Plastic Optical Fiber
for Automotive

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IEEE 802.3 Multi-Gigabit Automotive Optical PHYs(OMEGA) Study Group
Geneva, Switzerland, Jan 2020

Topics of today's talk

History of Data link for automotive

Data rate	1980	1990	2000	2010	2020	2030
10Gbps≤ (Future)					OMEGA	
1Gbps≤			Most system		1000BASE-T1 / 1000BASE-RHC (IEEE802.2bv)	
<1Gbps	CAN	D2B	MOST25 / Flex Ray	MOST150 / IDB1394		

- Copper or SI-POF have been used for automotive network.
- Regarding POF, SI-POF has been used for about 20 years in MOST system, and no critical error has been observed in the field.
- Recently, demand for over 10Gbps data transmission was raised due to increase of sensors and cameras in a car.
- SI-POF has limitation to transmit 10Gbps data, but GI-POF can transmit data with 10Gbps or higher data rate.
- GI-POF will be one of candidate for optical fiber in automotive.

Achievement of POF for automotive

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Audi
- A1, A3, A5, A6, A7-sports back, A8
- Q3, Q5, Q7

BMW
- 1s, 3s ,5s, 6s, 7s
- X1, X3, X5, X6, Z4

Mercedes-Benz
- A, B, C, CLS, E, S, SL, SLK, GL, M, R, Maybach
- Smart forfour

VOLVO
- C30, C70, S40, S60, S80, V40, V50, V60, V70,
- XC60, XC70, XC90

Land Rover
- Range Rover, evoque, Freelander, Discovery3&4

MINI (MINI, Coupe, Clubman, Countryman)

Porsche:
- Cayenne, Boxster, Cayman, 911('11), Panamera

VW
- Touareg
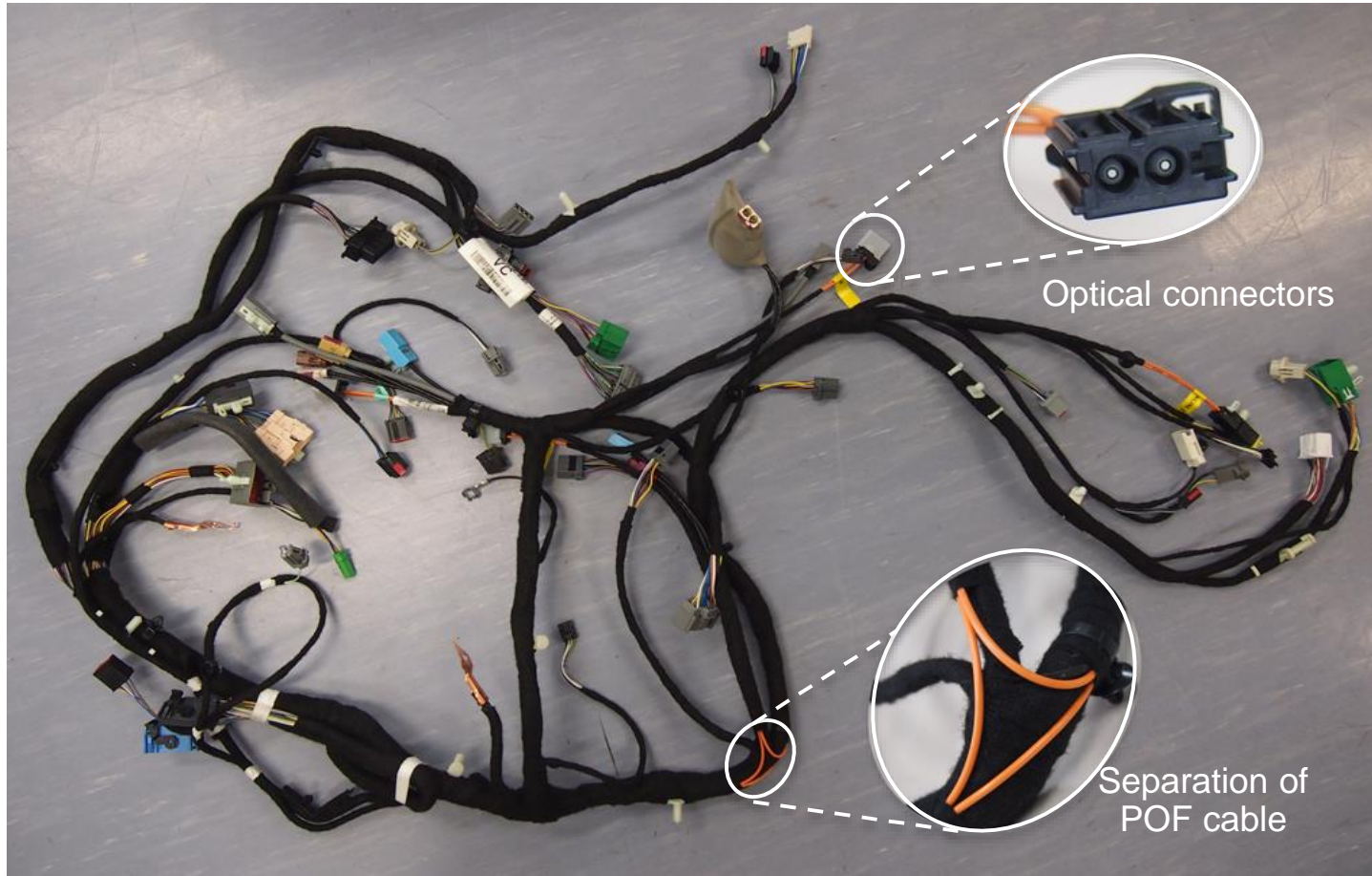
Hyundai
- Genesis, Mohave, Equus

