V1.0

# Co-packaged Optics External Laser Source Guidance Document

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# 1. Introduction

## 1.1 Scope

This document provides guidance on the requirements for an external laser source designed for network equipment applications using co-packaged optics.

## 1.2 Introduction

The CPO JDF plans to release three documents to provide guidance to vendors pursuing different elements of Co-Packaged Optics (CPO) including the optical module, the External Light Source (ELS) module, and the CPO assembly.

This document is for the ELS module. This first revision is intended to facilitate a structured conversation about the ELS module. This document will be revised as input are collected from vendors.

## 1.3 Common Terms

The following terms and acronyms are used in this document.

- CPO – Co-Packaged Optics
- CW – Continuous Wave
- 400GE – 400 Gigabit Ethernet
- 400G FR4 – 400GE optical standard utilizing 4 wavelengths on a 1310nm CWDM grid with each wavelength transmitting 100Gb/s using 56Gb/s PAM4 modulation
- 400G DR4 – 400GE optical standard utilizing ribbon fiber with 4x100Gb/s transmit and 4x100Gb/s receive lanes/fibers. 1310nm is used for all lanes
- QSFP-DD –Quad Small Form-factor Pluggable Double Density used for 400GE
- OSFP – Octal Small Form Factor Pluggable
- CMIS – Common Management Interface Specification
- ESD – Electro-Static Discharge
- ELS – External Laser Source used as a CW light source for the co-packaged optical module
- OBO – On Board Optic
- COR – Clear on Read
- OPT - Optional
- RO – Read-Only
- RQD – Required
- RW – Readable and Writable

## 1.4 References

The following specifications are referenced in this document.

- IEEE Std. 802.3bs – Media Access Control Parameters, Physical Layers and Management Parameters for 200 Gb/s and 400 Gb/s Operation
- IEEE Std. 802.3cu – Media Access Control Parameters, Physical Layers and Management Parameters for 100 Gb/s and 400 Gb/s Operation over SMF at 100Gb/s (currently in draft)
- CMIS revision 4.0 – Common Management Interface specification
- COBO 8-lane and 16-lane On-board Optical specification release 1.1.
- OSFP Octal Small Form Factor Pluggable Module Specification Rev 2.0
- IEC 60825-1, Edition 3.0 Safety of laser products - Part 1: Equipment classification and requirements
- IEC 60825-2, Edition 3.2 Safety of laser products – Part 2: Safety of optical fibre communication systems (OFCS)

## 2. Absolute Maximum Ratings

The values in Table 1 below are for guidance and discussion and subject to change.

| Parameter | Symbol | Min | Typical | Max | Unit | Note |
|---|---|---|---|---|---|---|
| Storage temperature | T_st | -40 | | 85 | °C | |
| Relative humidity, storage and transportation | RH | 5 | | 95 | % | Noncondensing |
| ESD, electrical PINs | ESD | -1 | | 1 | kV | Human body model |
| Power supply voltage | Vcc | -0.3 | | 3.6 | V | |

**Table 1: Absolute maximum ratings**

# 3. Operating Conditions

| Parameter | Symbol | Min | Typical | Max | Unit | Note |
|---|---|---|---|---|---|---|
| Power supply voltage | Vcc1 | 3.14 | 3.3 | 3.47 | V | |
| Operating case temperature | Tcase | 20 | | 70 | °C | |
| Power consumption | P | | | 15 | W | With QSFP-DD form factor |
| | | | | 20 | W | With OSFP or other pluggable form factor |
| | | | | 20 | W | With 8x OBO form factor |
| | | | | 40 | W | With 16x OBO form factor |
| Power consumption in Low Power Mode | P_lpm | | | 1.5 | W | |
| Steady state current | Icc | | | 5 | A | For max 15W power consumption |
| | | | | 6.5 | A | For max 20W power consumption |
| | | | | 13 | A | For max 40W power consumption |
| In-rush, instantaneous peak current | I_peak | | | Icc max +30% | A | Peak inrush current for the supply rail |
| Relative humidity | RH | 5 | | 85 | % | Non-condensing |

**Table 2: Operating conditions**

# 4. Optical Requirements

## 4.1 Background

An example of a CPO assembly with an ELS module is illustrated in Figure 1. The CPO assembly consists of a high-density organic substrate, switch IC and 8x optical modules arrayed around the switch IC. Each optical module in Figure 2 has three fiber arrays: one for Tx function, one for Rx function and one to connect to the ELS module.

