Fiber Components for Optical Automotive

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Purpose: Establish technical feasibility

- A ≥ 10Gbps link standard targeted for automotive use is needed to address emerging use cases
- Optical fiber complements copper by providing exceptional bandwidth, light weight, low power consumption, electromagnetic immunity, and harsh environment resistance
- Optical fiber technologies are mature with proven reliability and are widely used in harsh environments
- An optical PHY objective is proposed
  - **"Define the performance characteristics of an automotive link segment and an optical PHY to support ≥ 10 Gb/s point-to-point operation over this link segment supporting up to 4 inline connectors and up to at least 15m on automotive cabling"**

What we know

- OEMs are willing to use optical fiber √
- Support data rate of ≥ 10Gbps √
- Support maximum temperature of 105°C √
- Support maximum delay of 1ms √
- Startup must be achieved within 100ms √
- Support 15m link length √
- Support 4 in-line connectors √
- Support low power consumption √
- Minimize EMI √
- Minimize weight √

Technical feasibility for optical automotive components

- Harsh environment fiber components are available on the market today
  - Utilized in several applications
    - Access Networks
    - Industrial Networks
    - Aerospace and Defense Applications
- Optical fiber
  - Multimode bend insensitive optical fiber with high-temperature coatings
- Optical fiber connectors
  - High Reliability connectors have been designed for applications requiring excellent reliability in high shock, vibration and temperature environments

High reliability optical fibers are available

- Rated for ≥105 °C
- Hermetic coating available for improved fatigue resistance
- Consistent strength over time at elevated temperatures
- Minimum bending radius of 7.5 mm
- Fully compliant with ITU-T Recommendations
- Compatible with current optical fibers and practices
- Test data available

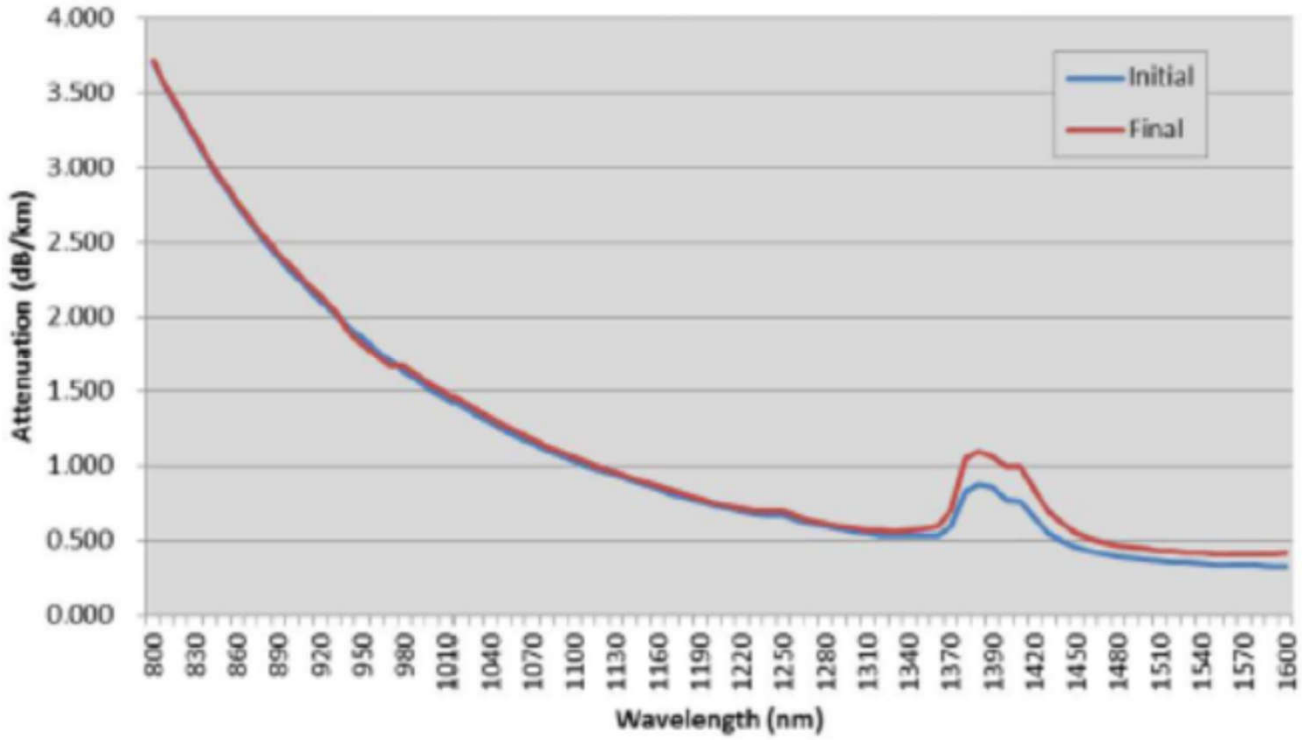
- Operating Wavelength (nm)
  - 850, 1060, 1300
- Maximum Attenuation (dB/km)
  - 2.5 @ 850 nm
  - 0.7 @ 1300 nm
- Bandwidth (MHz-km)
  - 700 @ 850 nm
  - 500 @ 1300 nm
  - Higher bandwidths available
- Operating Temperature (°C)
  - -60 to +105 °C

