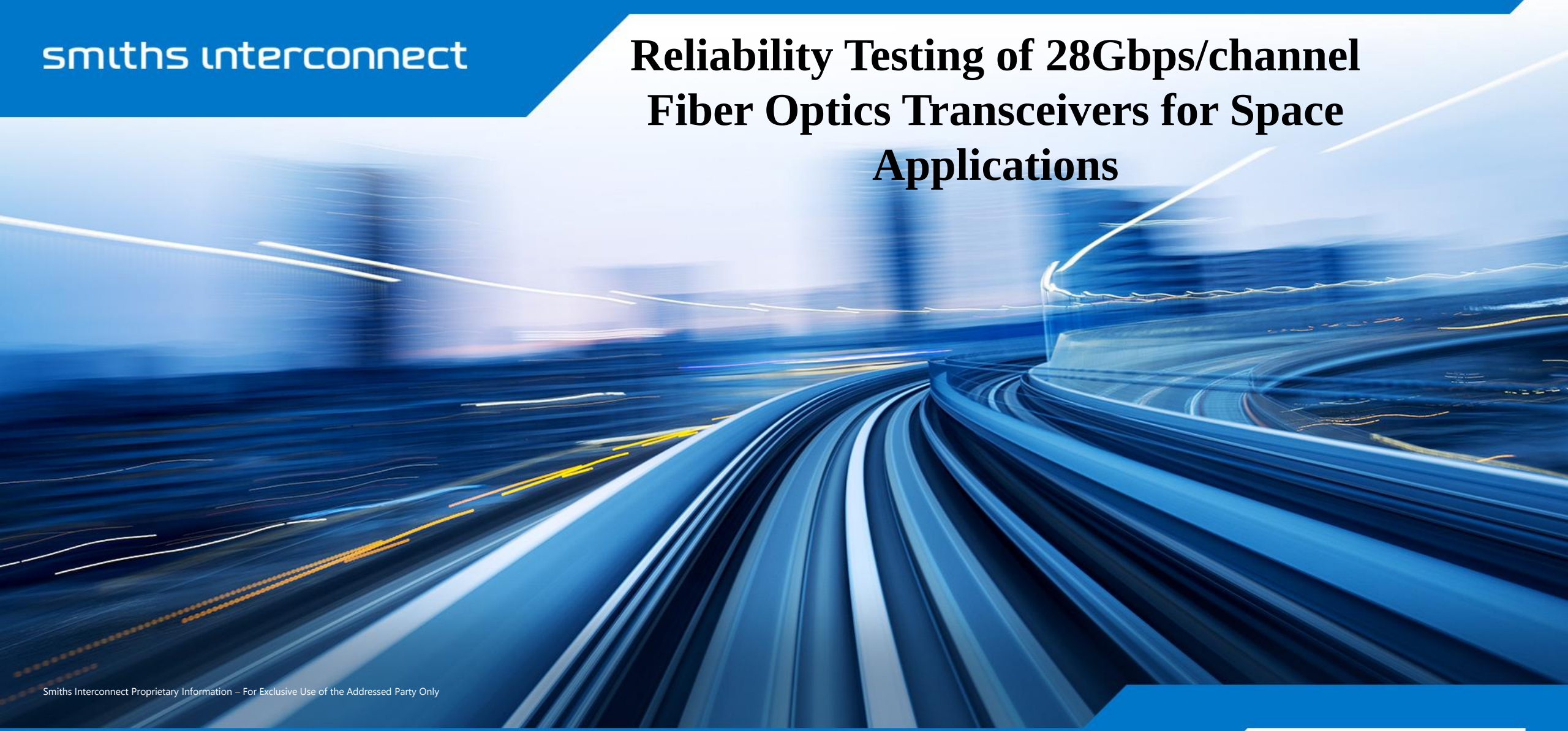
smiths interconnect

Reliability Testing of 28Gbps/channel Fiber Optics Transceivers for Space Applications



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BEYOND CONNECTIVITY

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Agenda

- How optical modules can make large volume of data processing possible through fiber optic cable?
- Smiths Interconnect Multi-channel parallel optical modules
  - Types of optical modules
  - Functionality
  - Physical characteristics
  - Performance
  - Compatibility
- Space Qualification Tests Results
  - Heavy ions radiation
  - Total Ionization Dose (TID)
  - Total Non-ionization Dose (TNID)
  - Outgassing test results
  - Thermal Vacuum (TVAC)
  - Random vibration and mechanical shock
- Conclusion + Q&A

How optical modules can make data-intensive application possible through fiber optic cable?

Parallel multimode optical fiber communications offer the largest data processing capacity compared to any other technology:

- Higher data transfer rate
- Small size and lightweight
- Low power consumption
- Electro-Magnetic Interference (EMI) insensitive
- Best choice of technology for optical data communication

- Optical modules and optical data communications
- **Smith Interconnect manufactures high speed optical modules for space applications.**
  - 28Gbps
  - Up to 12 independent channels
  - Wide range of operating temperature
  - Lightweight (3.0g max)
  - Best for point-to-point data communication up to 100 meters
  - Can be use as mid-board or edge-board mounting configuration
  - Space ready technology
  - Radiation hardened

Types of Multi-channel Parallel Optical Modules

1. 12-channel Transmitters (12Tx)

Converting differential electrical input signals to multi-mode optical output signals

2. 12-channel Receivers (12Rx)

Converting multi-mode optical input signals to differential electrical output signals

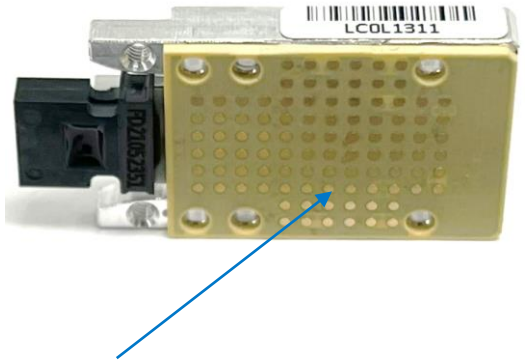
3. 4-channel Transceivers (4TRx)

