VIAVI Solutions

White Paper

Testing pluggable coherent optics

Coherent optics for DWDM transport have been used for some time but these have typically been closed engineered systems which are vendor specific. Recently pluggable coherent modules designed against MSAs and other standards have lead to the emergence of a coherent pluggable optics ecosystem. The IEEE 802.3[1] works on a ZR PMD for 80 km link budget for 100G and 400G links using DWDM has led to a wider interest in development and deployment of pluggable coherent optics.

This VIAVI white papers serves as an introduction to pluggable coherent optics and the testing and validation challenges and methodology required to successfully develop, validate and deploy pluggable coherent optics for 100G and beyond.

Optical Interfaces Today

The flexibility of pluggable interfaces today has been a major contributor to the success of Ethernet and allows users to scale the bandwidth and reach in an 'as required' with the appropriate cost scaling. If we look at the case of 400G Ethernet an end user has a wide range of interface types to support each potential application:

PMD	Reach	Application	Technology
DAC	2 to 3 m	Intra-rack & server	Passive copper cable, 50G PAM-4 electrical
SR8	100 m	Enterprise	Parallel multi-mode. 50G/λ – PAM-4
DR4	500 m	Datacenter and enterprise	Parallel single-mode, 100G/λ – PAM-4, can also support 4 x 100G breakout as each 100G has a distinct fiber.
FR4	2 km	Large scale datacenter	Single mode, 100G/λ, PAM-4
LR8	10 km	Telecom reach	Single mode, 50G/λ, PAM-4
ZR	80 km	Metro and DCI	Single mode / coherent, PAM-4

Table 1 – PMDs, characteristics and applications of standardized 400G Ethernet interfaces

1. http://www.ieee802.org/3/

Traditionally, most of the applications for pluggable optics fell at 10 km and below and so can be effectively addressed by direct attached copper, multi-mode VCSEL based or single-mode, direct detect optical technology. The signalling rates have increased steadily as data rates have increased and with 400G a move to higher order modulation (NRZ => PAM-4) occurred. However, the vast majority of applications were covered with conventional 'direct detect' technology.

Longer reaches have been traditionally addressed with high-performance, vendor specific coherent line card modules based on customized photonics and ASICs, but recently vendors like Acacia have developed high performance pluggable modules compatible with client optics 'slots' (albeit with more demanding power, cooling and management requirements). Initially the focus was telecoms applications, but a broader and larger market has appeared in areas such as data centre interconnect (DCI). The reach is best addressed from a coherent photonic interface and to reach market potential high density form factors (including power and cooling) and aggressive price expectations have to be met to align with market expectations.

Client Optics Today

A wide range of form factors are deployed today but the two most popular in client interfaces come from one of two families. The SFP family typically has one electrical lane matched with one optical lane and is often found in 'end devices' such as servers or cell phone base stations while the QSFP family uses parallel optical and electrical lanes (it has traditionally used 4 electrical lanes and the majority of cases use 4 photonic lanes either as a parallel optics or a single fiber with the signals on a CWDM optical grid). We shall focus on the QSFP-DD[2] for our deeper dive into client optics as it is typically found in elements like switches, routers and transport equipment handling the most bandwidth.

A typical state of the art 400G pluggable module today for a client interface would be a QSFP-DD module. This engineering marvel incorporates high-speed digital electronics, broadband & low noise analogue electronics, DSP firmware, microcontrollers, integrated photonics, and mechanical integration all against aggressive price and performance expectations.

Several key areas need to be addressed:

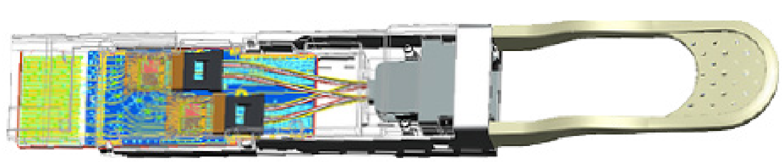

Figure 1 – An inside view of a 400G QSFP-DD module

A pluggable electrical interface (in a QSFP-DD it is a double sided, dual stack connector) brings in a parallel high speed electrical host to module interface. At 400G Ethernet this is typically 8 parallel differential lanes using PAM-4 electrical modulation using high performance digital SERDES with support for equalization of the host-to-module interface. The connector also needs to provide a command/control interface, typically these are based on a two wire interface like I²C using a protocol. The latest 400G QSFP-DD typically use CMIS 4.0, an advanced stateful protocol designed for the needs and applications of 400G optics. Also going over the connector is the power (typically 3.3V at over 4A) providing the power needs for the electronics & photonics in the module.

2. http://www.qsfp-dd.com/

The highly integrated ICs inside the module include SERDES, often now DSP based that support the equalization between host and module as well as providing mux & demux from 8 lanes of 28Gbd PAM-4 to the 4 lanes, 100G/ lambda (56Gbd PAM-4) used on the photonic interface (for example DR4 and LR4). The ICs require complex firmware, especially DSP code, and the management and control of the module is orchestrated via a microcontroller which pulls together a protocol stack for the module management (i.e. CMIS 4.0), all the normal housekeeping and management like cooling and power management, firmware load and management for the DSP and of course all the requirements of the photonics. The photonics will consist of highly integrated lasers and receivers all compliant with robust and exact standards such as IEEE 802.3. Both the transmitter and receivers need to exhibit wide bandwidth, low noise, and good linearity all against power and thermal requirements.

The components are mounted on a tiny PCB which must manage the signal integrity issues and then all integrated in the demanding volume requirements of the QSFP-DD form factor! The QSFP-DD is indeed a multi-discipline engineering marvel!

Coherent Optics Today

Coherent optics have played an important part in modern long haul fiber optic communications links. They typically focused on the highest performance and used custom photonics and ASICs on a large fixed module.

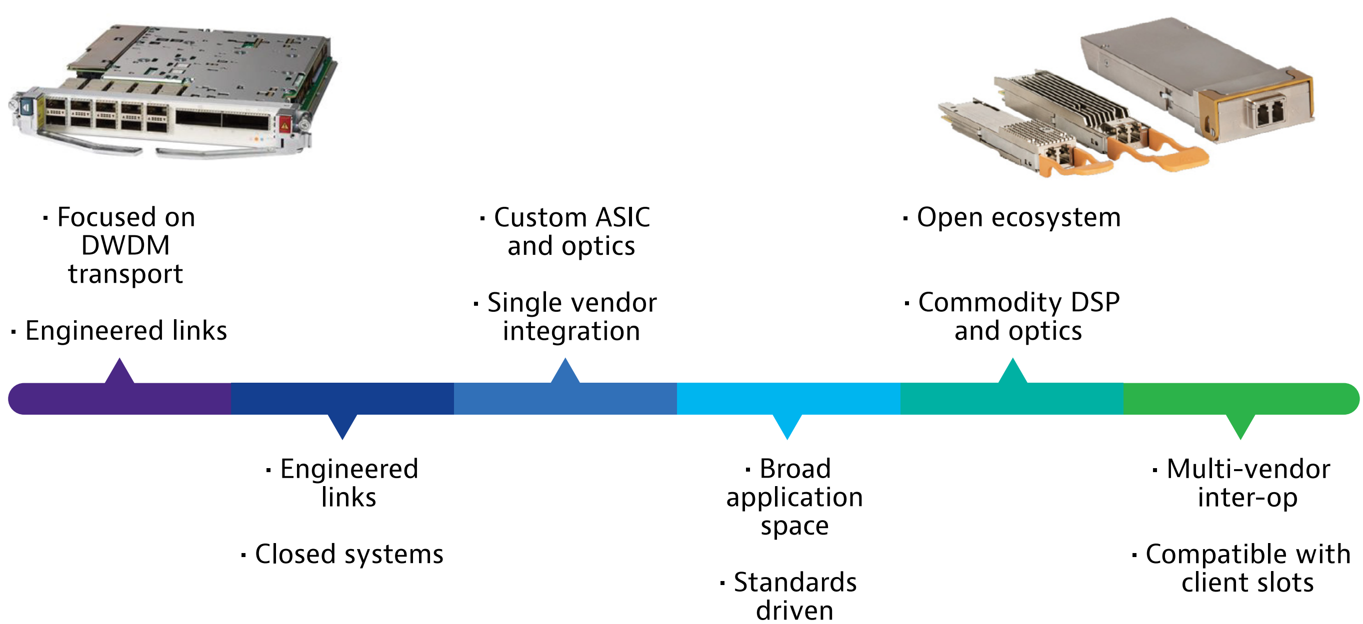

Figure 2 – The evolution of coherent optics – from line cards to pluggables

As the figure above shows, the evolution from engineered high performance line cards to an open inter-operable ecosystem needs many parts to come together and also presents multiple challenges for test, validation and production. Although vendors produced pluggable coherent modules for 100G and 200G (in CFP and CFP2 form factors), the sweet spot for this ecosystem emerges at 400GE with applications in DCI, Metro and classic DWDM served in two distinct markets.