Testing objective, samples and methodology

- Objective: Test Corning multimode fibers at 105°C for 3000 hours to measure any changes of functional fiber attributes and integrity of coatings
- Key tests
  - Spectral Attenuation
    - Pre and Post Measurements
  - OTDR Attenuation
    - Hourly in-situ monitoring at 105°C for 3000 hours
  - Microscopy Pre and Post Aging Exams - 200x magnification
    - Criteria is no cracking, splitting, swelling, etc.

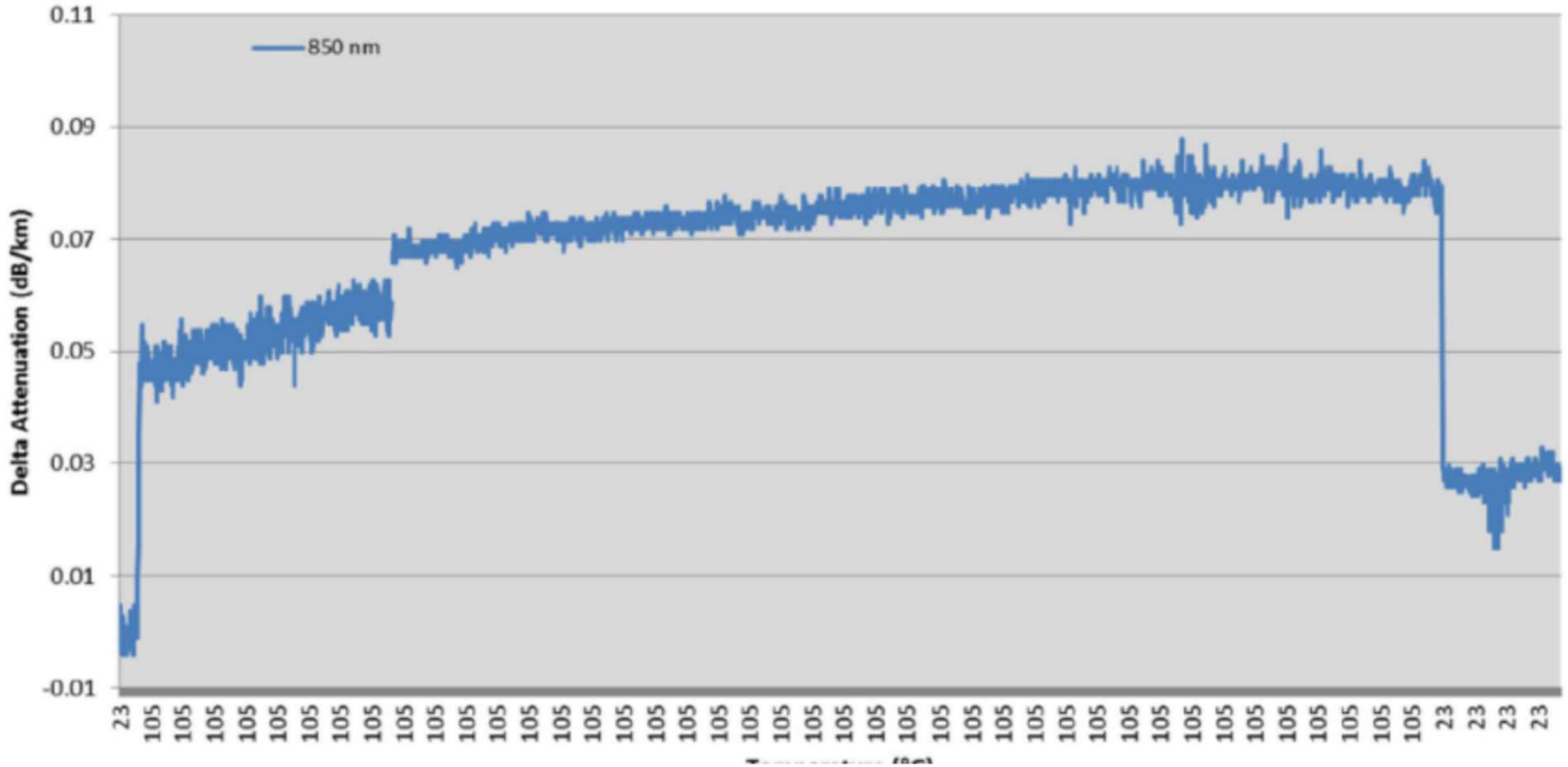
