Radiation hardness in single-mode optical links for Accelerator Instrumentation

Carmelo Scarcella

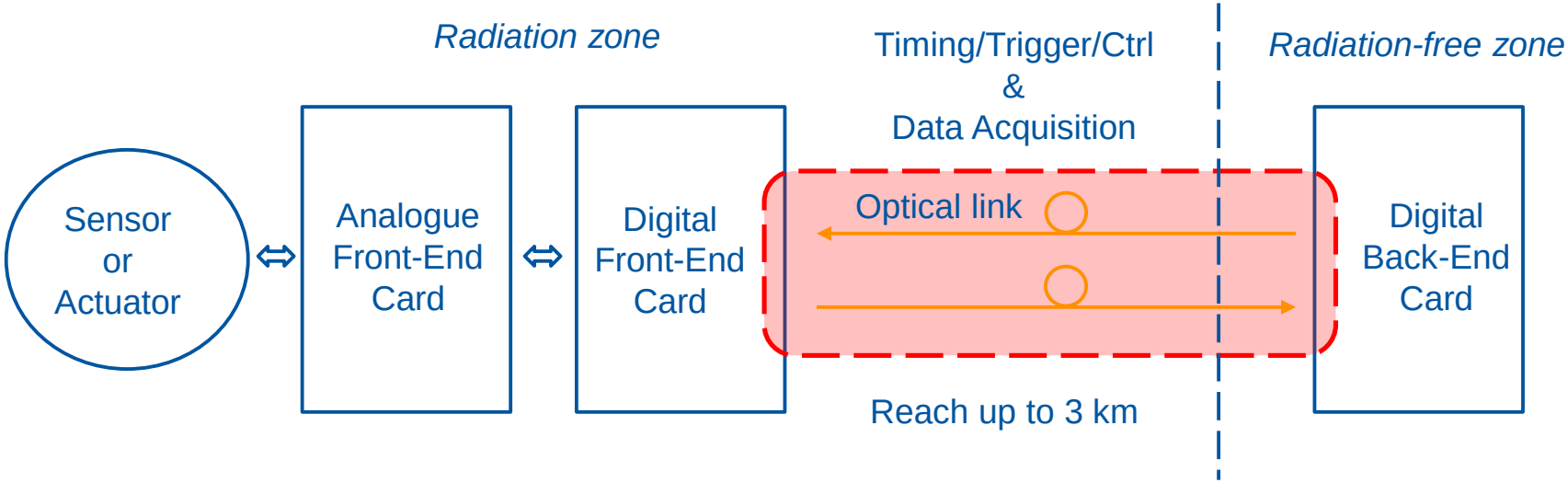
Indico link: https://indico.cern.ch/event/760345/

Outline

- Optical Links for Accelerator Instrumentation
  - Versatile Link and Single-mode VTRx
  - project timeline
- Edge-Emitting Laser selection
  - displacement damage
- Wavelength division multiplexing CWDM
- Summary and future steps

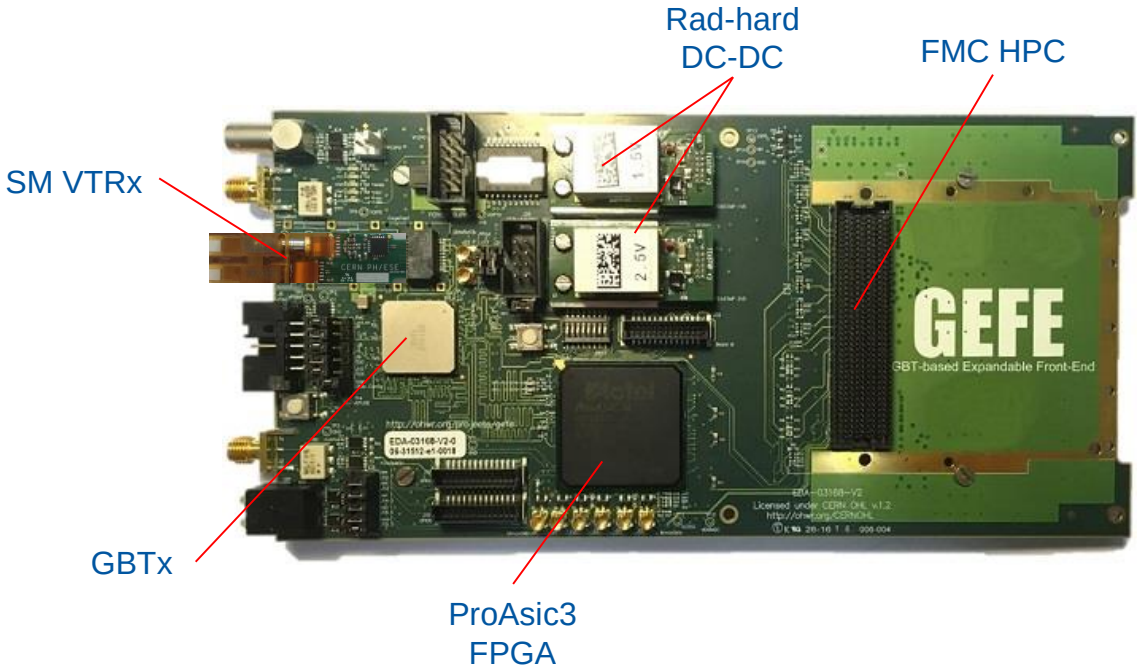
Optical Links for Accelerator Instrumentation