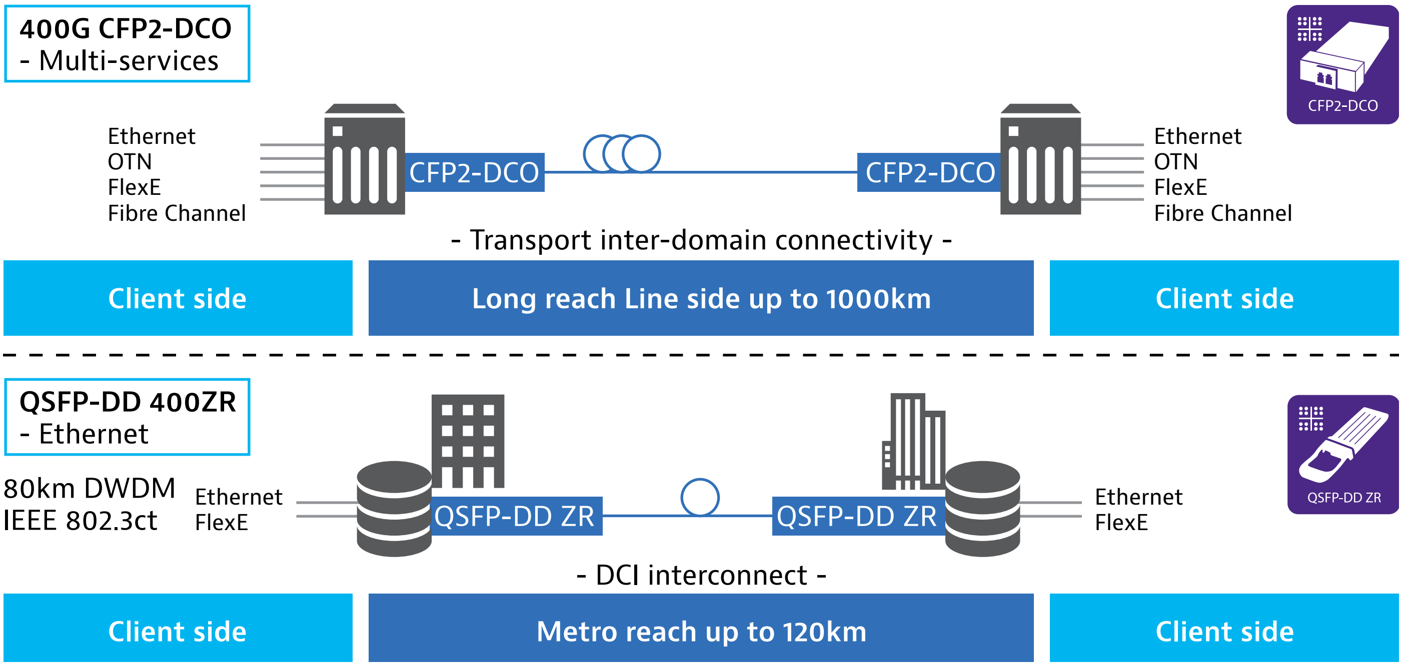

Figure 3 – The two distinct DCO markets emerging at the 400G sweet spot.

The Metro/DCI space may become further segmented with applications in ZR, ZR+ and OpenROADM[3] although it is likely medium term that these applications (based on more compact form factors like QSFP-DD and OSFP) will be addressed by one type of module with user selectable operating modes enabled through software and firmware.

Client optics typically use simple intensity modulation (traditionally NRZ – on/off keying – OOK) but with the emergence of 400G we see PAM-4 modulation now commonplace for all rates of 50G and above on a per lane basis. Coherent modulation utilizes both the phase and polarization of light to provide far higher modulation capabilities and because the receiver has phase and polarization state sensitivity, dispersion compensation can also be performed electronically. Conventional modulation would require compensation for link dispersion on reaches above 40 km. The simple intensity modulation used in conventional client optics is intuitive and simple, the laser (either directly – direct modulated laser, DML or via an external device – externally modulated laser, EML) has its optical intensity modulated in sympathy with the data. This is sometimes called on-off keying, OOK. The practical upper limit for this is around 50 GHz today, so 28Gbd & 56Gbd (100G/lane) is practical with commercially available mass-produced (and hence reasonable cost) devices, higher bandwidths for 200Gb/lane have been demonstrated but these are still novel.

With coherent modulation the advanced properties of light, polarization and phase, can be exploited to give far higher data rates at the expense of more complexity in the transmitter and receiver.

3. http://openroadm.org/

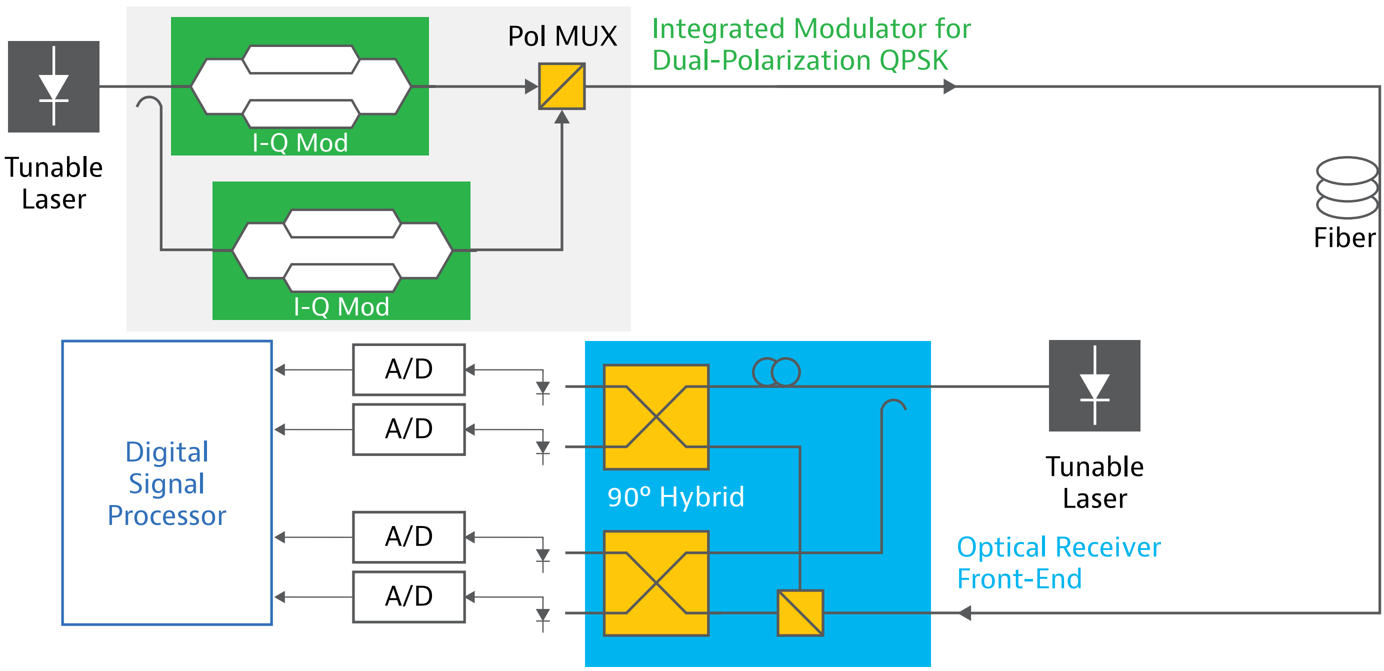

Figure 4 - Illustration of the key aspects of a coherent transmission system.

