

The widest range of
mission-critical interconnect
technologies in the world

Space-grade parallel optical transceivers and fibre optic connectors for SpaceFibre datalinks

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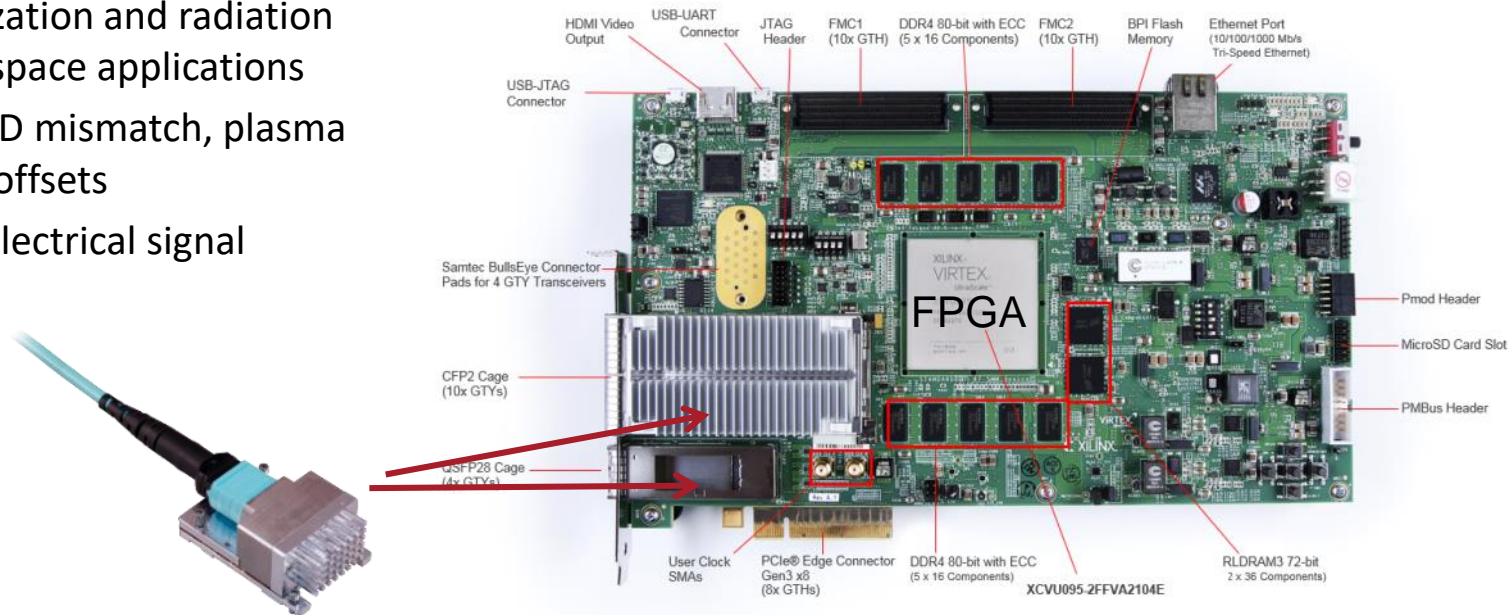
Outline

- Problem:
 - Space grade board-mounted multichannel photonic transceivers and fibreoptic connectors are needed
 - Few solutions exist to support SpaceFibre fibreoptic deployments
- Solution: Ruggedized parallel optical transceivers and MT parallel optic connectors
- Approach:
 - Develop novel hermetic optoelectronic hybrid using COTS chips
 - Develop ruggedized MT circular and rectangular connectors
 - Perform extensive qualification and radiation testing
- Results:
 - Promising performance in space and launch environments
- Summary and discussion

Rugged photonic transceiver

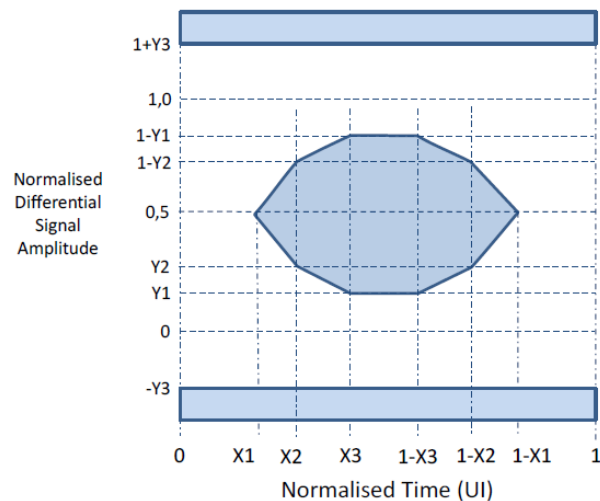
SpaceFibre use cases and benefits

- Board-to-board spacecraft data links
- Support FPGA I/Os 1 Gbps to 28-56 Gbps
- Need ruggedization and radiation tolerance for space applications
- Eliminates GND mismatch, plasma charging, CM offsets
- Regenerates electrical signal



