# Concept of test points in in-vehicle optical physical layer standardization for multi-vendorization

*Japan Automotive Software Platform and Architecture*

IEEE SA Ethernet & IP @ Automotive Technology Week
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**JASPAR Next Generation High-Speed Network WG**

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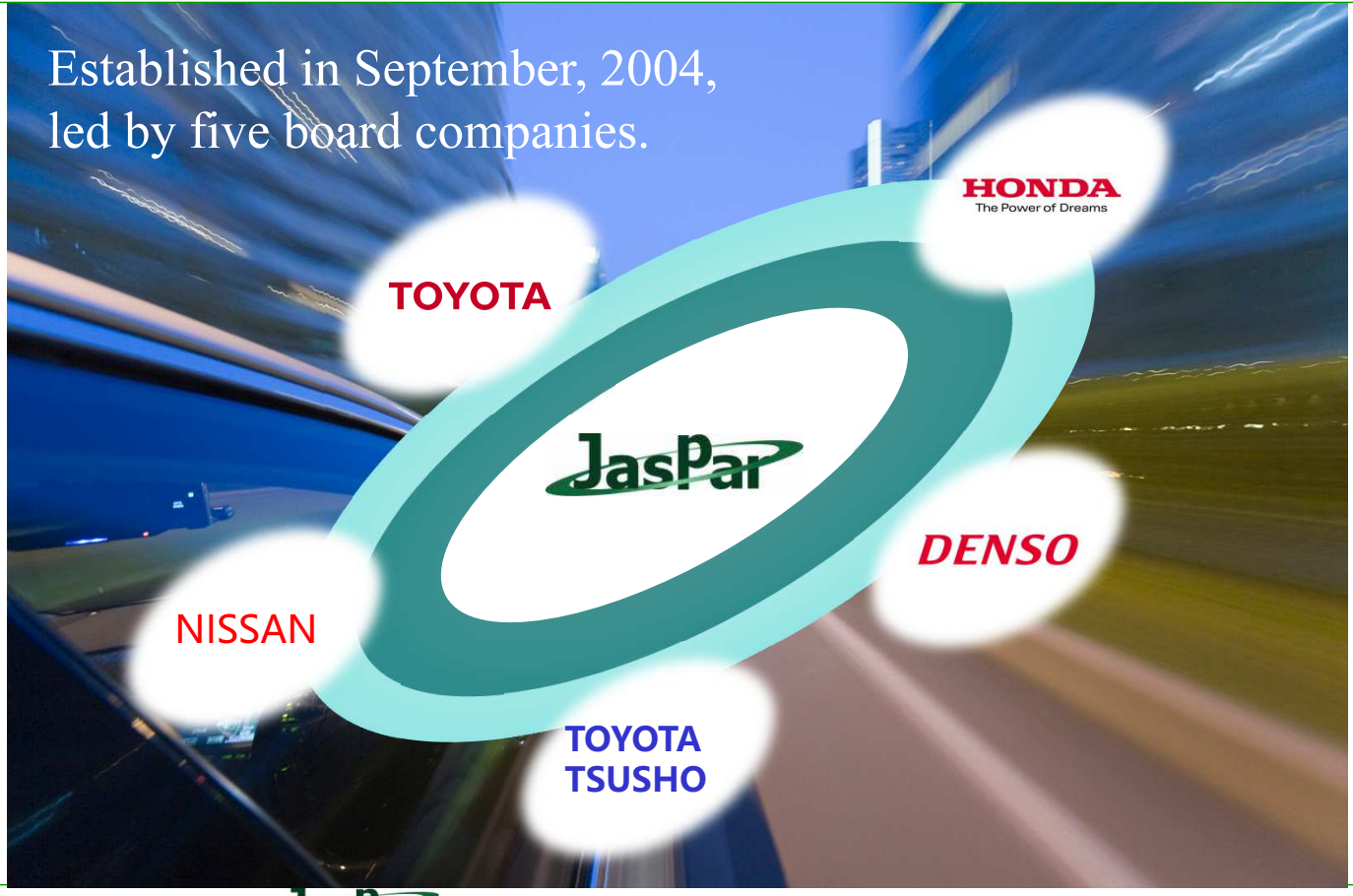
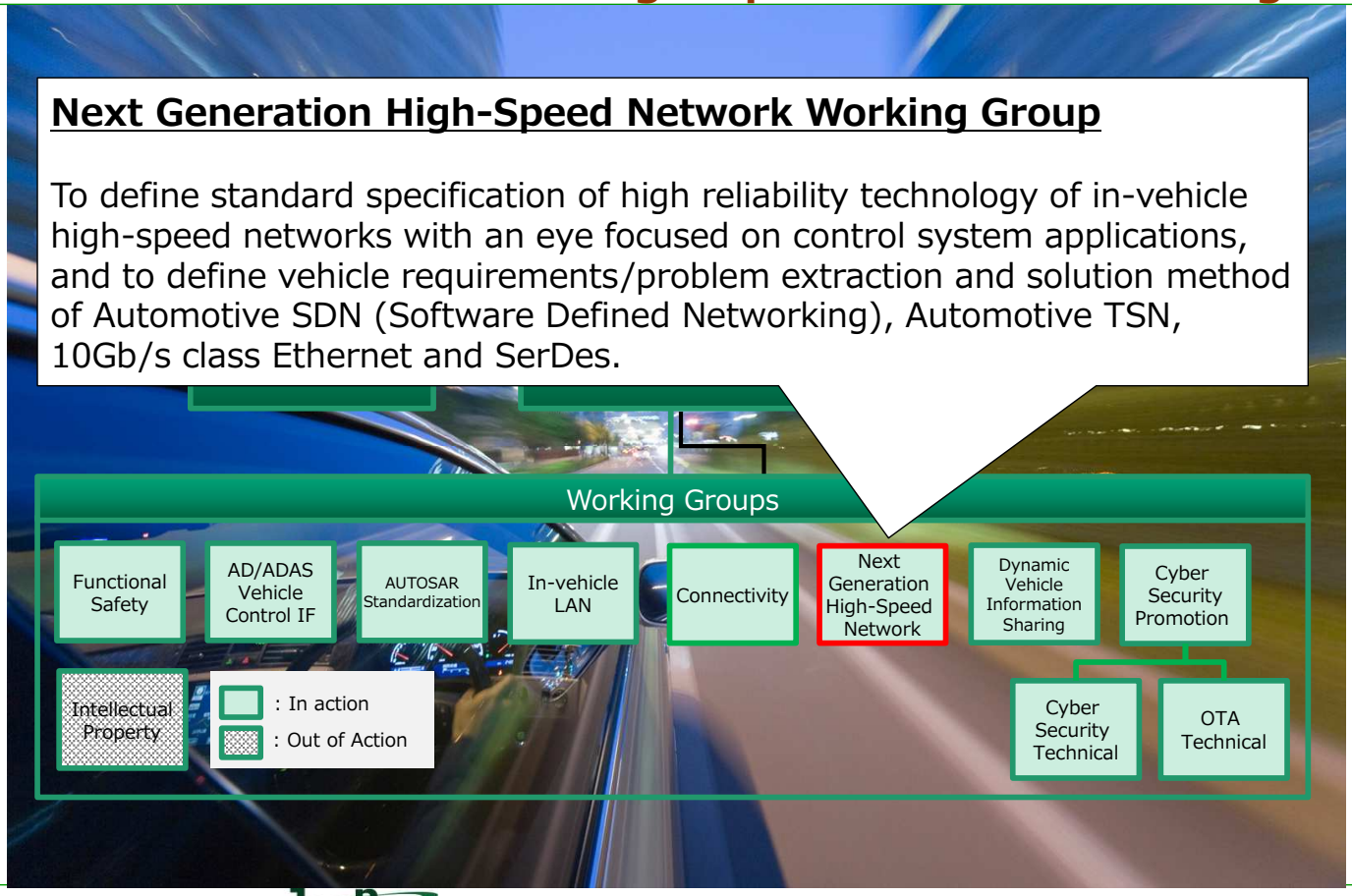
**Takumi Nomura, Honda**
**Hideki Goto, Toyota**