4-channel transmit and 4-channel receive in the same packaging

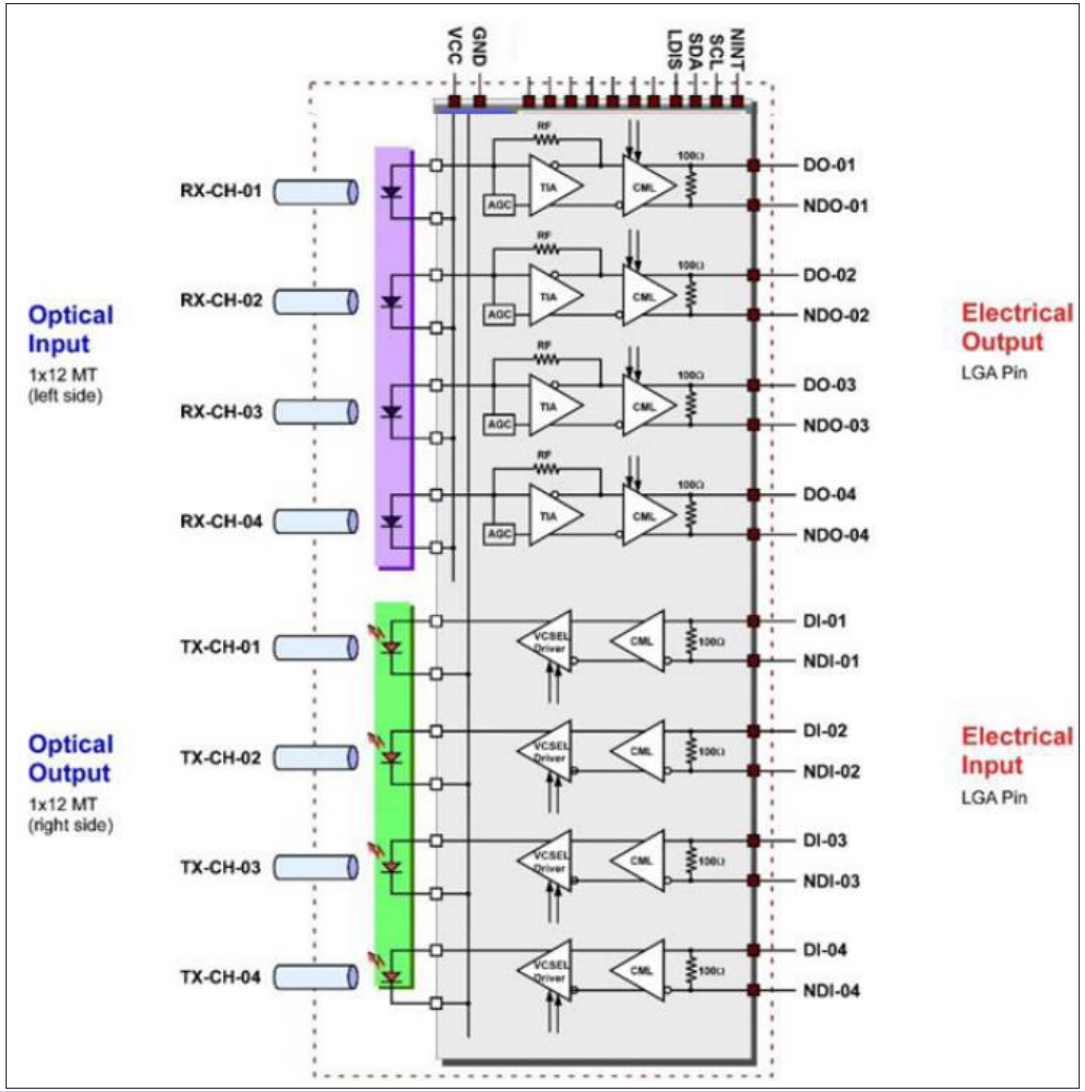
Converting differential electrical input signals to optical output signals and differential electrical input signals to optical output signals

Functionality

- **Signal converters**
- **28Gbps / channel**
- **4TRx is full-duplex**
- **12Tx and 12Rx are half-duplex**

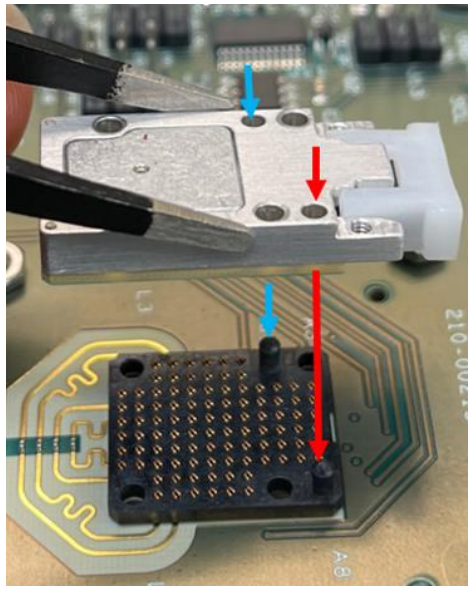


- **Electrical interfaces are 96-contact Land Grid Array (LGA) based on Common Mode Logic (CML)**
- **Optical interface is based on industry standard mechanically transferable (MT) type connector up to 12-channel with fiber graded-index of 50µm core and 125µm silica glass cladding diameter.**
- **Low power consumption: 0.314 watts per channel (12TX-12RX optical link)**



Physical characteristics

- 4TRx Module size: 28.38 x 14.1 x 4.40 mm
  - Plus the interposer height of 1.55 mm
- Weight: 3 grams
- 12Tx and 12Rx have almost the same dimensions and weight as the 4TRx modules.