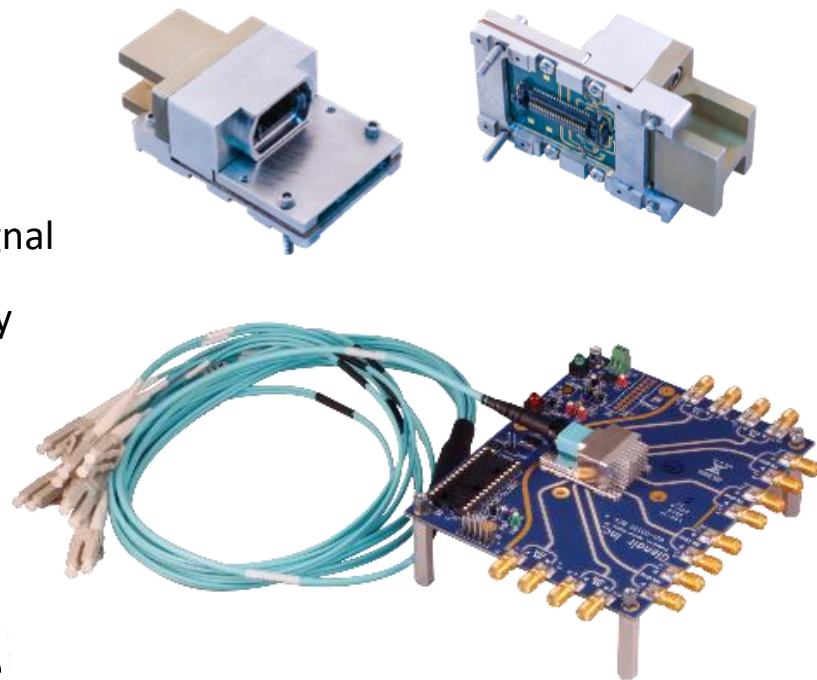
Key Specifications for SpaceFibre Photonic Transceivers and Fibreoptic Connectors

- 1 – 6.25 Gbps today; up to 28-56 Gbps envisioned
- Compatible with SpaceFibre eye mask
 - ECSS-E-ST-50 11C
- FPGA CML levels and commercial grade transceivers such as SFP, QSFP
- EQ, gain, pre-emphasis adjustments for signal integrity optimization, including over temperature
- Shock, vibration, thermal and radiation tolerance
- Low outgassing materials
- Radiation Lot Acceptance Testing (RLAT) may be needed
- Cost-effective and short lead-times

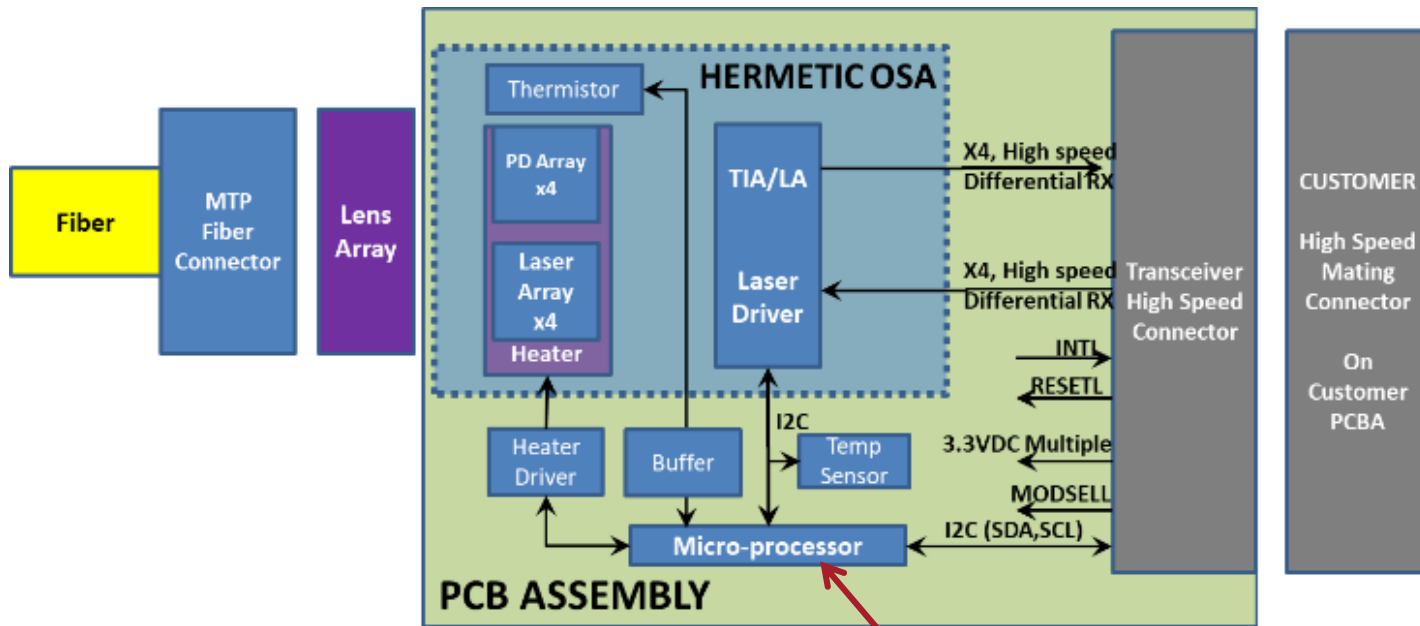


Multi-channel Photonic Transceivers

- 4x10 Gbps, 12x10 Gbps and 4x25 Gbps
 - MTP optical connectors
 - Rugged electrical connector
 - Hermetic opto-electronic hybrid
 - EQ, gain, pre-emphasis adjustments to optimize signal integrity
 - Optical lens coupling, high-output power/sensitivity
 - -40 to +85C
 - ASTM-E595 low-outgassing
 - Radiation tested
- Conduction-cooled option for space applications
- High shock, vibration tolerance
- High-volume automated manufacturing line

