Self-Tuning Optics Interoperability Specification

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Acting Editor:

Ernest Muhigana
Lumentum
ernest.muhigana@lumentum.com

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Revision History		
Revision	**Date:**	**Notes**
1.0	March 2, 2022	First public release
2.0	March 2, 2024	2nd public release with addition of 25G operation Updated Figures for Clarity Indicating that Timer T3 should be configurable

Self-Tuning Optics Interoperability

Self-Tuning Specification

1 Introduction

DWDM (Dense Wavelength Division Multiplexing) systems and tunable transceivers are widely deployed in the Access aggregation and Metro transport networks of today. Among other things, such networks require the host equipment together with the network operator to accurately provision the laser transmit channels (frequency or wavelength). The present document defines an interoperable Self-Tuning Specification that will automatically set the laser transmit channels in a passive or un-amplified DWDM optical link. The management of Self Tuning SFP+ (10G) and SFP28 (25G) transceivers, as described in this document, is fully compliant to the SNIA SFF-8690 and SFF-8472 specification.

The mechanisms described here involves a (local) transceiver that is sequentially scanning through all its transmitter frequency range. In this scanning state, on/off messages are exchanged between the (local) transceiver and a remote transceiver. In a DWDM network, only the laser signal (and associated channel number) allowed through the multiplexer port will traverse the network. Hence, the receiver connected to the corresponding (de)multiplexer port, will receive its own unique message and the received encoded laser channel in the message will be echoed in the (outgoing) transmit messages as the (remote) transmitter is also sequentially scanning through all its transmitter frequency range. When transceivers on both sides of the link receive messages that includes both transmit and receive frequencies, the self-tuning session is declared complete and both transceivers have then successfully tuned to the frequencies allowed through the DWDM filters.

It is important to highlight that transceivers at either end of the link do not need to have the same channel plan or channel encoding numbers as denoted by the transceivers' defined first and last laser frequency (SFF-8690). Such configuration, although not optimum in performance, enhances the interoperability between transceivers.

2 Scope

As indicated above this document defines requirements for interoperability of passive filter based DWDM topologies using tunable optical transceivers over the full C-Band wavelength range. The document currently applies to both 10 and 25Gb/s tunable transceivers at a frequency specified in the Recommendation ITU-T G.694.1 ITU-T standard.

Future revisions may include transceiver operating rates of 50 Gb/s and higher

The main purpose of the **Self Tuning Optics** specification is to:

- Specify the operational frequency range of the transceiver
- Specify the connection behavior
- Specify the packet information
- Specify timing and state machines
- Specify registers for host command control and monitoring.

3 References

- ITU-T G.694.1 ITU-T: Spectral grids for WDM applications: DWDM frequency grid
- SFF-8472 Management Interface for SFP+
- SFF-8690 Tunable SFP+ Memory Map for ITU Frequencies

4 General Architecture

4.1 Duplex Fiber Architecture

The architecture consists of an optical transceiver connected to an optical multiplexer for aggregating transmitters into one single mode fiber, an optical cable plant span, and demultiplexer for disaggregating the transmitter signals to separate receivers. For the connection in the other direction, a second optical transceiver is connected to an optical multiplexer for aggregating transmitters into a second single mode fiber, and a demultiplexer for disaggregating the transmitter signals to a separate receiver.

The basic architecture for duplex fiber is shown in Figure 4-1.