ELS modules will consist of a high-power laser array providing a Continuous Wave (CW) light source to support CPO modules with different optical specifications. The most common optical standards for first-generation CPO modules will be 400Gb/s as described in as described in IEEE 400GBASE-DR4 (IEEE 802.3bs, clause 124) and 400GBASE-FR4 (IEEE 802.3cu, in draft).

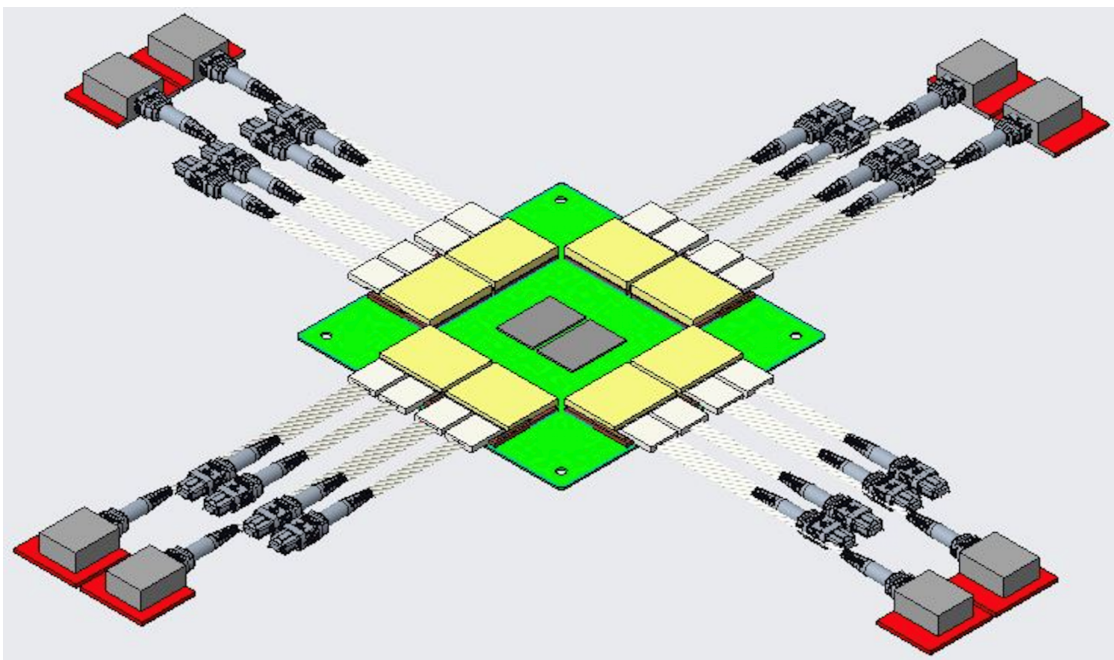

**Figure 1: Example embodiment of a 51Tb/s CPO assembly with OBO ELS modules**

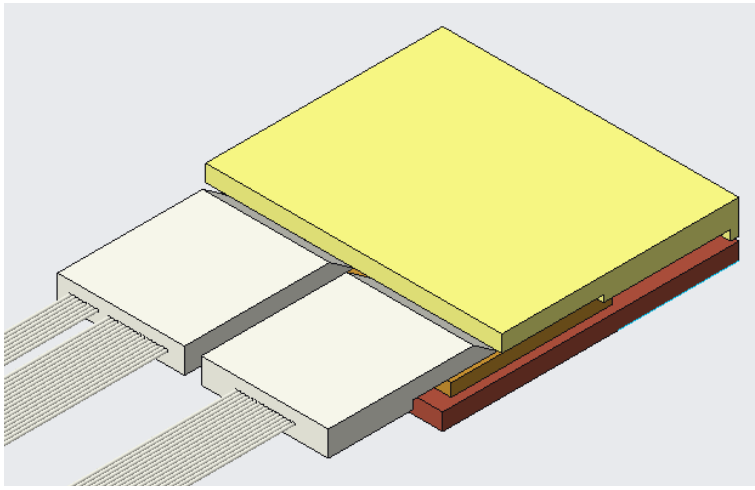

Figure 2: Example of an optical module for CPO applications

## 4.2 Optical Specification

### 4.2.1 Number of Optical Lanes

Each laser of the ELS module will provide CW light to the optical module using optical fiber. The power from a laser can be split to multiple optical channels within the optical module. The total number of lasers and fibers depends on application, number of optical modules and optical power of each laser. For example, a CPO assembly with 8x6.4Tb/s optical modules using 400GBASE-FR4, each optical module requires four lasers at four wavelengths and four fibers if each laser can support 16x 100Gb/s lanes (see Figure 3), or eight lasers (two for each wavelength) and eight fibers, if each laser