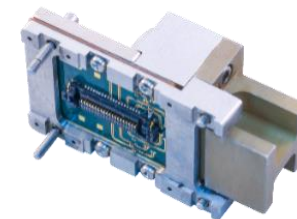
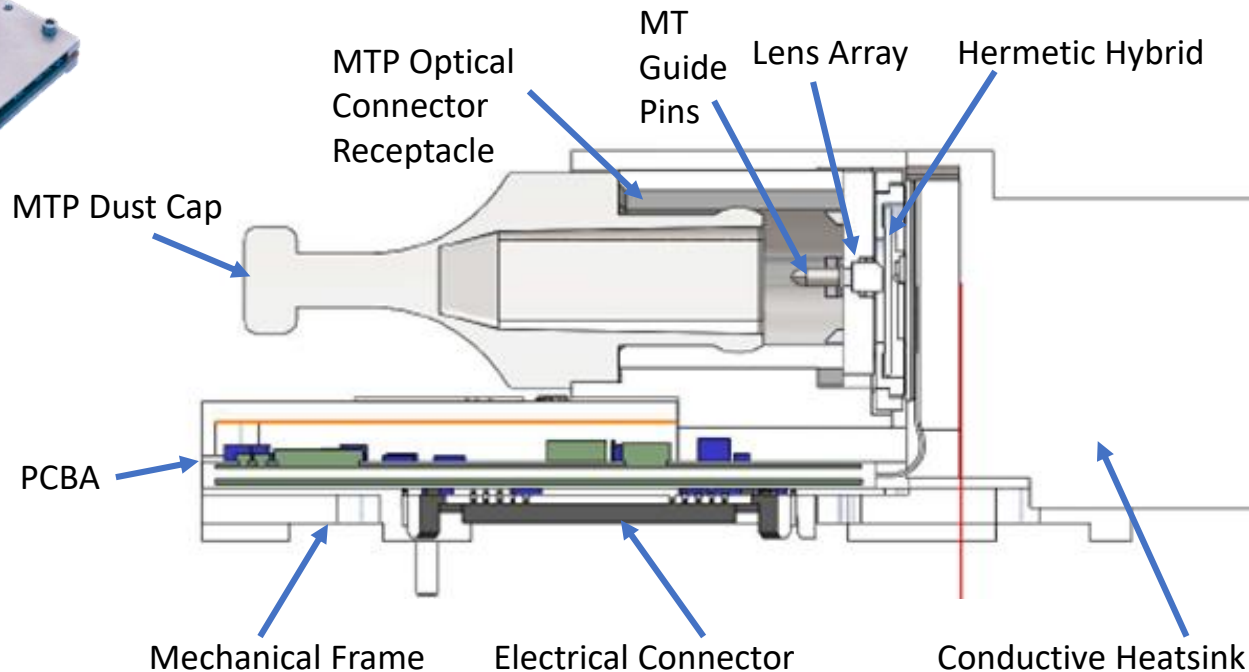
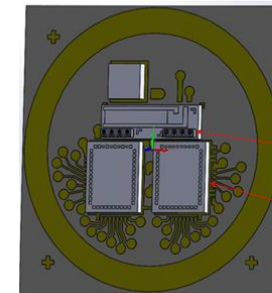
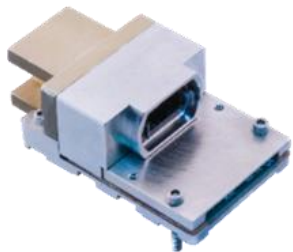


Transceiver functional partitioning



- Option to use external microprocessor for radiation tolerance

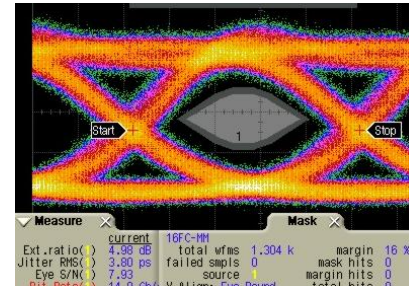
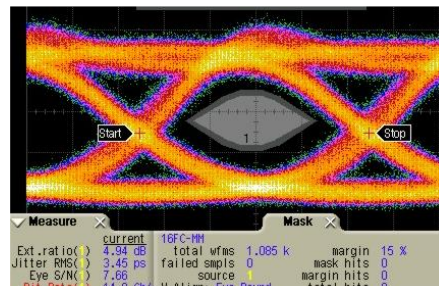
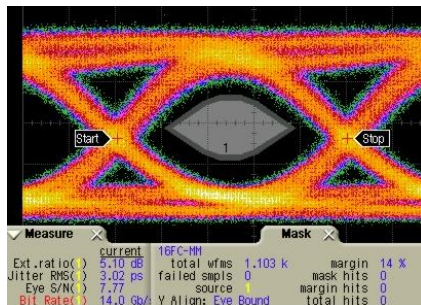
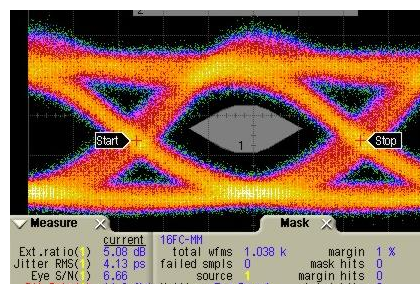
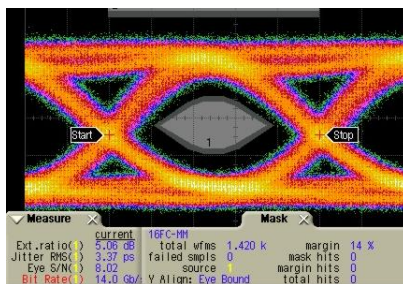
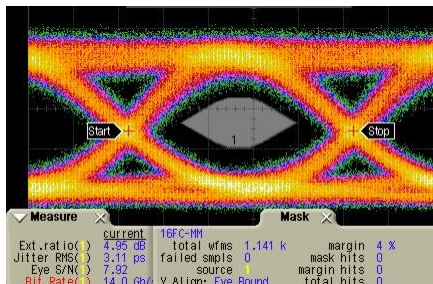
Transceiver construction



