Fiber Connector End-Face Inspection Project, Phase II

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- Ed Forrest, Chemtronics
- Harvey Stone, Microcare
- John Culbert, Megladon Mfg
- Yutaka Sadohara, Sumitomo Electric
• Introduction
• Project Objectives
• Accumulation of Particles Near the Core during Repetitive Fiber Connector Matings and De-matings
• Development of Cleanliness Specifications for Single-Mode, Angled Physical Contact MT Connectors
• The Influence of Contamination on Optical Performance of APC connectors
• Modeling and Experimental Analysis of Contamination Effects on Lens-Based Optic Modules
• Next Steps
• Conclusions
• Contaminated optical connectors result in degradation of optical performance, functional failures, and increased deployment costs.

• Continuing iNEMI research on development of a cleanliness specification for single mode connectors.

• Angled Physical Contact (APC) single fiber and multi-fiber MT connectors are widely used in optical communications
  – Card edge connectivity
  – High density optical backplanes
  – Passive Optical Networks (PONs).

• Impact of contamination on optical performance of MT connector systems has not been thoroughly investigated.

• No data reported on particle redistribution phenomenon for APC single fiber and multi-fiber MT connectors during repetitive mating cycles.
Introduction

- Continuing iNEMI research on development of a cleanliness specification for single mode connectors.
- Quantitative experiments evaluated contamination impact on performance of 1.25 & 2.5 mm ferrules.
- Research supported development of IPC-8497-1 “Cleaning Methods and Contamination Assessment of Optical Assembly” standard.
- In 60% of LC and MU connectors examined, five mating cycles increased IL 0.5 to 1.1 dB due to particle movement from the ferrule and cladding areas towards the core, which suggests a risk of signal performance degradation during the service life.
- Based on our research, the cleaning process using a standard cleaning cassette may result in an electrostatic charge of the connector end face.
• Previous research and cleanliness criteria presented to IEC86B for optic connectors (starting in 2003)
  – 2.5mm ferrule, 1.25mm ferrule, APC & MT connectors
• Research started on receptacle fiber-stub devices
  – Receptacle (stub devices) cleanliness paper published (Sep 2005)
  – Initial work started on lens devices (2006)
• Additional research needed to propose standard criteria for multiple receptacle types (fiber stub, lens)
• Benefits of receptacle research and criteria
  – Clarify receptacle design categories, common language
  – Development of standard inspection criteria
  – Increased awareness of impact of contamination
  – Less down time due to contaminated transceivers
• The Fiber Connector End-Face Inspection Specifications is a follow-on initiative to the NEMI Fiber Optics Signal Performance Project
  – Optical Signal Performance Project (Dec, 02- Oct, 04)
  – The Fiber Connector End-Face Inspection (Oct, 04- Jan, 07)
  – The Fiber Connector End-Face Inspection, Phase II (Jan, 07- Mar, 09)
Objectives

- Develop cleanliness criteria for SMF APC connectors and for Single-Mode, Angled Physical Contact MT Connectors based on quantitative data.
- Investigate the mechanism of particle accumulation near the core during a series of repeated mating cycles.
- Develop potential solutions to prevent this phenomenon.
- Perform a series of experiments to determine aggregate dust location.
- Development cleanliness specification for Lens-based optic modules.
- Update the criteria in IEC doc “61300-3-35: Basic test and measurement procedures.”
- Develop a recommendation for singlemode connector pass/fail criteria for consideration by the members of WG6 and WG4 for possible inclusion into an IEC SC86B standards document on fiber optic connector end face requirements.
• The iNEMI team conducted experiments to compare the effects of specific contamination on the optical performance of fiber optic connectors.
• The similarities and some differences in optical performance of contaminated 2.5 mm ferrule (SC, FC) and 1.25 mm ferrule (LC, MU) connectors were found.
• The zone of 25 μm diameter was identified as critical zone in terms of the contamination influence on optical signal performance for all types of investigated connectors.
• In 60 % of all examined LC and MU connectors, a series of five repeated matings/demating operations resulted in an increase of IL of 0.5 to 1.1 dB due to particle movement from the ferrule and cladding areas towards the core.
• Developed empirical model between IL and the Gaussian Weighted % Occluded Area.
• The cleanliness specification for SMF Pigtail and Patchcord Connectors has been developed.
• The acceptance of industry standard for SM connectors will result in significant cost savings by:
  – elimination of insufficient cleaning and over cleaning
  – reduction of contaminated non-conforming material.
• The standard IPC -8497-1” Cleaning Methods and Contamination Assessment’ for Optical Assembly” was been published in Feb 2006.
Accumulation of Particles Near the Core during Repetitive Fiber Connector Matings and De-matings