Aston Martin, Bentley, Jaguar, Rolls-Royce

Source: MOST Cooperation

>100M MOST nodes have been shipped for about 150 car models for 20 years.

4

Example of harness in a car

Optical connectors

Separation of POF cable

Example of hybrid harness using copper and POF cable

All cables used in a car are assembled into a "harnesses" before installing in a car. A Harness should have durability against rough handling and small bending during installation process. POF was adopted because it is suitable for such a harsh condition.

POF in IEC standard

- In the new IS for POF (IEC60793-2-40 Ed.5 to be published by May, 2020), two new sub categories will be added. (Red columns in the below table)
- A variant of A4i that has 105ºC rating can be a candidate for automotive.

Sub category	A4a.2	A4g	A4h	A4i
Type	SI	GI	GI	GI
Core dia.(µm)	~1000 [a]	120	62.5	55
Fiber dia.(µm)	1000	490	245 [b]	490
NA	0.53	0.19	0.19	0.24
Operating wavelength (nm)	650	650 850 1300	850 1300	850
Applications	Automobile IEEE802.3bv	Data trans-mission	Data trans-mission	Industrial Data trans-mission

a Typically 15 µm to 35 µm smaller than the cladding diameter.
b Cladding diameters of 490 µm and 750 µm are also possible.

This table is modified from table 1 in IEC60793-2-40 Ed.5

Assumed spec of automotive grade GI-POF

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Key features

- Temperature range
  -40 ~ 105ºC

- Transmission capability
  10Gbps for 10m x 5 ea. (with 4 connections)

- Low bending loss

- Fatigue characteristic
  Static and dynamic

- Easy fiber end processing
  Productivity, cost

## Other test items for automotive (TBD)

Mechanical test	Optical and Reliability test
Operation Temperture Range	Long term winding test
Minimum bending radius	Resistance to flame propagation
Flexibility	Long term heat aging
Tensile Strength	Long term Temperature and humidity aging
Shrinkage	Low/High Temp. cycling
Pistoning	Resistance to Hot water
Impact	Repeted bending
Low Temp. bending	Single bending
High Temp. bending	Resistance to gas
Low/High Temp. cycling	Resistance to fluid
	Torison change

