Optical Multi-gigabit Ethernet

on the Verge of Standardization and Implementation

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Does Optical Make Sense?

Main Reasons

- Cost effective
- Galvanic isolation in electrical powertrains
- Superior EMI performance
  - Critical areas like antennas
- Superior EMS performance
  - In very noisy environments like those of electrical powertrains
- Easy engineering
- Ethernet technology

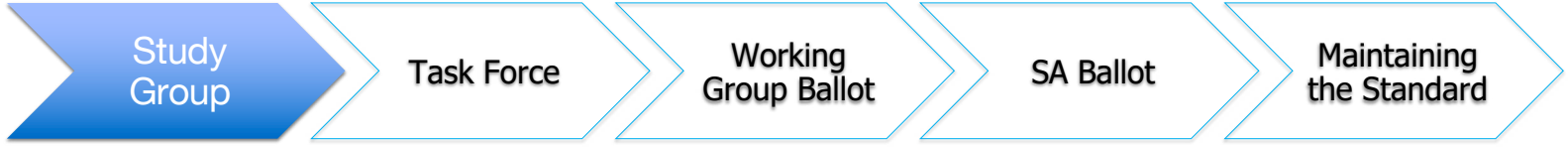
Other Reasons

- Weight
- Robust and reliable solution (building on almost 20 years of optical automotive)
- Standardized solution
- Seamless integration
- Copper and optical links co-exist in the same car
  - Different use cases
  - Redundancy for safety requirements
- Path to very high speeds (x00 Gb/s)

Multi-gigabit Optical: IEEE & ISO Standards

- Standardization effort is split in two International Standard Bodies:
  - ISO: PWI 24581: "General Requirements and Test Methods of Optical Harness for up to 100 Gbit Communication"
    - Current stage: Preliminary Working Item
    - Project Leader: Takashi Fukuoka
    - Convenor: Naoshi Serizawa

  - IEEE P802.3cz "Multi-Gigabit Optical Automotive Ethernet"
    - Current stage: Task Force