Spectral attenuation summary

- After 3000 hrs, little to no change in spectral attenuation was observed
  - 0.01 to 0.02 dB/km increase in attenuation at 850 nm
    - This change is negligible for a 15m automotive link



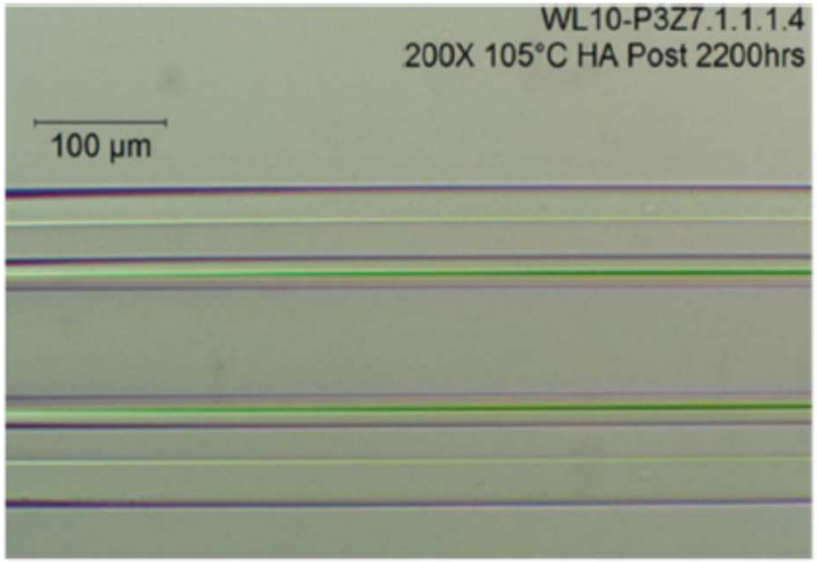
OTDR In-Situ Measurement Summary

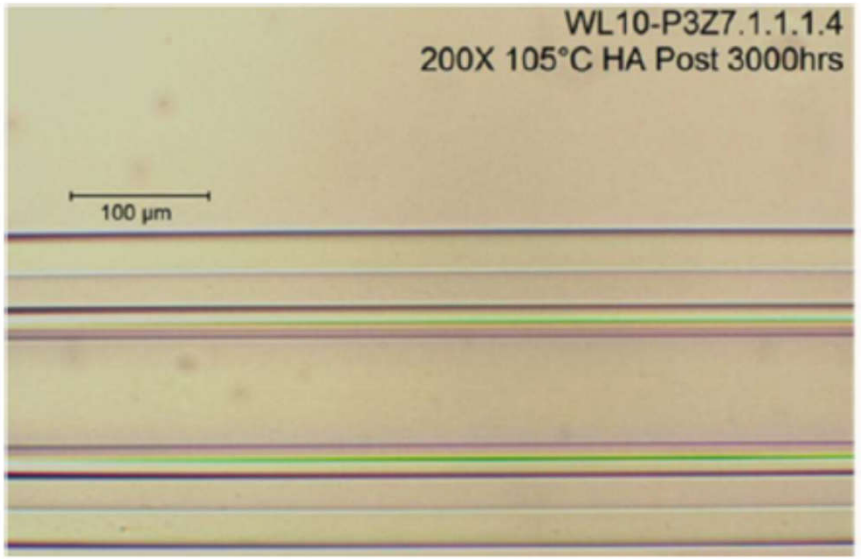
- 105°C Heat Aging
  - Change in attenuation at 850 nm was ≤ 0.03 dB/km (again, negligible for a 15m automotive link)