Introduction of automotive grade GI-POF

Item	Plastic Optical Fiber
Material	Perfluorinated polymer
Type	Grated-Index
Bend characteristic	Bend insensitive
Operation Temperature	-40C ~ 105ºC
Core diameter	50µm (TBD)
Fiber diameter	490µm (TBD)
NA	0.20 ~ 0.24 (TBD)
Operating wavelength	650~1300 nm

Bending loss (dB) vs Bending radius (mm)
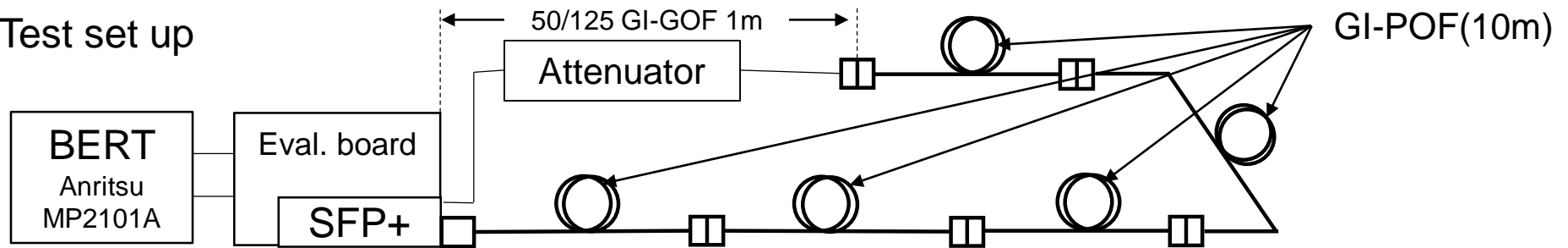- Bend insensitive GI-POF
- Normal GI-POF
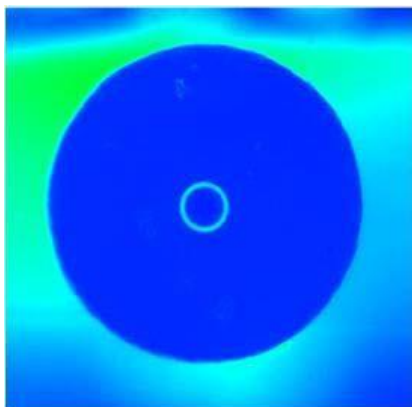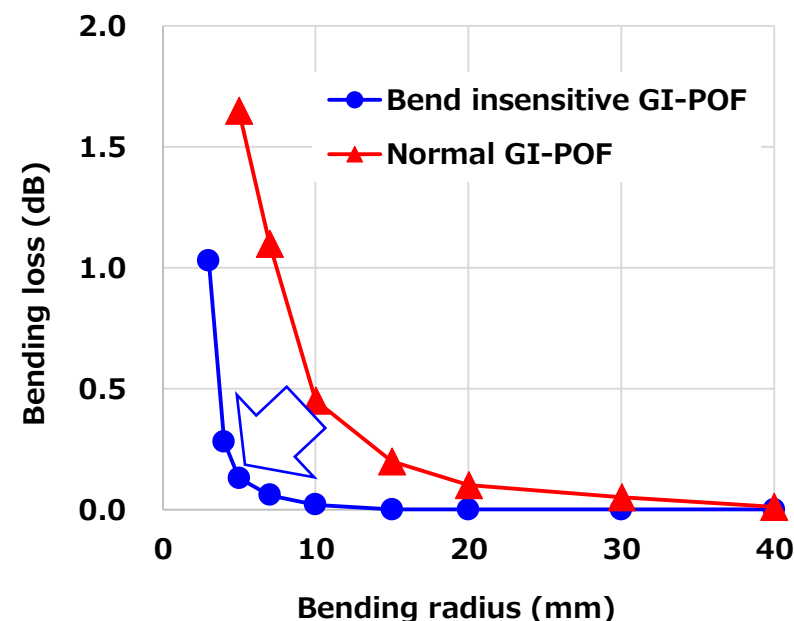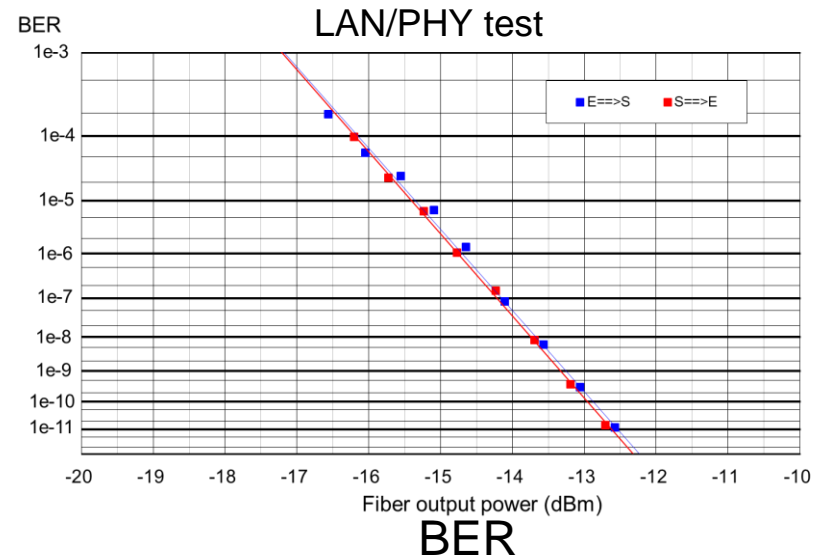