The Accelerator Instrumentation Group (BE/BI) is moving towards common readout solutions

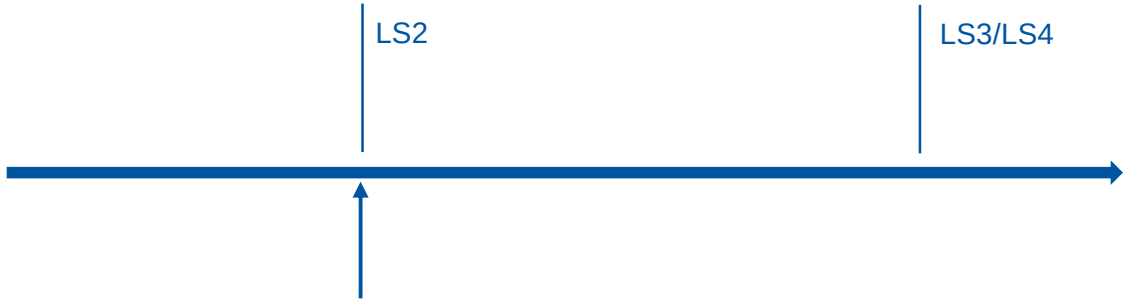


The GBT-based Expandable Front-End (GEFE)

Common hardware development ongoing for LS2 upgrades



Project timeline



Rad-Hard Link	GBTx + SM VTRx
Rad-Hard DFE	GEFE & S-GEFE
Users	New SPS BPM system (“ALPS”) Motor control optical interface (“MCOI”) …
Total links	~ 300
Data-rates	GBTx Tx 4.8 Gbps Rx 4.8 Gbps

Single-mode Versatile Link Transceiver - VTRx

Front-End pluggable module

Receiver

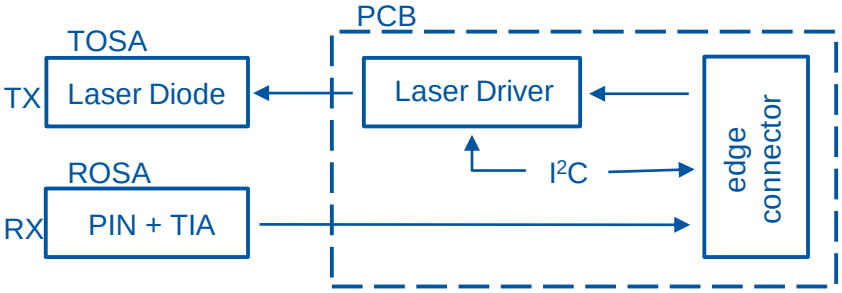
- COTS InGaAs Photodiode
- Transimpedance amplifier GBTIA v3