JASPAR, General incorporated association

# Introduction : About JASPAR



# Introduction : Next Generation High-Speed Network Working Group



# Introduction : 3 presentations from JASPAR

All layers are covered

| OSI REFERENCE MODEL LAYERS | |
|---|---|
| 7 | APPLICATION |
| 6 | PRESENTATION |
| 5 | SESSION |
| 4 | TRANSPORT |
| 3 | NETWORK |
| 2 | DATA LINK |
| 1 | PHYSICAL |

**Next Generation High-Speed Network Working Group**

WG is composed by 4 teams and 2 sub-teams

***Next Generation Technology Study Team***

- Next GenerationTechnology Study Team — ***SDN Sub-Team***
- ***Functional Development Team***
- ***Functional Verification Team***
- ***Hardware Team***
- Next GenerationTechnology Study Team — ***Next Gen. Physical Layer Sub-Team***

***3 presentations from JASPAR***

**Automotive SDN**
Proposal of Dynamically Configurable In-Vehicle Network as an Enabler of Software Defined Vehicle

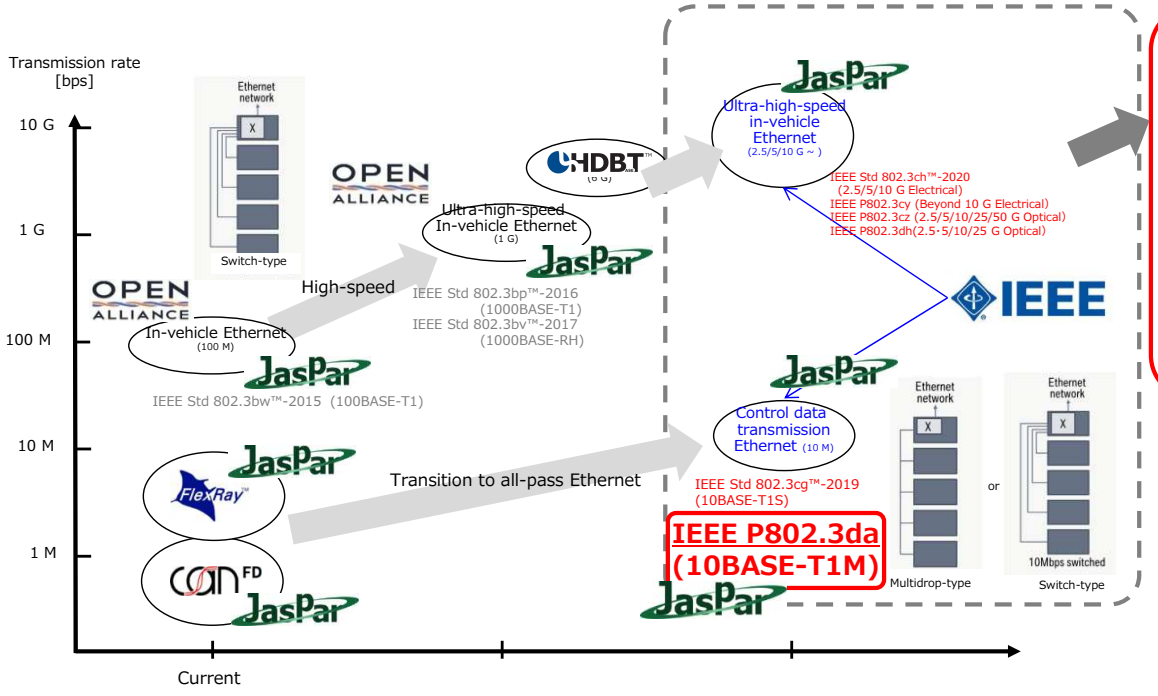
**Ethernet TSN**
A study of Ethernet TSN profile based on JASPAR's automotive use cases

**Optical Physical Layer**
Concept of test points in in-vehicle optical physical layer standardization for "**multi-vendorization**"

**Team Composition of Next Gen. High-Speed Network WG**

# Contents

# JASPAR Next Generation Technology Study Team




**IEEE**

**IEEE P802.3cy (Electrical)**

**Greater than 10 Gbps Electrical Automotive Ethernet(25 Gbps)**

**IEEE P802.3cz (Optical)**

**Multi-Gigabit Optical Automotive Ethernet (~ 50 Gbps)**

**IEEE P802.3dh (Optical)**

**Multi-Gigabit Automotive Ethernet over Plastic Optical Fiber (~ 25 Gbps)**

Focus on Automotive Ethernet Multi-Gig (Electrical/Optical) and 10 Mb/s

# Background : Why Optics?

## *OEMs Requirements*

(1) EMC resistant

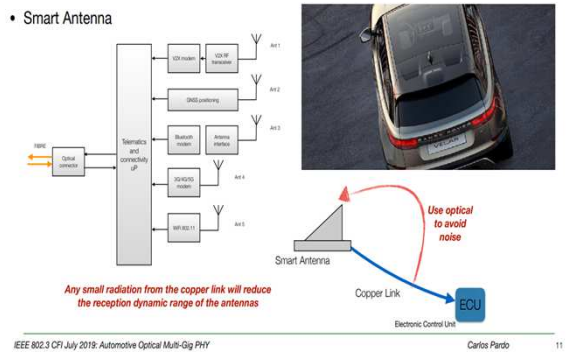
(2) High-speed communication

(3) Weight saving and low power consumption for CO2 reduction

## *Feature of Optical component*

- Optical fiber is no emission noise and no affected noise
- Quick response and Broadband
- Light weight
- Low power consumption

(1) Use cases – Why optics?