can support 8x 100Gb/s lanes. Figure 4 shows an example of 3.2Tb/s optical module using 400GBASE-DR4 configuration where one optical module requires one ELS module with two lasers at the same wavelength. Each laser supports 16x 100Gb/s lanes.

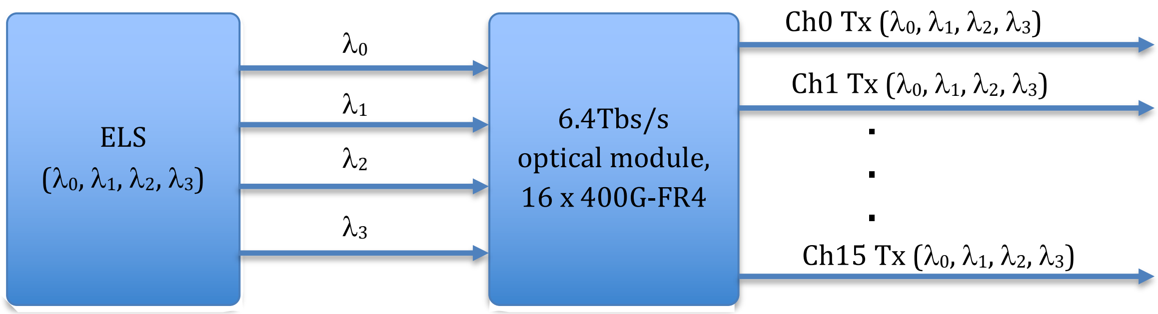


**Figure 3: Example of ELS for 6.4Tb/s, 400GBASE-FR4 optical module**

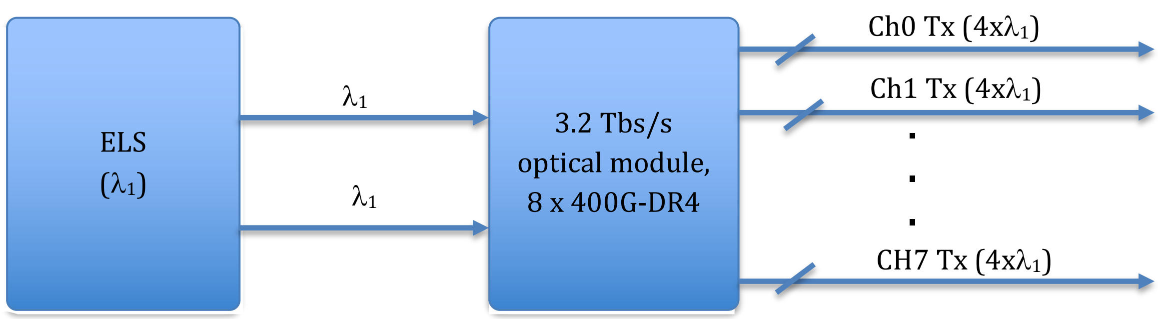


**Figure 4: Example of 3.2 Tb/s, 400GBASE-DR4 optical module**

### 4.2.2 Specifications for 400GBASE-FR4 Application

Specification of an ELS module to support CPO's 400GBASE-FR4 application is shown in Table 3.

| Description | Value | Unit | Note |
|---|---|---|---|
| Lane wavelength | | | Ref: IEEE 802.3cu |
| Side-mode suppression ratio (SMSR) (min) | | | Ref: IEEE 802.3cu |
| Average launch power, each lane (max) | 27 | dBm | See section 4.2.4 |
| Average launch power, each lane (min) | 23 | dBm | Expected min power accepted in order to minimize input fiber quantity |
| Average launch power of OFF transmitter, each lane (max) | -15 | dBm | |
| RINc (max) | -141.5 | dB/Hz | Note 1 |
| Note:<br>1. RINc can be calculated from measured RIN_OMA. RIN_OMA can be measured using method in IEEE 802.3ae with 17.1dB reflection coefficient. | | | |

