VIAVI Solutions

Whitepaper

Evaluating and Validating 800Gb Optics with the VIAVI ONT and MAP

Photons to firmware coverage is critical to 800Gb optics development, evaluation and validation.

Introduction

800Gb pluggable optics are now available and have a broad range of applications and reaches – from short reach intra-rack, through single mode fabric, to 120 km+ with ZR.

A combination of broad application space, coupled with 112G electrical SERDES speeds, advanced CMIS module management, and demanding cooling and power requirements make evaluation and validation of 800Gb pluggables a critical step in any product or service deployment. In a multi-vendor ecosystem, interoperability – not just on the optical interface but on the module-to-host – adds to the challenge.

VIAVI has enabled and accelerated pluggable optics development, validation, debugging and evaluation since the first days of 100G, and our experience and unique applications have continuously grown ready for the challenges of 800G today, and for 1.6Tb tomorrow!

800G Interfaces

800Gb modules have a wide application space, from high-speed AI/ML through to high-performance fabric, and on to longer span coherent.

Although related to 800Gb Ethernet, many applications also involve 2 x 400Gb in one plug to deliver high density. The host interface is based on 8-lanes of 112G electrical SERDES pairs. These lanes can be configured to support a wide range of services through CMIS management. This can range from 8 x 100G breakout through to one 800Gb Ethernet service. In the future, expect to see FlexO (advanced OTN services) on the host interface.

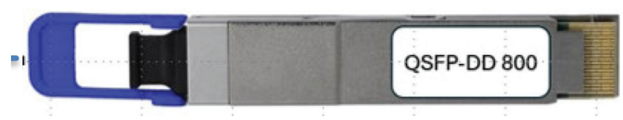
The reality is that 800Gb can mean a lot of things, and is application specific. This also has a significant impact on the evaluation and validation phase.

A multi-domain and integrated approach is required for 800G modules

The optical domain, the electrical data domain, and the control domain are all intimately related in 800G optics. Interoperability and performance are all related through the module DSP and corresponding firmware.

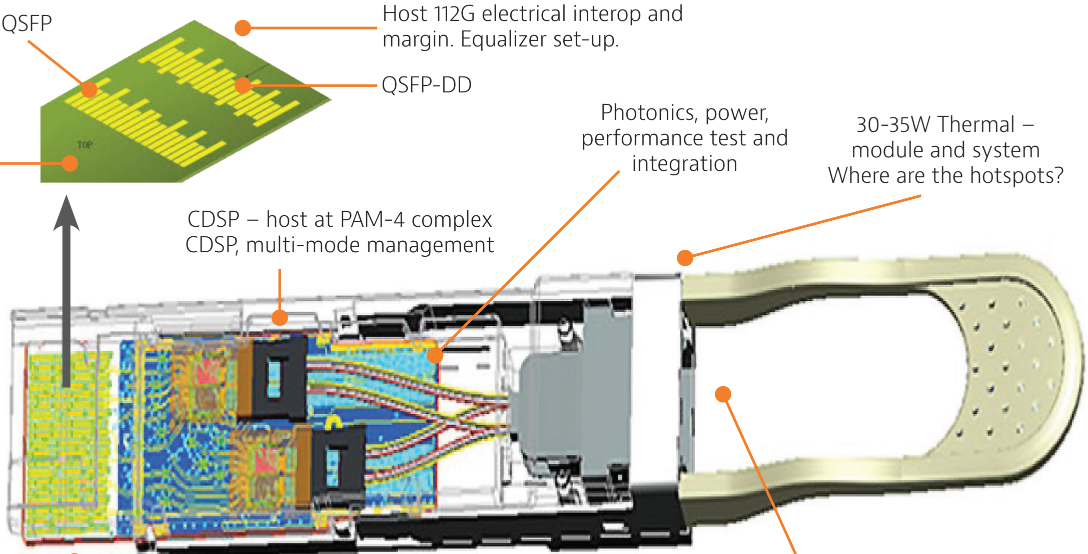
Interfaces:

- DAC/AEC/ACC/AOC
- SR8
- DR/FR
- ZR/ZR+



8x112G SERDES can support a wide range of services – from 8x100GbE through 800Gb Ethernet CMIS (and C-MIS) module management and control. Host power and cooling to 35 W.

800G modules are a multi-domain engineering marvel!



How to Evaluate and Validate Pluggable Optics

Four key areas need to be evaluated, and they need to happen in an integrated manner to ensure the testing reflects real world operation.

