End Face Termination for Butt Coupling (GI−POF)

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IEEE P802.3cz Multi-Gigabit Optical Automotive Ethernet Task Force
Agenda

• Laser Cut Process
  – GI-POF
    • Connection Loss
    • Modal Dispersion
    • Eye Pattern and BER
    • End Face Shape

• Additional Evaluation from Sept. 15th
  – 15m / 4 inline connection
    » Eye Pattern and BER
    » Modal Dispersion
Prepared Evaluation Fiber

• GI-POF
  – In this presentation, I evaluated with typical Graded Index (e.g. 50 micron core) plastic optical fiber.
  • Prepared the End Faces Combination of Optical Cables with LC Connecter (3m)
    – #1 Polished and Polished
    – #2 Polished and Laser Cut
    – #3 Laser Cut and Laser Cut
GI-POF Connection Measurement

**Referenced Measurement**

- Light source ($\lambda=850\text{nm}$)
- Mode Scrambler
- LC Connector
- Master Cable 3m
- Optical Power Meter

**Actual Connection Measurement**

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>GI-POF</td>
<td>Polishing</td>
<td>Polishing</td>
<td></td>
<td>0.725</td>
<td>0.397</td>
<td>0.613</td>
</tr>
<tr>
<td></td>
<td>Polishing</td>
<td>Laser cut</td>
<td></td>
<td>0.702</td>
<td>0.370</td>
<td>0.590</td>
</tr>
<tr>
<td></td>
<td>Laser cut</td>
<td>Laser cut</td>
<td></td>
<td>0.355</td>
<td>0.497</td>
<td>0.526</td>
</tr>
</tbody>
</table>

- Faces of Combination with Polished or Laser Cut End Face

- Referenced Measurement
- Actual Connection Measurement
Probability Plot of Connection Loss

- 95% CI, (Confidence Interval)
  - Normal distribution [Upper/Lower] Fitted line
NFP: Near Field Pattern, Measurement (EF: Encircled Flux, Results)

Light source ($\lambda=850\text{nm}$) → Mode Scrambler → LC Connector → Master Cable → LC Connector → DUT Cable 3m → LC Connector → LC Connector → NFP Measurement System

Faces of Combination with Polished or Laser Cut End Face

Polishing | Polishing
---|---
Polishing | Laser cut
Laser cut | Laser cut

Polishing and Polishing
Polishing and Laser Cut
Laser Cut and Laser Cut

Polishing and Polishing
Polishing and Laser Cut
Laser Cut and Laser Cut
**Eye Pattern and BER Evaluation with Optical Transceiver**

- **Evaluation with SFP28(25GBASE-SR) Transceiver**
  - **Bit Rate**: 25.78Gb/s
  - **Data Pattern**: PRBS2^{31-1}
  - **BERT (Bit rate Error Ratio)**: $10^{-12}$

<table>
<thead>
<tr>
<th>End Face Combination</th>
<th>Polished and Polished</th>
<th>Polished and Laser Cut</th>
<th>Laser Cut and Laser Cut</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Eye Pattern</em></td>
<td>![Eye Pattern Image]</td>
<td>![Eye Pattern Image]</td>
<td>![Eye Pattern Image]</td>
</tr>
<tr>
<td><em>BER</em></td>
<td>$10^{-12}$ [Error Free]</td>
<td>$10^{-12}$ [Error Free]</td>
<td>$10^{-12}$ [Error Free]</td>
</tr>
</tbody>
</table>

*Ambient Temperature = 25 deg. C. (Room Temp.)*
Details Views of Fiber End Face

- Measurement on 3D Laser Scanning Confocal Microscope

GI-POF
Polished Fiber End Face

GI-POF
Laser Cut Fiber End Face
Additional Evaluation from Sept. 15th
Eye Pattern and BER Evaluation with Optical Transceiver

- **Evaluation with SFP28(25GBASE-SR) Transceiver**
  
  Bit Rate: 25.78 Gb/s  
  Data Pattern: PRBS2^{31-1}  
  BER (Bit rate Error Ratio): $10^{-12}$

**GI-POF Eye Pattern Measurement and BER Results with Laser Cut End Face Combination**

<table>
<thead>
<tr>
<th>Number of Connection(s)</th>
<th>Length</th>
<th>*Eye Pattern</th>
<th>*BER</th>
<th>*Connection Loss [dB]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td><img src="image1" alt="Eye Pattern" /></td>
<td>$10^{-12}$ [Error Free]</td>
<td>0** [**Origin of measurement]</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td><img src="image2" alt="Eye Pattern" /></td>
<td>$10^{-12}$ [Error Free]</td>
<td>0.226</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td><img src="image3" alt="Eye Pattern" /></td>
<td>$10^{-12}$ [Error Free]</td>
<td>0.337</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td><img src="image4" alt="Eye Pattern" /></td>
<td>$10^{-12}$ [Error Free]</td>
<td>0.504</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td><img src="image5" alt="Eye Pattern" /></td>
<td>$10^{-12}$ [Error Free]</td>
<td>0.791</td>
</tr>
</tbody>
</table>

**Note:** Ambient Temperature = 25 deg. C. (Room Temp.)

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NFP: Near Field Pattern, Measurement
(EF: Encircled Flux, Results)

Light source ($\lambda=850\text{nm}$) → Mode Scrambler → LC Connector → DUT 3m → LC Connector → DUT 3m → LC Connector → DUT 3m → LC Connector → DUT 3m → LC Connector

NFP Measurement System

All Faces of Combination with Laser Cut End Face

NFP(EF) Measurement with Laser Cut Combinations

Radius [μm]

EF

- 3m
- 6m
- 9m
- 12m
- 15m

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Summary

- I evaluated laser cut process for GI-POF
  - Laser cut process had successful with GI-POF
    - The connection loss probability plot are shown under 1.5dB with 95% CI, (Confidence Interval)
    - The modal dispersion is similar as usual polishing end-face combination and stable until 15m / 4 inline.
    - The eye pattern and BER looks good with 15m / 4 inline connection.
    - The end face shape could modified and improve with laser cut process.
  
- So, I confidence the laser cut process is even practical for automotive applications.
Thank you!