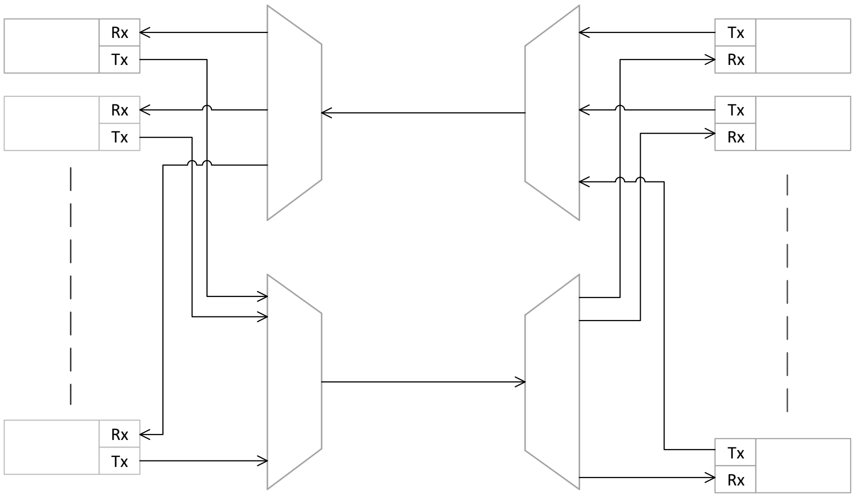

FIGURE 4-1 GENERAL DWDM DUPLEX FIBER ARCHITECTURE

4.2 Simplex Fiber architecture

The architecture consists of an optical transceiver connected to an optical multiplexer/demultiplexer for aggregating a transmitter and receiver to a single mode fiber, a cable plant and a second multiplexer/demultiplexer for disaggregating the receiver and transmitter of the second transceiver. The resulting bidirectional communication on a single fiber requires specific channel plan rules to be implemented.

The basic architecture for simplex fiber is shown in Figure 4-2.

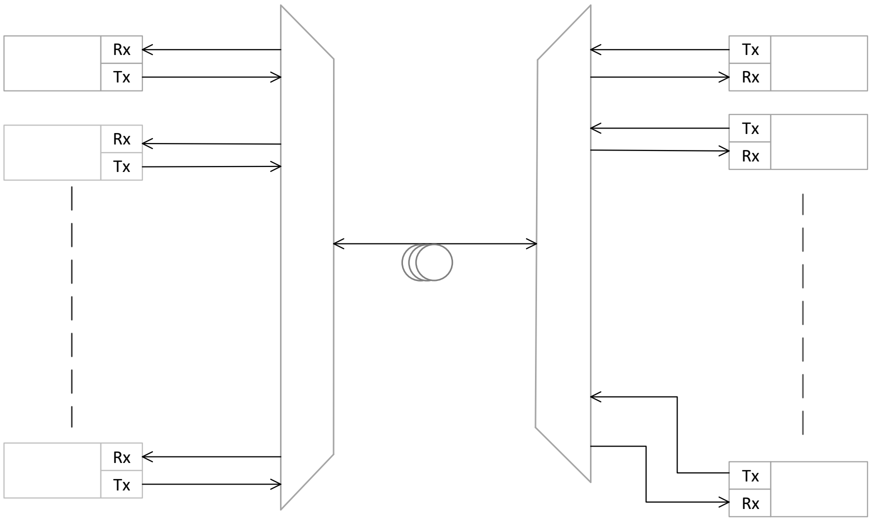

FIGURE 4-2 GENERAL DWDM SIMPLEX FIBER ARCHITECTURE

5 DWDM Channels

To support multi-vendor interoperability, modules compliant to this specification shall at a minimum, provide the 40 channels on 100 GHz spacing listed in Table 1. Detailed channel plans may be defined by network operators and may include a greater number than in Table 1. In those cases, modules at both ends of the link must comply with the customer specific channel plan. For 100 GHz spaced grids, an example set of filter characteristics for Mux & Demux is provided in subclause 11.

In the case of 10G transceivers, the same self-tuning procedure specified in this document could be used for a 50 GHz spaced grid if there are suitable channel filters. The definition of such filters is not in the scope of this specification.

TABLE 1 MINIMUM CHANNEL PLAN FOR STM MSA MODULES

ITU Channel (#)	Frequency (GHz)	Wavelength (nm)	ITU Channel (#)	Frequency (GHz)	Wavelength (nm)
21	192100	1560.61	41	194100	1544.53
22	192200	1559.79	42	194200	1543.73
23	192300	1558.98	43	194300	1542.94
24	192400	1558.17	44	194400	1542.14
25	192500	1557.36	45	194500	1541.35
26	192600	1556.56	46	194600	1540.56
27	192700	1555.75	47	194700	1539.77
28	192800	1554.94	48	194800	1538.98
29	192900	1554.13	49	194900	1538.19
30	193000	1553.33	50	195000	1537.4
31	193100	1552.52	51	195100	1536.61
32	193200	1551.72	52	195200	1535.82
33	193300	1550.92	53	195300	1535.04
34	193400	1550.12	54	195400	1534.25
35	193500	1549.32	55	195500	1533.47
36	193600	1548.52	56	195600	1532.68
37	193700	1547.72	57	195700	1531.9
38	193800	1546.92	58	195800	1531.12
39	193900	1546.12	59	195900	1530.33
40	194000	1545.32	60	196000	1529.55