Domain	Characteristics	Notes
Electrical (data, signal integrity)	Error performance and margin, characteristics under disruption	Focus is data integrity (BER and error margin) for both unframed and framed traffic.
Optical	Optical loss budget, accuracy of reported optical parameters	The optical domain is considerably more complex for coherent/ZR type modules as optical factors have a direct impact on CDSP and firmware
Management (CMIS/C-CMIS)	Accuracy, stability, compliance	CMIS has many features and the host and module must be tightly aligned through CMIS
Environmental (mechanical, thermal)	Power consumption and thermal dynamics	

Electrical Domain

The electrical domain is primarily concerned with the host-to-module interface, but it is also the gateway for end-to-end performance evaluation. We use the host interface for our data patterns and traffic analysis – and this needs to be done under both benign lab conditions, and also real operating conditions which might include frequency PPM and skew variation.

Optical Domain

The optical domain has a significant impact on link performance in areas like error rates and margin. There are two key drivers for optical test. The first is validation of monitoring functions (timing and accuracy) and the second is ensuring the module will work over the specified limits of the standardized PMD. While wavelength ranges may change, IMDD optics and coherent/ZR optics do share some common test requirements. Required test modules are listed in the table below.

Optical Test Equipment	Use Case	VIAVI Example
Variable attenuator with shutter	Adjust optic link to vary optical signal level to allow optical signal level vs. BER. Actuate shutter to validate LOS timing and recovery validation	mVOA-C1
Optical power meter	Validate optical power levels of module transmit, and receive optical power readings over CMIS	mOPM-C1
Optical spectrum analyzer	Validate optical module transmitter wavelength accuracy and stability	mOSA-C1
Stabilized CW light sources	Calibrate module receiver power level monitors	mSRC-C1 (IMDD) mTLG-C3 (ZR)
Optical amplifier	Ensure receiver signal can reach the high-power limit	mOFA-C1 (IMDD) mEDFA-C1 (ZR)
Optical inspection microscope	Inspect optical connector quality of module	FVAm

With coherent/ZR, a whole new challenge occurs. Photonic layer effects have a direct impact on firmware performance. Parameters such as OSNR, state of polarization variation and wavelength have a huge impact on what the DSP and firmware do. In some cases, changes in optical parameters can lead to firmware errors or even a crash! In this case additional advanced modules need to be considered.

Optical Test Equipment	Use Case	VIAVI Example
Broadband noise source	Inject noise to allow ranges of OSNR to be created	mBBS-C1
Polarization controller/ scrambler with rate change	Change the statistic of how the state of polarization changes in term of rate and limit coverage	mPCX-C1
Tunable wavelength/ bandpass filter	Change center wavelength and bandwidth to match PMD system definition or test impact of ROADM nodes	mTFX-C3

Whether it is IMDD or full ZR, all of the optical modules can be deployed in a single 3U MAP-300 platform

Module Management

Optical modules need to be tightly integrated into the host to meet the performance needs of modern fabric and network. The close coupling of module and host comes from the module management running over the I^2C two wire interface using CMIS or C-CMIS. This stateful interface is required by the host to orchestrate module operation for both normal clients and especially coherent/ZR modules. CMIS provides a defined set of registers and functions for standard module management including:

- Inventory data
- Module and traffic configuration
- Module monitoring (alarms/defects, performance monitoring)
- Capability advertising

Environmental

We have seen the power for client pluggable optics quickly grow, from the nominal 3.5 W of a client QSFP28 interface at 100Gb Ethernet, to around 30W for 800Gb ZR/ZR+ coherent modules. Without stable power and adequate cooling, testing and evaluation cannot commence. Furthermore, testing needs to be done over a range of power supply conditions (voltage margin) to ensure robust and stable operation during deployment.