**Table 3: ELS characteristics for FR4 applications**

### 4.2.3 Specification for 400GBASE-DR4 Application

Specification of ELS module to support CPO's 400GBASE-DR4 application is shown in Table 4.

| Description | Value | Unit | Note |
|---|---|---|---|
| Lane wavelength (range) | | | Ref: IEEE 802.3bs |
| Side-mode suppression ratio (SMSR) (min) | | | Ref: IEEE 802.3bs |
| Average launch power, each lane (max) | 27 | dBm | See section 4.2.4 |
| Average launch power, each lane (min) | 23 | dBm | Expected min power accepted in order to minimize input fiber quantity |
| Average launch power of OFF transmitter, each lane (max) | -15 | dBm | |
| RINc (max) | -141.5 | dB/Hz | Note 1 |

Note:

1. RINc can be calculated from measured RIN_OMA. RIN_OMA can be measured using method in IEEE 802.3ae with 17.1dB reflection coefficient.

**Table 4: ELS characteristics for DR4 applications**

### 4.2.4 Laser Safety Limit Consideration

To reduce the number of lasers needed, it is desired to have the output power for each laser in the range of +23 to +27dBm. The laser eye safety implications of such power levels need further study and input from industry. The applicable safety standards, IEC 60825-1 edition 3.0 (2014) and IEC 60825-2 edition 3.2 (2010) do not currently align in 1250nm-1400nm range. It is not clear when IEC 60825-2 will release a new amendment and whether it will adopt the recent change in the IEC 60825-1 specification.

Laser safety protection mechanisms can be implemented for the ELS module such as auto-laser-shutdown scheme when the fiber connector is detected to be unterminated. The JDF is interested in practical proposal for ELS module shutdown technique from vendors to promote laser safety. The factors for design should include both DR4 and FR4 applications, power of each wavelength, number of fibers, connector type, fiber separation and arrangement.

# 5. Mechanical Design Considerations

## 5.1 Form factor

The ELS module will provide CW light to the CPO module though external optical fibers. It should be serviceable in the case of a laser failure. There are three design options for the ELS module. The first option is a standard pluggable module to be used on the switch faceplate. An example of a CPO assembly with standard, pluggable form-factor is shown in Figure 5. QSFP-DD and OSFP are good candidates for a front-panel pluggable form factors as they are compact and can dissipate >15W of power. With such pluggable module design, the ELS can be powered up and managed though any QSFP-DD or OSFP port. There is potential laser safety concern with this approach when the laser power is accessible on the switch front panel. Special shuttered ports might be required.

The second option is a customized pluggable module to improve laser safety protection. The ELS module is also installed the switch faceplate. However, there is only a pull-tab at the front of the module. Both electrical and optical connections are on the back side of the module. The JDF is interested in proposals for a pluggable ELS with a back-side optical connector.

The third option is an OBO module on the main switch PCBA. An example of a CPO assembly with OBO ELS modules on the switch PCBA is illustrated in Figure 6. The OBO form-factors defined in the COBO specification for 8x OBO and 16x OBO are well-defined candidates.

This guidance document does not intend to define a fixed form factor for the ELS module. The vendor would consider several factors for the design for example serviceability, number of lasers, optical connector and power dissipation, laser safety. The JDF welcomes input on the form factor definition for an ELS module.