Cross-section
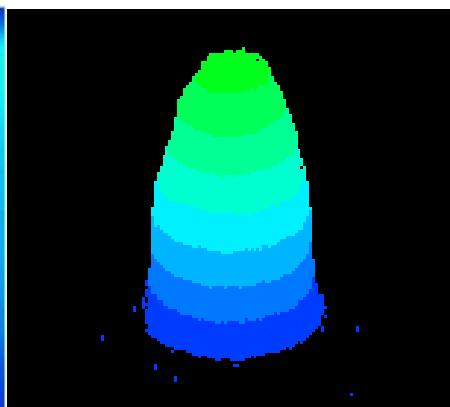
3D of NFP

- GI-POF made from Perfluorinated Polymer can use light sources between 650~1300 nm.
- Core and fiber diameter can be changed according to application because it is plastics.
- Bend insensitive GI-POF (A4i type) has lower bending loss than normal A4h type GI-POF.

10G Transmission test for automotive link

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Test set up

50/125 GI-GOF 1m → GI-POF(10m)

Attenuator

BERT
Anritsu
MP2101A

Eval. board

SFP+

Eye diagram

LAN/PHY test

BER
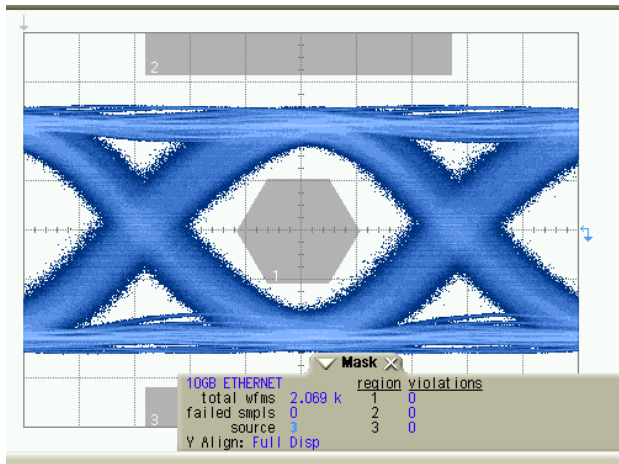
- GI-POF can transmit 10Gbps for 10m x 5 ea. with 4 connections.
- Further transmission capability of GI-POF is reported as follows.
  - 25Gbps at 100m Ref. : Prof. Stephen E Ralph, C Patrick Caputo, Sriharsha Kota Pavan,"25G POF Links,ICAPP2011"
  - 40Gbps at 100m Ref. : S.R.Nuccio, L. Christen, X.Wu, S. Khaleghi, O.Yilmaz, A.E. Willner, and Y.Koike,
      Proc,"Transmission of 40 Gb/s DPSK and OOK at 1.55µm Through 100 m of Plastic Optical
      Fiber ,ECOC,2008"