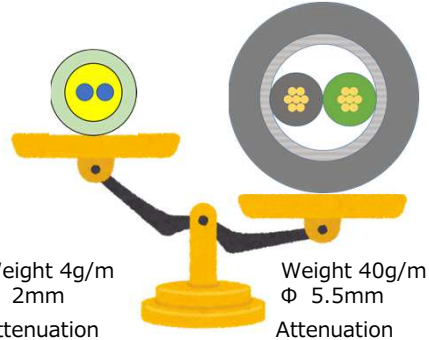

(2) Market Drivers Optical multi-gig use cases

• Provided by OEMs specialists:

| | 2.5 Gbps | 5 Gbps | 10 Gbps | 25 Gbps | 50 Gbps | Unidirectional |
|---|---|---|---|---|---|---|
| Backbone | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Smart Antenna | ✓ | | | | | |
| Cameras, Sensors | ✓ | ✓ | ✓ | ✓ | | ✓ |
| Display | ✓ | ✓ | | | | ✓ |
| Data Loggers | | ✓ | ✓ | ✓ | ✓ | |

IEEE 802.3 CFI July 2019: Automotive Optical Multi-Gig PHY Carlos Pardo

(3) Optical fiber vs Electrical wire



Weight 4g/m
Φ 2mm
Attenuation
0.003 dB/m @ 850nm

Weight 40g/m
Φ 5.5mm
Attenuation
2.2 dB/m @ 4GHz
(IEEE Std 802.3ch™-2020, IL Fmax 4GHz)

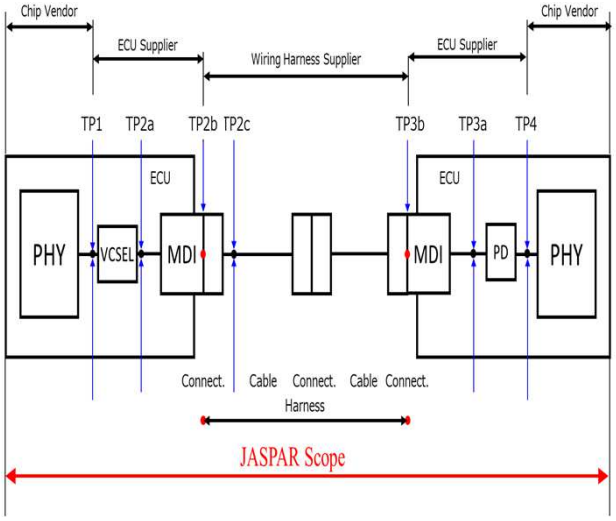
Source: https://www.ieee802.org/3/cfi/0719_1/CFI_01_0719.pdf

# JASPAR Optical Physical Layer Scope

## *JasPar Scope*

**-PHY to PHY**

**-10 Gb/s**



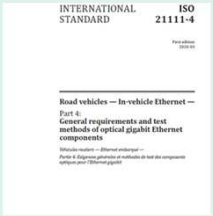

| | |
|---|---|
| Media | Glass, Plastic |
| Length | ~ 40 m |
| Wavelength | 850 nm ~ 980 nm |

■JASPAR has started two types of **VCSEL tests** as light source candidates for IEEE P802.3cz and P802.3dh

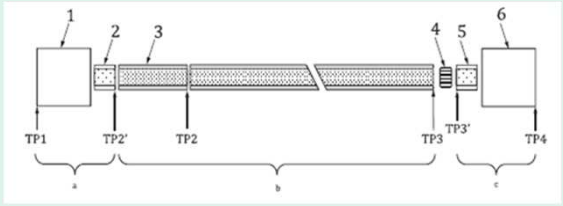
■**Test points are required for component test and third-party certification**

-JASPAR contributed to the standardization of ISO21111-4 as a component standard and test standard for gigabit optical Ethernet communication using POF

-ISO21111-4 clarifies the test points for the purpose of component test and third-party certification


INTERNATIONAL STANDARD ISO 21111-4

Road vehicles — In-vehicle Ethernet —
Part 4:
General requirements and test methods of optical gigabit Ethernet components




Test points of ISO 21111-4

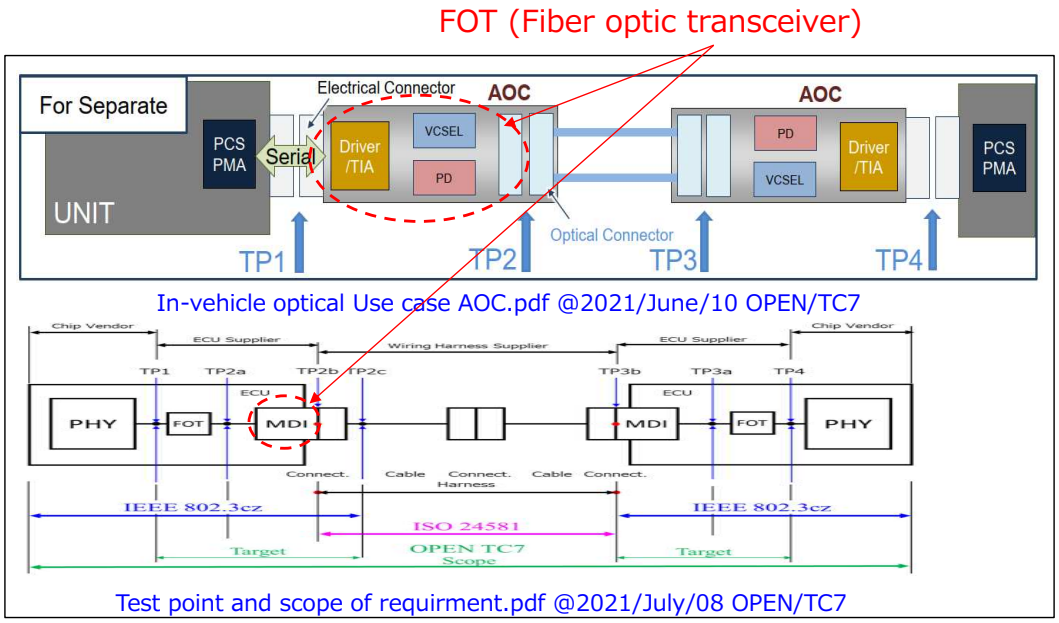
■**Third-party certification** is required

-To develop and manufacture components that comply with standards

-To ensure interoperability

# VCSEL Test : Objectives

- JASPAR believes that multivendor environments for components are essential for the spread of Automotive Optical Ethernet
- In OPEN Alliance TC7, the necessity of setting test points is discussed before and after FOT (Fiber optic transceiver)
- However, regarding the semiconductor laser light source (or VCSEL), which is the main component of FOT, two wavelengths have been discussed in IEEE P802.3cz and P802.3dh, but only one manufacturer has been reported for each wavelength (1),(2)
- This presentation finds a VCSEL that can be substituted for each wavelength and evaluates its communication performance

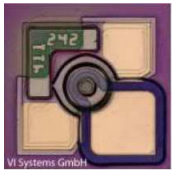



Ref.
**(1) Wavelength: 850 nm (Broadcom):** https://www.ieee802.org/3/cz/public/15_jun_2021/giovane_3cz_01a_150621.pdf
**(2) Wavelength: 980 nm (Trumpf):** https://www.ieee802.org/3/cz/public/may_2021/perezaranda_3cz_01_0521_VCSEL_980nm.pdf