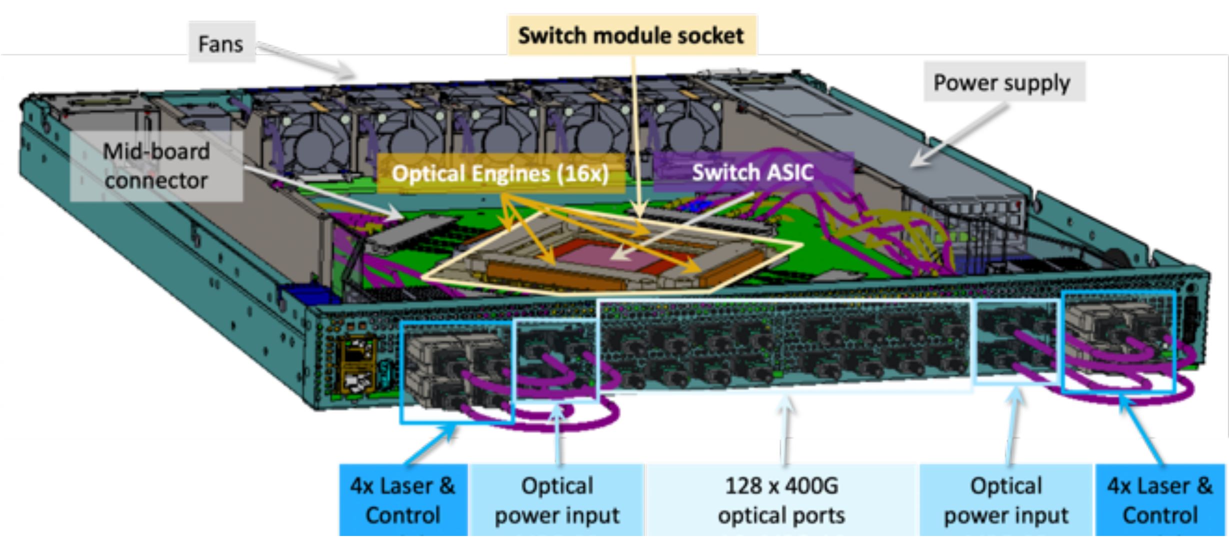


**Figure 5: Example of CPO assembly with pluggable ELS module on the switch faceplate (courtesy of Rockley Photonics)**

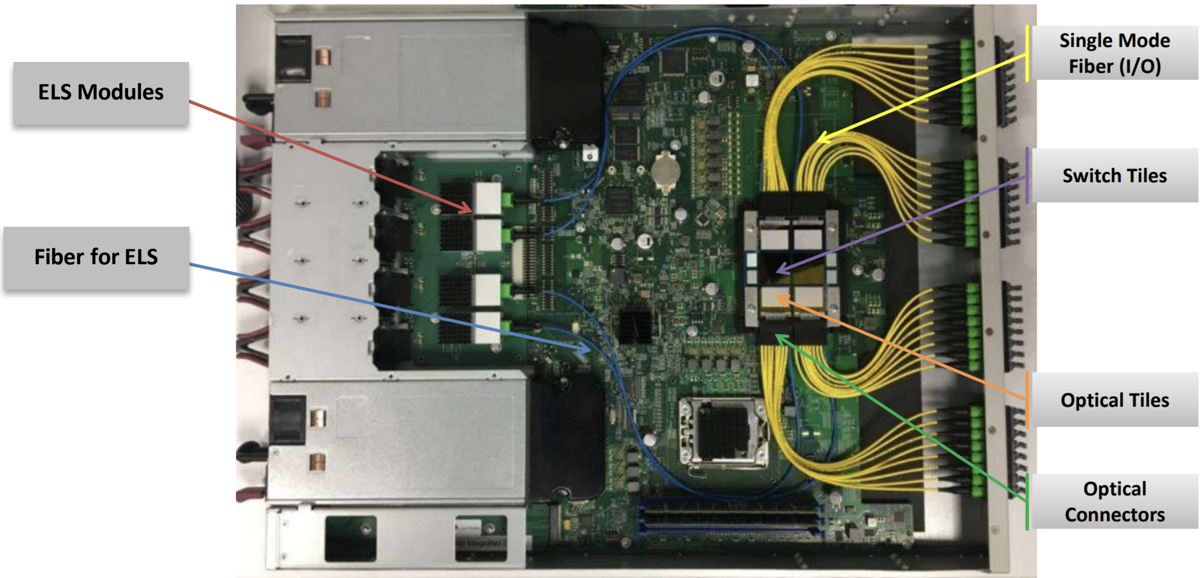


**Figure 6: Example of CPO assembly with pluggable ELS module on the switch PCBA (courtesy of Cisco)**

## 5.2 Optical Connection to the Optical Module

Depending on design, applications and output power, each optical module requires at least one fiber for each wavelength to connect to the ELS module. For some CPO optical modules, PM fiber will be required. With multiple lasers in one ELS module, the ELS module may have a pigtailed fiber assembly or an integrated, high-density, optical connector such as MPO. If one ELS module provides CW signal for multiple optical modules, a fiber breakout scheme may need to be developed. The JDF looks forward to proposals from vendors for optical connection schemes.

## 5.3 Thermal Considerations

If a standard QSFP-DD/OSFP form factor or another customized pluggable form factor is used, the host cooling system should support 15 to 20W power dissipation. For OBO designs, the ELS module can incorporate an integrated heatsink on the top surface. The JDF looks forward to proposals for power dissipation and heatsink designs for OBO designs.