6 Modulation and Frame Format

6.1 Modulation Format

The message exchange between transceivers is based on turning on and off the CW laser output signal and transmitting (Manchester coded) messages at a low frequency of 62.5 baud (31.25 b/s). Detection at the receive side is based on detecting the "presence" or "absence" of light (Loss-of-signal indicator, LOS specific to the self-tuning session). The LOS specification is covered in Table 8–1. The physical coding is Manchester as specified in Clause 7.3.1 of the IEEE 802.3 Ethernet standard.

6.2 Frame Format

The frame format is shown in Figure 6-1, and includes the following fields:

SOF: Start of Frame
MC: My Channel
YC: Your Channel
EOF: End of Frame

The transmission format is a Manchester encoded 16-bit frame structure. The values for each field are listed in Table 6–1.

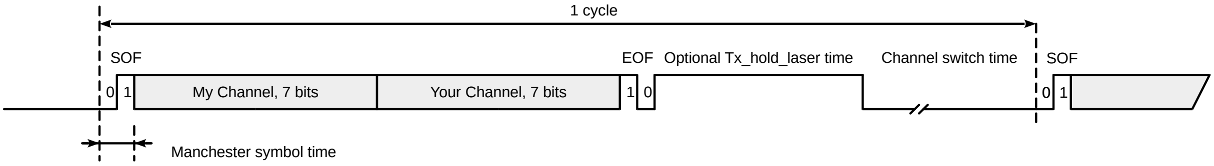

FIGURE 6-1 FRAME FORMAT

6.3 Frame Description

TABLE 6–1 FRAME DESCRIPTION

No	Field	Bits	Value(s)	Description
1	Start of Frame (SOF)	1	"1"	Start of frame bit
2	My Channel (MC)	7	7-bit unsigned integer value	7-bit local reference value representing current transmitted channel. Transmitted MSB to LSB [Tx_mc<6> to Tx_mc<0>].
3	Your Channel (YC)	7	7-bit unsigned integer value	7-bit reference value contained in the receive message from the other end of the link. Transmitted MSB to LSB [Tx_yc<6> to Tx_yc<0>].
4	End of Frame (EOF)	1	"0"	End of frame bit
5	Optional hold high		"1"	At the end of the frame, the transmitter may optionally set the transmitter high for a minimum time specified in Table 8–1. Receivers shall accept this optional "high period" and may ignore it.

7 Detailed functions and state diagrams

This section is composed of state diagrams, including the definitions of variables, functions and counters. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails.

The transmitter state machine and receiver state machine run independently and are implemented on both the near and far end transceivers. The Rx_LOS signal may be used for detection of light through the filters, and for the measurement of specific states at the receiver from the transmitter connected at the other end of the link.

7.1 State variables

7.1.1 Variables

Variable name	Description
Pwr_class_1	Boolean variable indicating that the module has level 1 maximum power dissipation (1.0 W max). This may be mapped to the SFF-8472 memory at A2h, byte 118, bit 1.
Hi_pwr_mode	Boolean variable that indicates the module has been enabled to operate at a power level higher than level 1. This may be mapped to SFF-8472 memory at A2h, byte 118, bit 0.
Tx_mc<6:0>	7-bit binary value corresponding to "my channel" for the transmitter.
Tx_yc<6:0>	7-bit binary value corresponding to "your channel" for the transmitter.
Rx_mc<6:0>	7-bit binary value corresponding to "my channel" for the receiver.
Rx_yc<6:0>	7-bit binary value corresponding to "your channel" for the receiver.
Tx_mc_max	7-bit binary value equal to the maximum number of channels supported by the transmitter.
Rx_los	Boolean variable that indicates the optical signal at the receiver input is below the threshold defined for "loss of signal" for the module.
Timeout_t1	Boolean variable indicating that the t1_count has reached its limit value.
Timeout_t2	Boolean variable indicating that the t2_count has reached its limit value.
Timeout_t3	Boolean variable indicating that the t3_count has reached its limit value.
UCT	Unconditional transition.