# VCSEL Test : Two VCSELs Evaluation

| Chip vendor | VIS |
|---|---|
| Model number | V25-850C-HT |
| wavelength | 850 nm |
| bandwidth | 25 Gb/s |

225 µm




https://v-i-systems.com/wp-content/uploads/2020/12/VIS-Datasheet-V25-850C-HT.pdf

| Chip vendor | Inneos |
|---|---|
| Model number | V980-10GXA-1TGA |
| wavelength | 980 nm |
| bandwidth | 10 Gb/s |

250 µm

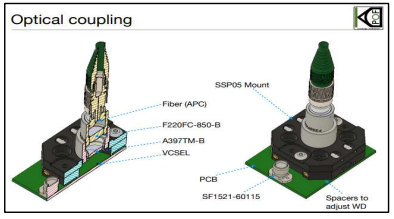
https://www.inneos.com/wp-content/uploads/2022/02/Inneos-Datasheet-VCSEL-10Gbps-980nm-40C-to-125C.pdf

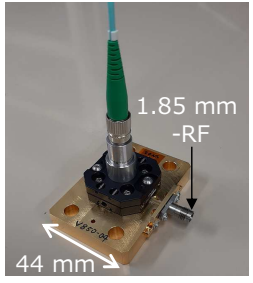
**Test items:**

- Static characteristics (I-V-L)
- Frequency response
- Relative intensity noise (RIN)
- Eye pattern improvement by applying DSP

**Evaluation module**

The VCSEL chip was implemented in the evaluation module reported by KDPOF in IEEE (1)

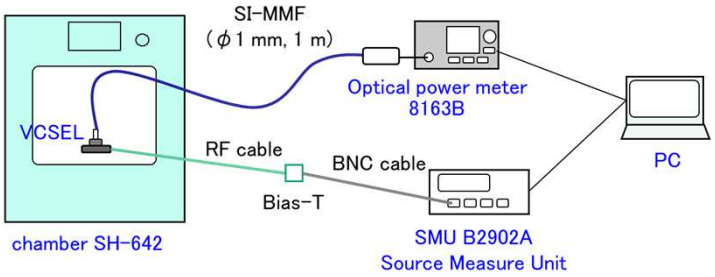


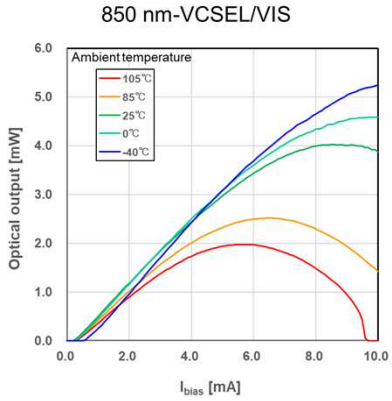



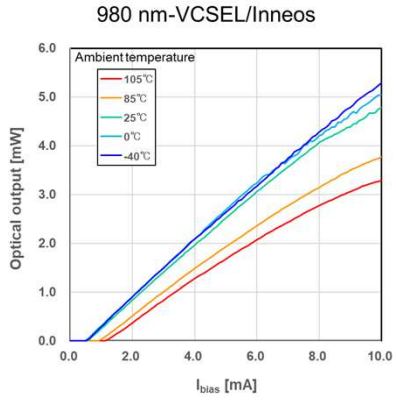

(1)_https://www.ieee802.org/3/cz/public/jul_2020/perez aranda_OMEGA_01b_0720_VCSEL_test_methods.pdf