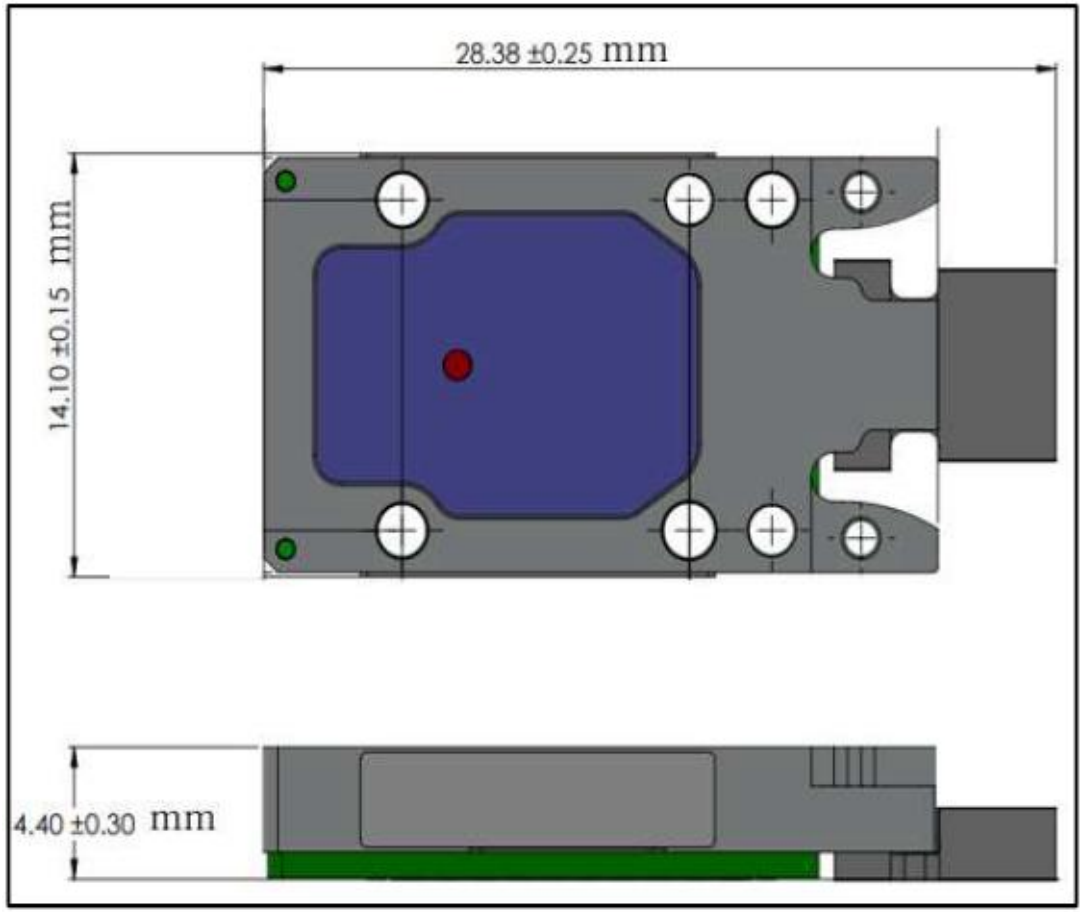


Fig. 4. Transceiver Dimensions

Performance

- **Table 1 presents the key specifications for the 12TX and 12RX optical performance.**

TABLE 1. Transceiver Optical Performance

Parameter	Min	Typ	Max	Unit
Bit rate	1	25.78125	28.05	Gbps
Link budget margin	7			dB
Transmitter				
Avg optical power (per channel) at 25°C	2			dBm
Extinction ratio		5		dB
Center wavelength	840	850	860	nm
Receiver				
Sensitivity (per channel) at 25°C for BER 1E-09	-5			dBm
Optical power saturation limit	10			dBm
Peak sensitivity wavelength	840	850	860	nm

Compatibility

The *Space*ABLE 28 optical modules features:

- Industry standard 1x12 (MT) optical interface
- Link distance up to 70 meters with OM3 and 100 meters with OM4 fibers
- 850nm wavelength multimode light emitted from a vertical-cavity surface-emitting laser (VCSEL)
- 12 differential CML inputs or outputs
- Asynchronous channel operation
- Mid-board and edge-board mount configurations

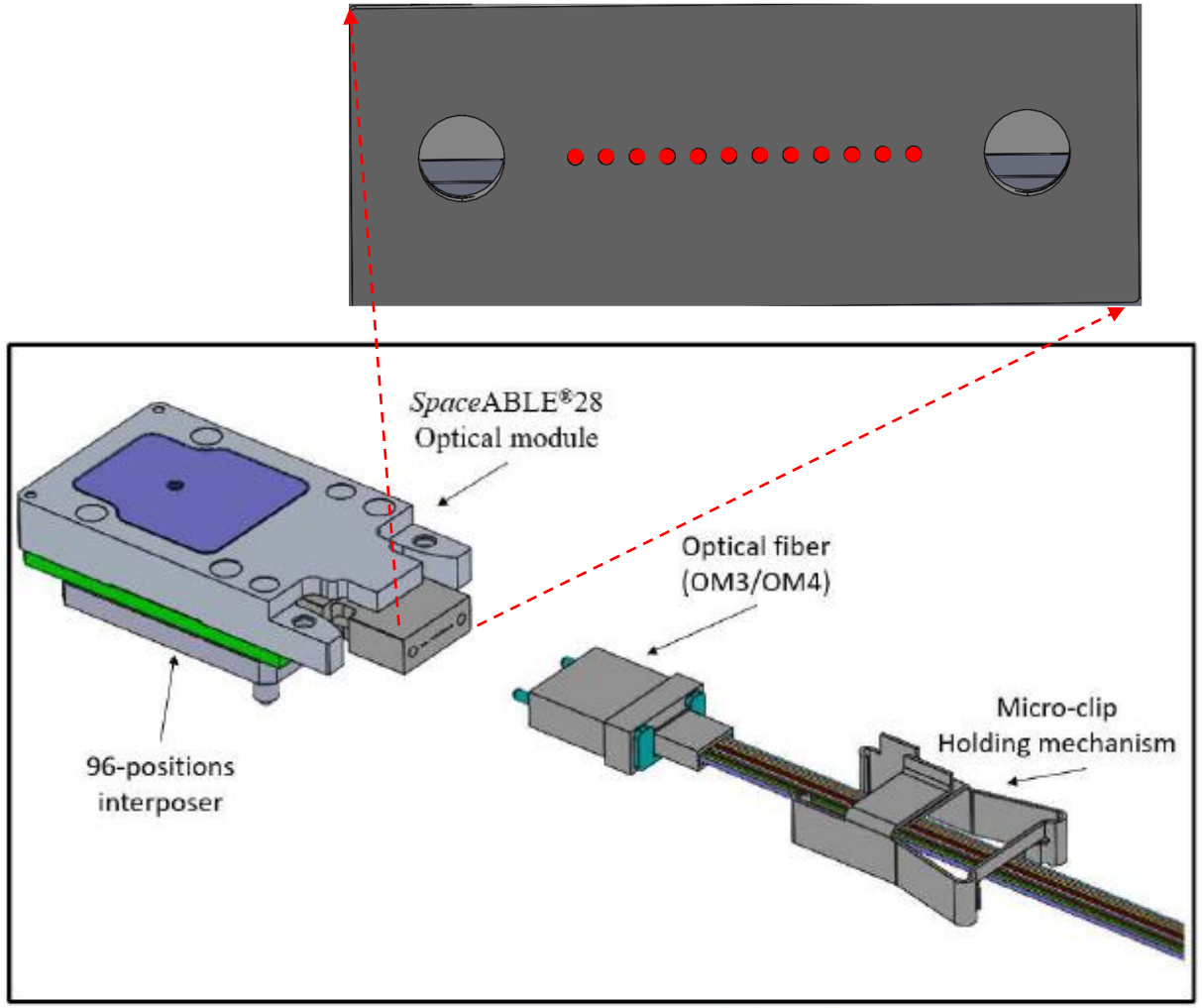


Fig. 3. Transceiver Optical Connection to Optical Fiber

Space Qualification Tests Results *(Heavy Ions Radiation)*

Heavy ions radiation test conditions:

- **Flux:** $3.3x10^4$ (ions/cm^2s)
- **Total fluence:** $1x10^7$ (ions/cm^2)
- **Radiation exposure time:** 5 min
- **Test Temperatures:**
- +25ºC and +85ºC
- **Heavy ions:**
  - Neon (Ne) [2.6] LET
  - Argon (Ar) [8.0] LET
  - Copper (Cu) [18.7] LET
  - Silver (Ag) [40.3] LET
  - Holmium (Ho) [66.7] LET
  - Tantalum (Ta) [74.8] LET

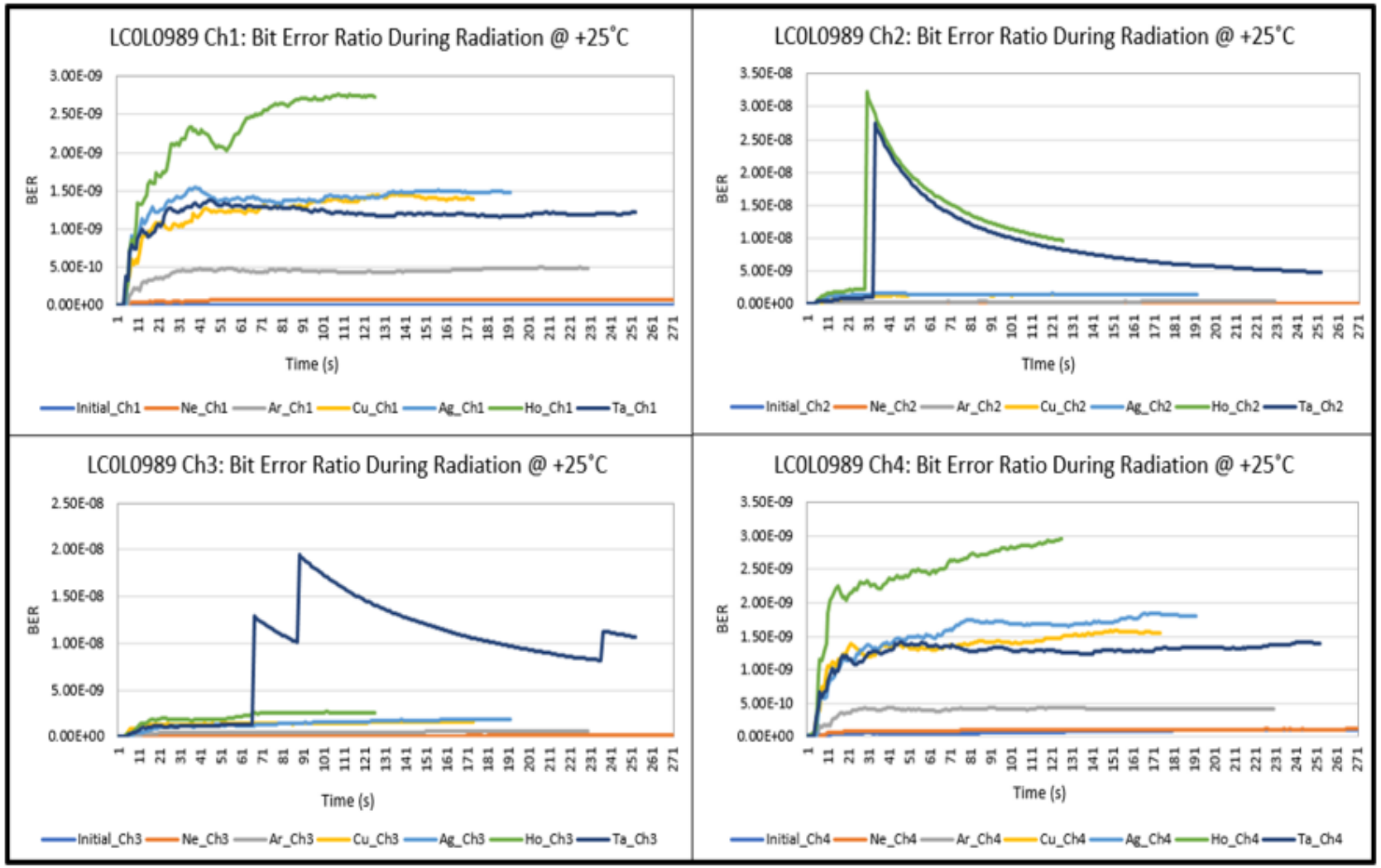


Fig. 6. Transceiver BER Monitoring Under Heavy Ions Radiation

Space Qualification Tests Results

(Heavy Ions Radiation continue …)

Power consumption of one optical module during heavy ions radiation

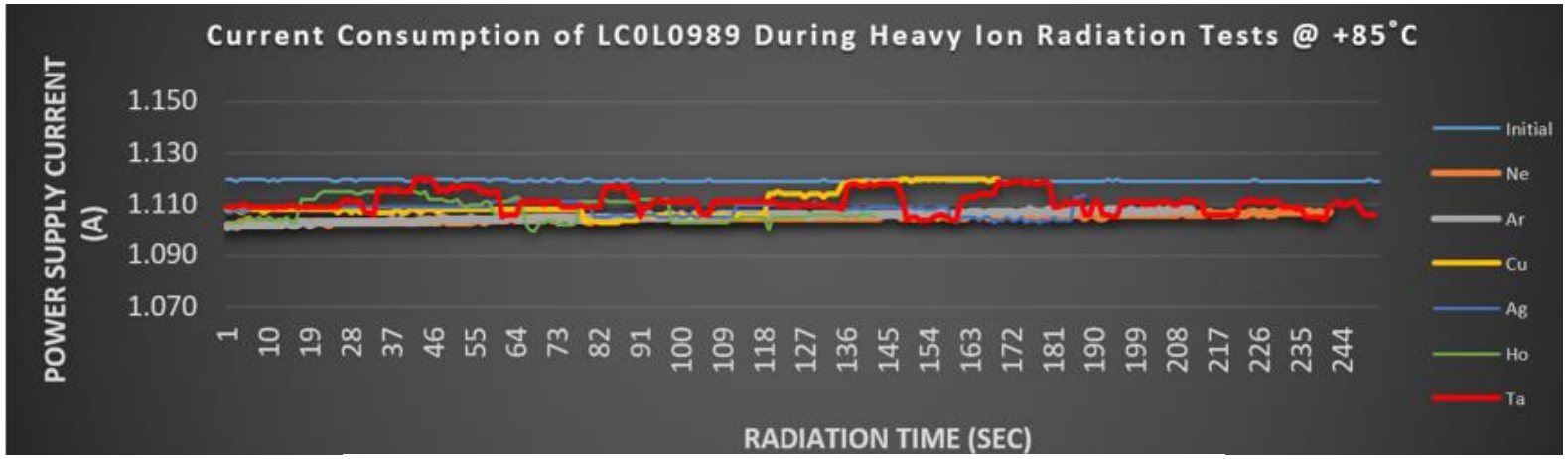


Fig. 7. Transceiver Power Consumption Under Radiation

Heavy Ions Radiation SEE Results

The SEU rate calculation is done using Petersen's Figure of Merit (FOM)