# 6. Electrical Specifications

The module should contain relevant circuitry for controlling and monitoring each laser channel as shown in Figure 7. The voltage supplied should be +3.3V. Each laser channel should include circuitry to individually enable each laser and obtain the laser's bias current ($I_{LD}$), bias voltage ($V_{LD}$), and output optical power ($P_O$).

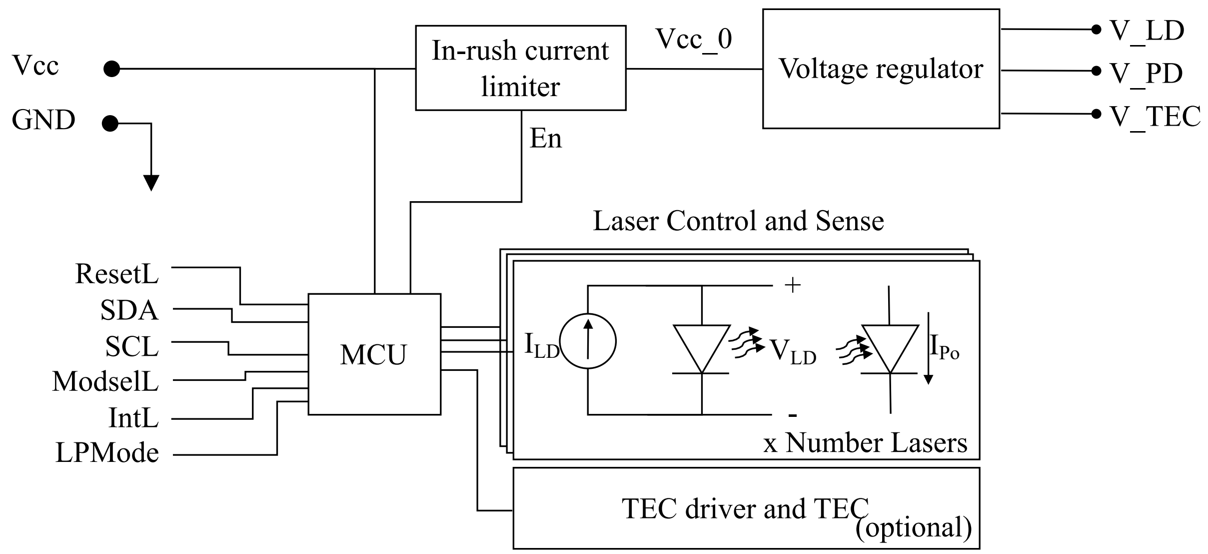


Figure 7: Electrical block diagram of an ELS module

## 6.1 Low Speed Pins and Signaling

Low speed pins should follow the layout and timing requirements of the hardware form factor used. Low speed pins supported should include Vcc, GND, IntL, ModPrsL, LPMode, ResetL, ModselL, SCL and SDA. Signaling should follow the I2C standard supporting speeds up to 400 kHz.

## 6.2 Low Power Mode or Power Shutdown

In some use cases, not all of the optical lanes of an ELS module will be used. Ideally, these unused lanes could be shut down independently such that they consume no power. The maximum launched optical power for each shut-down lane can be found in Table 3 and Table 4 for FR4 and DR4 applications respectively.

When the ELS module is in low power mode, all the lasers should be shut down. Max power consumption of the ELS module in low power mode is provided in Table 2.

# 7. Management Interface

The management interface for the ELS module uses the QSFP-DD CMIS and communicates over a two-wire interface. This includes the read/write operations over the I2C interface. The CPO JDF welcomes proposals for the management interface including low speed pins, signaling and memory map and operation. A proposal is made in the following sections.

## 7.1 Memory Map

The management interface for the ELS module shall implement the customized memory map as described below. The entire memory map fits within 256 bytes, and thus compared to more complicated optical transceivers can be implemented in a flat memory map.