# VCSEL Test : I-V-L (static) Characteristic

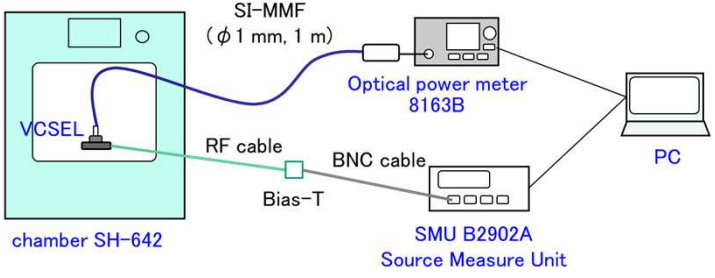
## VCSEL I-L property

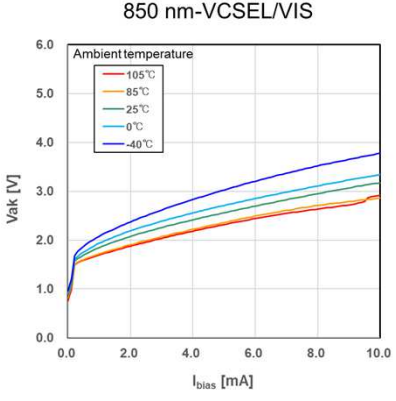


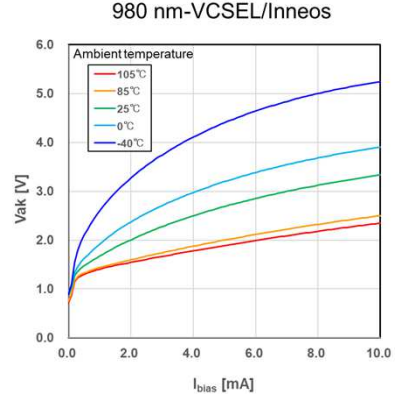




## VCSEL I-V property

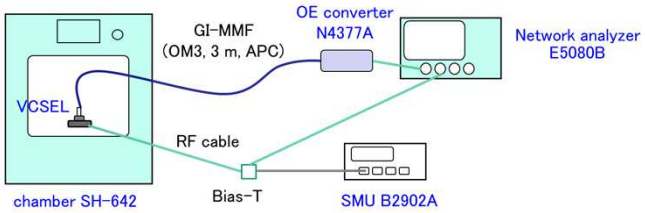


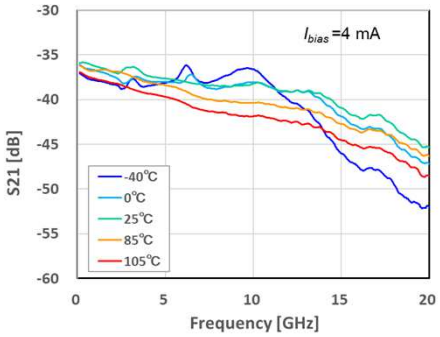



# VCSEL Test : Frequency Response and RIN OMA

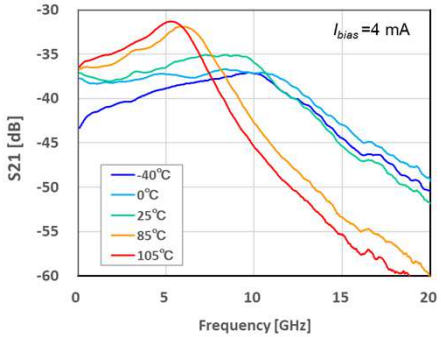
## Frequency response



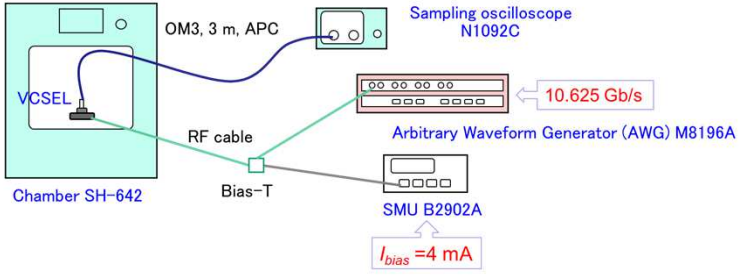

850 nm-VCSEL/VIS



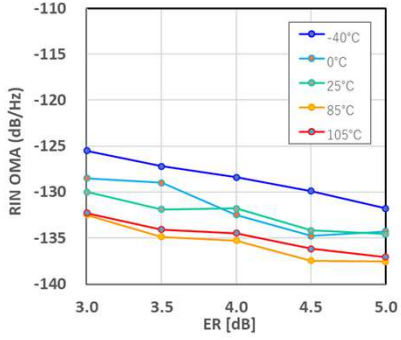

980 nm-VCSEL/Inneos



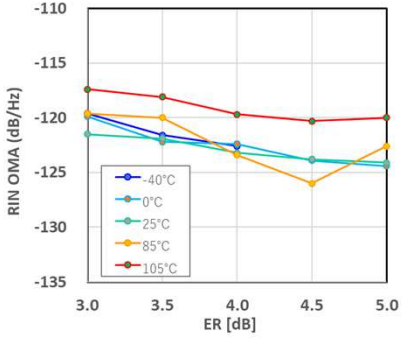

## RIN OMA




850 nm-VCSEL/VIS

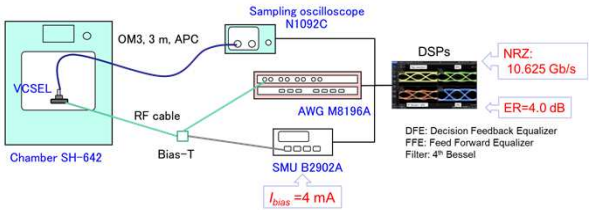



980 nm-VCSEL/Inneos

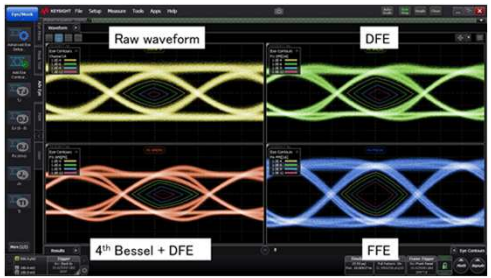
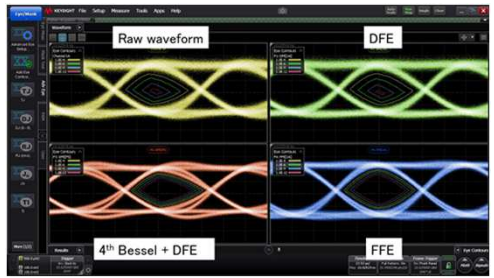
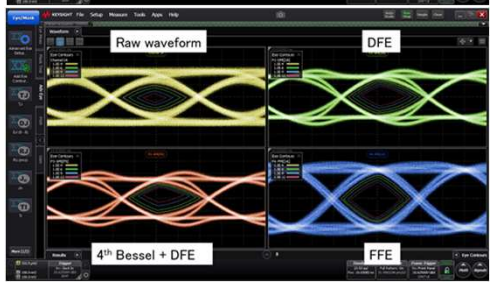
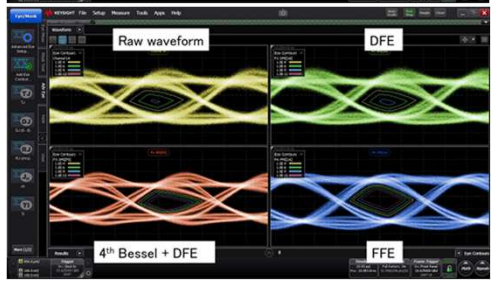
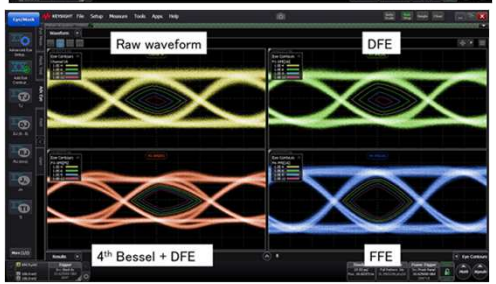
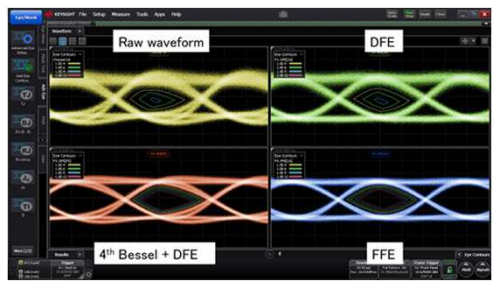


# VCSEL Test : Eye Pattern Evaluation

10 Gb/s




| Bit rate | 10.625 Gb/s |
|---|---|
| Signal pattern | PRBS$2^{11}$-1 |
| $I_{bias}$ | 4 mA |
| ER | 4 dB |
| EQ Tap # | 4 |

| | 850 nm-VCSEL/VIS | 980 nm-VCSEL/Inneos |
|---|---|---|
| 25 ºC |  |  |
| 105 ºC |  |  |
| -40 ºC |  |  |

# VCSEL Test : Summary

## Tested two commercial VCSEL chips:

(1) I-V-L, (2) frequency response, (3) RIN OMA, (4) eye pattern evaluation (-40 ~ +105 ºC)

| VCSEL vender | Catalogue spec. | | Actual operation |
|---|---|---|---|
| | wavelength | rate | 10 Gb/s (-40 ~ +105 ºC) |
| VIS | 850 nm | 10 Gb/s | Excellent |
| Inneos | 980 nm | 10 Gb/s | Excellent |

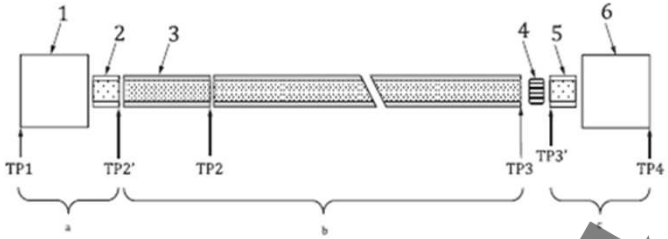
## Future work:

- Evaluate the actual system performance
- Optimize the launching optical condition, VCSEL bias current and optical waveform DSPs, etc.