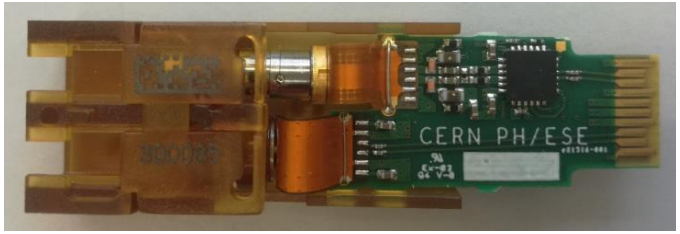
Transmitter

- COTS Edge emitter Fabry-Perot laser
- Laser driver GBLD v4.2

Calorimeter grade radiation tolerance

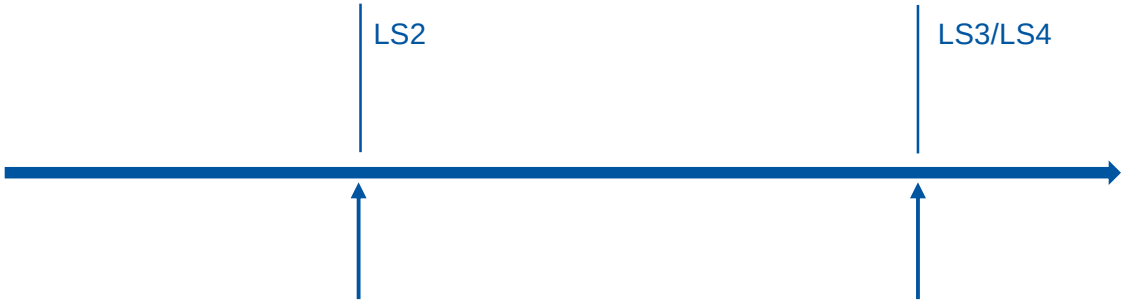
- 10 kGy TID
- $5 \cdot 10^{14}$ n/cm^2 MeV neutrons





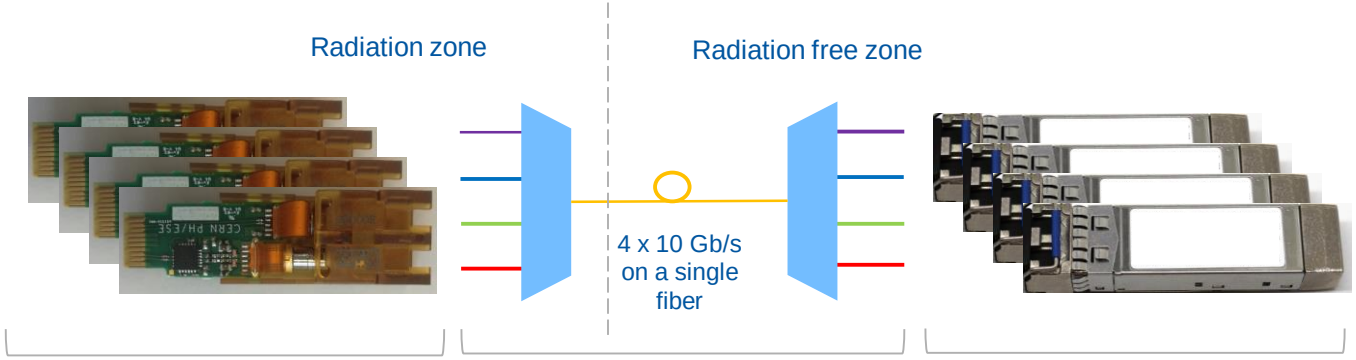
https://espace.cern.ch/project-versatile-link/public/default.aspx

Project timeline



	LS2	LS3/LS4
Rad-Hard Link	GBTx + SM VTRx	LpGBT + New SM VTRx
Rad-Hard DFE	GEFE & S-GEFE	Distributed IO Tier (BE-CO) or S-GEFE 2
Users	New SPS BPM system (“ALPS”) Motor control optical interface (“MCOI”) …	LHC BPMs (LS3) SPS BLMs (LS3) / LHC BLMs (LS4) …
Total links	~ 300	~ 5000 - 10000
Data-rates	GBTx Tx 4.8 Gbps Rx 4.8 Gbps	LpGBT Tx up to 10.24 Gbps Rx 2.56 Gbps