Optical Use Cases

BMS
Galvanic Isolation

Safe backbone

Smart Antenna
modules

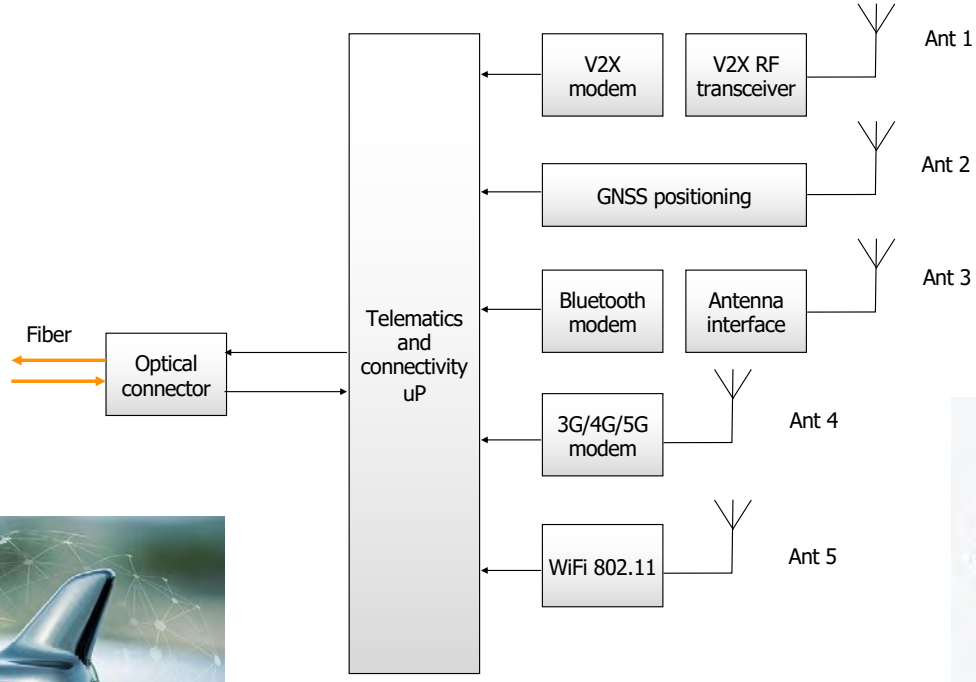
Infotainment

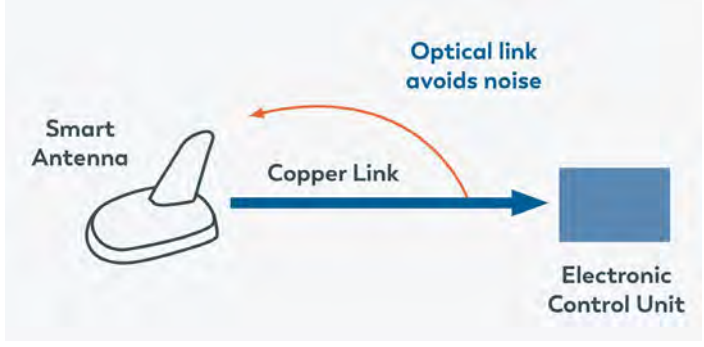
Lower speed
EMC-tight links

Autonomous driving
safety redundancy

ADAS sensor
interconnection

Smart Antenna

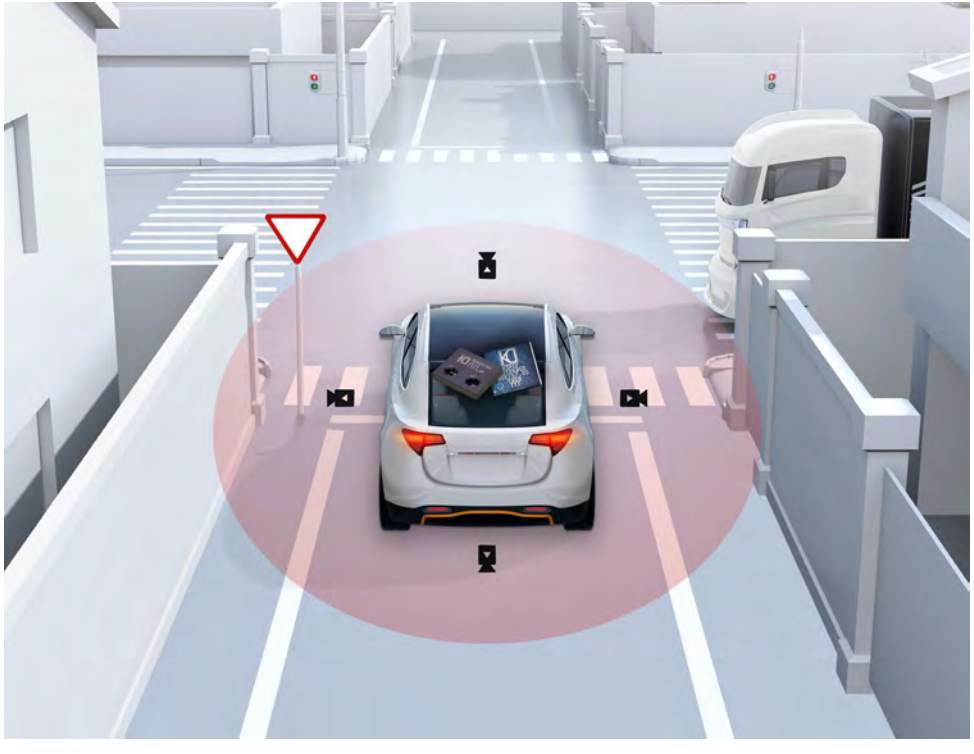




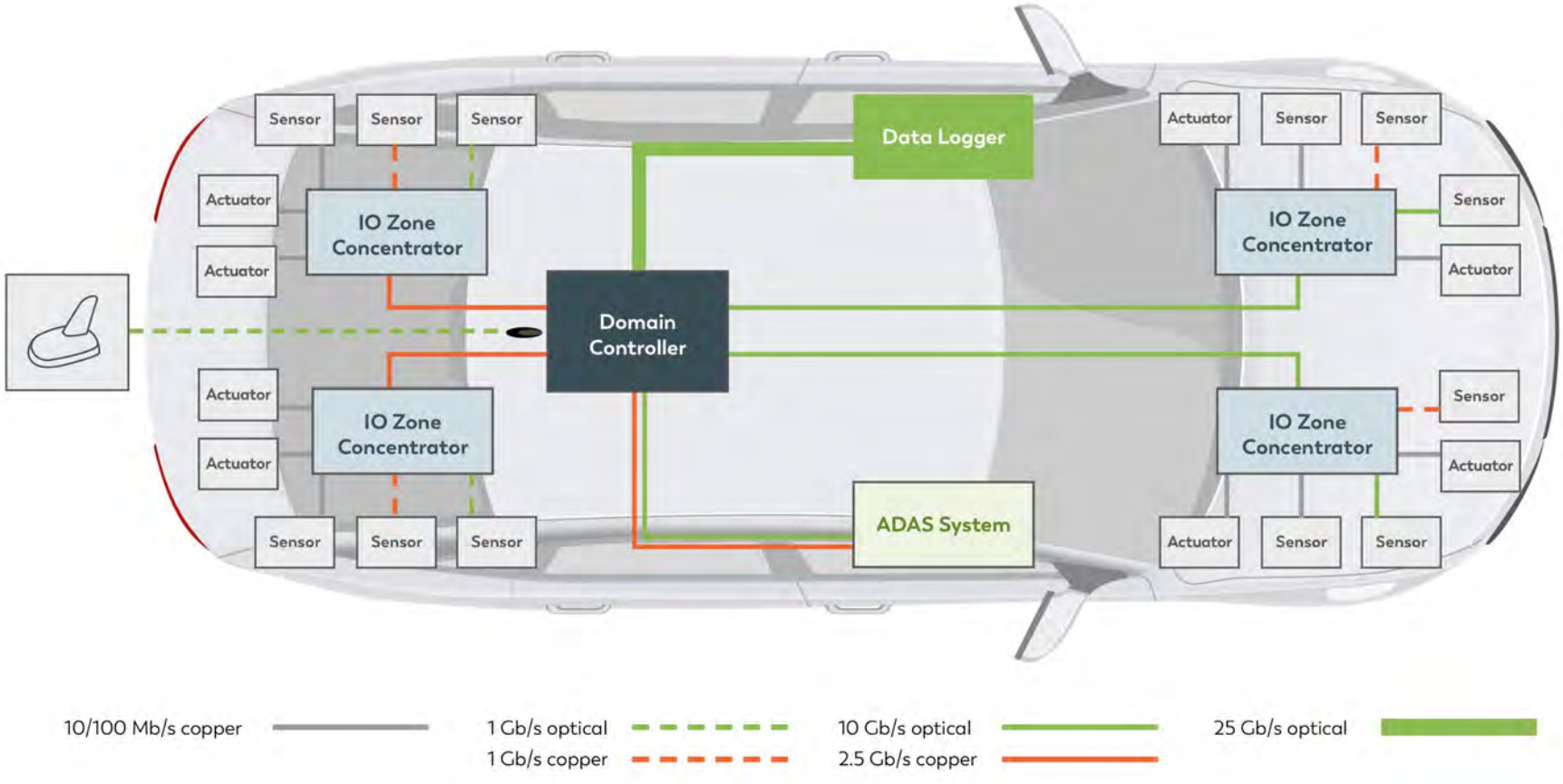
Any minor radiation from the copper link will reduce the reception dynamic range of the antennas