7.1.2 Functions

Function name	Description
Tune (tx_mc)	This function tunes the laser to the center frequency corresponding to the value of Tx_mc.
Send (tx_mc, tx_yc)	This function sends a Manchester encoded frame in the format of Figure 6-1, including SOF, Tx_mc, Tx_yc, and EOF.
Tx_hold_lsr	This function holds the Tx output high after transmitting a frame. As the hold value is optional for transmitters, the time of the hold can be either zero or a value within the limits given in Table 6–1.
Receive (x, y)	This function receives a Manchester encoded frame in the format of Figure 6-1, and extracts the 7-bit value in the "My channel" field as x, and the 7-bit value in the "Your channel" field as y.

7.1.3 Counters

Counter name	Description
t1_count	This counter counts the interval from when the Rx state machine receives a message with a non-zero value of Rx_mc and a zero value of Rx_yc until a message with a non-zero value of Rx_yc is received.
t2_count	This counter counts the interval from when the Rx state machine first receives a message with non-zero values of both Rx_mc and Rx_yc, until Rx_los is deasserted.
t3_count	This counter counts the time that Rx_los is asserted when the Rx state machine is in the RX_MISSION state.

7.2 State Diagrams

The state diagrams in Figure 7-1 illustrate the operational state changes for the self-tuning optics.