Product	SEL	SEFI	SEU Event/Day (LEO)	SEU Event/Year (GEO)
12Tx	No SEL	No SEFI	2.66E-3	2.13E-2
12Rx	No SEL	No SEFI	1.89E-1	1.52
4TRx	No SEL	No SEFI	7.75E-2	9.65E-3

Total Ionization Dose (TID) test results

- **As per ESCC 229900 standard**
- **Dose rate: 100 rad/h**
- **Dose levels: 0, 25, 51, 76 and 107 kilorads**
- **Post irradiation annealing for 24 hours at +25ºC**
- **Post irradiation annealing for 168 hours at +100ºC**

Table 6. TID Biased Units Interim Tests

Biased Pairs	Channels	Pretest at TRAD (# of errors)	Interim Test After 25K (# of errors)	Interim Test After 48K (# of errors)	Interim Test After 76K (# of errors)	Interim Test After 104K (# of errors)	Interim Test After 24h Annealing (# of errors)	Interim Test After 168h Annealing (# of errors)
LC0M0344 - LC0N0467	ch1	0	0	1	32	3	0	1
	ch2	1	0	1	0	0	0	0
	ch3	0	20565	8	4	7	1	0
	ch4	167	38	117	62	5927	128180	0
	ch5	34222	101275	5799	28099	140	50935	39
	ch7	6173	6218	3736	1126029	324467	13147	23760
	ch8	826	0	0	0	0	0	77
	ch10	7	64	8	67	244976	34	0
	ch11	1	29	5	755	5	193	0
	ch12	0	0	0	0	1510	0	0
LC0M0359 - LC0N0517	ch1	0	0	0	7	2	1	0
	ch2	1	0	0	0	0	0	0
	ch3	0	0	0	0	0	0	0
	ch4	0	0	0	0	258	2	0
	ch5	0	0	0	0	0	0	0
	ch6	9	29	0	2	0	61	10
	ch7	0	0	0	17	0	0	0
	ch8	0	0	0	0	0	0	0
	ch10	0	0	0	0	0	0	0
	ch11	0	0	0	0	0	0	0

Total Non-ionization Dose (TNID) test results

- **Proton beam energy: 100 MeV**
- **Dose Levels:**
  - $5x10^{10}$ protons/cm^2
  - $5x10^{11}$ protons/cm^2
  - $5x10^{12}$ protons/cm^2
- **Post irradiation annealing at 100°C for 168 hours**

TABLE 9. TNID Units Performance Results

		Total Fluence of 5E+10 p/cm2		
	channels	Sensitivity Level (dBm)	Initial Error Count	Final Error Count
Reference Tx			LC0M0445	LC0M0450
LC0N0522	Ch1	-5	413	0
	Ch2	-5	65	0
	Ch3	-5	211	4
	Ch4	-5	1	0
	Ch5	-5	2	0
	Ch6	-5	2	0
	Ch7	-5	0	0
	Ch8	-5	0	0
	Ch9	-5	0	2
	Ch10	-5	467	0
	Ch11	-5	1	64
	Ch12	-5	25	112
Reference Tx			LC0M0442	LC0M0479
LC0N0531	Ch1	-5	0	0
	Ch2	-5	0	0
	Ch3	-5	0	0
	Ch4	-5	0	0
	Ch5	-5	1	0
	Ch6	-5	0	0
	Ch7	-5	0	0
	Ch8	-5	0	0
	Ch9	-5	0	0
	Ch10	-5	434	0
	Ch11	-5	0	0
	Ch12	-5	1.64E+12	0

		Total Fluence of 5E+11 p/cm2		
	channels	Sensitivity Level (dBm)	Initial Error Count	Final Error Count
Reference Tx			LC0M0445	LC0M0479
LC0N0529	Ch1	-5	413	0
	Ch2	-5	65	0
	Ch3	-5	211	0
	Ch4	-5	1	0
	Ch5	-5	2	0
	Ch6	-5	2	0
	Ch7	-5	0	21
	Ch8	-5	0	0
	Ch9	-5	0	0
	Ch10	-5	467	0
	Ch11	-5	1	0
	Ch12	-5	25	0
Reference Tx			LC0M0478	LC0M0450
LC0N0536	Ch1	-5	0	0
	Ch2	-5	0	0
	Ch3	-5	0	0
	Ch4	-5	0	0
	Ch5	-5	9	0
	Ch6	-5	0	0
	Ch7	-5	0	0
	Ch8	-5	0	0
	Ch9	-5	0	15
	Ch10	-5	303	9
	Ch11	-5	41	3
	Ch12	-5	31	83

		Total Fluence of 5E+12 p/cm2		
	channels	Sensitivity Level (dBm)	Initial Error Count	Final Error Count
Reference Tx			LC0M0439	LC0M0479
LC0N0578	Ch1	-5	0	1
	Ch2	-5	2	0
	Ch3	-5	0	0
	Ch4	-5	87	0
	Ch5	-5	0	1
	Ch6	-5	4	0
	Ch7	-5	0	0
	Ch8	-5	0	0
	Ch9	-5	0	0
	Ch10	-5	2	0
	Ch11	-5	2	0
	Ch12	-5	0	0
Reference Tx			LC0M0435	LC0M0450
LC0N0591	Ch1	-5	1535	0
	Ch2	-5	792	0
	Ch3	-5	8	3
	Ch4	-5	0	0
	Ch5	-5	14	0
	Ch6	-5	0	0
	Ch7	-5	0	0
	Ch8	-5	1	1
	Ch9	-5	0	0
	Ch10	-5	0	2
	Ch11	-5	0	100
	Ch12	-5	3	384

Outgassing test results

Outgassing determines the ability of devices under test to operate in a vacuum space environment, such as circuits inside satellites, without risk of contaminating the elements with which it is in close proximity.