Typical coherent & DWDM systems use the 1550 nm band, this is the area of minimum loss which is a useful factor for longer reach. The light from the transmitter laser (which is often tuneable and part of an integrated tuneable laser assembly – ITLA) is split into two paths and each path is then phase modulated (I-Q modulation), the two paths are then recombined as two perpendicular polarization states. This photonic assembly will often be highly integrated and may exploit silicon photonics to meet the density, performance and price expectations of pluggable optical form factors. In the majority of cases the four I/Q modulators will be driven by high performance DACs which will be integrated into a DSP. This will perform a range of encoding functions including framers, FEC and symbol mappers and will normally be part of the IC which also performs the coherent receiver functions.

The optical signal, which is now phase, polarization and amplitude modulated (as opposed to the simple amplitude only modulation on simpler client interfaces) is transmitted along the fiber link were it will be subjected to attenuation (loss), chromatic and polarization dispersion and other effects which degrade the transmitted signal to noise ratio (optical SNR = OSNR).

At the receiver the input optical signal is separated into perpendicular polarization states and then split into the in-phase and quadrature (I & Q) components where it is then heterodyned with another (tuneable) laser to produce a baseband signal which impinges on the photodetectors. The resulting signals are then digitized and processed by the receiver portion of the DSP which is described in detail below.

Pluggable Coherent Optics

Large amounts of network equipment are deployed with pluggable module slots – the CFP2 family is widely deployed in telecom applications with the QSFP family dominating enterprise. The OSFP is also gathering support in some quarters due to improvements over QSFP-DD.

Figure 5 - Pluggable form factors for DCO QSFP-DD, OSFP, CFP2 – courtesy of Acacia[4]

Coherent pluggable modules for line side transmission are far more flexible than typical pluggable client modules. In pluggable client modules such as QSFP-DD we normally see identical signal structures on the ingress and egress side of the module. The framing and encoding is consistent across the electrical (host) and optical (client) interface. In contrast, a coherent transponder may support those same structures on the host side, but there will be a very different output signal structure (for example, a single-carrier coherent DP-16QAM modulated signal, using C-FEC (concatenated FEC) on a ZR interface).

This significant difference between client and lineside coding impacts test coverage. In a coherent CFP2-DCO transponder the complexity can be even higher. In telecom applications a CFP2-DCO module can support both Ethernet and multi-service based clients. 400GE, 4 x 100GE have broad appeal for Ethernet applications while OTN and FlexO offer powerful capability for multi-service needs which is an important application for telecoms.

The bandwidth can also scale with the dynamic bandwidth requirements from the clients, an example is the scalability of n x 100G Ethernet which can scale from 1 to 4 clients to fill the 400G. For OTN host signals, there are a number of choices: 1 or 2 * OTL4.4 with NRZ, or PAM-4 coded 4 * OTL4.2 / 4 * OTLC.2 at 400G with different service capabilities. The mentioned interfaces reflect the migration path from older structures or earlier 400G structures.

4. https://acacia-inc.com/products/

Future OTN interfaces can be based on FOIC (FlexO Interface) technology with 100G, 200G or 400G variants. The host FOIC interfaces are protected by a KP4 FEC

FOC standard	description
FOIC 1.4	100G OTN carried by 4 electrical lanes of 25G NRZ
FOIC 1.2	100G OTN carried by 2 electrical lanes of 28 Gbd PAM-4
FOIC 2.4	200G OTN carried by 4 electrical lanes of 28 Gbd PAM-4
FOIC 4.8	400G OTN carried by 8 electrical lanes of 28 Gbd PAM-4

The line side structure is based on 100G, 200G and 400G entities, but there is no longer mixed structures as seen at the host side. Depending on the link parameters (such as loss, optical signal to noise & dispersion) different FECs can be used to match the required coding gain, performance etc. Examples include CFEC (concatenated FEC), OFEC (open FEC) as well as proprietary FECs.

A pluggable digital coherent optical module (DCO) needs to integrate much of the functionality of a large coherent line card into a compact pluggable module. It includes a highly integrated optical coherent receiver and transmitter using a tuneable laser, often advanced techniques like silicon photonics are required for many of these elements. The coherent optics also require a highly integrated DSP to provide all the functions of the digital coherent receiver. A block diagram of the receive portion is shown below.

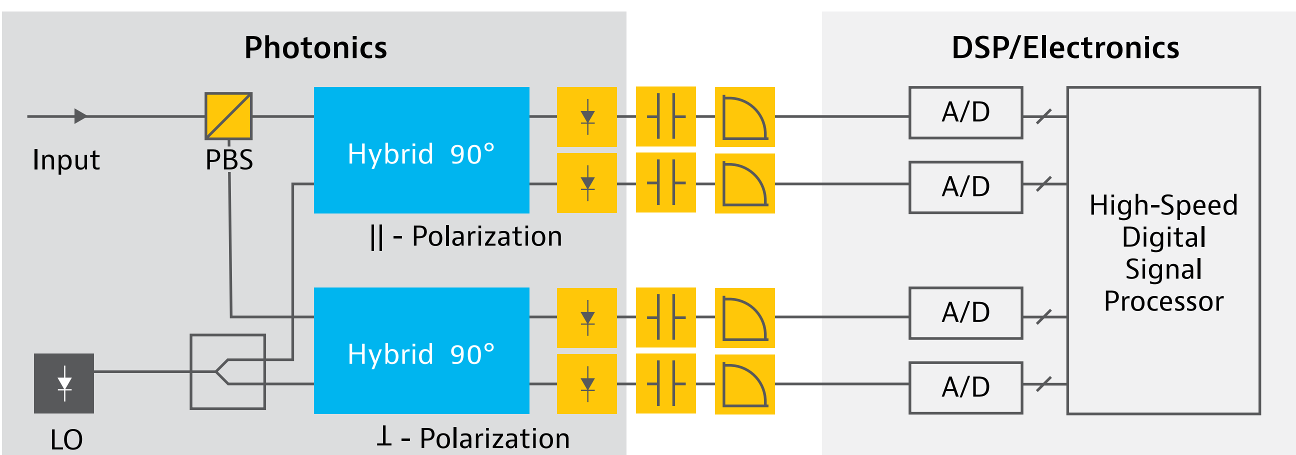

Figure 6 - Block diagram of receive section of a DCO

Analog to Digital Conversion

The input from the receiver must be digitized at or above the Nyquist frequency and since a typical coherent system uses phase and polarization diversity you need at least 4 very fast ADC. They need to have suitable resolution and linearity and although they would be proceeded by a photodiode and transimpedance amplifier (TIA) they may need a wide dynamic range.

DSP Functional Blocks

The DSP coherent receiver requires function blocks including:

Function	Description
Clock recovery	Digital CDR to track with received baud rate
Chromatic dispersion	Compensate fiber chromatic dispersion, fast buffer depth proportional to expected link length
Polarization diversity	Track the rapidly changing polarization changes (many krad/sec)
Carrier phase tracking	Track the phase of the input symbols & generate error vector magnitude (EVM)
Symbol recovery	Recover raw symbols
FEC	Multiple types of FEC may be used to correct errored symbols
Framer & demapper	The module may handle framed signals like OTN, FlexO, FlexE as well as Ethernet
SERDES	SERDES connects to host via high-speed pluggable interface. Also needs to perform electrical link equalization

Table 2 – Digital coherent module DSP functions required on receiver side

Of course, all of the functions must be controlled and orchestrated as well as being tracked in real time so the DSP has a large and complex control structure often intertwined with complex DSP firmware. The DSP may have to support many different operating modes and rates which could be a mix of standards like ZR or ZR+ and special vendor proprietary modes. Unlike a simple client module that has to occasionally report a few simple link parameters like loss of signal (LOS) or optical power, the DSP in a DCO must report multiple complex parameters in real time so the host can manage and track the link health and status. A small selection of the parameters include:

Parameter	Description
Loss of signal (LOS)	Since the module is likely to operate in a multi-carrier DWDM system a simple optical power detector cannot be used for LOS, the selected carrier wavelength needs to be resolved and checked.
Optical power	In a DWDM system the selected carrier wavelength must be resolved and measured.
Operating wavelength	A DWDM system can operate with a tuneable RX/TX
Chromatic dispersion	Chromatic dispersion measurement – usually proportional to link length
Polarization tracking	Polarization state may change rapidly (krad/sec) due to mechanical effects
Optical signal to noise ratio (OSNR)	Figure of merit of link health
Error vector magnitude (EVM)	IEEE & OIF use EVM as a figure of merit
Pre-FEC BER	Track BER before FEC – can be used to trigger link degrade alarms
SERDES status	Monitor SERDES state including equalizer, lock status (and even eye tracking could be possible)

Table 3 – Selection of module parameters that can be reported by DSP

Other general parameters could include module status, operating temperatures, laser parameters. The management, control and reporting of these parameters (many of which would need calibration over wavelength and temperature during manufacture) requires close coupling between the DSP, the module micro-controller and firmware and the host interface.