ADAS Sensor Interconnection

Cameras, Lidar, Radar Sensors for ADAS & AV

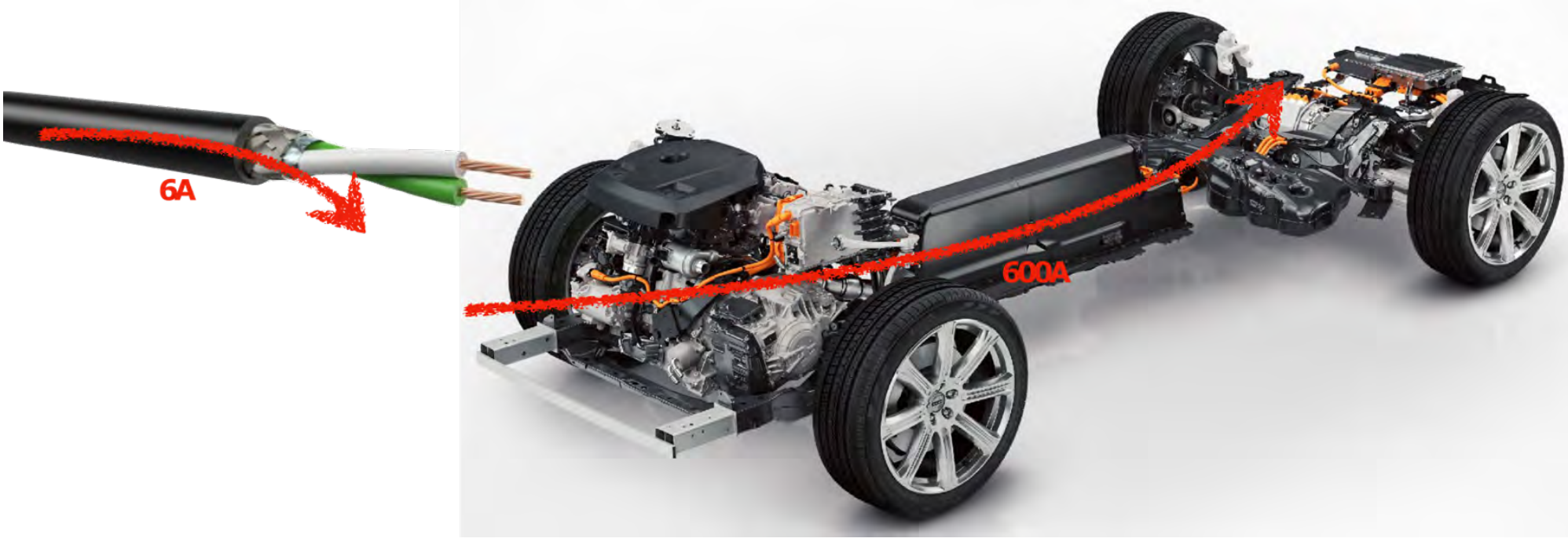


Copper and Optical Will Co-exist



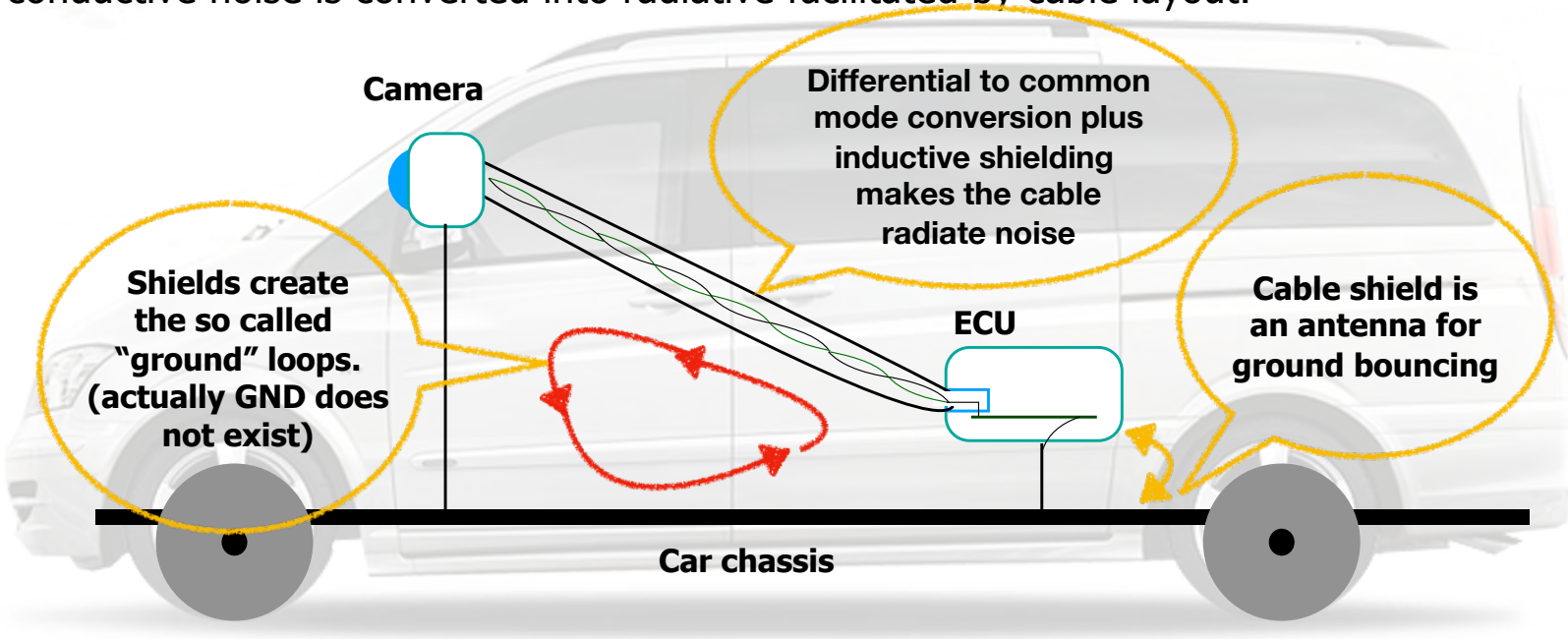
Jump Start Effect

- During car start, currents up to 600 A move through the chassis of the car.
- This large current generates voltage drops between different ECUs of the car.
- These voltages may create up to 6 A currents through the shield of data cables.
- The use of optical links in long backbone connections simplifies car engineering.



How Do Shielded Copper Cables Radiate?

- Shielding is an antenna for any ground bouncing ECU noise (E field).
- Common mode conversion plus inductive shielding generates shield currents and voltages, thus radiating noise as an antenna.
- Cable (inductive) shielding is a root cause of uncontrolled current loops (H field): conductive noise is converted into radiative facilitated by cable layout.