NFOEC 2007
Anaheim, CA
March 29, 2007
Design of the Experiment

- Two types of connector end face polishing conditions and one with a non-standard polishing treatment.
  - SC connector with a standard polishing treatment
  - SC connector with a non-standard polishing treatment
    - An extensive polishing process, creating an extremely smooth fiber/ferrule surface.

- Two grades of Arizona Dust particles:
  - 1-5 um and 6-25 um

- Different types of cleaning process:
  - Dry cleaning
  - Cleaning solvent
Experimental process followed to investigate any potential correlation between the amount of charge generated during the cleaning process and particle re-distribution after the dust was applied at clean connector end face.
Cleaning and Measurement Methods

- All DUTs and reference connectors cleaned
  - Cleaning cassettes (type 1 or type 2)
  - Fiber wipes with a cleaning solvent
  - Two cleaning fluids in the Hydrofluorocarbon (HFC) and Alcohol Blend families were evaluated.
- End-face inspected and images were saved
- Measured the number of particles, size, and locations and measured Occluded Area (OA)
  - FiberQA™-EFI software from PVI Systems
- A Faraday cup was used to measure the charge on a fiber tip (both standard SC and non-standard SC) after the cleaning process.
ESD Effects From Cleaning

• The increased accumulation of particles near the core during a series of mating/de-mating operations was investigated. One cause for this accumulation was ESD (electrostatic discharge) effects from cleaning. Methods to prevent this phenomenon were studied.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Test connector</th>
<th>Reference connector</th>
<th>Cleaning method</th>
<th>Air ionizer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Standard SC</td>
<td>Standard SC</td>
<td>Cleaning cassette, Type #1</td>
<td>No</td>
</tr>
<tr>
<td>2</td>
<td>Non-standard SC</td>
<td>Non-standard SC</td>
<td>Cleaning cassette, Type #1</td>
<td>No</td>
</tr>
<tr>
<td>11</td>
<td>Standard SC</td>
<td>Standard SC</td>
<td>Cleaning cassette, Type #1</td>
<td>Yes</td>
</tr>
<tr>
<td>16</td>
<td>Standard SC</td>
<td>Standard SC</td>
<td>Cleaning fluid, Type #1 and fiber swipes</td>
<td>No</td>
</tr>
<tr>
<td>18</td>
<td>Standard SC</td>
<td>Standard SC</td>
<td>Cleaning fluid, Type #2 and cleaning cassette, Type #2</td>
<td>No</td>
</tr>
</tbody>
</table>
• Images from all the experiments were analyzed for particle contamination using FiberQA software from PVI Systems.
• The results included summary spreadsheets for measured occluded area for each connector, cropped raw images, and cropped particle overlay images.
• Occluded area computed using a fine set of annular rings (2.5 µm spacing)
• FiberQA computes the occluded area for annular regions centered on the cladding with the occluded area defined as the total particle area for all particles within that annular region.
The raw image (left) was processed to detect and quantify the particles on the surface, shown in overlay (right).

Scratch processing was disabled for purposes of this analysis.
Labeled Detected Particles with 5 μm annular rings. Black area is ferrule and grey is fiber.