Module Management and Control

A DCO module is a complete DWDM line card integrated into a pluggable optics form factor. A key aspect of any functionality is the management interface. Client optics have evolved over the years using a two-wire interface (like I^2C) based on simple memory mapped protocols (SFF 8636[5] is widely used today for 4 lane modules like QSFP28) but with the advent of 400G class client modules it became clear that the legacy solutions could not meet the requirements of modern applications. The industry worked together, and this has led to the emergence of CMIS 4.0[6] as the management interface for 400G client optics such as QSFP-DD. The management of DCO is considerably more complex than client optics and the industry is looking at different paths for coherent module management. One approach taken by the OIF[7] C-CMIS is to build on the framework of CMIS 4.0 and add extensions for coherent applications, this is the likely path for QSFP-DD and OSFP modules. They are likely to be used in hosts that are required to support a CMIS 4.0 stack already as this is what QSFP-DD and OSFP clients will use. Another method is based on the CFP MDIO concept but significantly enhanced for DCO[8], which builds on the approach used on the 1st and 2nd generation CFP and CFP2 DCO modules used for 100G and 200G applications.

Testing Requirements Through the Product Lifecycle

Across any product lifecycle there is a range of test and measurement requirements which can vary in breadth, depth and complexity. The VIAVI ONT product line is designed to scale for the needs of each stage of the product development, validation, production and deployment lifecycle.

Module Lifecycle stage	Applications & examples
Technology and component evaluation	Evaluation of DSP, ROSA, TOSA
Module hardware development	Integration of hardware, signal integrity, data path connectivity
Firmware and software development	Module F/W and S/W integration, DSP features validation, module command interface
Standards validation	Validate host, photonic and command interface, standards, and MSA compliance
Production	Function test and calibration and the throughput and test stand density requirements
Module & vendor selection	NEMS evaluate and test modules for vendor selection against standards and RFQ
Module integration	Integration of module H/W and firmware with host, including comment interface etc

Table 4 - Summary of module lifecycle test requirements

5. https://www.snia.org/technology-communities/sff/specifications
6. http://www.qsfp-dd.com/wp-content/uploads/2019/05/QSFP-DD-CMIS-rev4p0.pdf
7. https://www.oiforum.com/technical-work/hot-topics-coherent-common-management-interface-specification-c-cmis/
8. https://www.oiforum.com/wp-content/uploads/2019/01/OIF-CFP2-DCO-01.0.pdf

Component and DSP Evaluation

One key aspect in developing a strong and reliable product and accelerating it to market is careful selection of components. Even before a module PCB layout has started, valuable work assessing the capabilities of the DSP can be done with a combination of the DSP evaluation board and an ONT test set connected with the appropriate electrical adapter. Such a setup can fully exercise DSP functionality and traffic throughput, framer and SERDES H/W and firmware to be developed and debugged in parallel with PCB design and mechanical floor-planning of the module. This approach can save months in a development cycle and allow more comprehensive design and DSP evaluation that cannot be achieved via simulation. It is also possible for the photonics and DSP compatibility to be evaluated and real measurements made across test fiber to baseline some of the system performance parameters like OSNR and EVM.

R&D

At this stage the components have been selected and the design concept reviewed. Validation of the layout is critical from both a signal integrity and a thermal point of view. Module firmware needs turning up to bring up the DSP and set up modes and the signal path. The ONT approach to the R&D phase is unique and comprehensive. It allows test, stressing and validation of the high speed 'phy' layer including the lower layer 'protocols' like the electrical equalization. The ONT supports the full range of traffic needs – from unframed signals to help check signal integrity and SERDES through to fully framed Ethernet and OTN signals that allow full signal path validation. All of this is down in a 'test slot' that meets the power and cooling requirements. Moreoever, it provides comprehensive test and validation features over the module command interface with tight synchronization and tracking between physical layer and protocol events and commands and responses over the management interface.

During the R&D phase four main themes need to be developed, debugged and validated:

Theme	Test Activities
Host interface – physical layer	Validation and functionality of SERDES and equalizers, signal integrity, dynamic and clocking, skew tolerance. Ability to support advanced phy modes such as 4 x 100G with different clock domains. Host interface squelch and recover. ONT applications include advanced error analysis (PAM-4 level & transitions and burst analysis), dynamic skew insertion, bit slip analysis and clock variation.
Host interface – protocol	Data path integrity, correct functionality of framers, FEC etc. Correct alarms and errors behaviour. Compatibility with Ethernet and multi-services (OTN, FlexO etc). ONT applications include alignment marker and FEC analysis and comprehensive Ethernet, OTN and FlexO testing.
Command interface	Correct functionality of module management interface, setting of DSP operating and traffic modes (validated together with protocol). Ability to read off key performance and photonic metrics. Correct and timely indication of fault and alarm conditions (LOS, frequency range, FEC etc). The ONT offers revolutionary module debug tools like transponder control environment.
Photonic performance	Behaviour of link under impairments such as OSNR, optical bandwidth shaping, LOS, state of polarization. Linearity, frequency tracking, laser tuning range, receiver AGC. The VIAVI MAP-300 offers a comprehensive set of photonic tools for this area.

It is useful to refer to the DCO function block diagram below. The key elements that require testing in R&D can be clearly seen. To ensure full end-to-end testing framed traffic must be used. A basic unframed tester can only really validate the basic connectivity of the SERDES. It cannot look inside the DSP and validate the complex functions including the FEC, framers and buffers. Complete data path coverage using framed signals (including OTN and FlexO if appropriate) is a must.

The SERDES block is one element where stressing above normal of frequency, phase and skew is important. The module functional elements like the SERDES must recover from disruptive events like signal and data frequency jumps and transients (caused by clock source switching) and skew (caused by time and temperature). When standards limits are exceeded it is important that the H/W and associated S/W correctly report the physical situation (frequency or skew out of range) rather than just failing. It is also important that when the clock frequency is brought back into the correct range the module can 'self recover' and signal this over the command interface.

Stressing like frequency ramping and dynamic skew can also be used to determine the error profile when the function blocks fail. A good example of this is excess dynamic skew causing bit-slips in a SERDES block. Having a test set that can differentiate between error burst and bit-slips provides insight into the exact failure mode under stress conditions.

Large IP blocks like FEC and framers rely on the framing of the traffic. The ability to manipulate and error the framed traffic is important to validate those IP blocks.