14 Gbps typical performance at temperature extremes

-40C

85C



14 Gbps typical performance at 85C



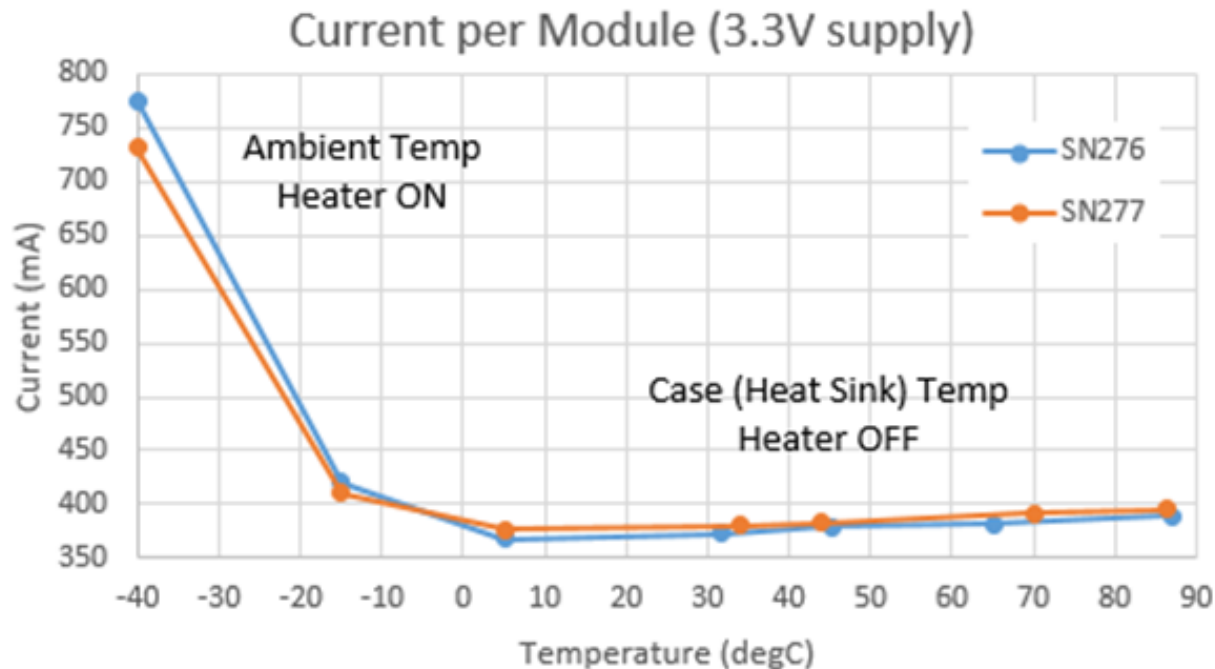
Transmitter

Data/Ch.	Ch1	Ch2	Ch3	Ch4
AOP (dBm)	-0.8	-0.1	-0.1	-0.1
ER (dB)	5.1	5.1	4.9	5.0
Jitter (ps_{rms})	4.1	4.1	3.5	3.8
SNR (dB)	6.7	7.1	7.7	7.9
Margin (%)	1	10	15	16

Receiver

Data/Ch.	Ch1	Ch2	Ch3	Ch4
V_{pp} -3dBm	514	529	540	520
V_{pp} -10dBm	479	492	495	473
Jitter-3dBm	3.5	3.2	3.8	4.0
Jitter-10dBm	4.7	4.1	4.9	5.3
BER $1e^{-12}$ (dBm)	-12.3	-12.4	-12.0	-11.6