Raw image for LC07-WD-5M taken with Westover Microscope
Experiment 1, “Original A” with Particle Overlay after dust applied at 400x (a), 200x (b) and 100x magnification (c).

The 100x magnification image (c), was utilized to reveal quantities of dust particles at distances of about 350 μm from the core center.
The connector end face was cleaned with the cleaning cassette, Type #1

<table>
<thead>
<tr>
<th>A. DUT First Mating, 100x</th>
<th>B. Ref First Mating, 100x</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td>C. DUT Fifth Mating, 100x</td>
<td>D. Ref Fifth Mating, 100x</td>
</tr>
<tr>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
</tbody>
</table>

Magnification 100x
The connector end face was cleaned with the cleaning cassette, Type #1.

A. Dust Applied, 400x

B. Dust Applied, 100x

C. Fifth Mating, DUT, 100x

D. Fifth Mating, Ref. Fiber, 100x
Electrostatic charges generated from cleaning process with cleaning cassette, Type 1 for standard and non-standard connector samples. Humidity is 28%, room temperature is 24°C.
Evolution of Particle Center Position for Experiment 1, 2, 11, 16, and 18

Exp 1 and 2 show a dramatic decrease in Rc during repeated matings. Radius decreases with increasing matings.
The dust particle distribution on the connector end faces can be described by a single parameter $R_c$, which is called the center of particles.

\[
R_c = \frac{\sum_{i=0}^{N} r_i a_i}{\sum_{i=0}^{N} a_i}
\]

\[
y = 166.18x \\
R^2 = 0.9073
\]

Relationship between the particle center moving speed and the charge
Conclusions

• During repetitive connector mating and de-mating cycles, dust particles can accumulate and re-distribute at the connector end face.

• Electrostatic charge force was one of the mechanisms responsible for the particle accumulation, re-distribution and their movement in the core area.

• A new metric, Center of Particles, $R_c$ was developed to characterize the distribution of particles at the connector end face.

• $R_c$ decreased during the series of mating/demating cycles, demonstrating movement of particles toward the core, based on our data.
Development of Cleanliness Specifications for Single-Mode, Angled Physical Contact MT Connectors

NFOEC 2008
San Diego, CA
Feb 28, 2008
Objectives

• Investigate the influence of contamination and scratches on optical performance (IL, RL) of MT APC ferrules.

• Analyze data on dust particle re-distribution phenomenon during repetitive mating cycles.

• Develop cleanliness inspection criteria for MT APC connectors.
The group of experimental samples included eight SM, MPO jumpers with low-loss MT Angled Physical Contact ferrules.
  - Each MPO connector contained one row of 12 fibers

Two grades of Arizona Dust particles:
  - 1-5 um and 6-25 um

Scratches manually introduced to the MPO connectors’ end-faces.
MT-APC experimental methodology was based on a Design Of Experiment (DOE) developed by the iNEMI team for SM 2.5mm and 1.25mm ferrules.
• DUTs and reference connectors were cleaned using reel style cleaning cassette and inspected using fiber scope.
• End-face images captured:
  – FiberChek 2 software and digital scope from Westover Scientific.
• Particle count, size, and locations, measured Occluded Area (OA) and Gaussian Weighted OA (GWpOA) calculated:
  – FiberQA™-EFI software from PVI Systems
• Insertion Loss (IL) and Return Loss (RL) measured:
  – RX 3000 Multi Channel Back Reflection meter from JDS Uniphase. Source wavelength was 1550 nm.
The occluded particle area, a new metric developed by PVI Systems, computed the total particle area within narrow annular rings.

The occluded area may also be accumulated within specific zones. A weighted Occluded Area using a user specified weighting function, most commonly with a Gaussian distribution correlated to the optical beam properties, was also computed.