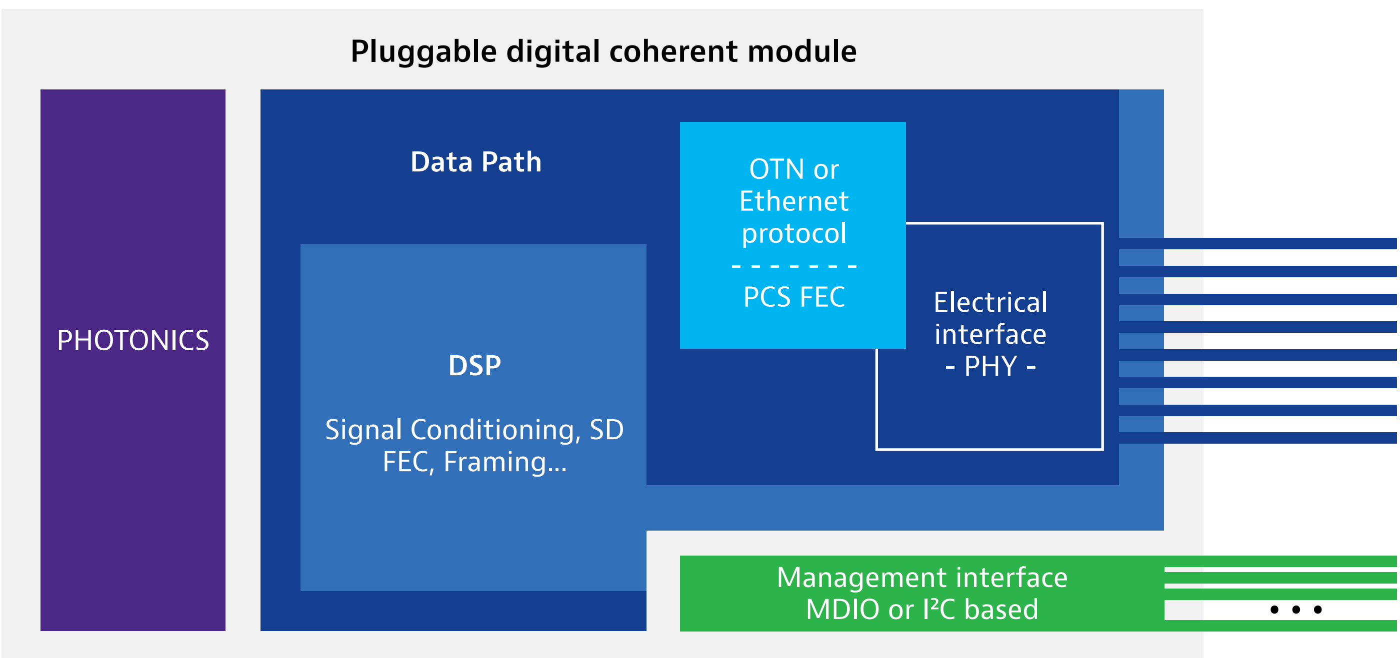

Figure 7 – DCO functional blocks

Physical Layer and SERDES Test Examples

The SERDES is a key part of any DCO module. Without a robust, standards compliant high speed data interface nothing can function. We will examine a couple of example tests to run on any DCO host interface to validate the SERDES.

Dynamic skew

The module data interface relies on a parallel high speed interface (8 lanes of RX & TX) running at 28 Gbps using PAM-4 electrical modulation. As with any parallel interface, we may get skew between the lanes which can vary over time. The IEEE lays out the skew tolerance of this interface so skew variation has applications for this standards validation. It can also be used to validate signal integrity. Varying the inter-lane skew will change the crosstalk between levels and so any change in error rate with the skew may indicate a cross-talk margin issue. Another key use of dynamic skew is to determine the failure mode of the SERDES when subjected to excessive skew.

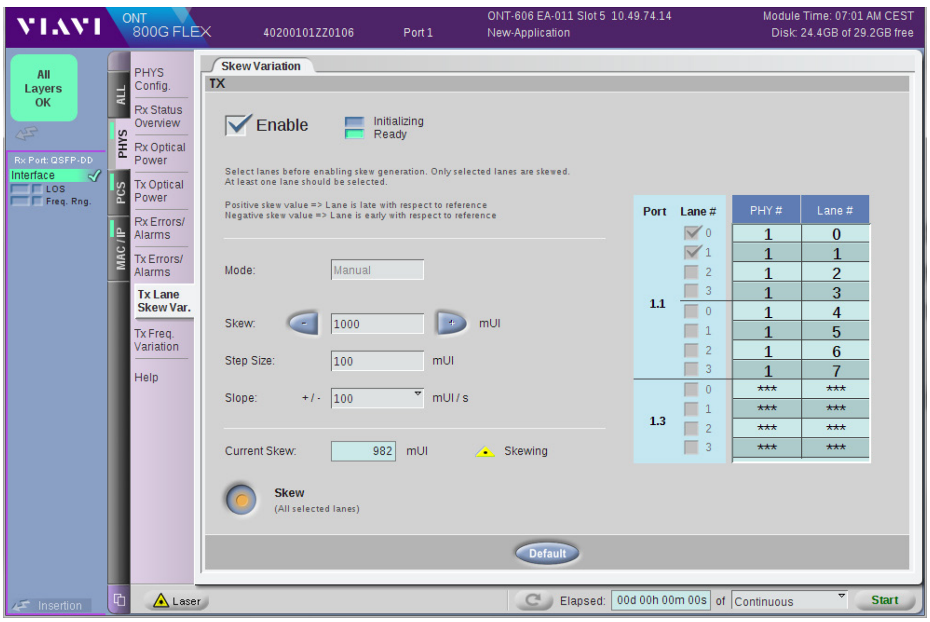

Figure 8 – Setting up dynamic skew on the ONT GUI

One issue that can occur with excessive skew, and is extremely difficult to troubleshoot without the correct applications, are bit-slips in the SERDES buffers. To most test sets it is reported as an error burst as they cannot identify a slip. The ONT can be used to stress this by running a dynamic skew test with framed traffic and then track the error profile seen on the SERDES output. The ONT can detect bit-slips on live Ethernet traffic. As the skew limits are exceeded on the ingress of the SERDES (module input) the failure mode can be observed.

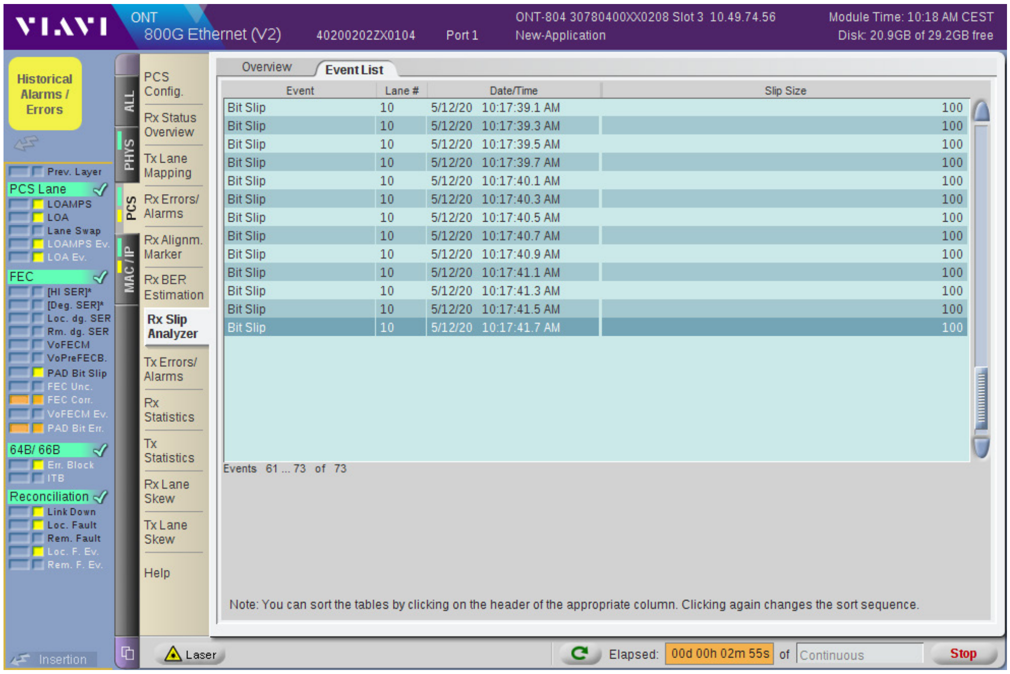

Figure 9 – ONT bit slip detect application

In addition to tracking large and disruptive errors like a bit slip, the ONT can also track the impact on the PCS layer which includes key elements like lane alignment markers and FEC. Correct and consistent tracking of the Ethernet alarms and errors is critical under fault conditions.

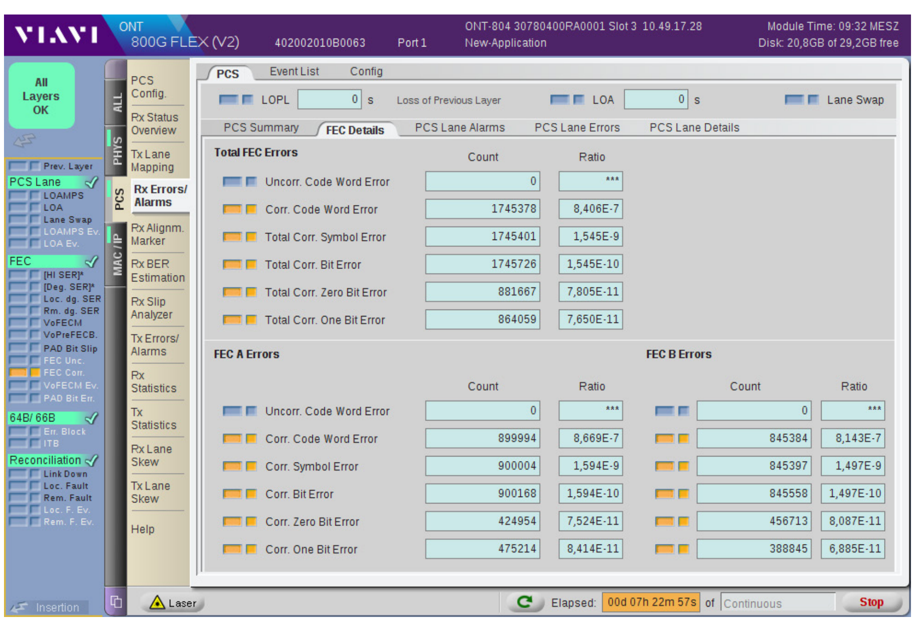

Figure 10 – Comprehensive FEC overview is critical in understand link error behaviour.