CWDM Single-Mode Versatile link



Front-end
Radiation hard
Transceiver - VTRx

Passive optics
Single-mode optical fibers
Optical MUX/DEMUX

Back-end
Custom off-the-shelf
transceiver

Parameter	Value	Units
Max Uplink Bit Rate	4.8 or 10.24	Gb/s
Max Downlink Bit Rate	4.8	Gb/s
Wavelengths	1270/1290/1310/1330	nm
Total ionizing dose (TID)	10	kGy
Fluence	$5 \cdot 10^{14}$	n/cm^2 MeV neutrons

CWDM Single-mode Versatile Link Transceiver - VTRx

Front-End pluggable module

Receiver

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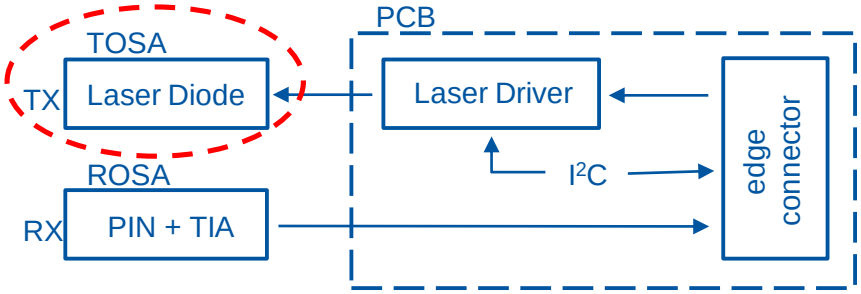
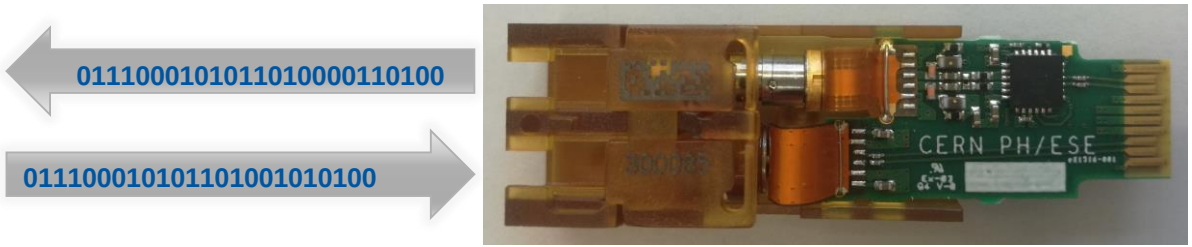
Transmitter