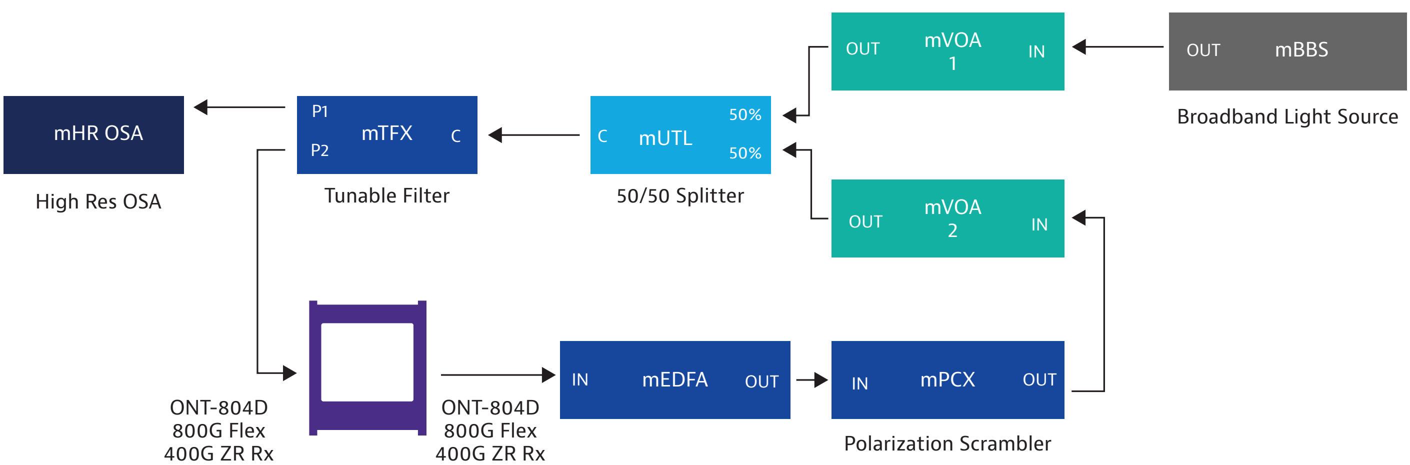
Typical Test Setup for Pluggable Optics

The VIAVI ONT 800G FLEX XPM provides the perfect test host for both client (intensity modulated direct detect – IMDD) and coherent optics. It integrates the key test and validation aspects of traffic generation and analysis (unframed PRBSQ for IMDD and framed traffic for both IMDD and coherent), full module management applications, and stable power and cooling to meet the needs of the most demanding 800G coherent modules.

The optical interface can be connected by appropriate fiber patch cords to the VIAVI MAP-300 for additional optical impairments, from simple loss and attenuation for IMDD, through OSNR degradation for coherent optics.

We will use the example of an 800G ZR coherent module here. Client IMDD is a subset of this test & validation.

Typical Test Setup for Coherent/ZR Optics



Tests

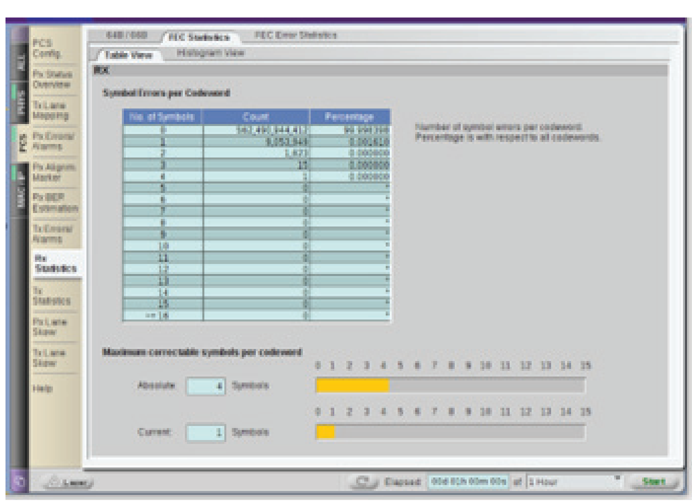
Data Integrity

The most fundamental function of an optical module is to allow data transmission. This must occur with the lowest possible error rate with sufficient margin. With 800G optical modules, we use 100G electrical lanes using PAM-4 signaling. Optically, we may have 100G or 200G per lambda PAM-4, or complex phase and polarization for coherent. Errors will occur in transmission so protocols such as Ethernet use forward error correction coding (FEC) to ensure error-free transmission at the packet layer.

Traditionally data integrity was done using PRBS patterns, and looking for errors and a suitably low bit error rate (BER) at the receiver, but with PAM-4 signaling 'always errored,' this method of screening is not as useful as in the past. BER measurements can still play a part in test and development, but looking at the framed traffic FEC tail is a more applicable method for 400G and especially 800G modules. It gives, at a glance, a clearer view of module performance and any potential issues with the module (like longer error bursts and bit slips) which are hard to see with a basic BER test.