Module Management

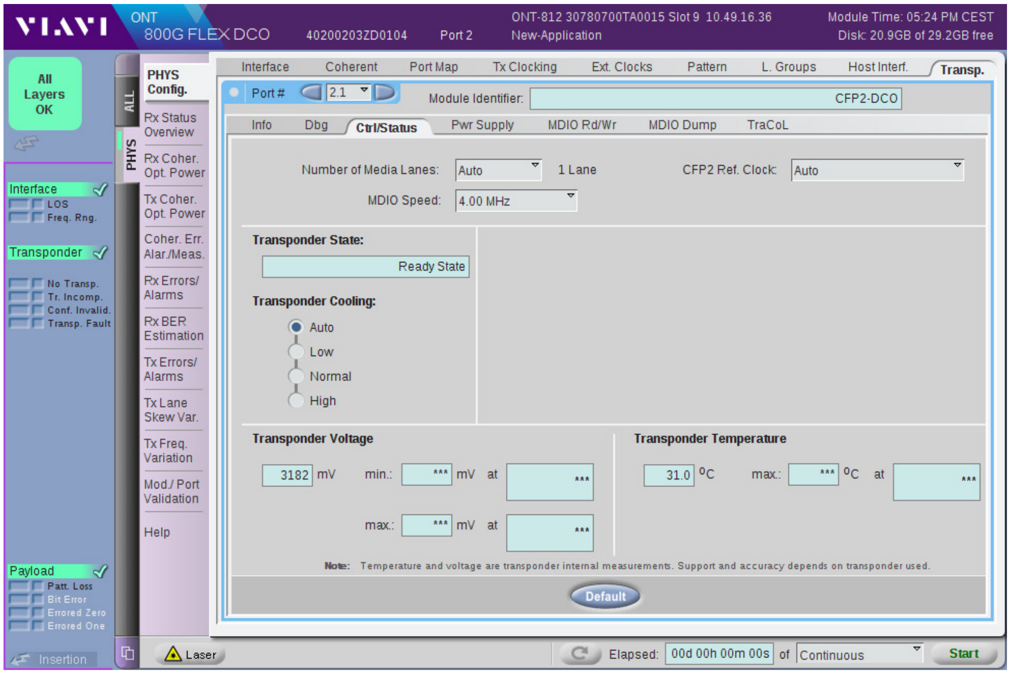

Figure 11 – ONT transponder status overview page

The management of a coherent pluggable module is extremely complex. Full insight and control of the management interface is critical to debug, validate and exercise the full system including the host module. Several elements must be taken into consideration when investigating the module interface and all need to be closely coupled with other interfaces, the host electrical interface and the photonic interface.

Area	Example	Drivers
Standard housekeeping	Correct module initialization, report vendor and model ID, standard parametric measurements.	Standard requirements to 'use' the module and correctly initialise it with a host so host correctly identifies the module and its capabilities.
Measurements, alarms & errors	Response to events like LOS, changes in OSNR (and pre-FEC BER), CD, PD, host interface issues	Photonic events can drive alarms and errors which should be quickly and unambiguously reported over the command interface. Parameters like optical power must be plausible and consistent.
Interface speed, throughput & stability	Ability to operate at various speeds over the two wire interface (TWI), stability of module firmware for repeated and rapid read/write access	The microcontroller in the module should be stable and not fail due to 'busy' traffic loading on the TWI. Also under heavy management interface loading other housekeeping tasks must still continue in a stable manner.
Interface time with respect to events	Validation of correct LOS response with respect to the alarms and also host electrical interface state. Recovery from LOS events – recovery time, stability, does it recover autonomously or host intervention required.	Service disruption and the ability to autonomously recover remains a significant challenge for both lineside and client modules. It is also important to characterise the interface messaging and timing with respect to photonic and host electrical interface status.

One very simple application which is widely used as a first order test for module stability is the ONT repeated read/write access. It loads up the command interface with user define read/write events and then other tests like normal traffic or stress tests (like skew) can be run to see if the module operation and stability is impacted by the repeated and heavy loading on the command bus and the module microcontroller.

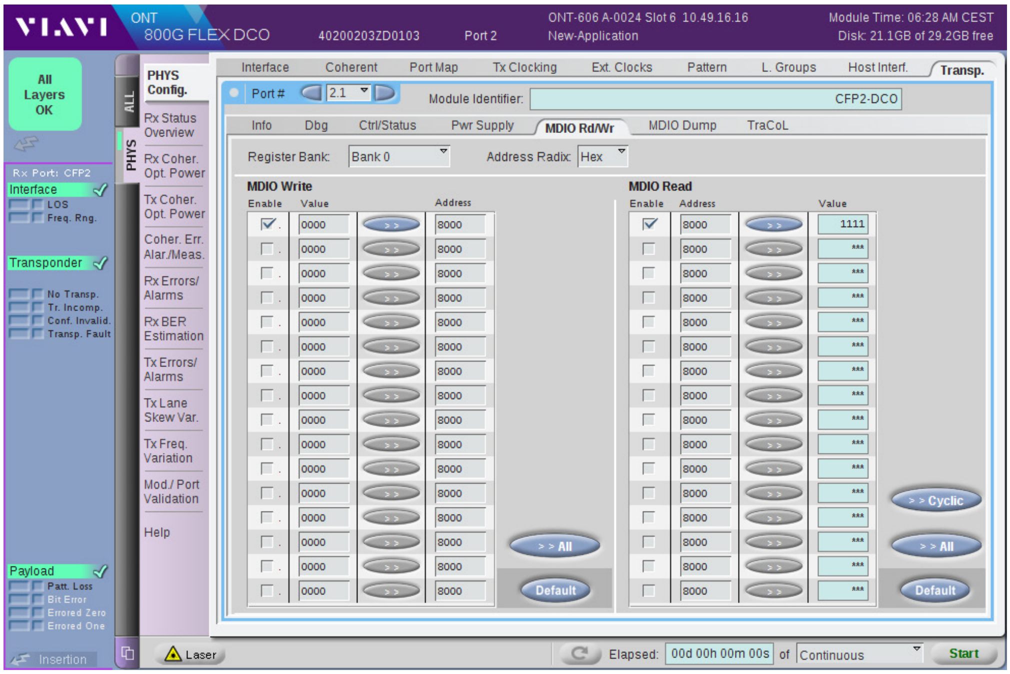

Figure 12 – ONT module read/write loading for MDIO command interface used on CFP2 DCO modules.

The ONT natively supports the extended management requirements of coherent modules (both QSFP-DD and full feature DWDM CFP2) and brings out the key parameters and status on the GUI in a clear and consistent manner. The key parameters such as operating wavelength can be easily set and tracked, both directly in the GUI and also via automated scripting for deep SVT testing requirements.