The memory map is suitable for up to 16 lasers. If a module implements fewer lasers, unused fields should remain read-only and equal to 0. Lasers should be identified by laser ID. An example of laser ID for FR4 application using eight lasers is shown in Table 5. Output fiber lane assignment should match the laser ID.

| Laser ID | Wavelength (nm) |
|---|---|
| 0 | 1271 |
| 1 | 1291 |
| 2 | 1311 |
| 3 | 1331 |
| 4 | 1271 |
| 5 | 1291 |
| 6 | 1311 |
| 7 | 1331 |

**Table 5: Example laser numbering for a 2-channel CWDM4 module**

For fields which occupy two bytes, the lower address refers to the MSB and the higher address refers to the LSB. See Table 6 for details.

| Address | Bit | Name | Description | Type |
|---|---|---|---|---|
| 0 | All | Identifier | Identifier - Type of Serial Module – Definition TBD | RO, RQD |
| 1 | All | Revision | Management interface revision; the upper nibble is the whole number part and the lower nibble is the decimal part. Example: 01h indicates version 0.1, 21h indicates version 2.1. | RO, RQD |
| 2 | 7-5 | Reserved | | RO, RQD |
| | 4 | Laser Grid | Laser wavelength grid.<br>0 = CWDM4<br>1 = DR4 | RO, RQD |
| | 3-0 | Laser Count | Number of lasers implemented in module minus 1 (0 = 1 laser, 15 = 16 lasers) | RO, RQD |
| 3 | 7-2 | Reserved | | RO, RQD |
| | 1 | Module State | Module state<br>0 = High power mode<br>1 = Low power mode | RO, RQD |
| | 0 | Interrupt | Digital state of interrupt output signal | RO, RQD |
| 4 | 7-1 | Reserved | | RO, RQD |
| | 0 | Module Low Power | Module low power. Module will be in high power either LPMode pin or Module low power bit are set to high power mode<br>0 = High power mode<br>1 = Low power mode (default) | RW, RQD |
| 5 | All | Laser Disable | Sets which lasers will be disabled in high power mode. Disabling or enabling a laser while in high power mode will take effect immediately.<br>0 = Enable (default)<br>1 = Disable<br>Bits 7-0 correspond to lasers 7-0, respectively | RW, RQD |
| 6 | All | Laser Disable | Same as above.<br>Bits 7-0 correspond to lasers 15-8, respectively | RW, RQD |
| 7 | All | Laser Active | Reports which lasers are initialized and active.<br>0 = Inactive (default)<br>1 = Active<br>Bits 7-0 correspond to lasers 7-0, respectively | RO, RQD |
| 8 | All | Laser Active | Same as above.<br>Bits 7-0 correspond to lasers 15-8, respectively | RO, RQD |
| 9 | 7 | Vcc Low Warning | Latched low Vcc warning flag. Clear on read | COR, RQD |

| Address | Bit | Name | Description | Type |
|---|---|---|---|---|
| | 6 | Vcc High Warning | Latched high Vcc warning flag. Clear on read | COR, RQD |
| | 5 | Vcc Low Alarm | Latched low Vcc alarm flag. Clear on read | COR, RQD |
| | 4 | Vcc High Alarm | Latched high Vcc alarm flag. Clear on read | COR, RQD |
| | 3 | Temp Low Warning | Latched low temperature warning flag. Clear on read | COR, RQD |
| | 2 | Temp High Warning | Latched high temperature warning flag. Clear on read | COR, RQD |
| | 1 | Temp Low Alarm | Latched low temperature alarm flag. Clear on read | COR, RQD |
| | 0 | Temp High Alarm | Latched high temperature alarm flag. Clear on read | COR, RQD |
| 10 | All | Laser Bias Warning | Latched laser warning alarm. Clear on read.<br>Bits 7-0 correspond to lasers 7-0, respectively | COR, RQD |
| 11 | All | Laser Bias Warning | Same as above.<br>Bits 7-0 correspond to lasers 15-8, respectively | COR, RQD |
| 12 | All | Laser Bias Alarm | Latched laser bias alarm. Clear on read.<br>Bits 7-0 correspond to lasers 7-0, respectively | COR, RQD |
| 13 | All | Laser Bias Alarm | Same as above.<br>Bits 7-0 correspond to lasers 15-8, respectively | COR, RQD |
| 14-21 | All | Reserved | | RO, RQD |
| 22-23 | All | Module Temp MSB | Internally measured temperature: signed 2's complement in 1/256 degree Celsius increments. | RO, RQD |
| 24-25 | All | Module Supply 3.3V | Internally measured 3.3 Volt input supply voltage in 100μV increments | RO, RQD |
| 26-27 | All | Laser 0 Current | Internally measured laser bias current monitor. Unsigned integer in 10μA increments. | RO, RQD |
| 28-57 | All | Lasers 1-15 Current | Same as above. | RO, RQD |
| 58 | All | Laser Voltage | Internally measured laser bias voltage monitor. Unsigned integer in 10μV increments. | RO, RQD |
| 59-74 | All | Lasers 1-15 Voltage | Same as above. | RO, RQD |