Labeled Detected Particles with 5 μm annular rings.
Gaussian Weighting Occluded Area

- Gaussian Weighted Occluded Area (GWAOA) is a single valued Figure of Merit representing the overall cleanliness of the end-face.
- Uses intensity distribution of fundamental fiber mode, \( I_0 \exp(-2r^2/\omega_f^2) \) as weighting function for occluded area
  - where \( I_0 \) is the peak intensity, \( r \) is the radial position and \( \omega_f \) is the mode-field radius of fiber mode.
- Gaussian weighting factor \( \Gamma = \exp(-2r^2/\omega_f^2) \) is normalized representation of this expression.
- The GWpOA is defined as:

\[
 f(\%) = \frac{\sum_{i=0}^{N} a_i \Gamma_i}{\sum_{i=0}^{N} A_i \Gamma_i} \cdot 100
\]

where \( a_i \) is the size of particle at ith ring, \( \Gamma_i \) is the Gaussian weighting factor for the ith ring, and \( A_i \) is the area of the ith ring. For \( i = 0 \) it denotes the initial circle.
Contaminated Core Zone Results

- For samples with contaminated core zones, increasing levels of contamination caused degraded optical performance — higher IL and lower RL.
Cladding Zone Analysis

Delta IL and RL data for 12 channels of contaminated MT connector. Note the positional tendency of loss of physical contact failures to occur on outer fibers in the array.

Mechanism believed to be loss of physical contact on the outer fibers due to contamination.
Cladding Zone Analysis

End-face images of DUT and Reference connector showing no impact to signal performance

<table>
<thead>
<tr>
<th>Robustness example #62</th>
<th>IL</th>
<th>RL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10X Average</td>
<td>0.045 dB</td>
<td>73.5 dB</td>
</tr>
<tr>
<td>10X Std Dev</td>
<td>0.011 dB</td>
<td>1.7 dB</td>
</tr>
<tr>
<td>Average + 3 Std Dev</td>
<td>0.078 dB</td>
<td>68.4 dB</td>
</tr>
<tr>
<td>Contaminated</td>
<td>0.02 dB</td>
<td>73 dB</td>
</tr>
</tbody>
</table>
• 65 fiber pair samples had significant cladding OA but NO IMPACT on signal performance.
• Some fiber pairs had up to 30% occluded area on cladding with no signal degradation. However, there were some fiber pairs in the cladding contamination study that did exhibit signal degradation.
• There are nine data points which had minimal cladding contamination (<5% OA from 12.5 - 115μm) with some impact to signal performance. These samples are considered to be specification limit samples as the concluded acceptance criteria must ultimately fail these data points to be effective.
Limit Sample #1: Minimal MT/APC Contamination on Limit Sample #1 with signal degradation
MT Scratch Analysis

Typical lack of impact on signal performance of light scratches on MT/APC connections
Redistribution of Particles - Multiple Mating

- Particle migration and IL signal degradation of second fiber in MPO connector after series of matings:
  - (a) Before mating $\text{IL} = 0.09\text{dB}$ (before contamination)
  - (b) After first mating $\text{IL} = 0.09\text{dB}$
  - (c) After fifth mating $\text{IL} = 0.29\text{dB}$
\( R_c \) decreased during the series of mating/de-mating cycles, demonstrating movement of particles toward the core for all twelve fibers of an MPO connector.
• MPO data initially had lower correlation between OA and IL than previous experiments.
• Hypothesized that cause was not including contamination on reference in OA.
• Developed new separation factor to estimate combined effect of DUT and Ref OA, since combined OA could not be calculated.
Separation factor

- Separation factor is defined to weight the OA data from both the reference and DUT end faces.
- The individual separation factor $s_i$ is defined as:

$$S_i = \frac{a_i}{a_{Di} + a_{Ri}}$$

- where $a_i$ is the size of particle during IL measurement, $a_{Di}$ is the particle size for the DUT fiber, and $a_{Ri}$ is the particle size for the Reference fiber at the $i^{th}$ ring, respectively.
IL Test