Confirmed VCSELs are applicable to in-vehicle applications

# Test Point : Why Standardized Test Points are Needed

ISO 21111
Road vehicles - In-vehicle Ethernet - Part 4:




IEEE 802.3

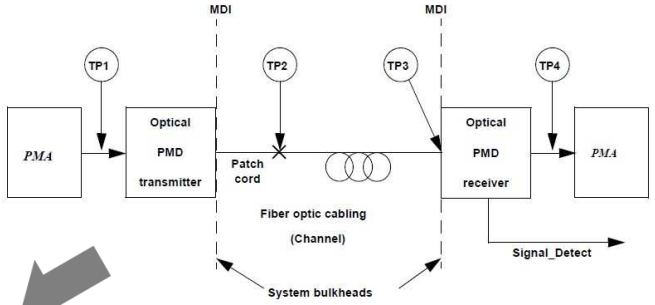
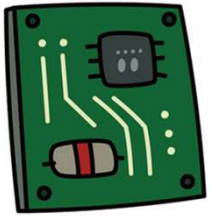



Figure 59–2—1000BASE-X block diagram

Test Point (TP)



Evaluation

Third-party certification

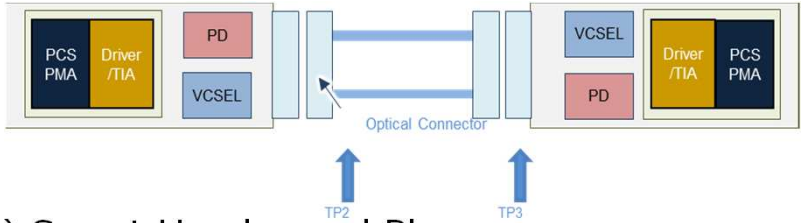
https://www.ac-illust.com/

As defined in ISO and IEEE,
Test Points(TPs) are required for component evaluation and third-party certification

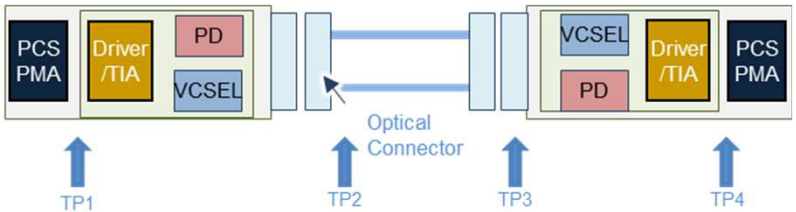
# Test Point : Use Case Study

## Use cases considered for in-vehicle Ethernet under OPEN Alliance

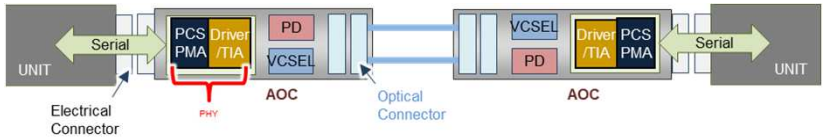
1) Smart Header and Plug
(Integrated PMD/PCS and Driver/TIA)




2) Smart Header and Plug
(Separated PMD/PCS and Driver/TIA)

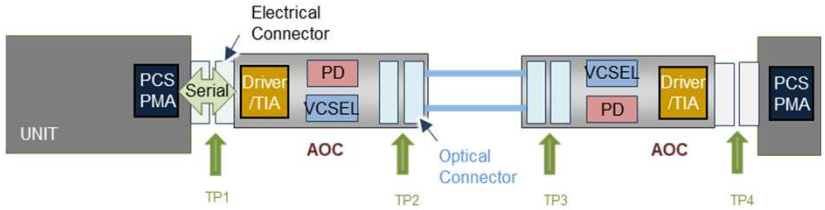



3) Active Optical Component (AOC)
(Integrated PMD/PCS and Driver/TIA)



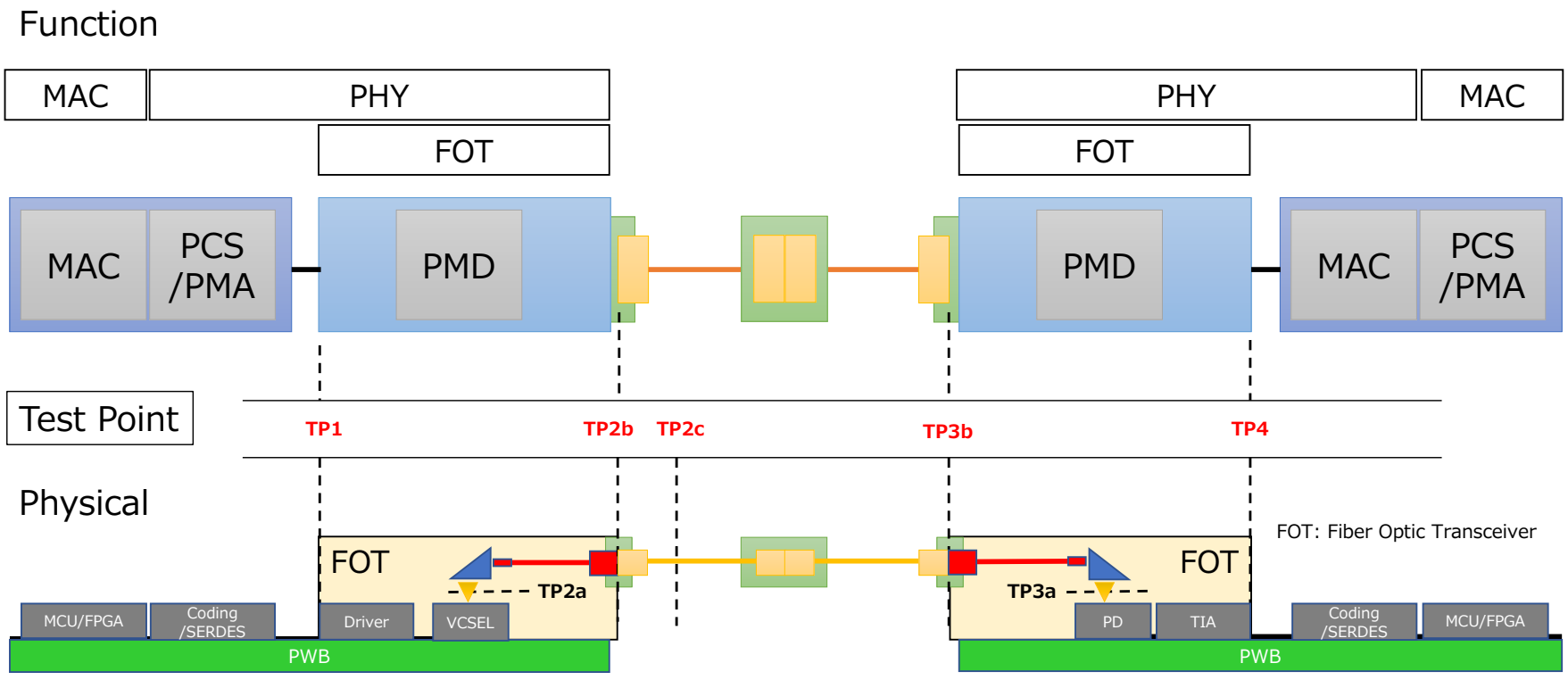

No test point can be defined (serial I/F)

4) Active Optical Component (AOC)
(Separated PMD/PCS and Driver/TIA)