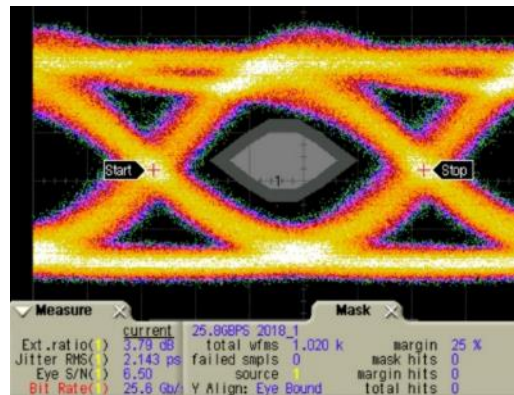
4ch 10G transceiver power consumption



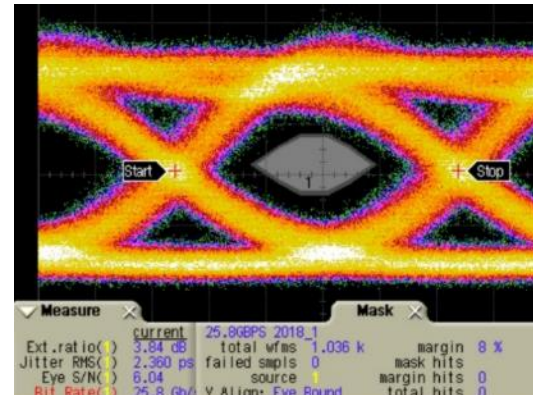
4-channel 25.8G Transceiver Data

- Optical lens coupling system
- +2 dBm optical output power
- High RX sensitivity for improved link margin compared to COTS
- Hermetic opto-electronic hybrid
- All components satisfy ASTM-E595 for low outgassing

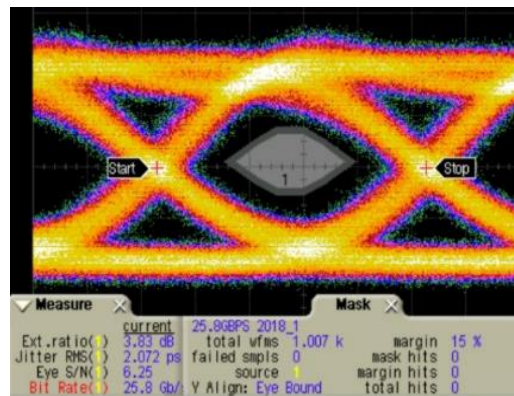
Tx1



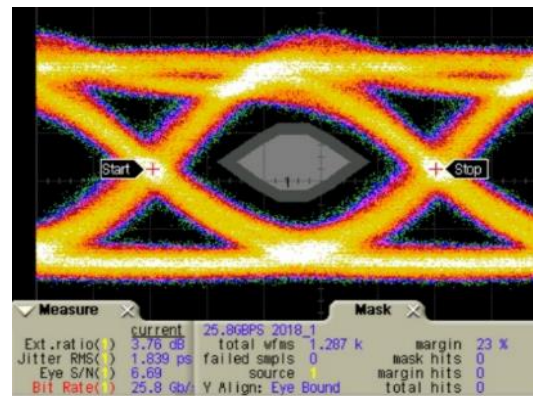
Tx2



Tx3



Tx4



4x10G Transceiver Testing Summary

- Accel. Aging: +85C, 1000 hours
- Temperature cycling: 100 cycles, -40C to +85C, operating
- Thermal shock: 500 cycles, -55C to +125C, non-op
- Random Vibration: 46 Grms, 2 hours per axis
- Shock: 1500 G, 0.9 ms, 10 shocks/axis
- Humidity: 10 days, temp cycling, 90% RH
- Radiation: Gamma, proton, heavy ions
 - Optical and electronic ICs exposed to direct ion irradiation
 - Microprocessor deleted