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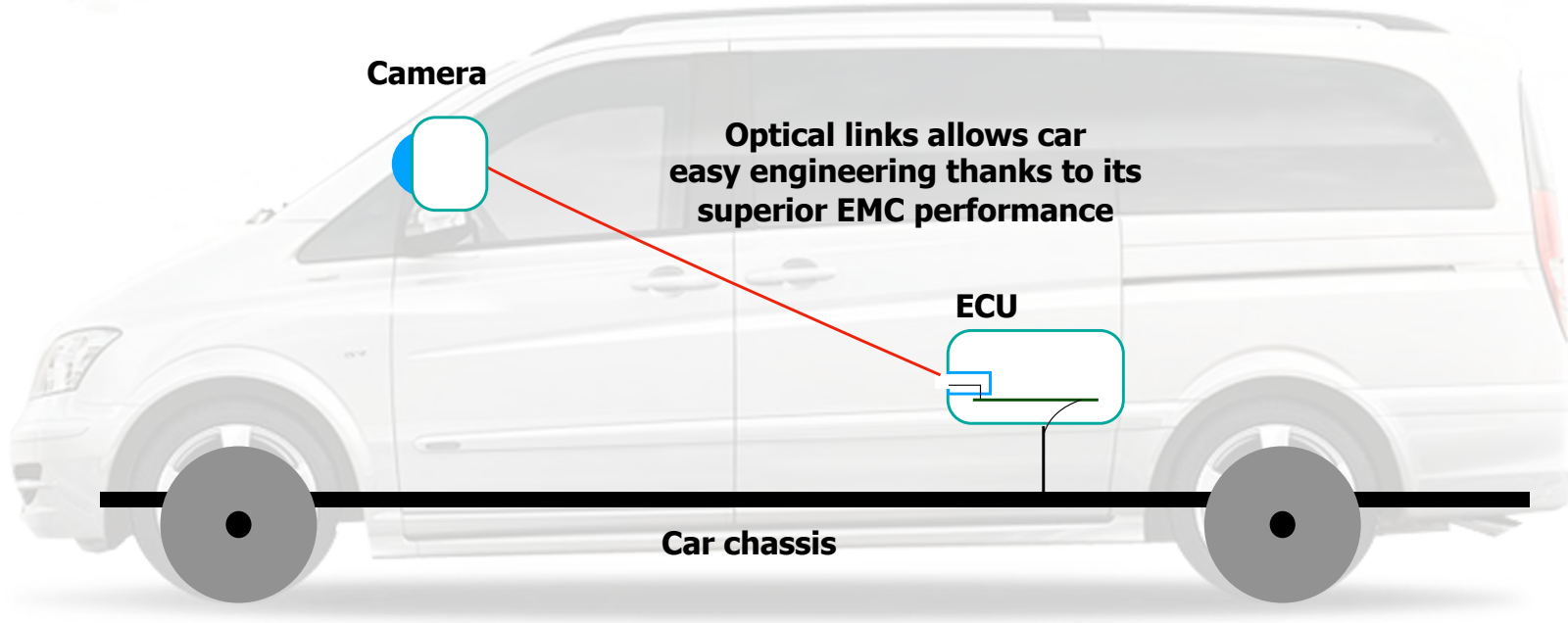


Multi-gigabit Use Cases

	2.5 Gb/s	5 Gb/s	10 Gb/s	25 Gb/s	50 Gb/s	Asymmetric
Backbone	✓	✓	✓	✓	✓	
Smart Antenna	✓					
Cameras, Sensors	✓	✓	✓	✓		✓
Display	✓	✓				✓
Data Loggers		✓	✓	✓	✓	

Main Drivers of IEEE 802.3 OMEGA Study Group

- High speed
  - 2.5, 5, 10, 25 and up to 50 Gb/s in a single lane
  - 100 Gb/s path to be decided
- High performance
  - Temperature range from -40 ºC to 125 ºC
  - 15 m and 4 inline connectors
  - 40 m and 4 inline connectors for buses and trucks
- Reliability
  - Fiber cannot physically be an aggressor or victim of electromagnetic emissions
  - Fiber provides galvanic isolation
  - Avoid grounding (current loops) problems in communication systems
  - Reliable photonics (light sources and detectors)
- Low complexity
  - Simple modulation
  - Multi Mode fibers with huge economy scale
  - Selection of extensively used light sources
- Topology
  - Highly asymmetric links supported from the beginning
  - Also support symmetric links for backbone communication

SAME LOW COST HARNESS AND CONNECTORS FOR ALL SPEEDS

IEEE 802.3 OMEGA Technology Leveraging

IEEE Std 802.3 already includes the 10, 25 and 50GBASE-SR specifications for data centers, but for the automotive industry we need:

- 2.5, 5, 10, 25 and 50 Gb/s per lane; 100 Gb/s multiplexing several lanes or single lane
- Temperature: -40 ºC — 125 ºC
- 15 years operation, less than 10 FIT
- Mechanical and chemical loads on fiber, connector and mated pair
- 15 m + 4 inline connectors or 40 m + 4 inline connectors
- Lower relative cost and power consumption
- OAM side-channel for dependability and link management