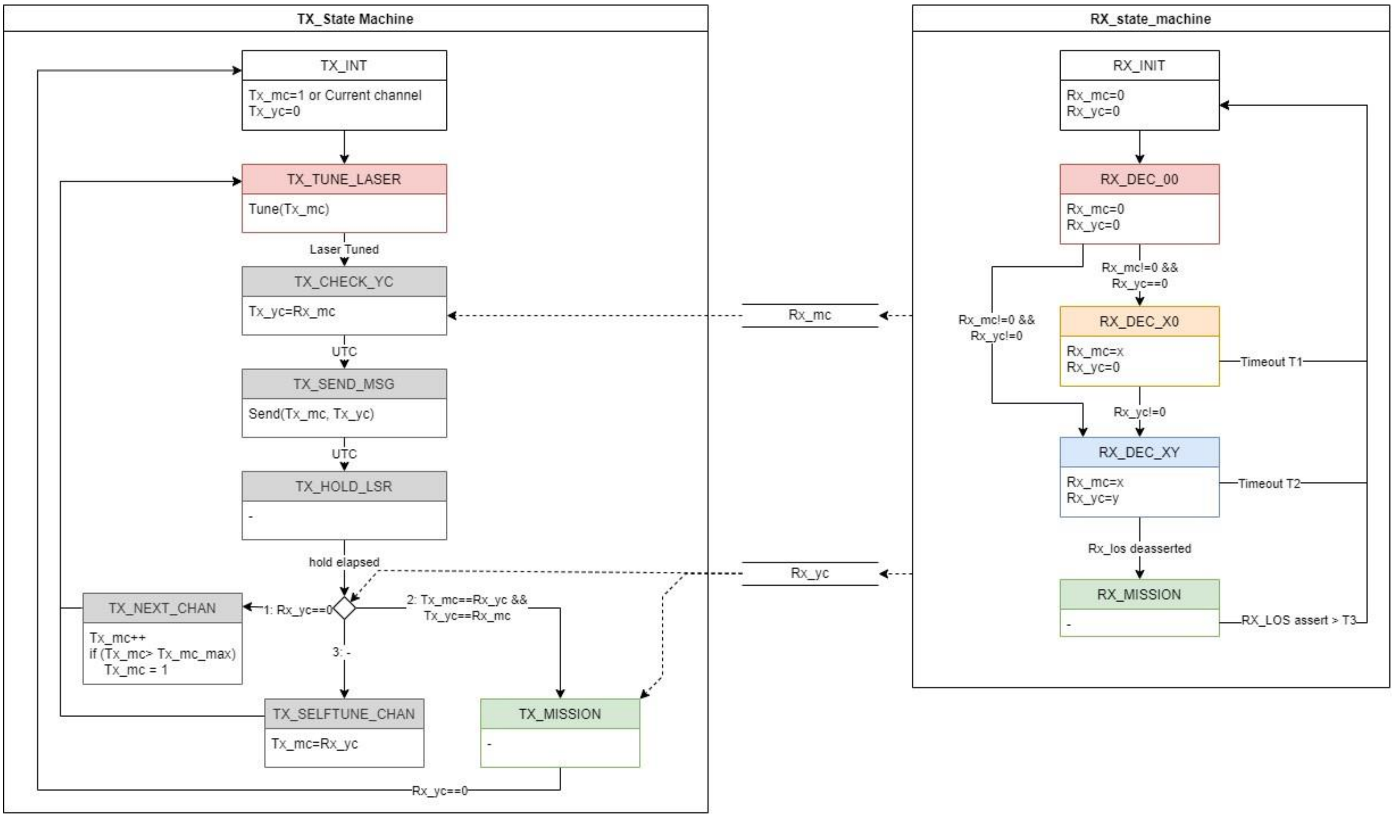

FIGURE 7-1 OPERATIONAL STATE DIAGRAMS

8 Timing Specifications

Table 8–1 outlines the timing requirements for self-tuning modules.

TABLE 8–1 TIMING SPECIFICATIONS

Parameter	Unit	Min	Typ	Max	Notes
Manchester symbol time	ms	30.4	32	33.6	
Bit Extinction Ratio	dB	20			10*log [(power of "1" in uW) / (power of "0" in uW)]
Optional Tx_hold_laser time	ms	96	160	160	If implemented, laser output is held at a "1" for a time within this range after each transmitted frame. If implemented the minimum shall be 3 bit periods. It is recommended to be 3,4,5 bit periods.
Channel switch time	ms	128		3200	Time after completion of frame to change laser channel and start transmission of next frame
T1 timeout	s	380	400	420	Rx wait time from receiving a non-zero Rx_mc with a zero Rx_yc to receiving a non-zero Rx_yc. This allows for transceivers with up to 100 channel capability.
T2 timeout	s	380	400	420	Rx wait time from receiving non-zero values for both Rx_mc and Rx_yc until Rx_los is deasserted. This allows for transceivers with up to 100 channel capability.
T3 timeout	s	1	60	180	Duration of Rx_LOS asserted while in the RX_MISSION state until the Rx state machine resets. The T3 timing should be configurable but there is currently no register defined for such purpose

9 Timing Diagram

The illustrative timing diagrams in Figure 9-1 and Figure 9-2 illustrate typical connection timing. In the case of Figure 9-2, a transmitter Tx1 and a second transmitter Tx2 are both sending message frames on sequential channels. The receiver of the first transceiver Rx1 is the first to receive a message, which is on channel 6. The first transmitter Tx1 then adds a value of 6 to the “YC” field of its message frames. Then the receiver of the second transmitter Rx2 receives a message on channel 5. The message also has a value of 6 in the YC field, so Tx2 now sends messages only on channel 6. The next message has MC=6 and YC=5, which is received by Rx1 and from then normal communication commences with Tx1 to Rx2 on channel 5, and with Tx2 to Rx1 on channel 6.