| Address | Bit | Name | Description | Type |
|---|---|---|---|---|
| 75-76 | All | Laser 0 Optical Power | Internally measured laser optical power monitor. Unsigned integer in 10µW increments. | RO, RQD |
| 77-106 | All | Lasers 1-15 Optical Power | Same as above. | RO, RQD |
| 122-123 | All | TEC Current | TEC current monitor signed 2's complement number in 1/32767% increments<br>+32767 is max TEC current (100%) - Max heating<br>-32767 is min TEC current (100%) - Max cooling | RO, OPT |
| 124-127 | All | Reserved | | RO, RQD |
| 129-144 | All | Vendor Name | Vendor name (ASCII) | RO, RQD |
| 145-147 | All | Vendor OUI | Vendor IEEE company ID | RO, RQD |
| 148-163 | All | Vendor PN | Vendor part number (ASCII) | RO, RQD |
| 164-165 | All | Vendor Rev | Vendor revision number (ASCII) | RO, RQD |
| 166-181 | All | Vendor SN | Vendor serial number (ASCII) | RO, RQD |
| 182-183 | All | Date Code Year | Date code year (ASCII). Two lower order digits of year (00 = 2000) | RO, RQD |
| 184-185 | All | Date Code Month | Date code month (ASCII). (01 = Jan. 12=Dec) | RO, RQD |
| 186-187 | All | Date Code Day of Month | Date code day of month (ASCII) (01-31) | RO, RQD |
| 188-189 | All | Lot Code | Custom lot code (ASCII), may be blank | RO, OPT |
| 190-199 | All | CLEI Code | Common Language Equipment Identification (CLEI) code (ASCII) | RO, OPT |
| 200 | All | Max Power | Maximum worst case power consumption in increments of 0.25W | RO, RQD |
| 201-255 | All | Reserved | | RO, RQD |

**Table 6: Memory map for ELS module**

## 7.2 Module Operation

The ELS module shall adhere to the behaviors described by the Module State Machine for modules with a flat memory map in the latest CMIS documents.

## 8. Environmental Conditions

The values in Table 7 below are for general guidance and discussion and subject to change.

| Parameter | Symbol | Min | Typical | Max | Unit | Note |
|---|---|---|---|---|---|---|
| Altitude, during operation, to sea level | | -50 | | 1800 | m | |
| Acoustic, during operation | | 55 | | | dBA | |
| Vibration, during operation | | | | TBD | | Note1 |
| Altitude, storage, to sea level | | | | 5 | km | |
| Altitude, transportation, to sea level | | | | 12 | km | |
| Gaseous contamination | | | | | | Note2 |
| Note:<br>1. Refer to IEC 68-2-36, IEC 68-2-6<br>2. Conform to Severity Level G1 per ANSI/ISA 71.04-1985. | | | | | | |

**Table 7: Environmental conditions**

# 9. Quality and Reliability

Detailed quality and reliability requirements will be tailored by customer and program. High-level guidance for ELS's used in CPO applications is provided below.

## 9.1 Environmental Stress Testing

As described in Telcordia GR-468-CORE section 4.2 for Integrated Modules.

## 9.2 Service Life

Maximum service life will vary between five and seven years. Over the service life, the maximum failure rate below applies.

## 9.3 Failure Rate

The exact FIT rate required for the ELS module will vary depending on the specific implementation. It must be low enough to ensure the end user's Annual Failure Rate (AFR) targets for the finished network equipment. The JDF is interested in vendor's perspectives on what FIT rates could be achieved for CPO ELS's and working together to ensure system AFR targets can be achieved.

Laser redundancy can be used to improve the reliability of the ELS module and overall network equipment. In this design, a secondary laser is called into service when the first laser fails. The JDF welcomes design proposals for redundancy including architecture, switching mechanism and switching time.

# 10. Revision History

The revision history of this document is captured in Table 8 below.

| Revision | Date | Description of Changes |
|---|---|---|
| 1.0 | TBD | Initial release |
| | | |
| | | |
| | | |

***Table 8: Revision history***