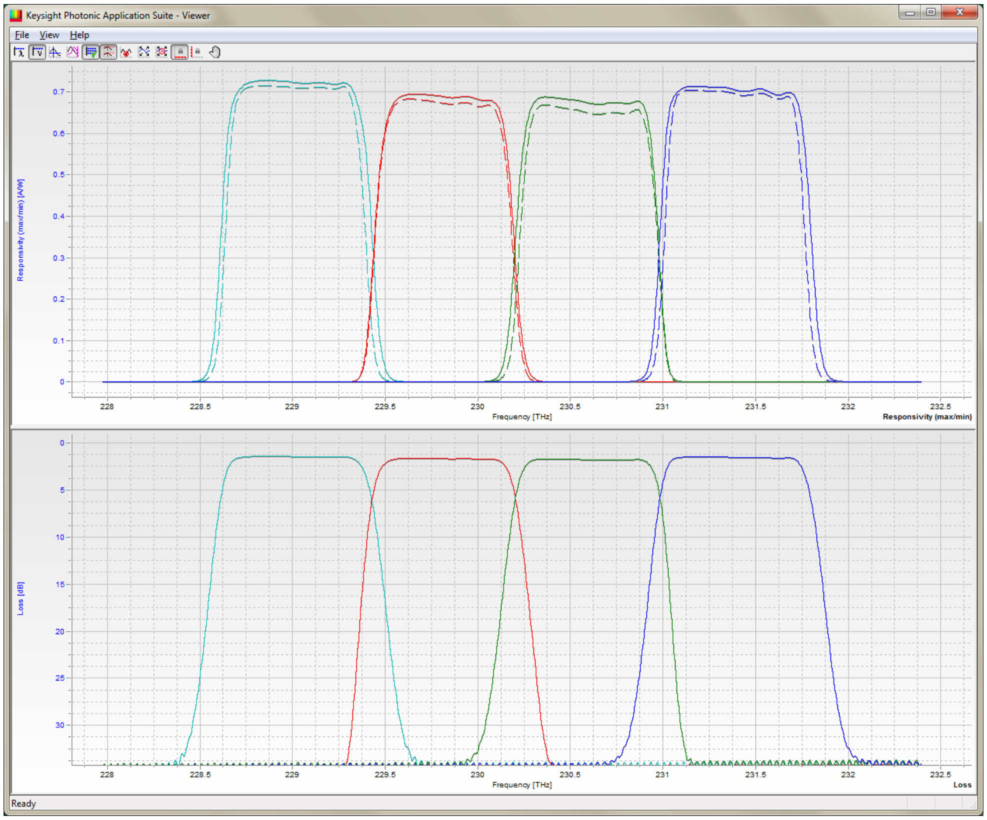

Figure 5. Sample measurement of an LR4-ROSA device

Test Solution Configuration

The core of these measurement setups is the tunable laser source that provides wavelength sweeps at a constant speed. The Keysight N7776C (or 81606A as module) or N7778C (81608A as module), with different accuracy specifications, have option 113 to cover the O-band with 1240 – 1380 nm, as well as options 114 and 216 for complete coverage to 1650 nm. These have a combination of important features including sweep rates up to 200 nm/s with excellent power flatness and specified wavelength accuracy and repeatability using the built-in real-time wavelength monitor, and very low background spontaneous emission to measure filters with high dynamic range. The high output signal power level supports use in setups that split the power for measuring return loss or multiple devices and for testing responsivity and crosstalk of O/E components with relevant input power. Two or three tunable lasers can be combined with a switch to extend the wavelength range. The LS software automatically switches the lasers and combines the measurement results.

The N7786C is a fast-switching polarization controller that can synthesize a chosen sequence of polarization states and then repeatedly run through this sequence while logging the output state of polarization (SOP) and power level using the built-in polarimeter and providing synchronization triggers for the detectors of the setup. For measuring polarization dependence vs. wavelength, a sequence of 6 SOP is repeated for each measurement point while the laser continuously sweeps across the chosen wavelength range. This single-sweep method samples all 6 SOP in as little as 300 microseconds, providing PDL results with low sensitivity to fiber vibration and temperature drift.

The resulting data are then interpolated to the chosen wavelength grid and analyzed in a generalized implementation of the Mueller Matrix method to determine the maximum and minimum response in dependence on polarization. Higher level analysis, such as resolving the response spectra for the principal axes of the device (TE vs. TM) or calculating the shift of a filter's center wavelength due to polarization, is also available from the matrix data. The LS software also supports setting the controller to the SOP that provides the maximum or minimum signal, or TE or TM, for alignment and optimization steps or for running a wavelength scan at this fixed SOP.

For measuring passive optical devices that output optical signals, the N7744C 4-port or N4475C 8-port optical power meter instruments are used as detectors for the solution. These combine wide dynamic range with high bandwidth to allow fast sampling in synchronization with the polarization states. Multiple units can be used in the same setup to simultaneously measure devices with many output ports, like splitters and switches or for measuring several components with the same wavelength scan. The unique clip-on quad-adapters speed up optical connections, even to unconnectorized bare fibers, and connections can be made to one set of adapters while another component is still being measured, to increase throughput. Other power meter models, like the N7742C with analog output signal for probe alignment or remote optical heads with large area detectors are also supported by the LS engine.

Similar for measuring detectors or devices including integrated optical detectors, the setup can use instruments to sample the output photocurrent from the device, while applying bias voltage. Two families of source/measure units are supported. The B2900-series provide one or two ports in a convenient stand-alone unit. In the new PXI format, the M9601A supports faster sampling rates, especially for signals weaker than 100 µA, while the 5-channel M9614A or M9615A allow high channel density in the setup for parallel measurement of many devices or devices with many ports.

These setups are controlled using the N7700 LS software engine. More details on the software and the configuration are available in the technical overview document at www.keysight.com/find/n7700. Other alternatives, like a simpler measurement without polarization dependence can be made at high repetition rates that can support alignment and calibration procedures, taking advantage of the fast bi-directional sweeping functionality of the tunable lasers using the same software engine.

Get Started Fast

The LS software gets a new test station up and running quickly, with accurate and repeatable results. The graphical user interface makes it intuitive to configure and make measurements manually while the engine also provides for rapid automation with its COM API. Automation is even simpler using the PAS TAP plugin (available from the PAS Package Manager) for Pathwave Test Automation.

www.keysight.com/find/n7700
www.keysight.com/find/tap

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