Fatigue characteristic

- Winding
  Mandrel diameter : Φ10mm
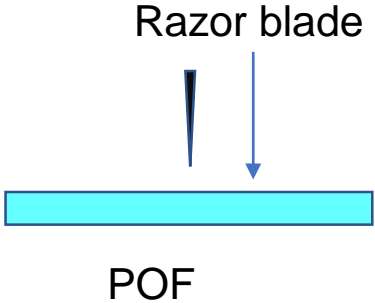 Turn number : 5
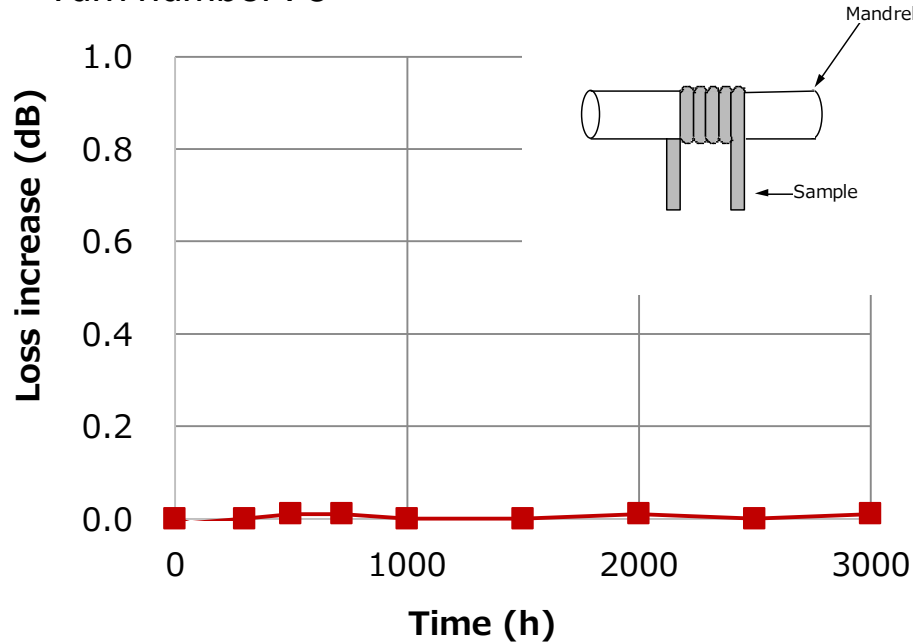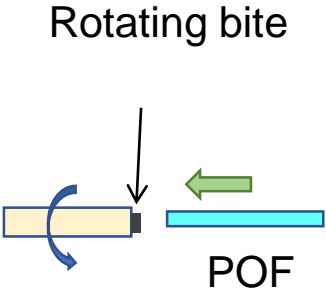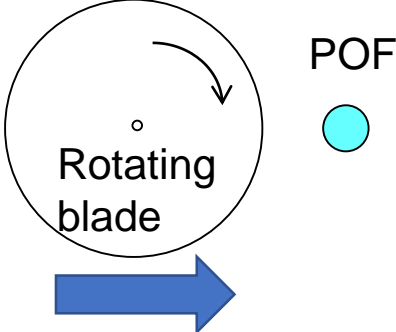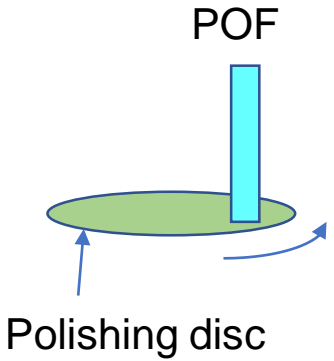