Set test points corresponding to various use cases

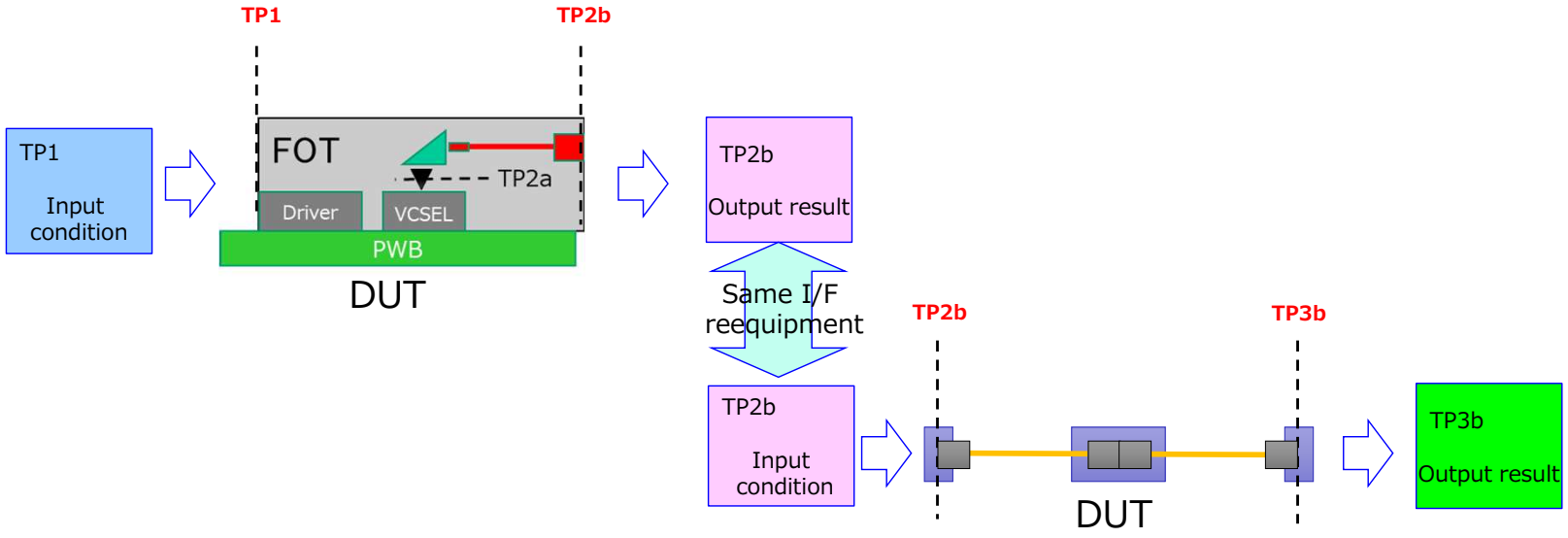
# Test Point : Proposal




The definition of TPs are necessary for a uniform evaluation

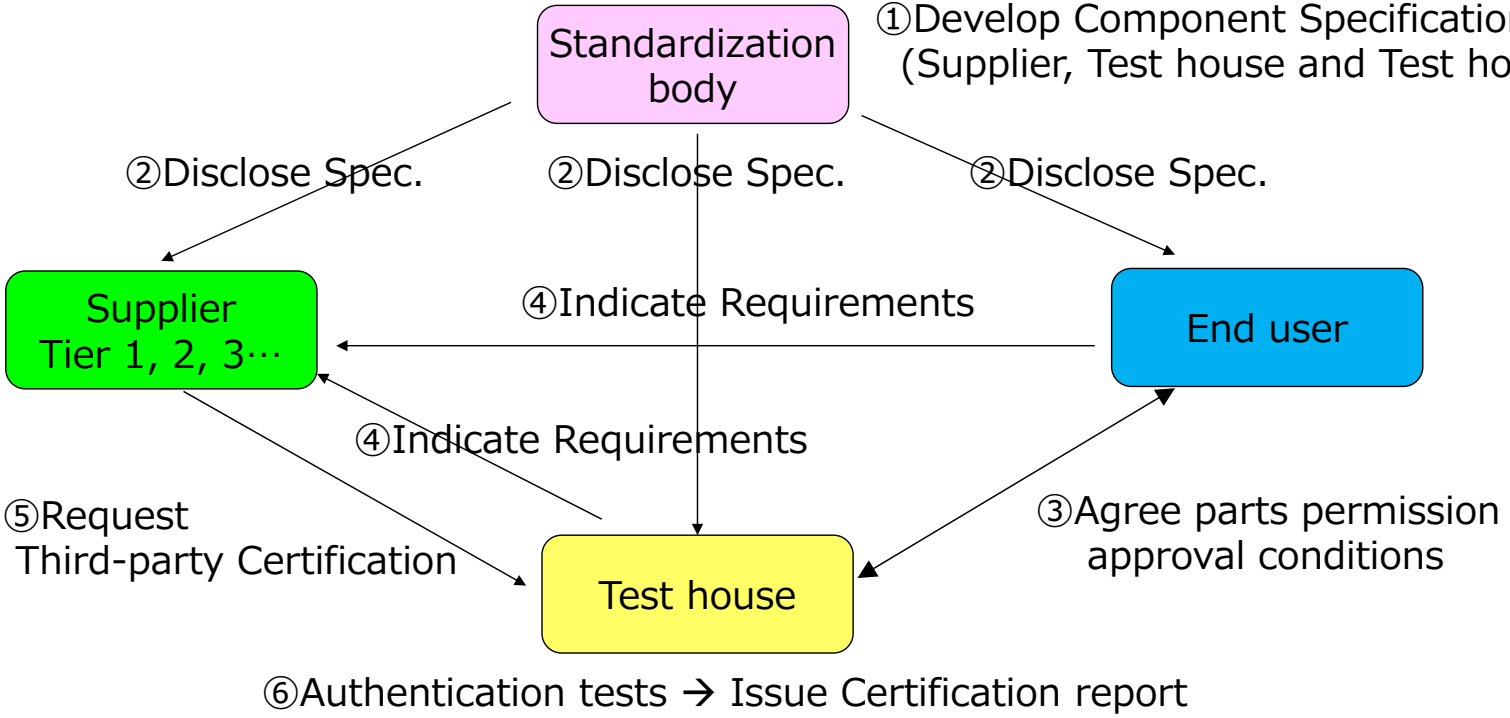
# Third-party Certification : Conformance Test

Test point: Define I/F requirements
→ Input / output condition of the component
→ The performance and quality of the component can be confirmed