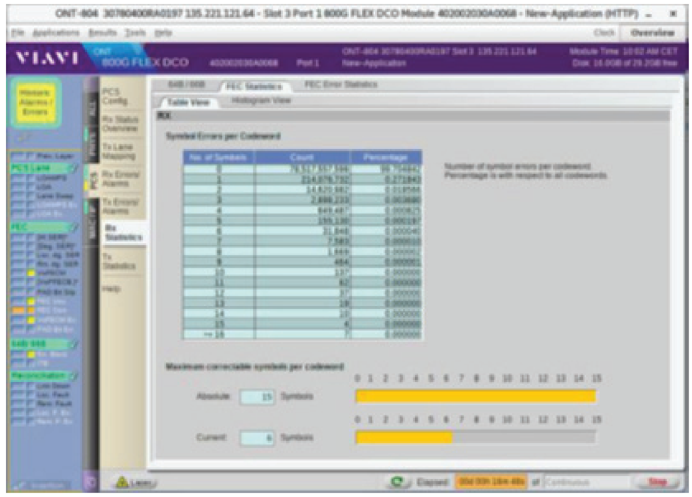
With the VIAVI ONT, this can be done very easily and quickly using the 800GbE application and the RX FEC overview. You get a clear display of the number of errored symbols in a codeword. Since 400GbE and 800GbE can correct and detect up to 15 errored symbols in a codeword, a few minutes of data gives a very clear and confident overview of module data performance. A well-behaved module would exhibit the FEC tail as below. It has several important characteristics:

1. Sufficient margin in maximum error count. Since the FEC can detect and correct a maximum of 15 errored symbols, you need a good margin (maximum of 6 or 7 errored symbols after an hour or ~5 errored symbols in a few minutes).
2. Monotonic – dropping off orders of magnitude each errored symbol count. In the example below we have a rapid drop for each symbol count. No long tail of roughly the same magnitude count extended out to 9, 10 or more errored symbols should occur. This indicates an unusual error burst mechanism and can be caused by poor CDR performance or incorrect or sub-optimal equalizer settings.
3. No isolated symbol counts separate from the main tail. Isolated 'peaks' of symbol counts indicate an unusual error mechanism not from noise but from other processes such as a CDR slip or long error burst.



FEC tail view

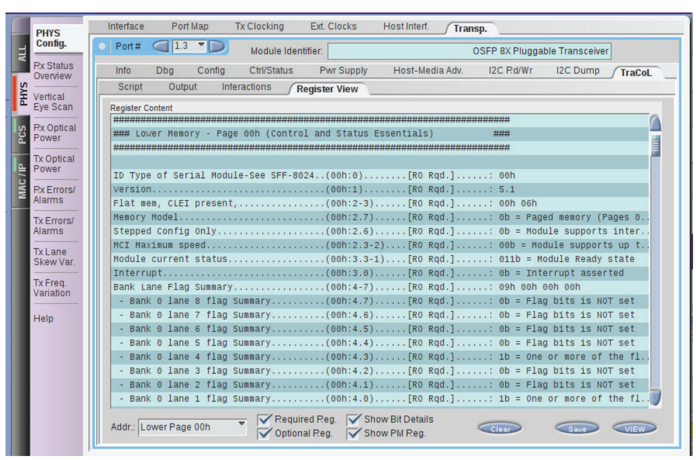
This test can be repeated at different optical power levels, or OSNR levels, and the VIAVI ONT also allows additional stressors such as skew and frequency variation. Repeating the test under 'stressed' conditions is important to 'real world' use case applications. For example, running the test with a variation in dynamic skew can quickly highlight issues with the module CDR which would cause a long FEC tail.



Device with a long FEC tail caused by incorrect electrical equalizer settings

CMIS and C-MIS – Control, Module Management and Result Reporting

In parallel with data integrity, the VIAVI ONT can validate the performance of the module management (CMIS/C-CMIS) interface. At the most basic level, the module must correctly advertise its type and application capabilities. The module must correctly accept and acknowledge the application selected and the desired data path settings.



Validation and debugging of module, CMIS requires visbility and clarity.
VIAVI integrates advanced CMIS tools into its ONT family.

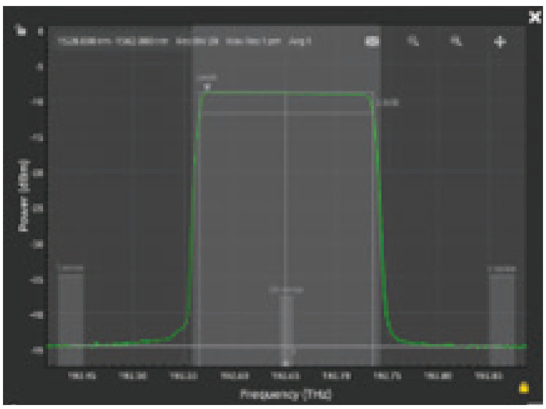
The VIAVI ONT can quickly determine the applications supported by modules and can validate the modules have correctly accepted the desired applications and data path mode. The unique 'Transp. Incomp' – transponder incompatible alarm is used on the VIAVI ONT to quickly highlight any anomalies with module applications programming.