- COTS Edge emitter Laser
- Laser driver GBLD v4.2

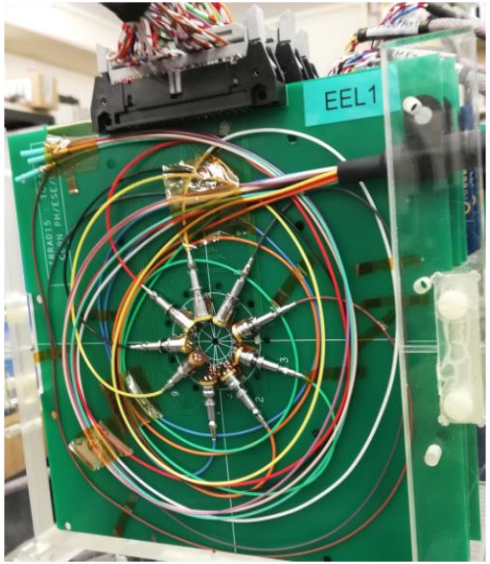


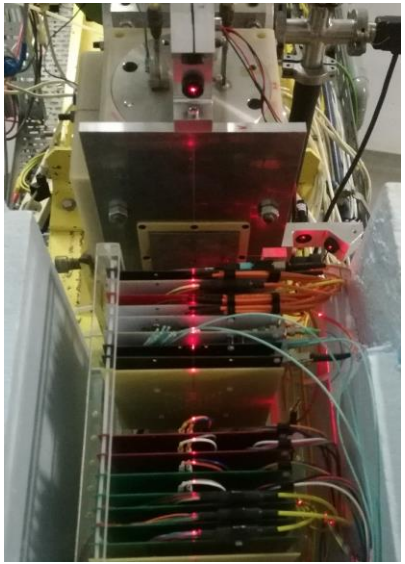


Displacement damage – TOSA in n-beam

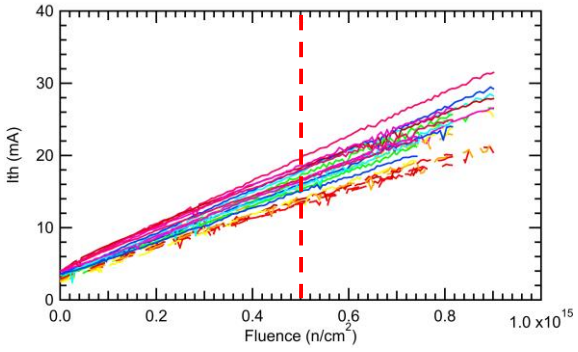
Single-mode TOSAs exposed to neutron beam at UC Louvain cyclotron facility (28/11/2018)

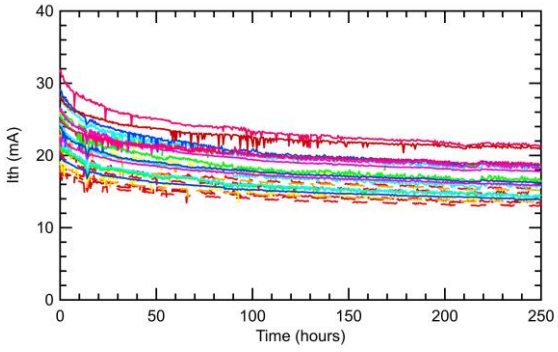
Irradiation with fluence up to 5 x 10^{14} n/cm^2 20 MeV neutrons

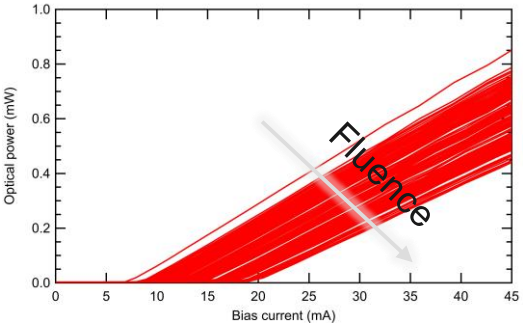


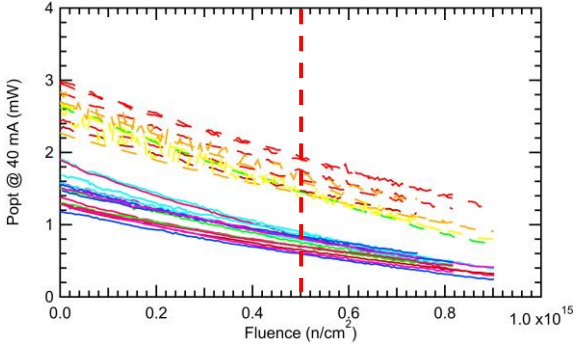


Displacement damage 1/2









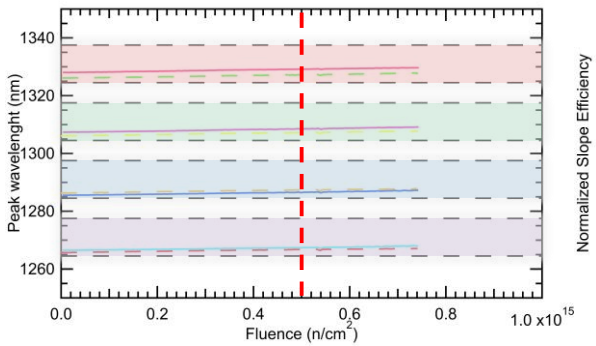
Moderate increase of threshold current for all tested devices

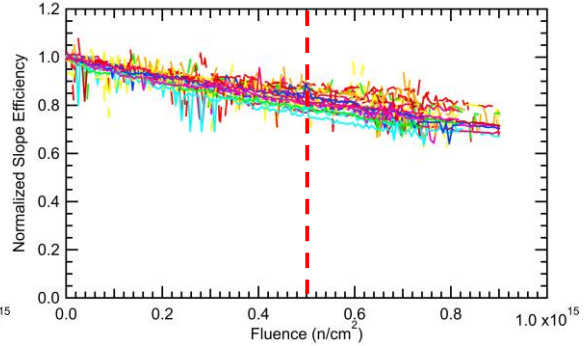
Full damage compensation possible adjusting bias current