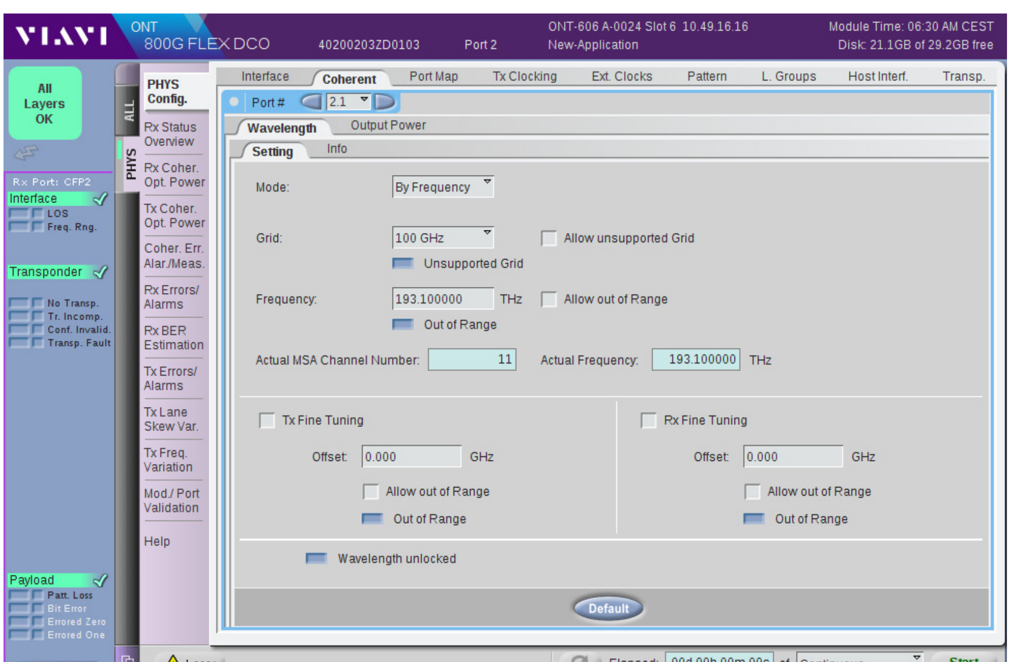

Figure 13 – ONT GUI to set key coherent module parameters

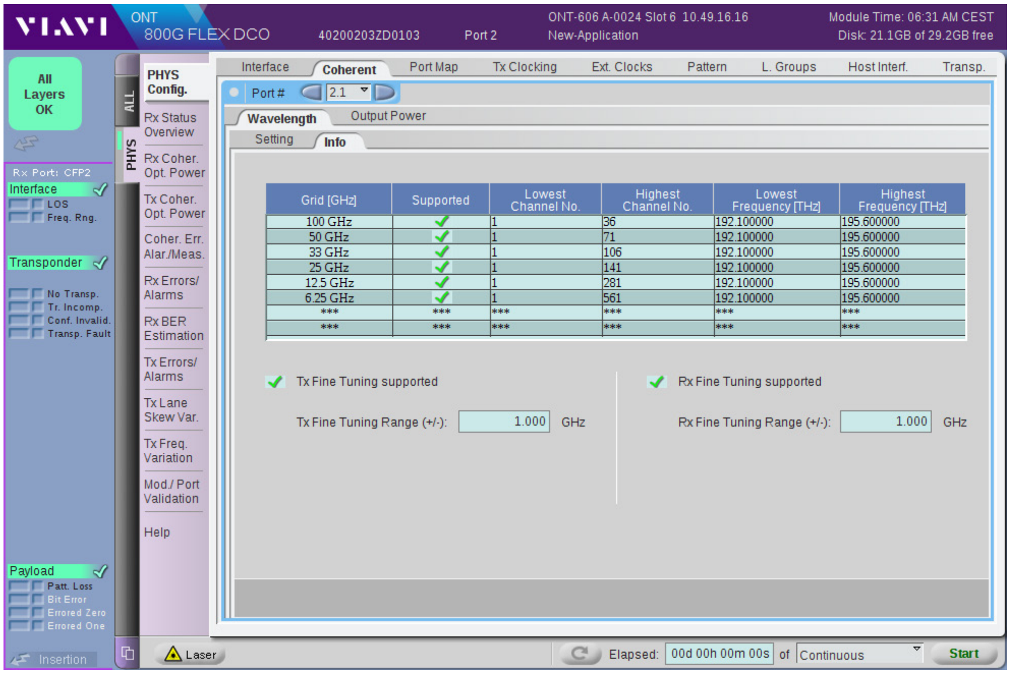

Figure 14 – ONT GUI reporting coherent transponder capabilities.

The command interface and associated module firmware must correctly report the optical parameters, which is far more complex and involved than the simple power measurements in a client module. A range of dynamic parameters including OSNR, CD, EVM, PD and DGD must be correctly reported and tracked (there may also be a range of user programmable limits). The ONT can be used together with the VIAVI MAP-300 product family range to allow generation and manipulation of optical parameters which in turn can be tracked and validated in the optical module under test in the ONT. This can also be used to support development and validation of DSP firmware.

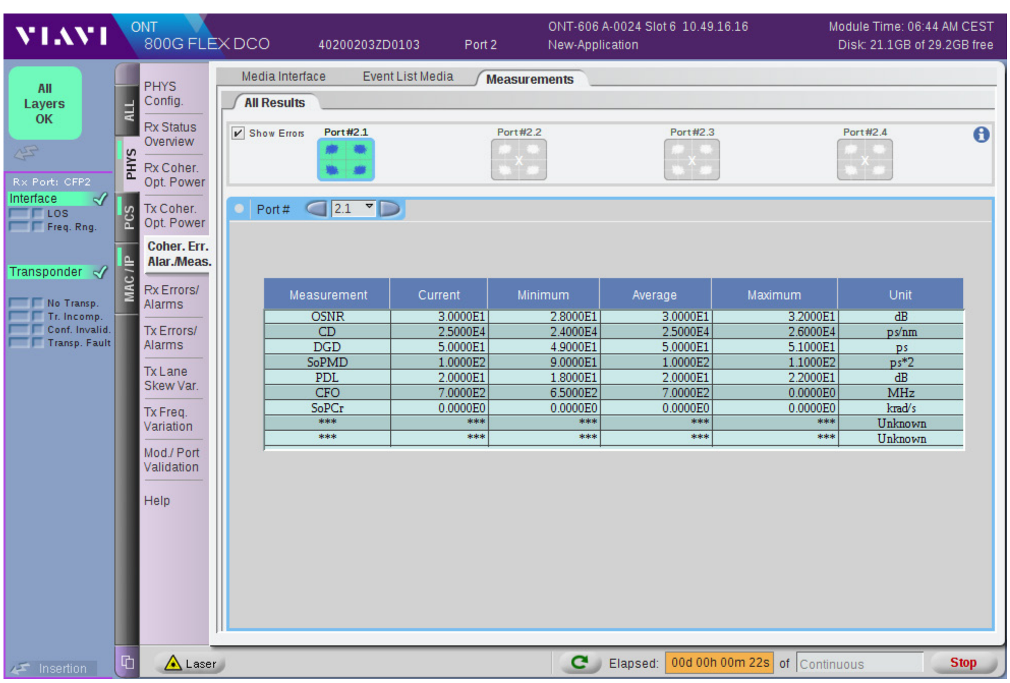

Figure 15 – ONT GUI showing module reported optical parameters for a coherent module.

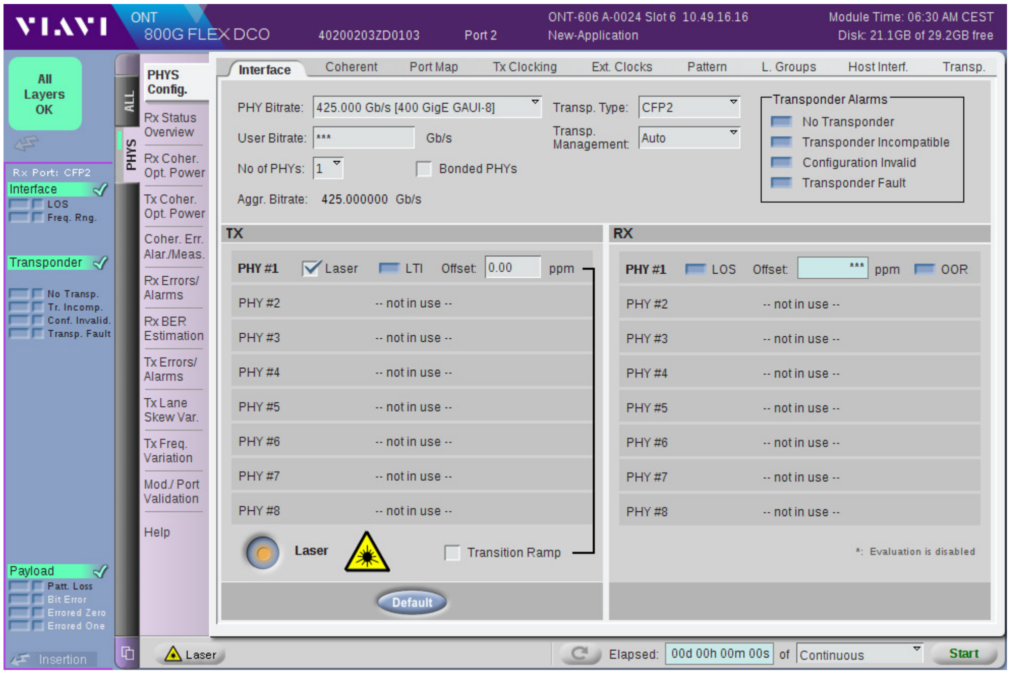

Figure 16 – ONT GUI overview of coherent module physical layer interface status

System Validation

System validation involves breadth and depth testing of the module, both the physical hardware and module firmware need to be tested. Testing is often multi-domain and under automation and is also a key stage when the module and the network are integrated together as the interaction between the module and the host is a critical system level feature. This stage builds on many of the applications used in the module development stage but with a strong focus on the software and performance aspects. Critical and timely reporting of alarms and errors up through the stack and reconciliation of the state of the photonics and what the module MIS is reporting to the host plays a central part. Link parameters (such as OSNR or pre-FEC BER) would be set and then the reference/ test optical link could be degraded (with VIAVI MAP-300 product family). As the link passes through the levels of degradation the module & host combination must raise the correct alarm and take the appropriate action (it may include switching to another link and raising system level alarms). Then as the link recovers, the system should follow the correct recovery procedure.