DUT

Reference

\[
\begin{align*}
 f_D &= \frac{\sum_{0}^{N} a_{Di} \Gamma_i}{\sum_{0}^{N} A_i \Gamma_i} \\
 f_R &= \frac{\sum_{0}^{N} a_{Ri} \Gamma_i}{\sum_{0}^{N} A_i \Gamma_i} \\
 Therefore,
 f &= \frac{\sum_{0}^{N} s_i (a_{Di} + a_{Ri}) \Gamma_i}{\sum_{0}^{N} A_i \Gamma_i} \\
 &= s(f_D + f_R)
\end{align*}
\]

Case 1: Vertical split (red particle)
\[s_v = a_i/(a_{Di} + a_{Ri}) = 1\]
where \(a_{Di} = a_{Ri} = 0.5a_i\)

Case 2: Horizontal split (green particles)
\[s_h = a_i/(a_{Di} + a_{Ri}) = 0.5\]
where \(a_i = a_{Di} = a_{Ri}\)
Of 45 data points, 4 have > 1 dB error, and 6 have error between 0.5 and 1 dB
The value of f% strongly depends on the particle movement, especially for large f% where the particle is close to core center.
### Table 1: Inspection Criteria for Single Mode APC MT Pigtail and Patchcord Connectors

<table>
<thead>
<tr>
<th>Zone/Description</th>
<th>Diameter</th>
<th>Defects (diameter)</th>
<th>Scratches (width)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A — Core Zone</td>
<td>0 to 25 microns</td>
<td>none</td>
<td>None &gt; 3µm</td>
</tr>
<tr>
<td>B — Cladding Zone</td>
<td>25 to 115 microns</td>
<td>any &lt; 2 microns 5 from 2 - 5 microns none &gt; 5 microns</td>
<td>No limit</td>
</tr>
<tr>
<td>C-Adhesive Zone</td>
<td>115 to 125 microns</td>
<td>No limit</td>
<td>No limit</td>
</tr>
<tr>
<td>d — Contact Zone</td>
<td>&gt;125 microns</td>
<td>No limit</td>
<td>No limit</td>
</tr>
</tbody>
</table>
Conclusions

• iNEMI team conducted experiments to investigate the effects of contamination on the optical performance of SM Angled Physical Contact MT fiber optic connectors.

• Contamination of the 25μm zone results in increase of IL for MT connectors (IL delta maximum ~1.5dB) and decrease of RL (RL delta maximum ~21dB).

• For more than 65 mated fiber pairs, no signal degradation was observed with significant contamination of up to 30% Occluded Area in the cladding zone.
Conclusions

- Particle accumulation toward the core was observed for repetitive connector mating cycles.
- Improved correlation between signal performance and GWpOA for MT connectors was observed when the Reference image was accounted for using the separation factor.
- Sensitivity to fiber center estimation and/or particle migration during the measurement process was estimated. Some discrepancies between calculated and measured data were removed by taking into consideration particle movement during a series of repetitive mating cycles.
Conclusions

• The iNEMI team continues to work with the International Electrotechnical Committee (IEC), Telecommunications Industry Association (TIA) and IPC (Optoelectronic Assembly and Packaging Technology) to develop endface quality standards.

• Based on results of this study, iNEMI has proposed acceptance criteria for SM Angled Physical Contact MT connectors.
Receptacle and Lens Device Criteria Development Project
Presentation Outline

- Introduction and Background
- Common MSA Package Types
- Lens Type Definitions & Table Development (Survey)
- Examples of TOSA/ROSA design
  - (Physical Contact and Non-Contact)
- Technology Matrix
- Next Steps (Modeling and Experiments)
- Details of Previous Work
- Summary
• iNEMI Research started on receptacle fiber-stub devices
  – Receptacle (stub devices) cleanliness paper published (Sep 2005)
  – Initial work started on lens devices (2006)

• Development of Cleanliness Criteria for receptacle fiber stub and lens devices was presented at IEC meeting, Prague, Apr, 08 and Kyoto meeting, Nov, 09

• Additional research needed to propose standard criteria for multiple receptacle types (fiber stub, lens)