IEEE 802.3 OMEGA Technology Leveraging

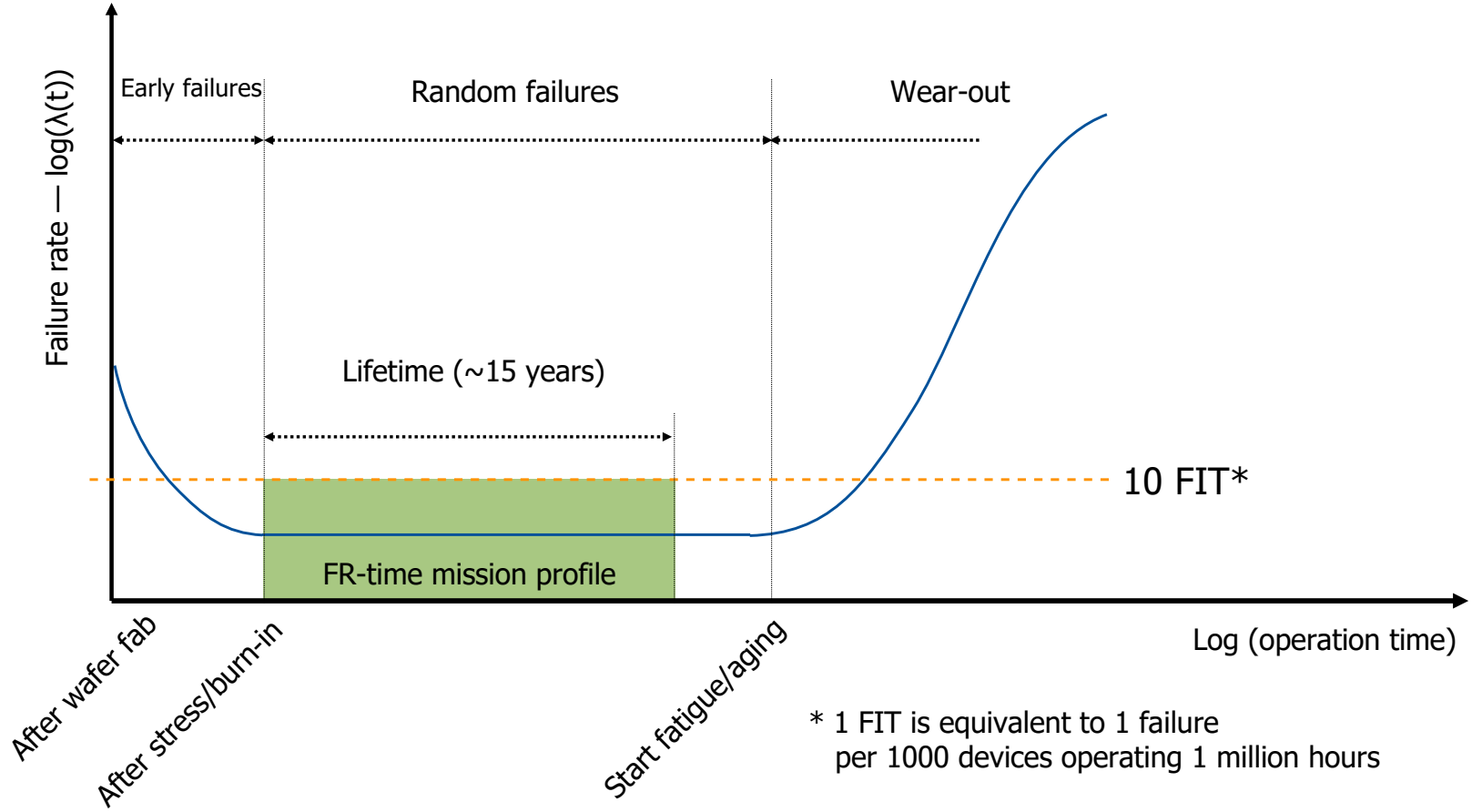
But we can reuse the optics, fibers, and electronics already developed for nGBASE-SR as our starting point:

- IR VCSEL
- Multimode fiber
- IR photodiodes
- Cable structures already used in harsh environment applications

And focus our work on automotive needs:

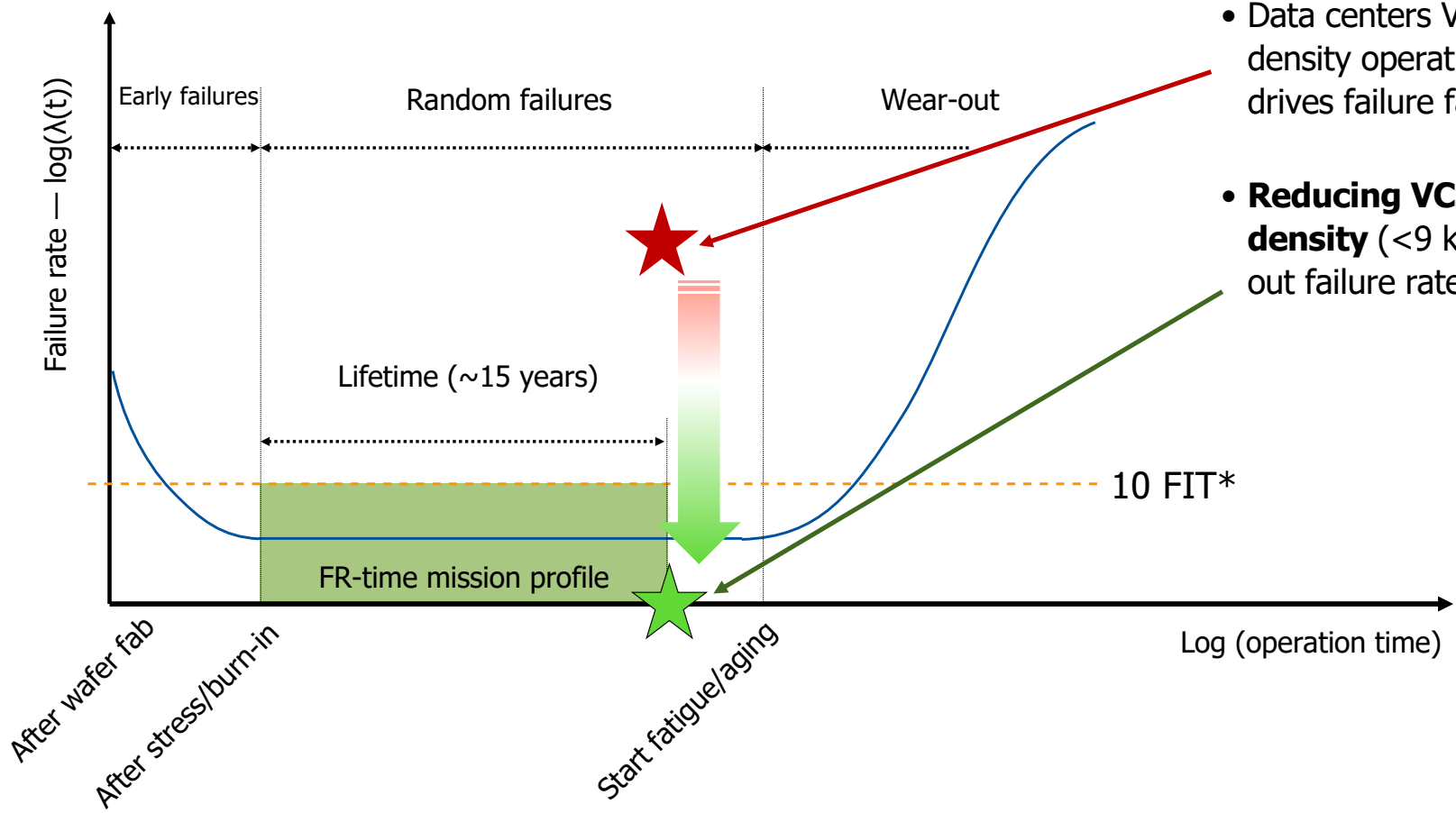
- VCSEL reliability for the operational temperature range
- Connector development
- Adaptive DSP to cope with VCSEL large parametric deviation
  - Increasing the yield percentage means cost reduction