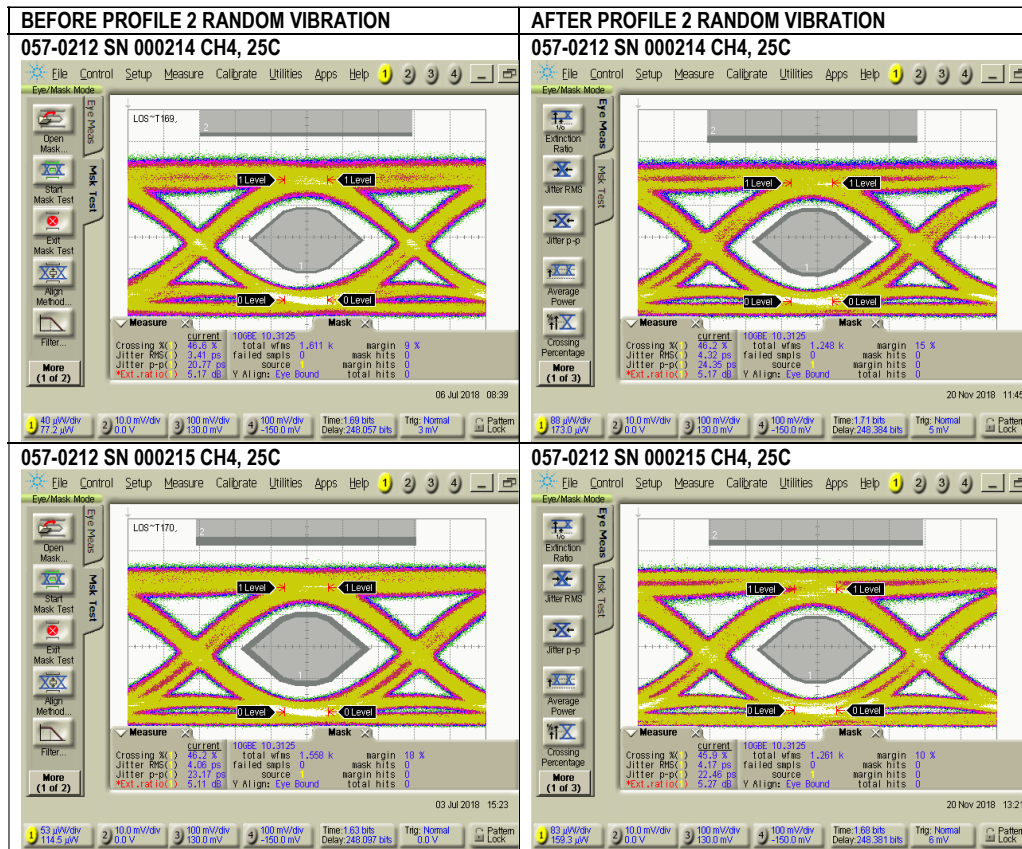




Transceiver environmental testing

Test Item	Description	Reference	Group Number	Sampling (Qty.)
Random Vibration, Operating	Profile 46 grms 2 hours per axis: x, y & z	Mil-STD-810, Para. 514.6, proc. I SAE ARP6318 (Draft)	1	2 required 4 tested
Mechanical Shock, Operating	X- axis 650g 0.9ms, 10 pulses (5+ & 5-)	Mil-STD-810, Para. 516.6 SAE ARP6318 (Draft)	2	2
	Y- axis 650g 0.9ms, 10 pulses (5+ & 5-)	Mil-STD-810, Para. 516.6 SAE ARP6318 (Draft)		
	Z- axis 650g 0.9ms, 10 pulses (5+ & 5-)	Mil-STD-810, Para. 516.6 SAE ARP6318 (Draft)		
Temperature Cycling, Operating	100 cycles, -40°C to +85°C	ARINC 804-1 (MIL-STD-883H), Method 1010.8, Cond A. SAE ARP6318 (Draft)	3	2
Thermal Shock, Non-Operating	-55C and 125C, 500 Cycle	ARINC 804-1 (MIL-STD-883H), Method 1010.8, Cond B. SAE ARP6318 (Draft)	4	2
High Temperature Operating Life (Accelerated Aging, Operating)	1000 hours, +85°C	ARINC 804-1 Section 4.9.6 SAE ARP6318 (Draft)	5	2 to 11 (2 only required per SAE)
ESD	500V HBV	ARINC 804-1 (MIL-STD-883H), Method 3015.8, Class 1C SAE ARP6318 (Draft)	6	1
Humidity, Operating (DC Power only)	10 days, RH 90% to 100%, Apply DC power only from step 1 to 6, then step 7 with subcycle DC disabled.	MIL-STD-883H, Method 1004.7 SAE ARP6318 (Draft)	7	2 required 4 tested
Fiber pigtail pull-test	Pull Test Force: 1 kg	Telcordia GR-468-CORE. Method 3.3.3.1.3	7	1

Pre- and post-vibration eye diagrams

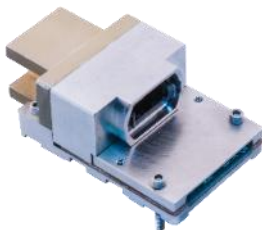




Radiation Testing, Quad 10G Hermetic Transceiver

Radiation Type Qualification

- Heavy Ion
 - No SEL observed
 - => LET >60 MeV cm²/mg
 - On-Orbit Heavy Ion SER estimates



GT-19-043
Radiation Effects Test Report
Glenair 4-Channel 10Gbps
Parallel Optics Transceiver
February 17, 2019

Radiation Lot Qualification

- Lot Qualification
 - Proton SEE/TID **Completed**
 - SEE 50 to 250 MeV
 - TID 10, 20 krad (Si)
 - DDD
 - Heavy Ion **Completed**
 - SEL => >45 MeV cm²/mg
 - NDSEE 1 to 45 MeV cm²/mg
 - Gamma TID 50, 100, and 250 krad
- On-Orbit SER estimates generated for protons and heavy ions



Overview of 10G Quad Space Transceivers

050-346 Quad 10G Transceiver Terrestrial/Naval/Aircraft Grade	0500-3048 Quad 10G Transceiver Space Grade	0500-3060 Quad 10G Transceiver Space Grade
Includes Internal Microprocessor Convection or Conduction cooling	Radiation Tolerant External microprocessor or Analog Mode Driver/TIA options Conduction cooling	Radiation Tolerant External microprocessor or Analog Mode Driver/TIA options Conduction cooling
Low outgassing, ASTM E595	Low outgassing, ASTM E595	Low outgassing, ASTM E595
Non-radiation environments	Radiation effects reports Components same “type” as 0500-3060 but not RLAT	Components qualified by Radiation Lot Assurance Testing (RLAT)
Standard PCB components 10 micro-inch Au on I/O connector	Standard PCB components 10 micro-inch Au on I/O connector	Group C PCB Components 30 micro-inch Au on I/O connector
TRL 9 (Avionics)	TRL 8 (Satellite)	TRL 8 (Satellite)



MT OPTICAL CONNECTORS

Decrease size and weight

Compatible with parallel optic transceivers

Low profile box intrusion

High density up to 24 channels

Environmental sealing

+85°C temperature tolerance

500 mating cycles

Tested to MIL-STD-202





Multi-channel MT Optical Connectors

- Incorporate MT parallel optical ferrules into ruggedized form-factors
- MT Circular D-38999 in production; 1, 2, 3 or 4 MT ferrules
- Rectangular micro-D (single MT) and D-subminiature (2 & 4 MT)
- Many other MIL-QPL and Glenair circular fiber-optic connectors and cable assemblies available