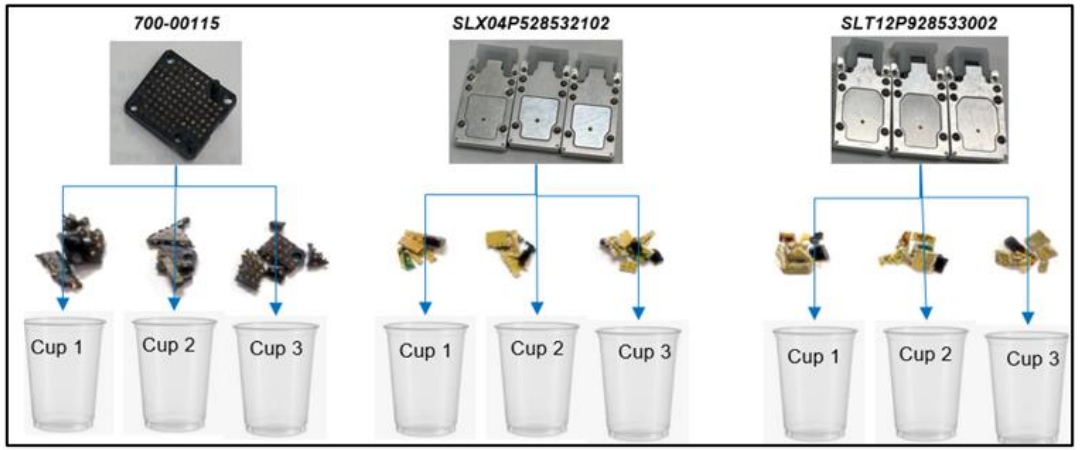


Fig. 10. Outgassing Test Samples

- **Standard: ECSS-Q-ST-70-02C**
- **Recovered Mass Loss (RML) < 1.00%**
- **Collected Volatile Condensable Material (CVCM) < 0.10%.**

Table 10. Outgassing Test Results

1X	1.55 mm 96pos 13743 Interposer			3X	SLX04P528532102			3X	SLT12P928533002		
	TML %	RML %	CVCM %		TML %	RML %	CVCM %		TML %	RML %	CVCM %
Cup 1	0.077	0.052	0.002	Cup 1	0.215	0.189	0.031	Cup 1	0.158	0.124	0.029
Cup 2	0.073	0.052	0.003	Cup 2	0.206	0.179	0.044	Cup 2	0.136	0.094	0.018
Cup 3	0.064	0.051	IR plate	Cup 3	0.204	0.177	IR plate	Cup 3	0.123	0.085	IR plate
Average	**0.071**	**0.052**	**0.002**	**Average**	**0.208**	**0.182**	**0.038**	**Average**	**0.139**	**0.101**	**0.024**
Passing Limits	Not defined	< 1.00	<0.10	**Passing Limits**	Not defined	< 1.00	<0.10	**Passing Limits**	Not defined	< 1.00	<0.10

Thermal Vacuum (TVAC) Test

- **Vacuum less than $5x10^{-5}$hPa**
- **20 temperature cycles from -40ºC to 85ºC with +/-5ºC precision.**
- **5 minutes of dwell time.**
- **Temperature ramp rate of 3ºC/min**
- **Live Bit Error Rate (BER) monitoring.**