IEEE 802.3 OMEGA Technology Leveraging. VCSEL



Source: perezaranda_OMEGA_05a_1119_ VCSEL_Reliability.pdf

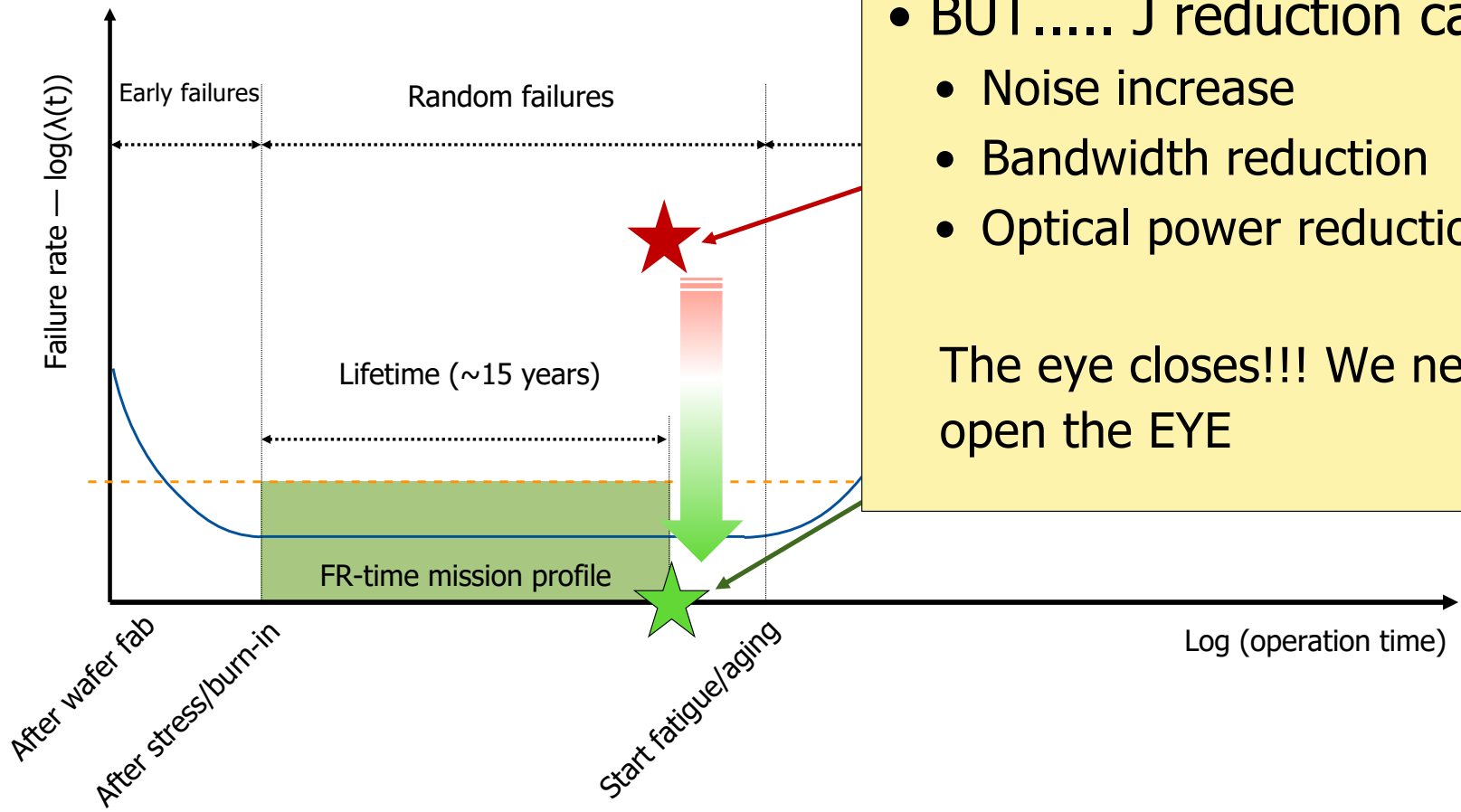
IEEE 802.3 OMEGA Technology Leveraging. VCSEL



- Data centers VCSEL current density operation at 125 ºC drives failure fate >>10 FIT.
- **Reducing VCSEL current density** (<9 kA/cm^2), wear-out failure rate reaches 0 FIT

Source: perezaranda_OMEGA_05a_1119_ VCSEL_Reliability.pdf

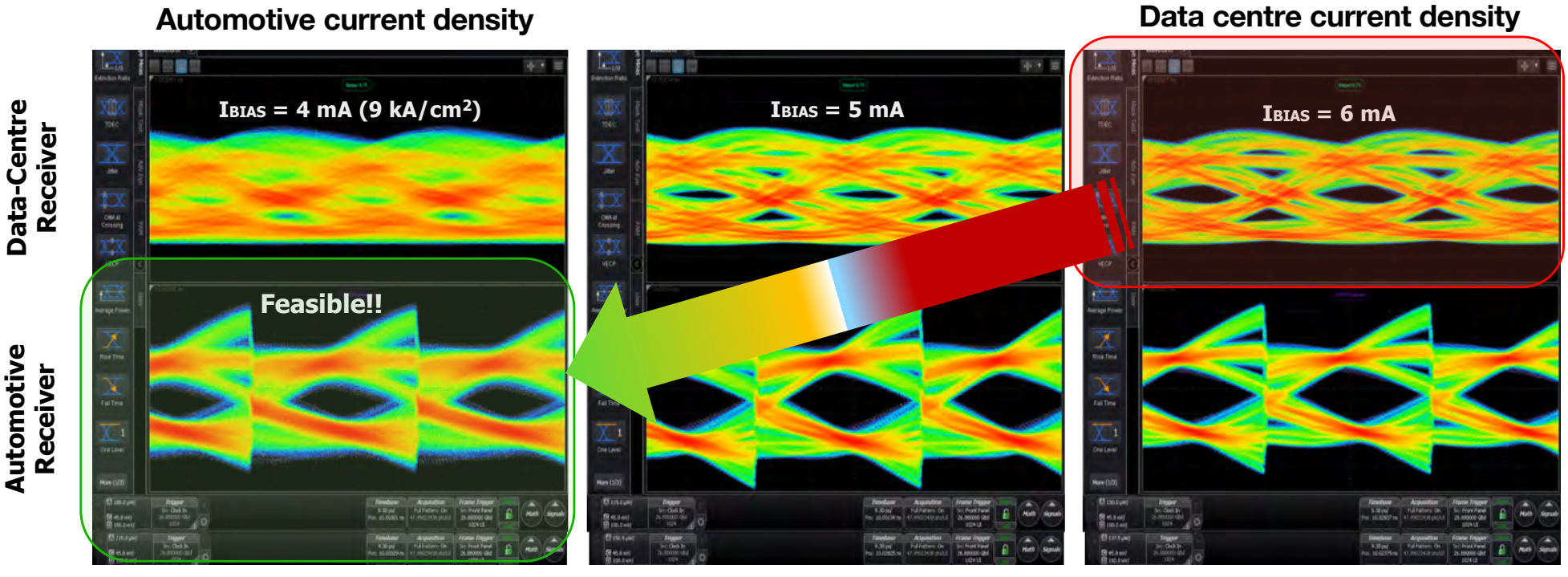
IEEE 802.3 OMEGA Technology Leveraging. VCSEL