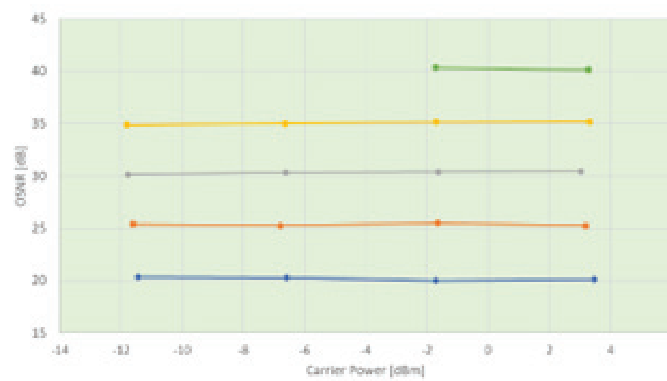
Power

The VIAVI ONT can continuously report the module power draw, and the supplied voltage can be adjusted across the MSA specified range to ensure robust operation.

OSNR and Change in Polarization

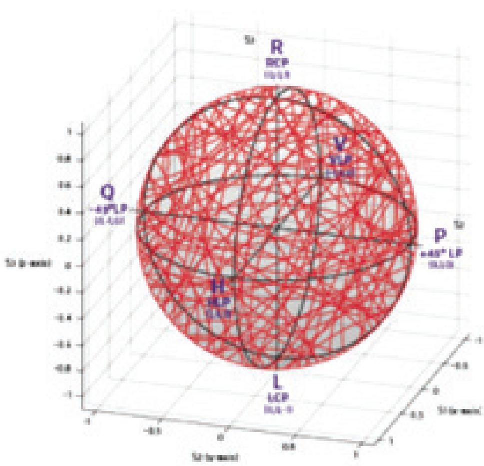
As shown below, the MAP-300 configuration enables two critical tests. Two independent precision VOAs enable the creation of an OSNR / Carrier Power matrix to test Rx compliance. The linearity of the OSNR and/or power change is critical and requires precision wavelength independent VOAs. An OSA is used to measure the initial OSNR of the transmitter, but changes can be controlled by the VOA directly.

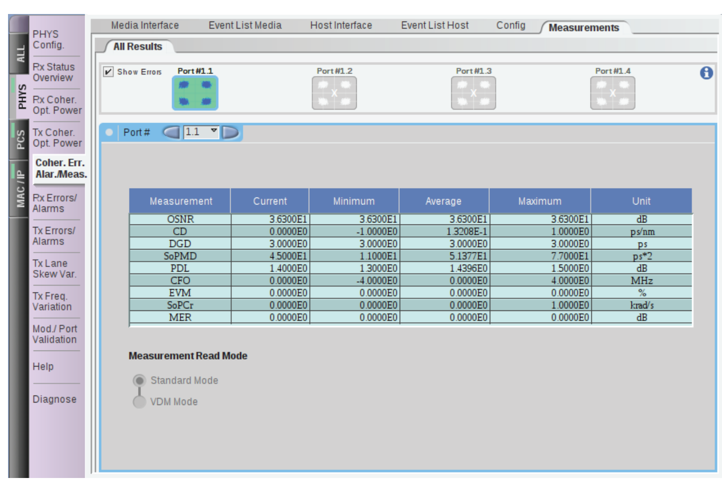




OSNR is measured on the mOSA module while the power and OSNR matrix is controlled by the VOA

In addition, the mPCX module can be used to emulate the dynamic changes to transmitter polarization due to environmental changes in deployed single mode fiber. The ability of the module DSP to manage these changes is critical to long-term module performance.





State of polarization is a demanding test that impacts the optical and DSP + firmware domain

Summary

800G optics are now becoming available in a wide range of optical interfaces, and are finding a broad range of applications. 800G modules use complex DSP based logic, PAM-4 electrical and optical interfaces and stateful module management all integrated into a small package with both power and thermal challenges. The ability to quickly validate all aspects of these complex optical modules is key to accelerating product and service delivery.

The VIAVI ONT integrates all the key requirements for data integrity, module management and power/cooling, and when coupled with the VIAVI MAP family, provides a complete system for module test, validation and integration.

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