- Repeated bending
  Bend radius : 5mm
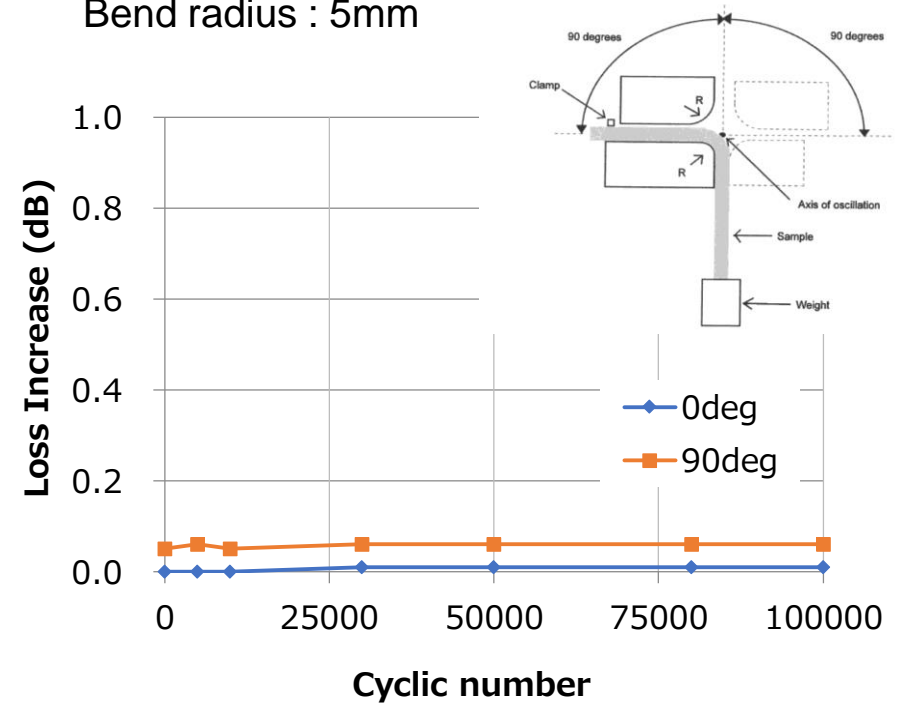
GI-POF has stable performance against static and dynamic fatigue.
- In winding test, GI-POF is wrapped around Φ10mm x 5 times.
  Loss is stable after 3000hours.
- In repeated bend test, GI-POF is bent at angle of 90deg to -90deg at 5mm bending radius.
  Loss is stable after 100k cycles.

Fiber end processing method

Method	Razor cutting	Milling	Rotary cutting	Polishing
schematic drawing	Razor blade / POF	Rotating bite / POF	Rotating blade / POF	POF / Polishing disc

Various fiber end processing methods can be applicable to GI-POF.
- "Razor cutting" is the simplest way that directly cut fiber by a razor blade.
- "Milling" is a way of scraping fiber end by rotating bite.
- "Rotary cutting" is a way of cutting like "cutting a log".
- "Polishing" is conventional method, and GI-POF can be polished by existing polishing machine.

Application examples of GI-POF

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AV systems for consumer

HMD

Projector

4K/8K satellite broadcasting

Mobility

Automotive

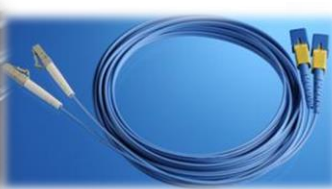### Select type according to application

Fiber   Passive Optical Cable   Active Optical Cable

Industrial equipment

Factory Automation

Medical Equipment

LAN

LAN in hospital

LAN in condominium

Summary

- Plastic Optical Fiber has been used for automobile for about 20 years.

- Technical feasibility of GI-POF for automotive optical link is promising
  in terms of following aspect:
  - Static and dynamic fatigue
  - 10Gbps and higher bit rate data transmission
  - Easy termination

- In the new international standard for POF, two new sub categories will be added.
  And a variant of A4i that supports 105⁰C rating will be a candidate
  for automotive.

- We would like to ask OMEGA members to consider GI-POF in your study.

Thank you for your attention.