- BUT..... J reduction causes:
  - Noise increase
  - Bandwidth reduction
  - Optical power reduction

The eye closes!!! We need to open the EYE

25 Gb/s 125 ºC: Opening the Eye !!!

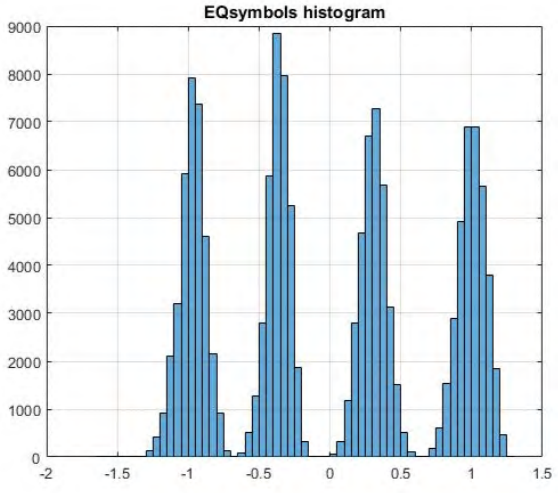


Using advanced DSP techniques we can make the link feasible:

- **Timing recovery** for optimum symbol sampling
- **Adaptive equalizer** coefficients calculation
- **Forward Error Correction**

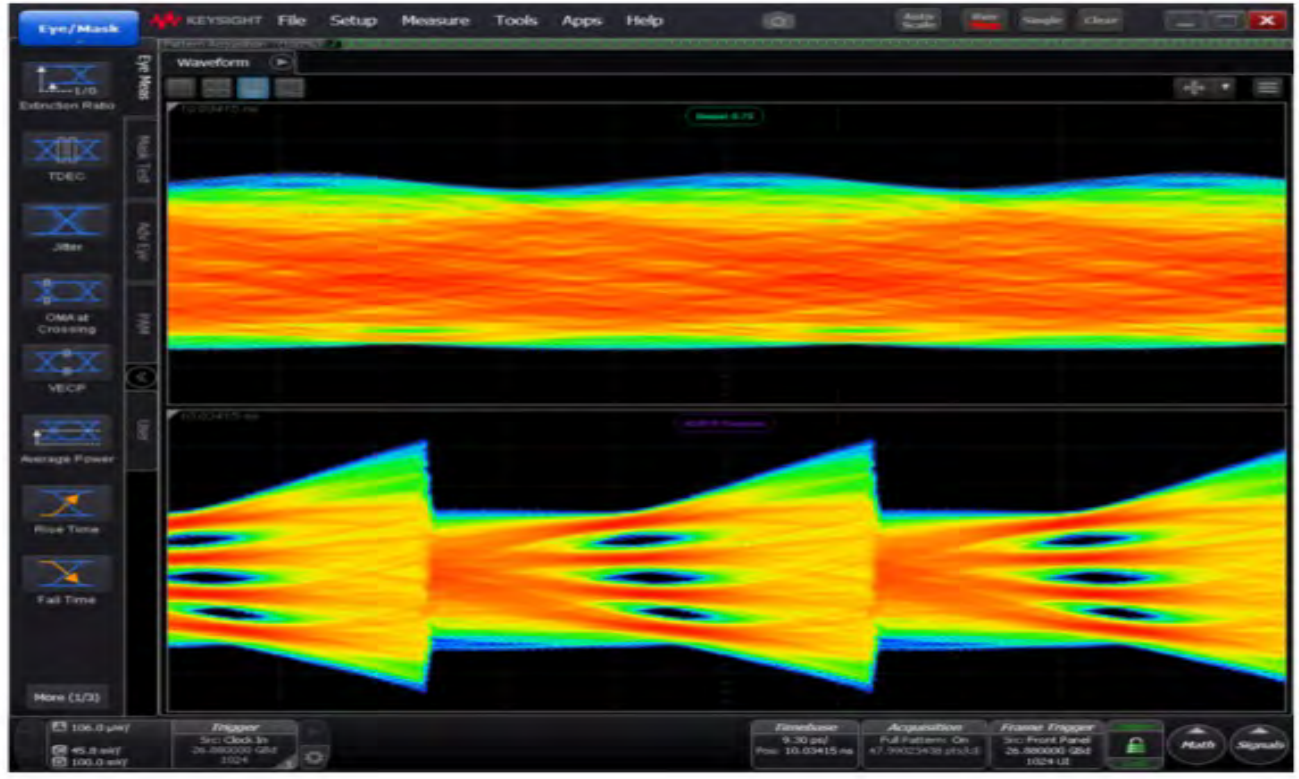
Source: perezaranda_OMEGA_02b_1119_ InGaAs_25G_VCSEL.pdf