MT Fibreoptic connector qualification

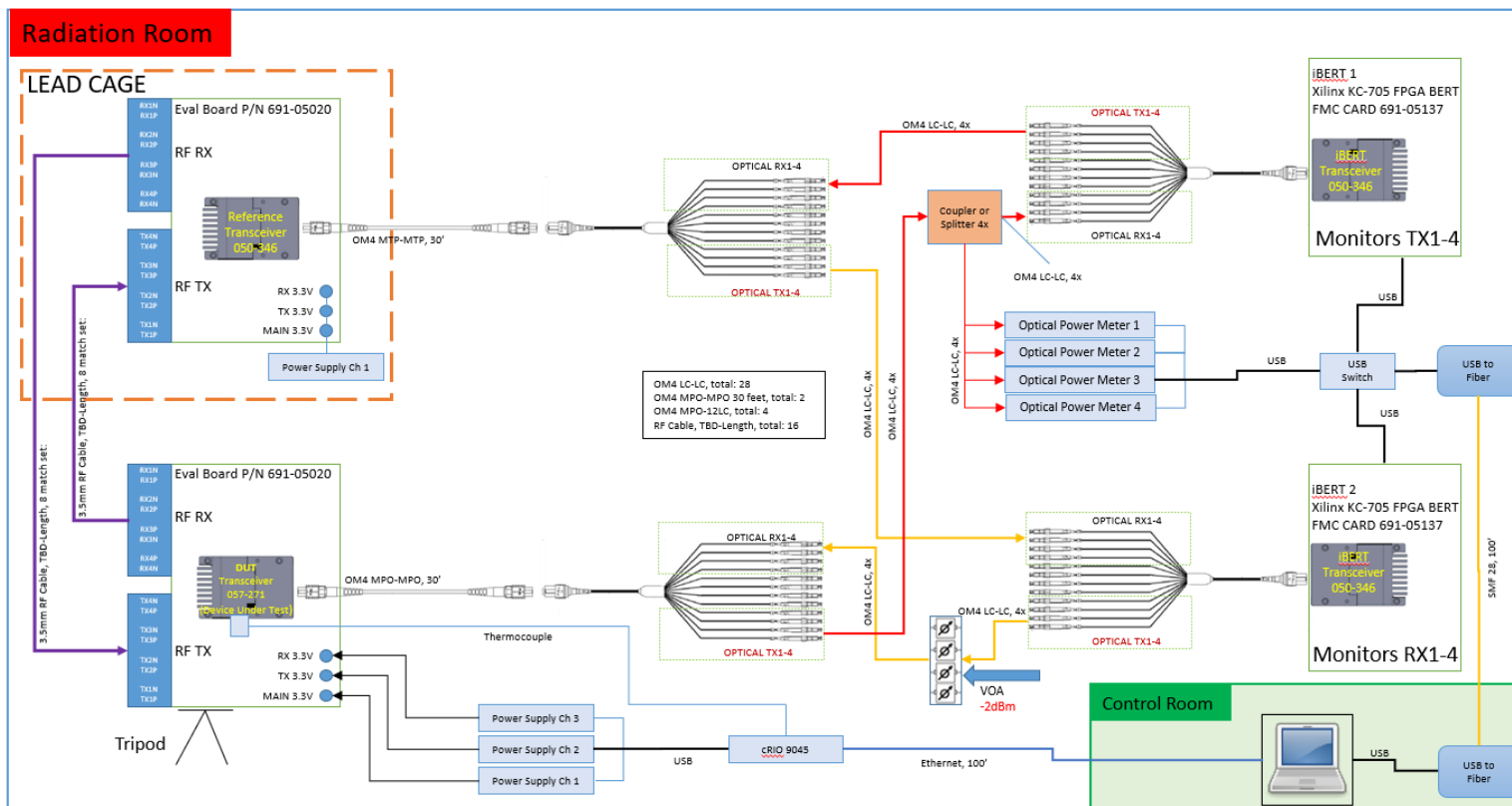
- Extensive qualification testing performed on 38999 and rectangular MT connectors
- PC, APC and expanded-beam types available

Test Parameter	Qualification Requirement
Mechanical Shock	300 G Half-sine Pulse, 3 ms Duration, 3 Times Both Direction Each Axis per TIA-455-14A
Vibration, Random	49.5 Grms at Ambient Temperature per MIL-STD-1678-3, Measurement 3201, Test Condition C, 5.3c, 8 hours exposure each axis
Mating Durability	500 Mating Cycles per TIA-455-21A
Humidity*	90%-95% RH, 96 hour Exposure per TIA-455-5C, Method A, Test Condition A *
Thermal Cycle*	5 Cycles, -40°C to 85°C with 1 hour Exposure per EIA-364-32F, Condition VIII, Method A
Temperature Life*	85°C for 336 hours per TIA-455-4C