Microscopy Summary

- Microscopy exams were performed prior to aging, after 2200 hours, and at the conclusion of the 3000 hours at 105°C
  - After 3000 hours of aging, the coating integrity was not compromised
  - No cracking, splitting, or swelling were observed



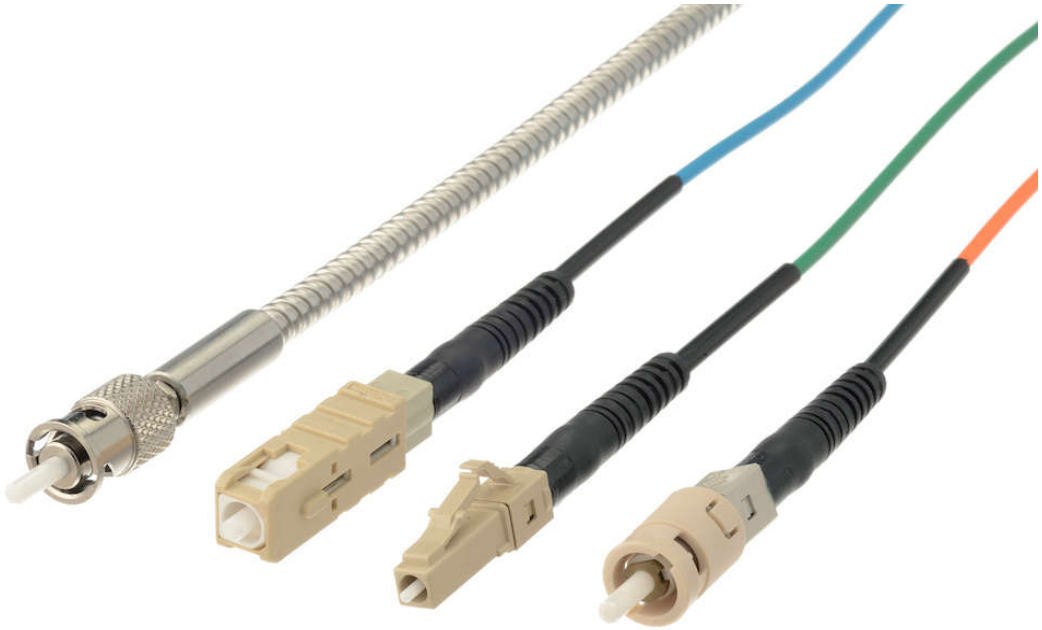


High reliability optical connectors are available

- High Reliability connectors have been designed for applications requiring excellent reliability in high shock, vibration and temperature
- Applications supported include
  - Navy Shipboard applications
  - Deployable military tactical networks
  - Oil and Gas surface applications
  - Homeland security and surveillance
  - Harsh industrial installations
  - Emergency restoration systems
  - Cabinet mounted communication systems
  - **AUTOMOTIVE?**

Key features of this connector

- TIA/EIA and IEC compliant
- Pre-radiused zirconia ferrule to minimize field polishing
- Field installable and maintainable
- Split zirconia sleeve for improved insertion loss



Performance criteria

Connector and Adapter Performance Criteria:	
Optical Insertion Loss	9/125 µm: 0.50 dB_{max}, 0.35 dB_{typ} 62.5/125 µm: 0.50 dB_{max}, 0.14 dB_{typ}
Return Loss	>30 dB MMF, >45 dB SMF with PC polish
Mating Durability	500 cycles per EIA-455-21
Boot Outgassing	Average value TML < 1%, Average value CVCM < 0.1% per ASTM E595-90
Torque	6.5 in-lb
Withdrawal Force	200-600 grams
Tensile Loading	20lb for 1 minute
Operating Temperature	-45°C to +110°C (epoxy dependent)
Cable Retention	> 22 Lbs