Even further: 50 Gb/s at 125ºC



Data-Centre Receiver

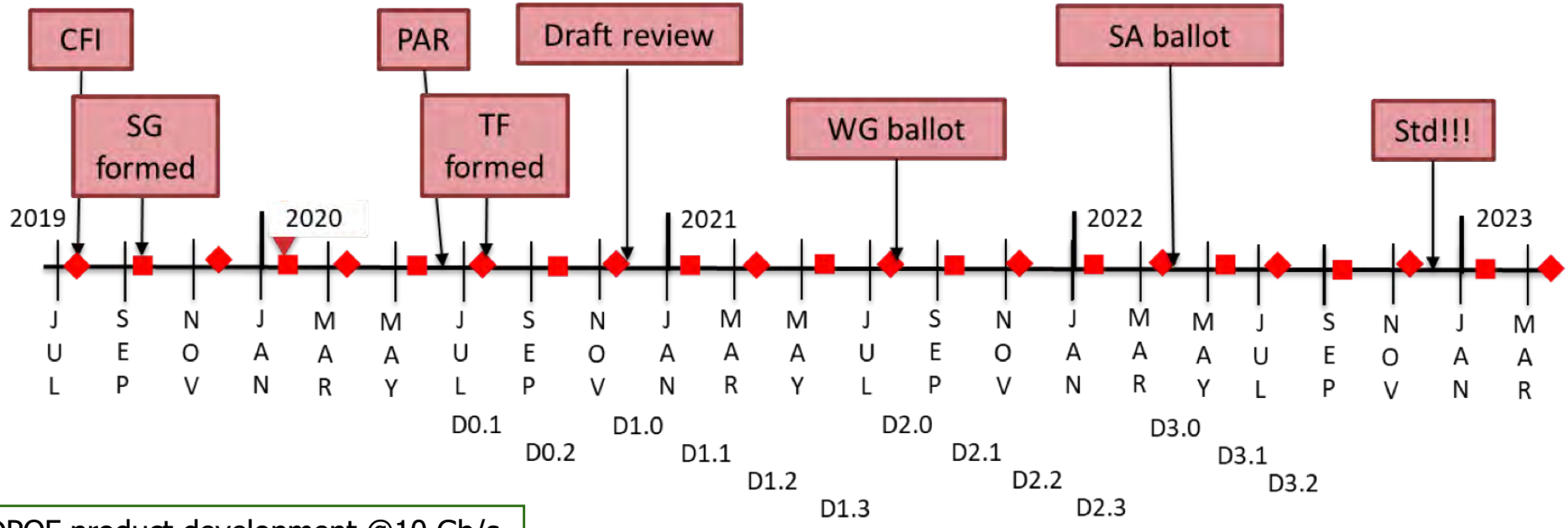
Automotive Receiver



IEEE 802.3 OMEGA Project Status

- **Technical system feasibility demonstrated** up to 50 Gb/s with reduced receiver complexity
  - Target data rates: 2.5, 5, 10, 25 and 50 Gb/s. Also considering 100 Gb/s.
  - Harness objective: 40 m - 4 inline connectors
  - OM3 is chief fiber class candidate: extensively used in data centres and avionics
  - Other fibers under discussion
- **Light source (VCSEL) reliability reachable** for -40 ºC to 125 ºC temperature range and OEM requirements
- **Asymmetric up and down links considered** right from the beginning
  - EEE (Energy-Efficient Ethernet) is a good candidate to implement this feature
  - Camera, display and other asymmetrical use cases included as OMEGA test cases.
  - OAM side-channel for dependability and link management

IEEE 802.3 OMEGA Roadmap

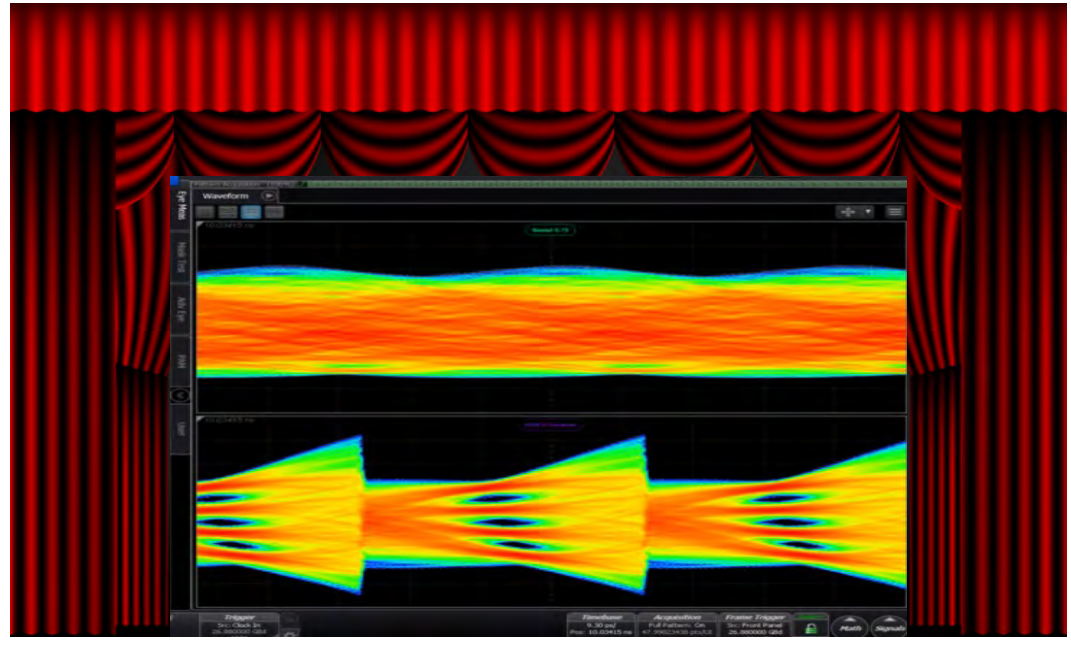


KDPOF product development @10 Gb/s

- Engineering samples: **Q3 2022**
- SOP: **Q3 2025**

Conclusions

- Optical communications in automotive is a **reality** that helps OEMs to easily overcome EMC and galvanic isolation issues
- Optical and copper will **co-exist** under the Ethernet umbrella
- Optical technology is a **future-proven** path to higher speeds in automotive
- IEEE 802.3 in collaboration with individuals from all over the industry have **started the job** towards making it a standard



50 Gbps over Optical Fiber from -20 to 125 ºC ... KDPOF opens the eyes!