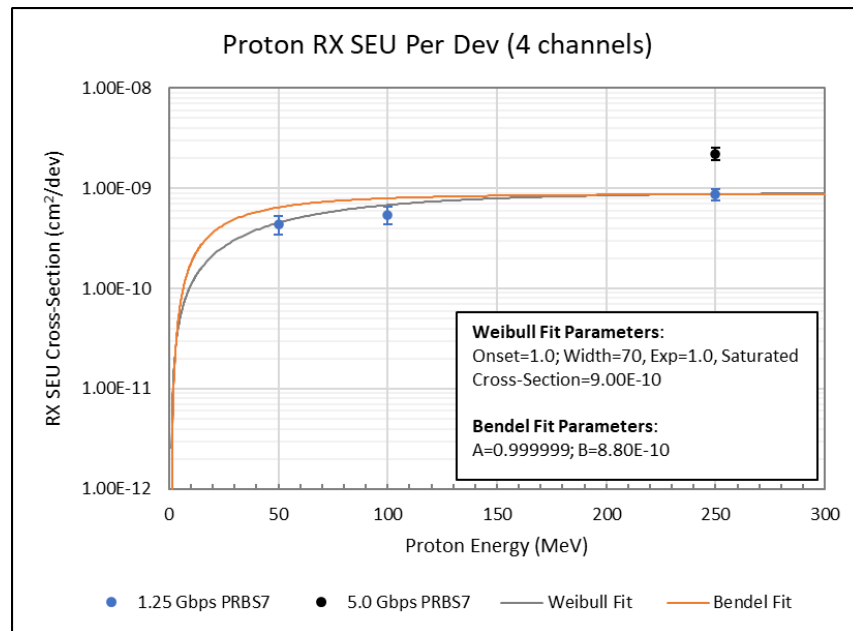
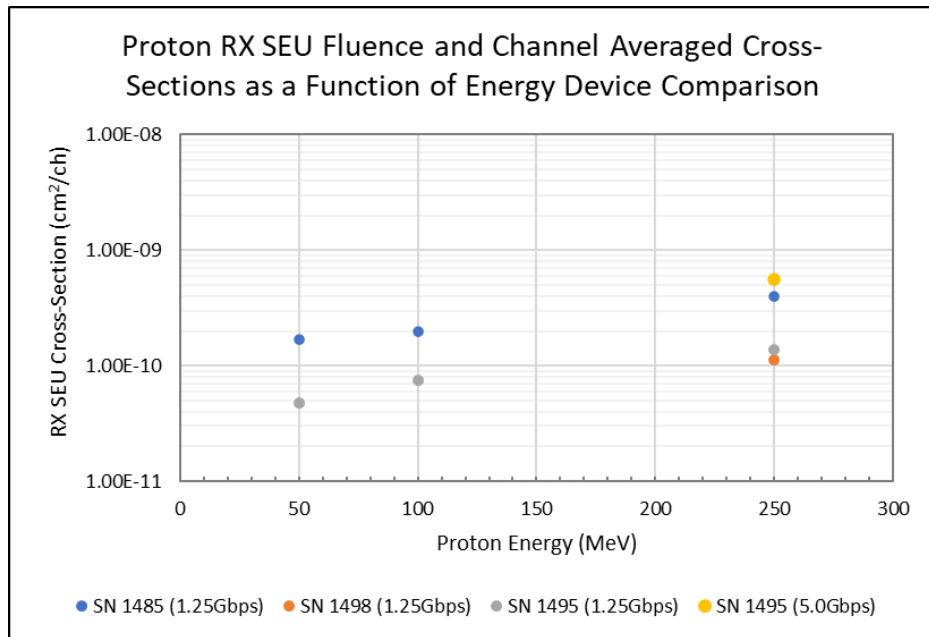
Summary

- Parallel optic photonic transceivers developed for space applications
- Support data rates 1-25 Gbps
- External microprocessor control option
- Demonstrated in launch and space environments, including radiation
 - Proton, heavy ion, gamma
 - On-orbit error estimates
- Compatible with SpaceFibre physical layer standard and common EGSE
 - SFP+, QSFP+, QSFP28
 - sRIO, Aurora, Ethernet, etc.
- Rugged MT circular and rectangular fiber optic connector and cable assemblies developed
- Available today – short leadtimes and no development required

Proton radiation test setup



Proton SEU data



CREME96 on-orbit estimates for 4-channel 10G transceiver

Environment	Polar Low Earth Orbit (700km 98.2° inclined circular orbit)		Equatorial Low Earth Orbit 1 (850km, 60° Inclined circular orbit)		Equatorial Low Earth Orbit 2 (1200km, 60° Inclined circular orbit)	
SEE Type	Expected Event Rate	Conservative (2 σ) Event Rate	Expected Event Rate	Conservative (2 σ) Event Rate	Expected Event Rate	Conservative (2 σ) Event Rate
RX SEU (days/dev)	15	14	26	20	23	11
TX SBU (years/dev)	7.7	N/A	10.7	N/A	9.6	N/A
TX MBU (years/dev)	81.4	N/A	119.3	N/A	106.5	N/A
Register Error (years/dev)	8.1	N/A	12.9	N/A	11.5	N/A
Device SEFI (years/dev)	265.4	141.5	383.0	203.7	343.6	182.7

CREME96 on-orbit estimates for 4-channel 10G transceiver

Environment		ISS		GEO		GPS – MEO (20,180KM 55° Inclined circular orbit)
SEE Type	Expected Event Rate	Conservative (2 σ) Event Rate	Expected Event Rate	Conservative (2 σ) Event Rate	Expected Event Rate	Conservative (2 σ) Event Rate
RX SEU (days/dev)	38	36	5	5	7	7
TX SBU (years/dev)	18.0	N/A	2.5	N/A	2.7	N/A
TX MBU (years/dev)	214.8	N/A	21.4	N/A	23.1	N/A
Register Error (years/dev)	23.0	N/A	2.4	N/A	2.6	N/A
Device SEFI (years/dev)	654.7	347.8	83.9	44.8	89.2	47.6