- **PASSING with BER better than E-12**

Figure 11. TVAC Testing Chamber and Test Station

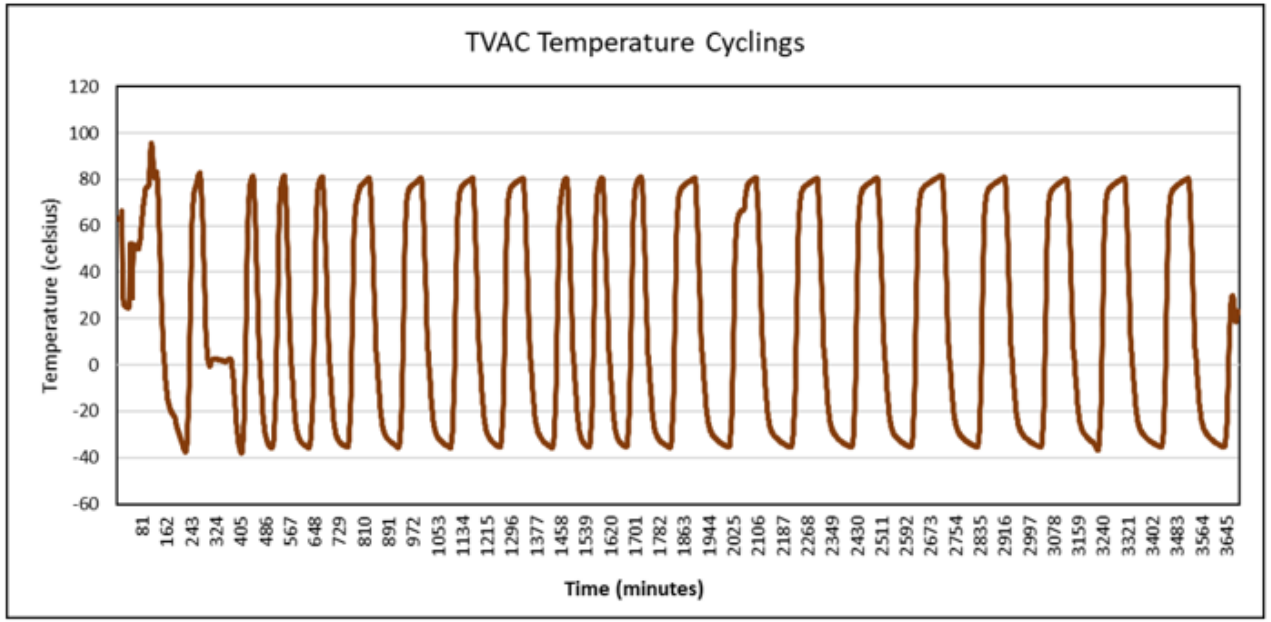


Fig. 13. TVAC Temperature Cycling

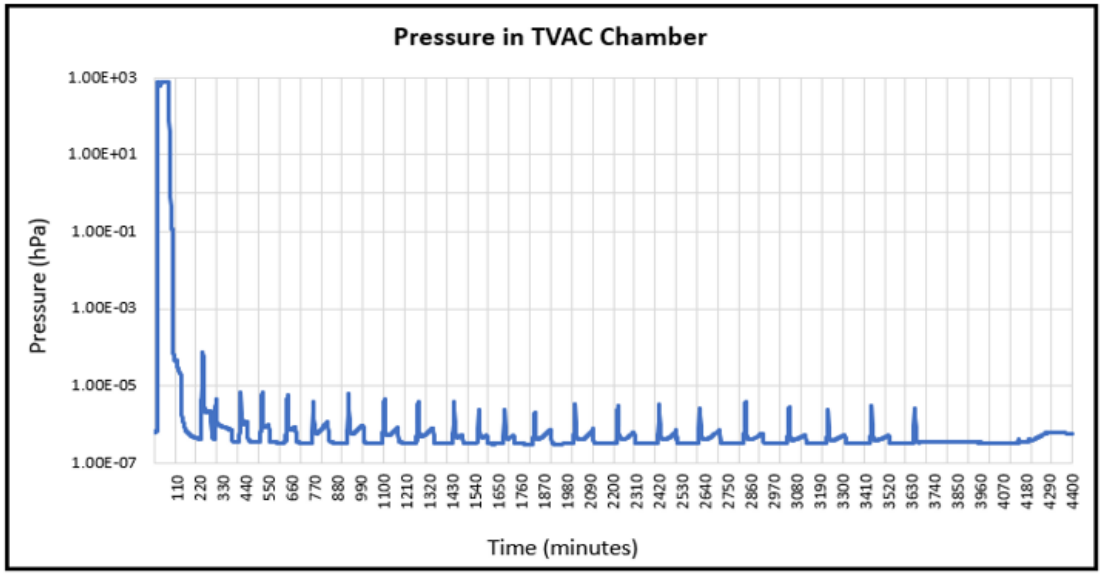


Fig. 12. Vacuum Pressure of TVAC Test

Random vibration and mechanical shock test results (Setups)

The random vibration testing was done in accordance with MIL-STD-883, TM 2007 12 with **28.4 Grms** perpendicular and **27.1 Grms** parallel accelerations.

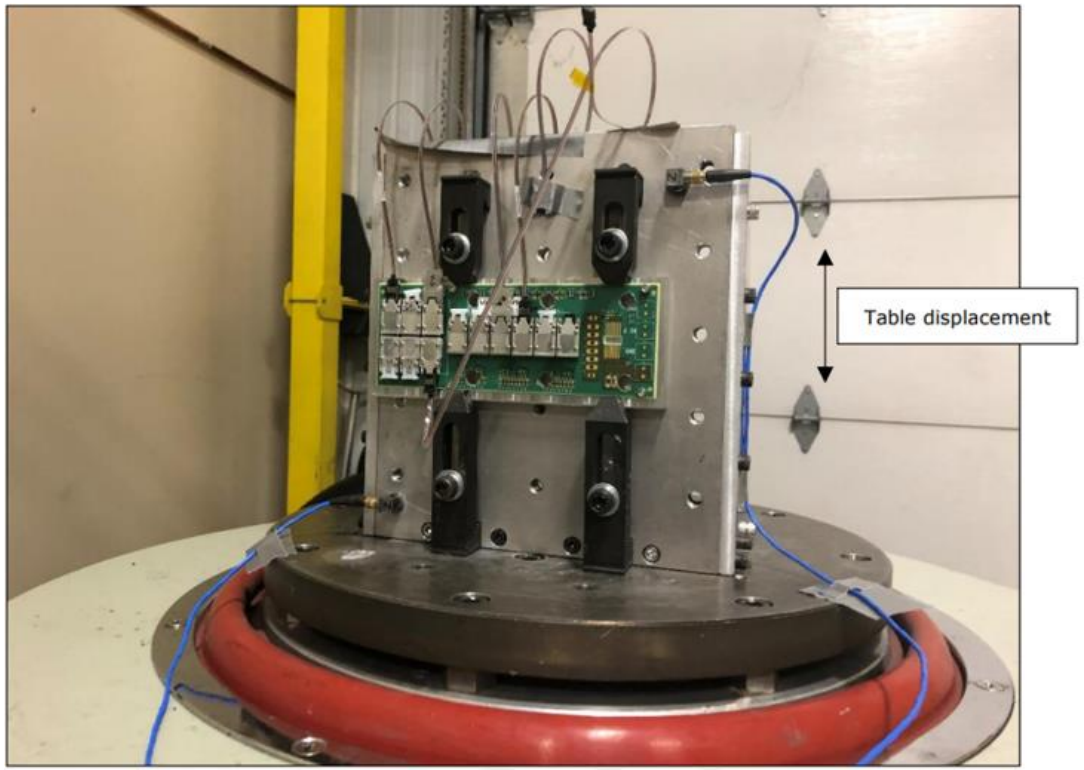


Fig. 14. Random Vibration Test Setup

The mechanical shock testing was done in accordance with MIL-STD-883 TM 2002 with **1500g** acceleration, **0.5ms** pulse width half-sine on all directions.

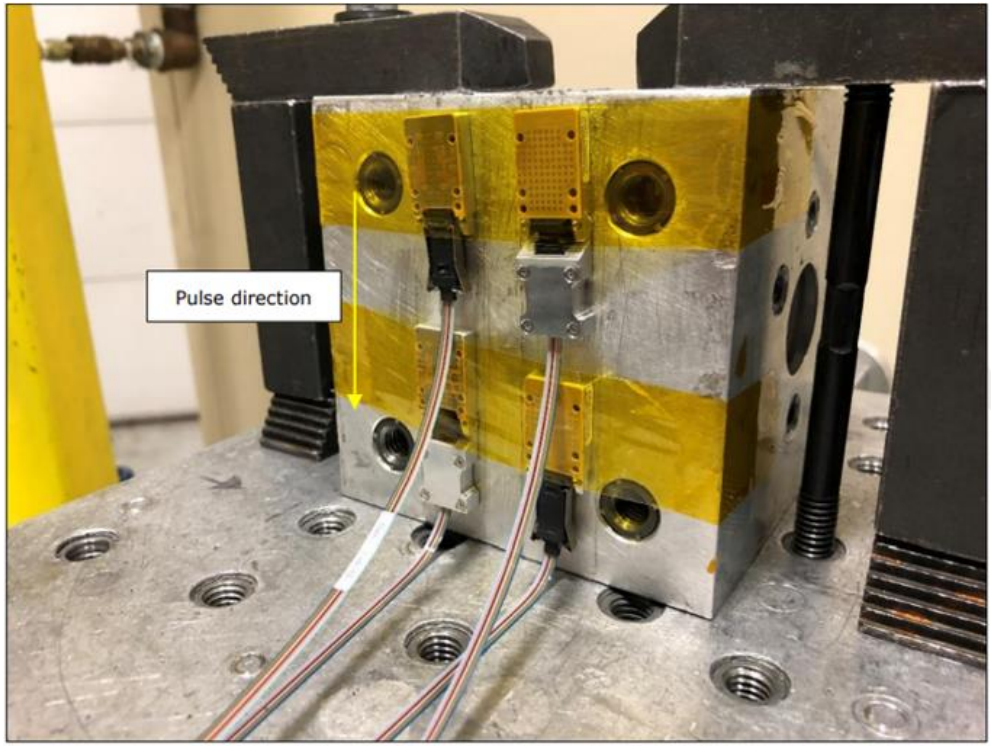


Fig. 15. Mechanical Shock Test Setup

Random vibration and mechanical shock test results: (Electro-Optical Performance Results)