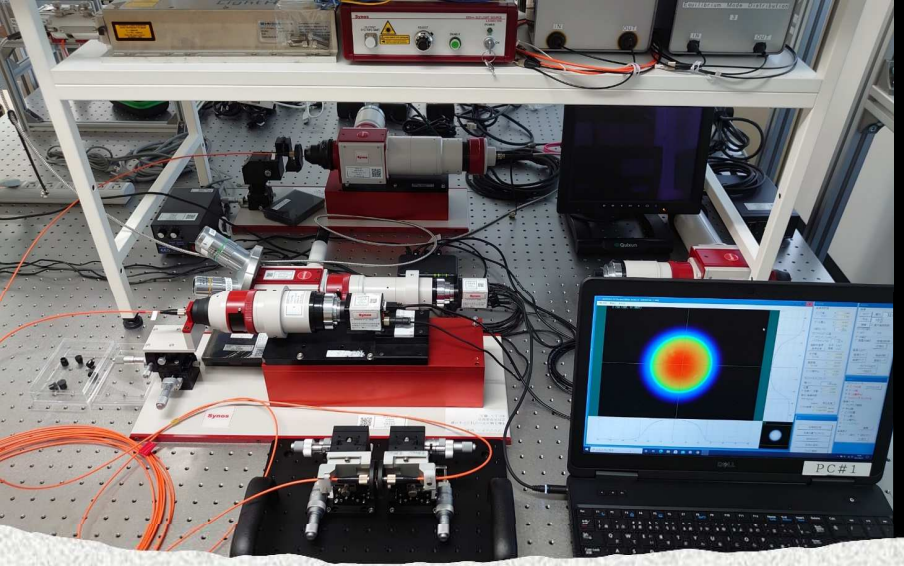


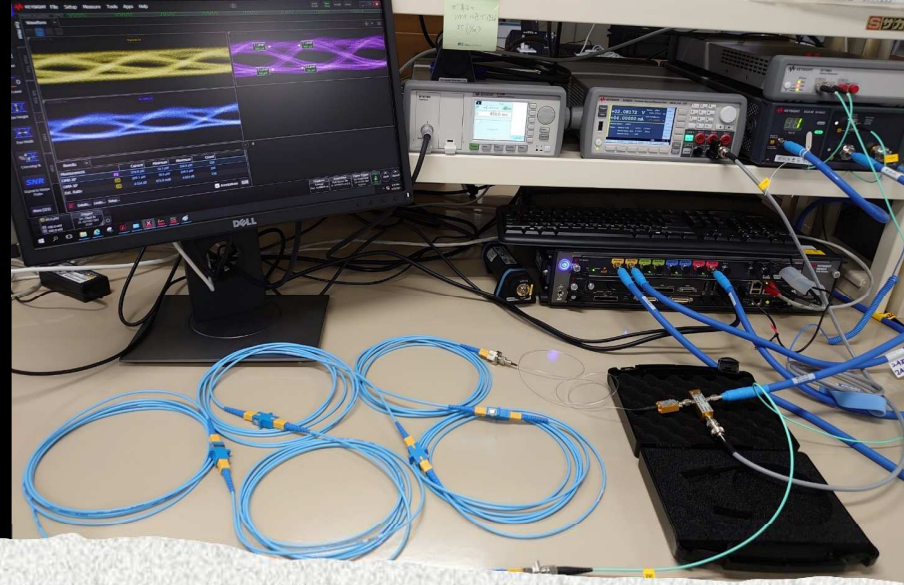

If each part satisfies the TP requirements,
the communication establishment of the entire system can be confirmed

# Third-party Certification : Procedure




Enable to ensure the establishment of overall communication even when parts from different suppliers are connected




# Optical Ethernet

**Time domain analysis (High-speed optical waveform evaluation system)**

- ~ 100 Gb/s (50 Gbaud-PAM4), @-50 ~ +150 ºC
- TDECQ / TDFOM evaluation

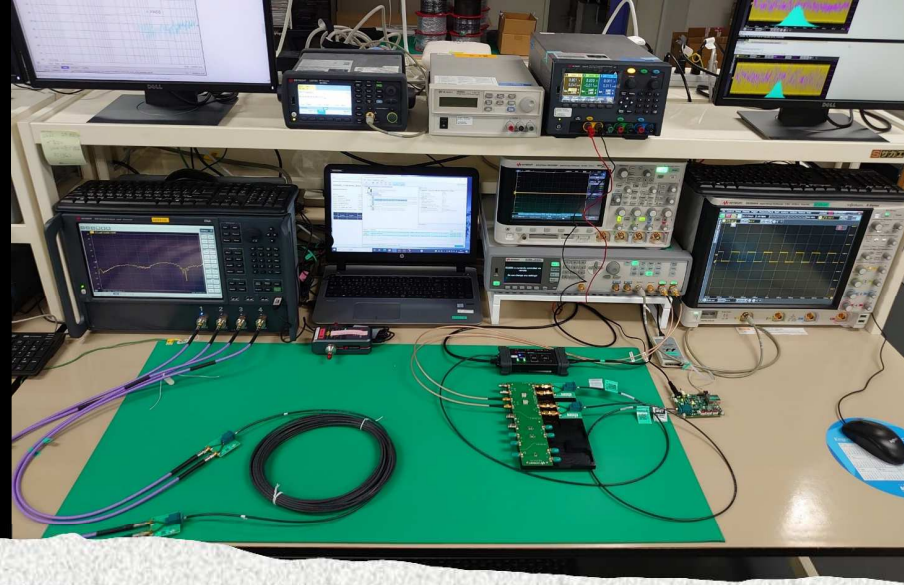
**Frequency domain analysis**

- 100 k ~ 44 GHz network analyzer (4ch)

**Space (or optical) domain analysis**

- NFP/FFP evaluation system
- Optical spectrum analyzer, wavelength: 0.6 ~ 1.7 μm

*CffC/NITech*



# Electrical Ethernet & EMC

**Compliance & Level evaluation**

- 100BASE-T1, 1000BASE-T1 (Tx, Rx, Lx)
- 10BASE-T1S (Tx)
- MultiGigBASE-T1 (2.5 GTx, Lx), other: 2023~

**Frequency domain analysis**

- DC ~ 40 GHz network analyzer (4ch)

**EMC**

- Emission / DPI / BCI&TWC / ESD
- Transmission Line Pulse (TLP) 2023~

*CffC/NITech*

# Third-party Certification : Test House

Center for Future Communication Research (***CffC***),
Nagoya Institute of Technology (NITech)

**Mission & Scope:**

Contribution to society regarding higher reliability of mobility communications, especially for automobiles

- Basic research (light propagation, QoS, EMC, …)
- Standards (ISO, IEC, IEEE)
- Test House (L1 (Opt/Elec), L2, EMC)

**History & Plan:**

Jan. 2021 Established ***CffC*** at NITech
Mar. 2023 Scheduled to open test house

http://cfcr.web.nitech.ac.jp/english/index_en.html

# Conclusions

- ✓ **Optical components are**
  - highly EMC resistant
  - able to communicate at high speeds
  - able to reduce $CO_2$
- ✓ **VCSEL has a good performance from -40 ~ +105 ºC temperature environment**
- ✓ **Confirmed VCSELs are applicable to in-vehicle applications**
- ✓ **Test point definition is mandatory for the component test to be guaranteed whole network system**
- ✓ **Establishing test house at Nagoya Institute of Technology (NITech) in Japan**

**Preparing to install optical communication system at any time!**

Thank you for your kind listening.