• Benefits of receptacle research and criteria
  – Clarify receptacle design categories, common language
  – Development of standard inspection criteria
  – Increased awareness of impact of contamination
  – Less down time due to contaminated transceivers
Pluggable Optics – Common MSA Package Types

- SNAP12 MSA Parallel Optic Device

- SFP Standard
- XFP
- X-PAK
- XENPAK

Dimensions:
- Length: from back of front panel to rear of the cage
- Width: defined as the pitch (how close the TxRx is spaced)

Pluggable Module MSA’s
Receptacle Designs: Physical Contact

- Receptacle device with internal physical contact fiber stub

- Physical Contact Definition
  - “Fiber endface of cable assembly plugged into device will make physical contact with lens (or fiber) surface.”
• Receptacles device with fiber stop
  – (10x magnification shown)

• Non-Contact Definition
  – Fiber endface of cable assembly plugged into device will not make physical contact with lens (or fiber) surface.
Matrix Development

• Small survey conducted with feedback from eight companies
• Objectives of survey:
  – Determine technologies available in industry
  – Set categories for receptacle technologies
## Receptacle Technology Matrix

<table>
<thead>
<tr>
<th>SM or MM</th>
<th>Data Rate</th>
<th>Lens, Physical Contact</th>
<th>Lens, Non-Contact</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Fiber Stub</td>
<td>Dome Lens</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.25 mm</td>
<td>2.5 mm</td>
</tr>
<tr>
<td>SM</td>
<td>&lt;10G</td>
<td>TOSA</td>
<td></td>
</tr>
<tr>
<td>MM</td>
<td>&lt;10G</td>
<td>TOSA</td>
<td></td>
</tr>
<tr>
<td>SM</td>
<td>10G+</td>
<td>TOSA</td>
<td></td>
</tr>
<tr>
<td>MM</td>
<td>10G+</td>
<td>TOSA</td>
<td></td>
</tr>
</tbody>
</table>

### Notes:
- Shading indicates technology types known to exist in the industry.
- Physical contact devices are generally more sensitive to contamination than non-contact devices.
- Lens, Non-Contact devices using a 1.25 mm connector may have a reduced opening above lens which makes any cleaning efforts difficult.
The test vehicle for iNEMI study was provided by Sumitomo Electric
DOE Block Diagram

1. Apply Dust to Test Device
2. Acquire Image
3. Measure Optical Properties
4. Acquire Image
5. Compute Performance using Model
6. Compare Experimental and Model Data
7. Develop Inspection Matrix
Which characteristic is sensitive to contamination?

**DUT : STUB (Transmitter side of SCM6308)**

<table>
<thead>
<tr>
<th>Term</th>
<th>Original</th>
<th>-</th>
<th>After Contaminated</th>
<th>Fluctuation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical Power</td>
<td>-6.7 dBm</td>
<td>-&gt;</td>
<td>-6.7 dBm</td>
<td>0 dB</td>
</tr>
<tr>
<td>Pulse Mask Margin</td>
<td>45 %</td>
<td>-&gt;</td>
<td>43 %</td>
<td>-2 %</td>
</tr>
<tr>
<td>Spectral Width</td>
<td>2.3 nm</td>
<td>-&gt;</td>
<td>2.3 nm</td>
<td>0 nm</td>
</tr>
<tr>
<td>ORL</td>
<td>58.7 dB</td>
<td>-&gt;</td>
<td>33.9 dB</td>
<td>-24.8 dB</td>
</tr>
</tbody>
</table>
### Critical parameters (Receiver)

*Sumitomo Special Lens  
Its purpose is to reduce RL (same as stub).  