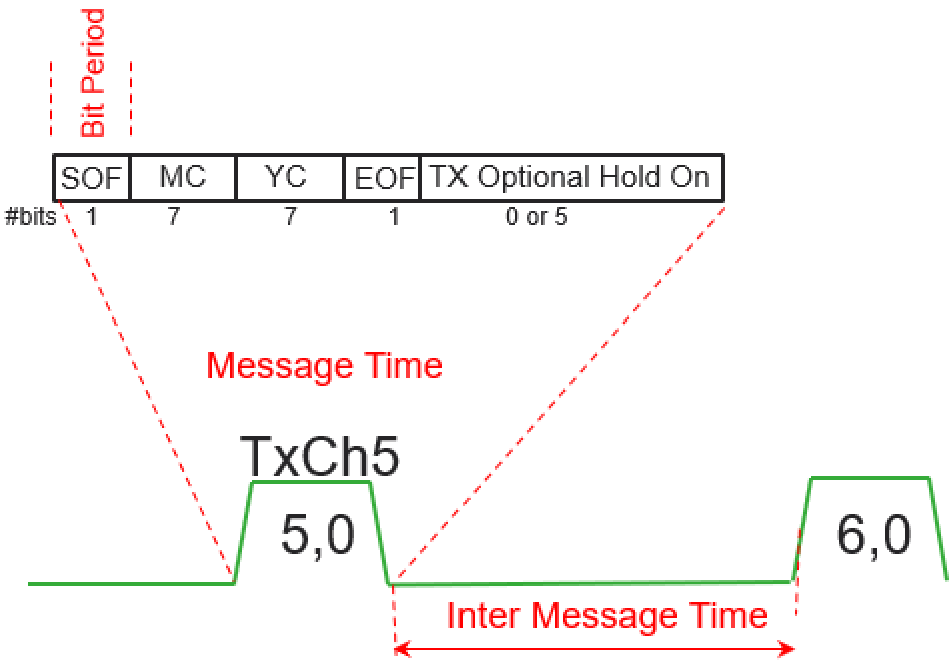

FIGURE 9-1

ILLUSTRATION OF MESSAGE AND INTER-MESSAGE TIMING

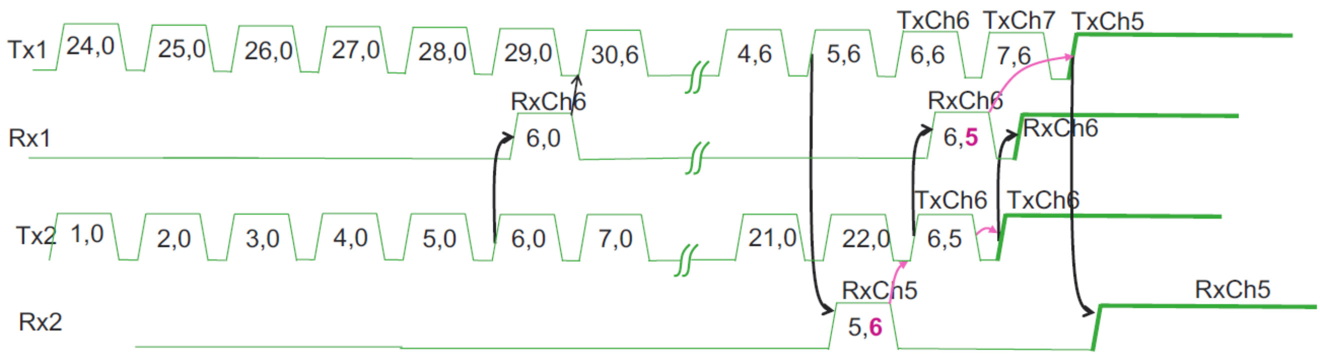

FIGURE 9-2 ILLUSTRATION OF MESSAGING INTERACTIONS BETWEEN TWO TRANSCEIVERS

10 Register Definitions

The bits listed in Table 10–1 are intended to support self-tuning operation in conjunction with transceiver module firmware. The bit locations are all in Page 02h of Device Address A2h and are in locations currently reserved by SFF-8472 and SFF-8690. Transceivers supporting the self-tuning specification will set a value of 1 in byte 128 bit 3, which will indicate that the self-tuning enable control (byte 151 bit 1) and the two self-tuning status bits (byte 168, bit 7, and byte 172, bit 7) are active.

TABLE 10–1 ADVERTISING, CONTROL AND STATUS BITS

Device Address	Page	Byte	Bit	Name	Description
A2h	02h	128	3	Self-tuning supported	1 = supported, 0 = not supported.
		151	1	Enable self-tuning	1 = enable (default). A2h page 02h bytes 144-147 are read only when this bit is set to a 1. 0 = disable self-tuning. Does not execute the state diagrams of Figure 7-1.
		168	7	Self-tuning current status	1 = tuning, 0 = locked.
		172	7	Self-tuning latched status	1 = tuning, 0 = locked.

11 Filter Characteristics (Informative)

The filter characteristics in Table 11–1 are guidance related to specific use cases for enabling self-tuning over a DWDM network with 100 GHz spaced filters. The values are provided as guidance for the necessary isolation between channels in order to ensure interoperability.

TABLE 11–1 INFORMATIVE CHARACTERISTICS FOR COMPONENTS IN SELF-TUNING DWDM SYSTEMS ON 100 GHZ GRID SPACING

Parameter	Units	Minimum	Typical	Maximum	Notes
Nominal Spacing	GHz	-	100	-	Transceiver channel count and spacing shall at a minimum align with filter specification for full loading of DWDM system
ITU Grid Accuracy	GHz	-3	ITU	+3	Maximum based on channel spacing and isolation.
1 dB Passband	GHz	+/-11	+/-15		Maximum based on channel spacing and isolation.
20dB Stopband	GHz	-35		35	Relative to ITU