One of the most demanding tests we see during this phase is the service disruption test. It basically tests the system response to the optical signal being fully disrupted and then recovering. The recovery process and timing are of particular interest. On a client system this is a relatively simple test where the single optical signal is interrupted by a shutter and the module response (including module MIS messaging) is monitored. The optical signal is then reconnected and again the response, including recovery time and MIS messaging noted. Even with simple direct-detect modules we see issues with modules locking up or sending misleading messages over the MIS. In the worst cases the module does not correctly self-recover and manual intervention via the host is required. The testing load for coherent modules is made worse as now the module is potentially operating in a multiple optical carrier DWDM system so the disruptive event could be only associated with one optical wavelength amongst many.

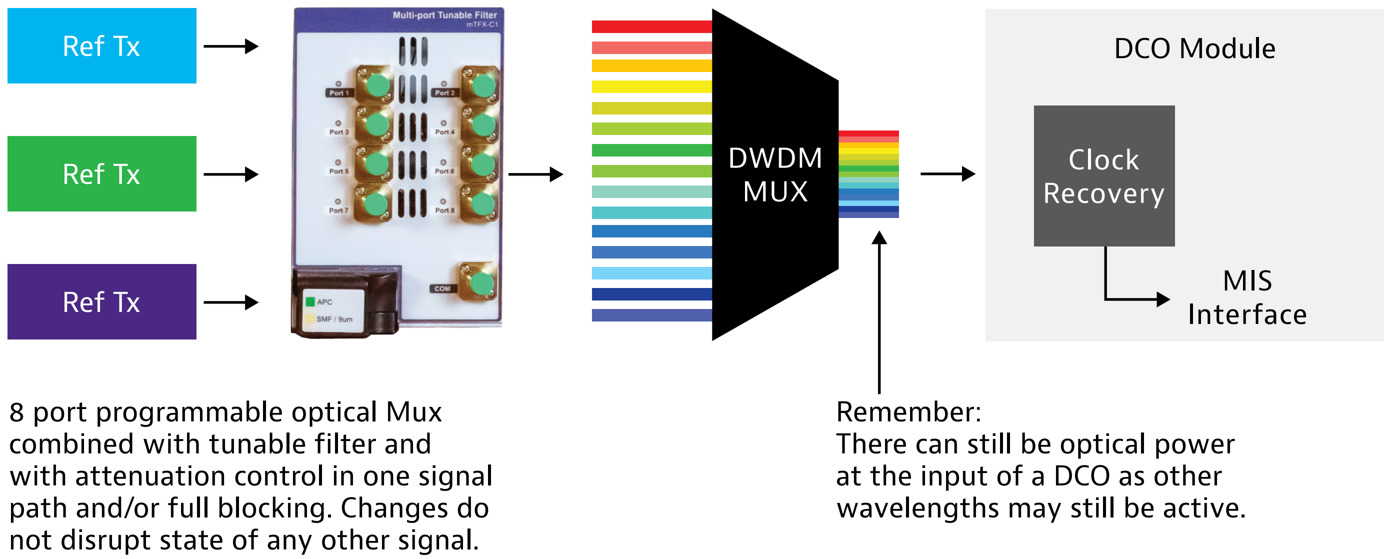

Figure 17 – Service disruption in a DWDM environment using MAP-300 Tunable Filter (mTFX)

The system relies on the module correctly tracking the one carrier selected and monitoring its optical power level so when the service disruption, loss of signal (LOS) level is reached the module indicates this correctly via the MIS interface. During this test, the module may also be required to mute the host interface and signal this over the MIS. The recovery process is a demanding test because the module must correctly re-acquire the re-asserted optical carrier and bring up the coherent RX signal chain, signal the host the link is recovering and also correctly set up the host-to-module electrical interface. The order and timing of these events is critical as well as the stability of this process. The VIAVI ONT provides an ideal test environment for validating and debugging the DCO module aspects of this test.

System validation also requires deep testing of the live traffic carried across the link and through the module. In many cases this will be multi-service traffic such as OTN as well as Ethernet. The capabilities of OTN offer end-users great flexibility but it does impose a more demanding test requirement. The VIAVI ONT supports full capability OTN including FlexO, FOIC 1.2, FOIC 2.4 and FOIC 4.8 which are critical for 400G class OTN services.

VIAVI ONT 800G

The latest member the industry reference ONT family is optimized for the needs of the coherent module ecosystem. Supporting both QSFP-DD and CFP2 DCO 400G form factors matched with the cooling and power needs and coupled with a host of applications that offer complete test and measurement coverage for the complete module lifecycle. From the deep dive needs of R&D to the breadth and depth of SVT and integration, the ONT DCO helps accelerate all aspects of development and debugging.

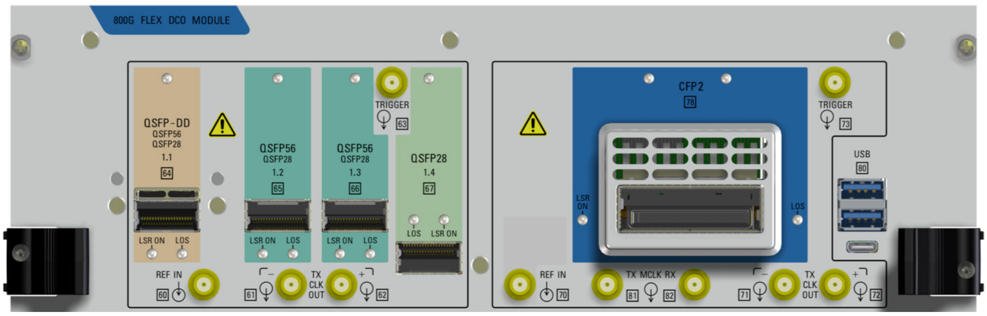

Figure 18 – ONT 800G DCO module

VIAVI MAP-300

Summary

Pluggable coherent optics promise to bring the benefits of pluggable client optics to a whole new range of applications including Metro, DCI and DWDM/Transport. The greater complexity of coherent modules places large demands on all stages of test and validation, from the early component validation through module development, S/W and F/W development, module validation, system integration and production. All of this must be met against a background of aggressive price expectations and time-to-market. This is further compounded by the increased complexity of the module command and management interface.

VIAVI has many years' experience in supporting the development and validation of coherent systems, from the full feature line cards used in the highest performance DWDM through to the emerging DCO modules used today at 100G and 200G. The challenges of 400G class DCO combined with PAM-4 electrical host signalling, new more advanced module management protocols and the new OTN services require a comprehensive and integrated test and validation approach. The tight orchestration between the module DSP, host interface, optical domain and management interface require applications and test tools that are fully integrated in this respect and can track events in each domain

The ONT DCO has been optimized for the test and validation needs through the product lifecycle and supports the challenging environmental and cooling requirements of coherent modules blended with applications that cover the needs of the physical layer (PAM-4) through the stack to multi-services Ethernet and OTN with unique tools that support the interaction over the module management and command interface.

By Paul Brooks, VIAVI Solutions

VIAVI Solutions

Contact Us **+1 844 GO VIAVI**
(+1 844 468 4284)

To reach the VIAVI office nearest you,
visit viavisolutions.com/contact

Testplug-coherent-optics-wp-opt-nse-ae
30191258 901 0820