A full suite of standardized test methods exist for extreme environments

Test	Severity	
	Connectors	Passive Components
Vibration (sinusoidal) IEC 61300-2-1	10 Hz – 55 Hz 15 sweeps (10 Hz – 55 Hz – 10 Hz) 1 octave/minute 3 axes 0,75 mm amplitude	
Cold IEC 61300-2-17	-40 °C ± 2 °C 96 h duration	
Dry heat – High temperature endurance IEC 61300-2-18	+85 °C ± 2 °C 96 h duration	
Change of temperature IEC 61300-2-22 Test Nb	-40 °C ± 2 °C to +85 °C ± 2 °C 1 h duration at extremes 1°C/min rate of change 12 cycles	
Dust IEC 61300-2-27	Particle size d < 150 µm Dust type talc 10 min duration 10,6 ± 7,1g/m^3	
Composite temperature humidity cyclic test IEC 61300-2-21	Z/AD profile with exposure to cold -10 °C ± 2 °C to +65 °C ± 2 °C 93 % RH ± 3 % RH at the maximum temperature 3 h dwells at the temperature extremes 4 cycles	
Industrial atmosphere IEC 61300-2-28	Sulphur dioxide SO_2 25 × 10^{-6} 96 h duration	
Salt mist IEC 61300-2-26	Salt solution 5% NaCl (pH 6,5 – 7,2) 96 h duration	
Durability by water immersion IEC 61300-2-45	Depth of water: sample shall be 5 cm below the surface of the water +25 °C ± 2 °C 1 h duration Immersion: 1 cycle	
Optical fibre cable flexing [a] IEC 61300-2-44	5 N for reinforced cable Cycle: ± 90° Number of cycles: 100	5 N for reinforced cable Cycle: ± 90° Number of cycles: 30
Fibre/cable retention [a] IEC 61300-2-4	100 N ± 2 N at 5 N/s for reinforced cables with diameter >2 mm 70 N ± 2 N at 5 N/s for reinforced cables with diameter ≤2 mm 5,0 N ± 0,5 N at 0,5 N/s for secondary coated fibres 2,0 N ± 0,2 N at 0,5 N/s for primary coated fibres 120 s duration at 70 N or 100 N 60 s duration at 2 N or 5 N	10 N ± 1 N at 5 N/s for reinforced cables 5,0 N ± 0,5 N at 0,5 N/s for secondary coated fibres 2,0 N ± 0,2 N at 0,5 N/s for primary coated fibres 120 s duration at 10 N 60 s duration at 2 N or 5 N
Impact (method A) IEC 61300-2-12	5 drops 1,5 m drop height	Not specified
Torsion/twist [a] IEC 61300-2-5	15 N at 1 N/s for reinforced cables 2,0 N at 0,1 N/s for primary and secondary coated fibres 25 cycles ± 180°	5,0 N at 0,1 N/s for reinforced cables 2,0 N at 0,1 N/s for primary and secondary coated fibres 10 cycles ± 180°

Test	Severity	
	Connectors	Passive components
Tensile strength of coupling mechanism IEC 61300-2-6	40 N at 2 N/s 120 s duration	Not specified
Static side load [a, c] IEC 61300-2-42	1 N for 1 h for reinforced cable 0,2 N for 5 min for secondary coated fibres Two mutually perpendicular directions	
Mating durability IEC 61300-2-2	500 cycles at not less than 3 s between engagements	Not specified
Bending moment IEC 61300-2-7	10 N	Not specified
Shock [b] IEC 61300-2-9	Not applicable	Acceleration forces: Components: 500g_n • Modules: • 0,125 kg ≤ module mass ≤ 0,225 kg: 200g_n • 0,225 kg ≤ module mass ≤ 1 kg: 50g_n • Nominal 1 ms duration, half sine pulse. 3 axes in 2 directions, 2 shocks per axis, 12 shocks total.

[a] These tests shall be applicable to passive optical components which incorporate fibre or fibre cable pigtails in their product design.

[b] If the product is normally mounted in a shock resistant mounting, then it shall be tested in this configuration.

[c] Static side load shall be applied in two mutually perpendicular directions as permitted by the product design. For example, a product with a base plate extending beyond the fibre exit may prohibit loading in that direction.

Hybrid connectors also in development

- Electrical power levels for current applications cover a broad range; a typical example is 12.5 W for POE+ devices to 400 W+ for large remote radio units
- Climatic environments span from controlled, indoor for optical LANs to extreme for petroleum exploration
- Fiber variants include single-mode, multimode, simplex, duplex, and multi-fiber array.
- Electrical power transmission may be either AC or DC, at voltages from 12V to 380V.
- Some connector design variants may required sealed interfaces, while others not

Summary and Future Work

- The extensive use of optical fiber components in challenging environments provides a basis for technical feasibility for automotive environments
  - Primary difference is temperature extremes and we confident in our ability to support 105ºC

- More work is needed to establish economic feasibility as part of a complete cable harness/link solution

- Further testing of fiber optic links and data will be presented to ensure link performance testing per automotive requirements

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