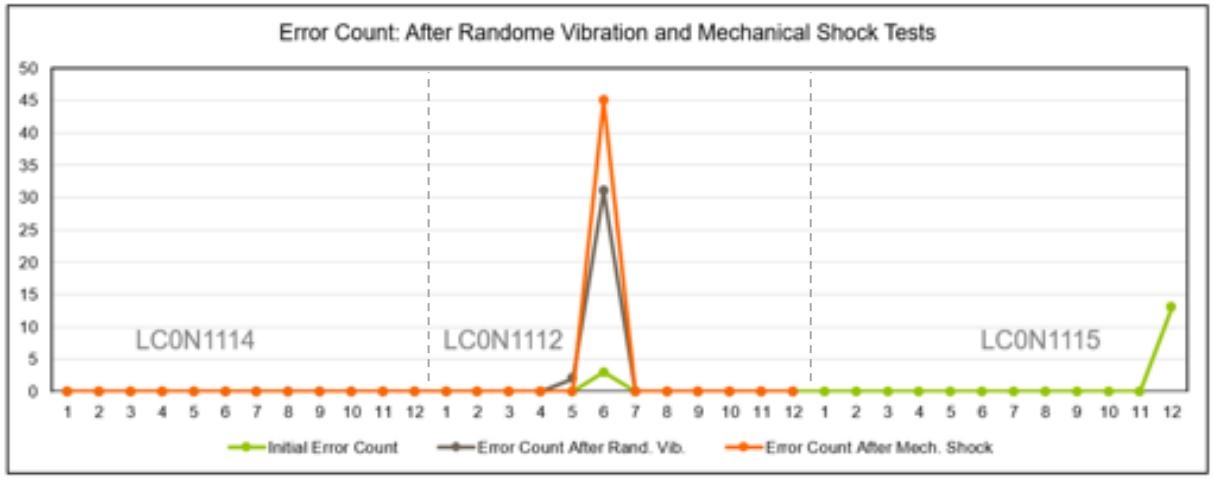


Fig. 18. 12RX Error Count Test Results

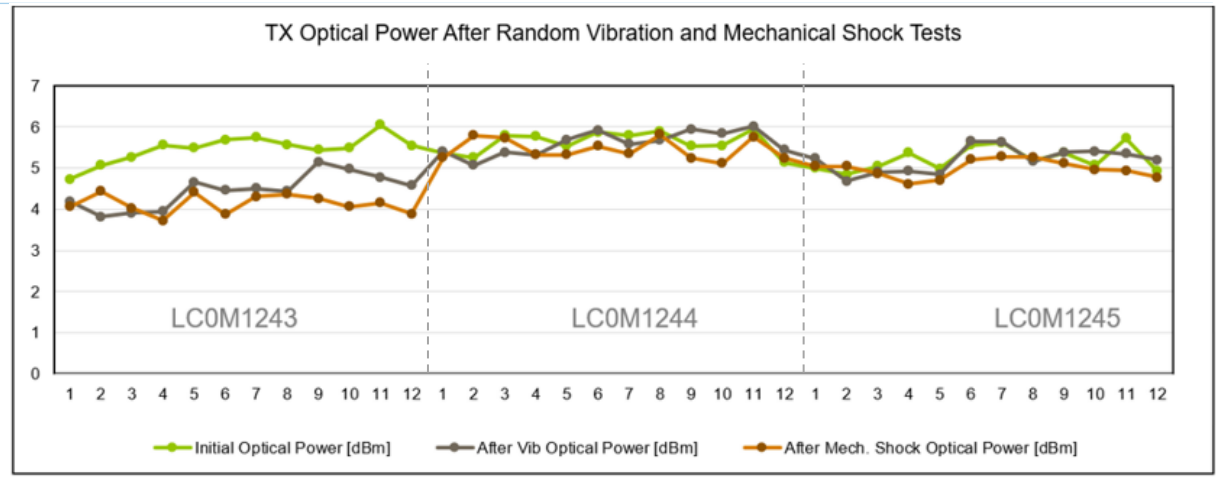


Fig. 16. 12TX Optical Power

No significant performance degradation after random vibration and mechanical shock tests

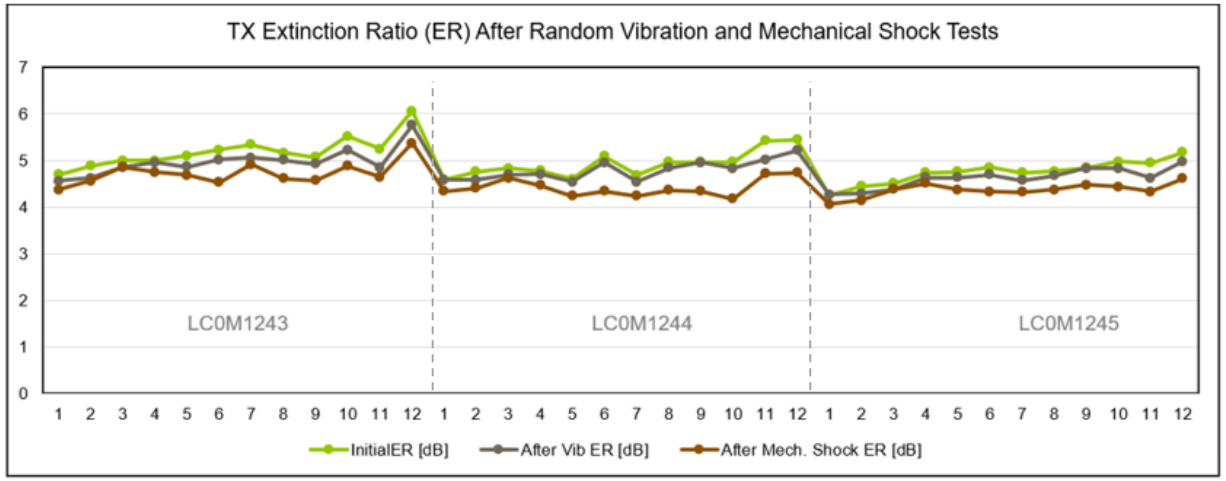


Fig. 17. 12TX Extinction Ratio

Conclusion

- Optical communication through fiber optic for intra-satellite applications is an absolute requirement
- Space qualified optical modules using parallel optics over OM3/OM4 multimode fiber provides the best data transfer service for SpaceFiber and space optical communication.
- The space qualified optical modules offer the best performance for any mid-board or edge-board mount configuration and pass both radiation and environmental qualification tests.
- The parts are available as Commercial Off-the-Shelf (COTS) product.

Q&A

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