*Focal point is different each other.  
If lens were clean, there is no target to focus.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Original</th>
<th>-</th>
<th>Contaminated</th>
<th>Change</th>
<th>Original</th>
<th>-</th>
<th>Contaminated</th>
<th>Fluctuation</th>
</tr>
</thead>
<tbody>
<tr>
<td>PD sensitivity</td>
<td>0.95 A/W</td>
<td>-&gt;</td>
<td>0.95 A/W</td>
<td>0 A/W (0.0 dB)</td>
<td>0.83 A/W</td>
<td>-&gt;</td>
<td>0.68 A/W</td>
<td>-0.15 A/W (-0.9 dB)</td>
</tr>
<tr>
<td>LOS activation level</td>
<td>-32.2 dBm</td>
<td>-&gt;</td>
<td>-32.2 dBm</td>
<td>0.0 dB</td>
<td>-24.9 dBm</td>
<td>-&gt;</td>
<td>-24.0 dBm</td>
<td>+0.9 dB</td>
</tr>
<tr>
<td>ORL</td>
<td>45.8 dB</td>
<td>-&gt;</td>
<td>26.9 dB</td>
<td>-18.9 dB</td>
<td>14.1 dB</td>
<td>-&gt;</td>
<td>14.2 dB</td>
<td>+0.1 dB</td>
</tr>
</tbody>
</table>

*Changing of ORL is within a measurement accuracy.
• Sumitomo collected a lot of the experimental data on the influence of the contamination on the optical performance of TOSA (2005) and ROSA (2006-2007)
• Process the lens images using PVI Systems software, calculate Occluded Area and bitmap of contamination
• Based on the details of the ROSA design and GW%OA, model the ROSA data (receiver sensitivity)
• Compare experimental and modeling data
Sumitomo DOE for the Receptacle with lens

1. Clean lens and reference cable
2. Take picture
3. Mate
4. Measure ORL
5. Demate
6. Visual check for cleanliness
7. Take pictures after 1st, 5th and 10th matings (lens & cable)
8. Clean if contaminated (lens & cable)
9. Change if damaged (cable)
10. Additional Contamination (to make ORL worse)

- Take picture
- Reject removables
- Apply contamination (lens)
- Measure ORL
- Demate
- Visual check for cleanliness
- Take picture after each mating (lens & cable)
- 1-4th
- 1-9th

End
## Test Result (sample-2, SFP receiver-side, lens)

<table>
<thead>
<tr>
<th>Before Contaminated</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
<th>5th</th>
<th>6th</th>
<th>7th</th>
<th>8th</th>
<th>9th</th>
<th>10th</th>
<th>Ave</th>
<th>Std Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>PD sensitivity (A/W)</td>
<td>0.64</td>
<td>0.64</td>
<td>0.63</td>
<td>0.64</td>
<td>0.64</td>
<td>0.64</td>
<td>0.64</td>
<td>0.64</td>
<td>0.64</td>
<td>0.64</td>
<td>0.64</td>
<td>0.00</td>
</tr>
<tr>
<td>ORL (dB)</td>
<td>-13.5</td>
<td>-13.3</td>
<td>-13.5</td>
<td>-14.2</td>
<td>-13.5</td>
<td>-14.5</td>
<td>-14.5</td>
<td>-13.4</td>
<td>-14.7</td>
<td>-13.5</td>
<td>-13.8</td>
<td>0.6</td>
</tr>
</tbody>
</table>

**Fiber Connector**

- Before 1st mating
- After 1st mating
- After 5th mating
- After 10th mating

**Lens (focused on PD)**

- After Contaminated
  - 1st
  - 2nd
  - 3rd
  - 4th
  - 5th
  - Ave
  - Std Dev

<table>
<thead>
<tr>
<th>After Contaminated</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
<th>5th</th>
<th>Ave</th>
<th>Std Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>PD sensitivity (A/W)</td>
<td>0.44</td>
<td>0.44</td>
<td>0.44</td>
<td>0.45</td>
<td>0.45</td>
<td>0.45</td>
<td>0.00</td>
</tr>
<tr>
<td>ORL (dB)</td>
<td>-13.9</td>
<td>-14.5</td>
<td>-14.4</td>
<td>-14.4</td>
<td>-14.3</td>
<td>-14.3</td>
<td>0.2</td>
</tr>
</tbody>
</table>