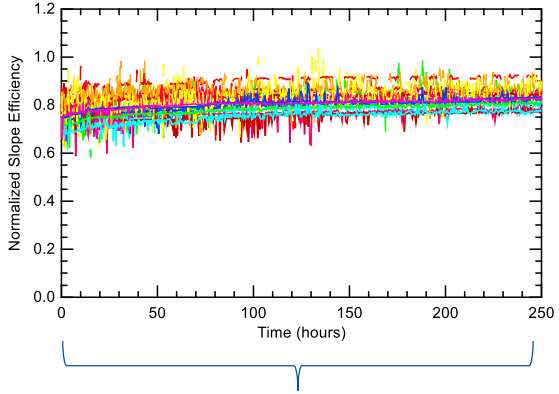
Annealing reduces radiation damage

~ halves the effect in 10 years lifetime

Displacement damage 2/2







Negligible central wavelength shift

Laser peak wavelength within the CWDM Passband

Moderate slope efficiency decrease

Negligible optical modulation amplitude penalty within the specification radiation levels

Edge-emitting Laser radiation tolerance

Two suitable Laser types showing moderate penalty due to displacement damage have been identified

TID test for optical components into TOSA package to be performed

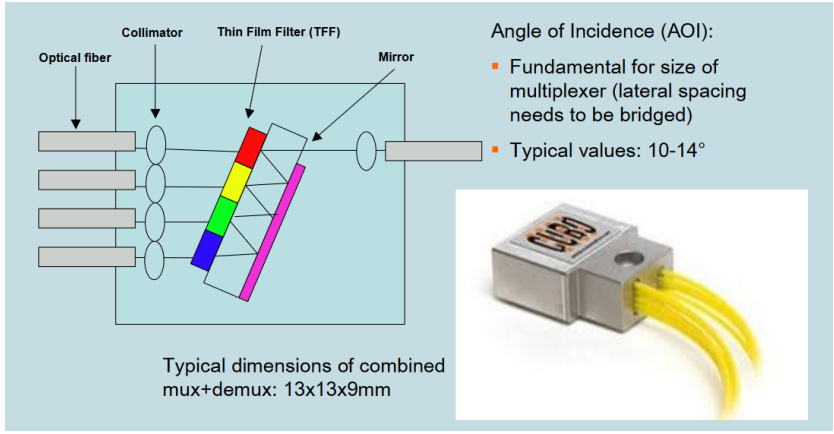
Further radiation tests required during production volume procurement

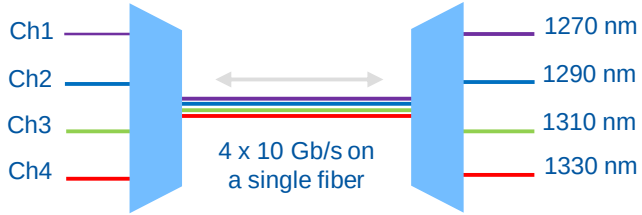
e. g. opto die wafer qualification

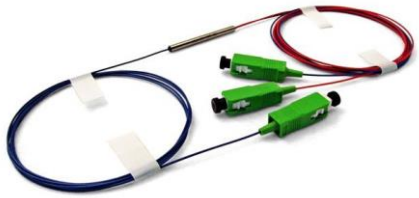
Coarse Wavelength Division Multiplexing

Based on optical MUX/DEMUX

- passive bidirectional component
- 4x10 Gb/s on a single fiber
- ~ 2 dB insertion loss (4ch MUX)
- Radiation tolerance to be investigated







Summary and further work

Common solution for accelerator instrumentation optical links

- based on the versatile link framework
- targeting 10.24 Gb/s upstream operation
- 4 channel wavelength division multiplexing scheme (CWDM)
- compatible with next generation rad-hard chipset for optical data links (LpGBT)

Project status

- demonstration of 10.24 Gb/s upstream operation
- Laser driver (GBLD) insensitive to TID in the specification range
- moderate displacement damage of CWDM Edge-Emitting Lasers

Next steps

- radiation tolerance validation of CWDM optical MUX
- solutions for standard SFP cage compatibility
- defining of final link architecture
- moving towards parts procurement, production and qualification

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