**Fiber Connector**

- Before 1st mating
- After 1st mating
- After 2nd mating
- After 3rd mating
- After 4th mating
- After 5th mating

**Lens**

- After 1st mating
- After 2nd mating
- After 3rd mating
- After 4th mating
- After 5th mating
Modeling Inputs

- Modeling tool: ZEMAX
- Bitmap files of contaminated receptacle lens processed to represent the light transmission pattern of the lens.
- Lens illumination area size and fiber location relative to lens.
- Fiber types (single mode or multimode).
- Wavelength.
- Coupling efficiency (power measured through fiber/power measured without fiber) before and after contamination for transmitters.
- Light output measurement data before and after contamination of dust for transmitters.
- Receiver sensitivity measurement data before and after the application of dust for receivers.
Examples: Sumitomo Receiver

Raw image viewed from fiber location

Processed image viewed from fiber location

Image viewed against illumination

Single mode fiber

Modeling
Comparison of simulated and experimental results of insertion loss change due to contamination

The processed zone diameter is 315um
• Simulated IL is typically lower than the measured IL.
• Good correlation between experimental data and modeling data has been achieved considering contamination in the central 315 μm diameter zone of the lens (Samples 1, 2 and 4)
• The discrepancy on Sample 3 may be attributed to the contamination effect from the fiber end-face which was ignored in simulation.
• Particle migration, obvious by examining before and after mating images, may also cause discrepancy between simulation and experiment.
• In the future, clean fiber and non-removable particles is preferred to be used for validation experiment, which is more representative of reality
Summary

• iNEMI plans for gathering data and experiments
  – Use DOE proposed
  – Select the test vehicle for the experiment based on receptacle technologies matrix
  – Use Modeling to Analyze Data
  – Compare Modeling and Experimental Data

• Strategy for Development of Criteria
  – Use data to develop criteria and propose to IEC for potential inclusion in future standard (IEC 86B and 86C)
  – Collaborate with JIS on standards development
  – Recommend updates to IPC-8497-1 for receptacle devices
Conclusions
Questions?
Collaboration with TIA, IEC and IPC

- The Project is collaborating with International Electrotechnical Committee (IEC), Telecommunications Industry Association (TIA) and IPC to develop a cleanliness standard.

iNEMI presentations:

- OMI conference, Ottawa, Apr-29-May 1, 2003
- **IEC meeting, Montreal, Quebec, Canada, Oct 6-13, 2003 (presented by T. Berdinskikh, Celestica)**
- APEX2004, Anaheim, California, Feb 19-Feb 26, 2004
- **IEC meeting, Locarno, Switzerland, Apr, 04 (presented by T. Mitcheltree, Cisco)**
- **IEC meeting, Warsaw, Poland, Sep, 04 (presented by R. Manning, Tyco)**
- APEX2005, Anaheim, California, Feb, 05
- **IEC meeting, Charlotte, NC, Apr, 05 (presented by R. Manning, Tyco)**
- A draft of IPC-8497-01 “Cleaning Methods and Contamination Assessment for Optical Assembly” has been submitted to IPC (June, 04)

- OFC2006, Anaheim, California, Feb, 06
- **IEC meeting, Quebec City, Canada, Oct, 06 (presented by T. Berdinskikh and Heather Tkalec)**
Publications

- “At the Core: How Scratches, Dust, and Fingerprints Affect Optical Signal Performance”, *Connector Specifier*, January 2004, pp.10-11
- “Cleaning Standard for Fiber Optics Connectors Promises to Save Time and Money”, *Photonics Spectra*, June 2004, pp.66-68
- “Contamination Influence on Receptacle Type Optical Data Links”, *Photonics North*, 2005, Toronto, Canada, Sep, 05.
- “Development of Cleanliness Specifications for 2.5 mm and 1.25 mm ferrules Single-Mode Connectors” – *Proceedings of OFC/NFOEC*, Anaheim, California, Mar 5-10, 06

9 Papers published by the Project Team