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Contamination effects on optical performance for short reach 10Gb/s SFP+ transceivers

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Abstract:
This research is to establish a modeling methodology to assess insertion loss due to contamination on a lens based, 10Gb/s, short reach Small Form-factor Pluggable (SFP+) module transceivers in multimode applications.

OCIS codes: (060.2340) Fiber optics component; (120.4800) Optical standards and testing

1. Introduction

While pass/fail criteria for contamination of optical connectors are defined, these criteria have not been developed for transceiver modules with lensed receptacles. Unlike receptacles with a fiber stub interface, receptacles with lenses vary significantly in design, technology and material composition. This makes the standardizing of inspection criteria based on the size of contaminants, as was implemented for fiber stub connectors, difficult. The primary goal of this research is to develop a method that can be used to determine the effect from lens contamination for a given transceiver module with a set of disclosed design parameters, such as wavelength, lens-fiber distance, effective optical area, etc.

The iNEMI (International Electronics Manufacturing Initiatives) working group has done substantial work, both theoretical and experimental, on the development of inspection criteria for 2.5Gb/s fiber-stubbed and lens-based receptacles [1,2].

2. Experimental Methodology

The experimental vehicle for this project was a short reach 10Gb/s SFP+ module, manufactured by Sumitomo Electric. The OSA (Optical Sub Assembly) structure is shown in Figure 1. The optical interface for both TOSA and ROSA were a non-contact plastic lens. This is a type of plastic molded lens where the barrel and lens is one structure.

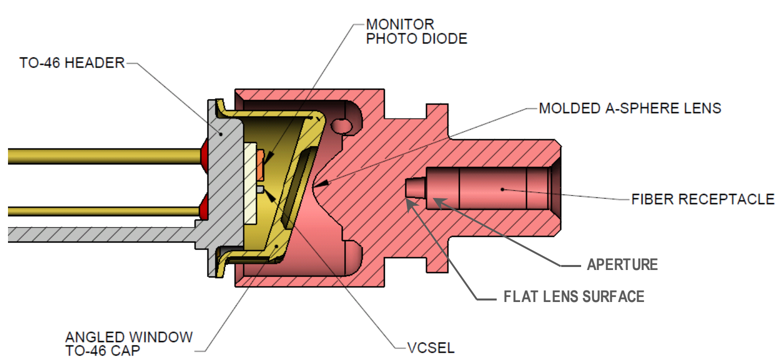

Figure 1: Example of non-contact TOSA/ROSA design

While this design is common in the industry, not all devices are constructed this way. Alternate non-contact, lens-based designs may have separate components for fiber receptacle, aperture, lens, etc. However, it is true that all TOSAs/ROSAs that do not contact the core of the mating patch cord have some aperture and a certain distance to the actual lens surface. This aperture is always less than 1.25mm in diameter, which is the smallest cleaning tool size, making it difficult to deliberately apply contamination to the lens surface and also difficult to make the contamination remain intact and in-place (non mobile).

The experimental methodology was similar to that which was described in [1, 2]. Initially the SFP module was inspected and cleaned if required. Images of the optical endface of both reference cable and lens were captured using a JDSU FBP-P5 probe and FiberChek software. Then optical characteristics such as Optical Power, Mask Margin, Extinction Ratio, Center Wavelength and Spectral Width were measured for the TOSA in a clean condition. The LOS (Loss of Optical Signal) Assert and Rx Input Power were recorded for the ROSA in a clean condition. After the measurement of clean conditions, the SiO2 test dust was applied to the lens surface using a modified cleaning stick.

All optical parameters were measured for the contaminated TOSA and ROSA. An image of the mating connector endface was recorded after every de-mating. All lens images were processed using FiberQA-EFI software from PVI Systems to generate binary bitmap images of the contamination for use in the modeling as shown in Figure 2.

It was found that Light Output Power (LOP) for the transmitter side and the power coupled into the detector for the receiver side (Rx sensitivity) were the parameters most sensitive to contamination. Five of the 10 samples demonstrated reduced LOP in Tx and detected power level in Rx. The maximum changes of LOP and detected power due to contamination were 1.24 dBm and 1.15 dBm respectively.

3. Image Analysis

It is important to inspect the active area of the lens for the presence of contamination and scratches. A standard probe FBP-P5 has high sensitivity at 850 nm. To observe the optical interface when the Tx is enabled, an additional filter is required. Filtered FBP-P5 can show the optical interface clearly whether Tx-Disabled or Tx-Enabled. The example of Tx Enabled image is presented in Figure 2a. Figure 2b is the processed binary image and Figure 2c shows the modeled image of the Rx.

a. **b.** **c.**

Figure 2. The example of raw fiberscopic image with Tx Enabled (a), processed image (b) and modeled image (c) for ROSA

4. Modeling Overview and Methodology

Multimode transceiver modules present additional challenges for modeling in comparison to the single-mode types. As the typical source for a transmitter, VCSELs (Vertical Cavity Surface Emission Laser) emit multiple transversal modes during operation. The mode field pattern of each individual mode can be calculated based on the detailed structure of the VCSEL design. In addition to the multimode emitting condition, the number of operating modes also varies according to the driving current, which also varies emitting pattern of the source, ultimately affecting the calculation of coupled power through the system. Some assumptions are made for the analysis of the transmitter. On the Rx side, the light output from a multimode fiber can vary substantially in terms of far-field emission pattern.

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Based on the experimental results, modules with coupled power significantly altered by contamination were selected for simulation. A comparison of simulation and experimental results is presented. The simulation was carried out with ZEMAX, a tool primarily used for ray tracing with an added module for physical optics propagation. The following assumptions have been made for the laser source: VCSEL operates at multimode condition with around 4 mode groups active; modes are supported by a circular shaped waveguide; a far-field pattern from such source was duplicated in a ray trace based modeling tool as for Tx simulation—shown in the top image of Figure 3. Several assumptions have been also used for 50um multimode fiber case: They considered that fibers were fully filled with all modes excited. A parabolic far-field pattern is duplicated in a ray-trace based modeling tool as the source for Rx simulation—shown in the bottom image of Figure 3.

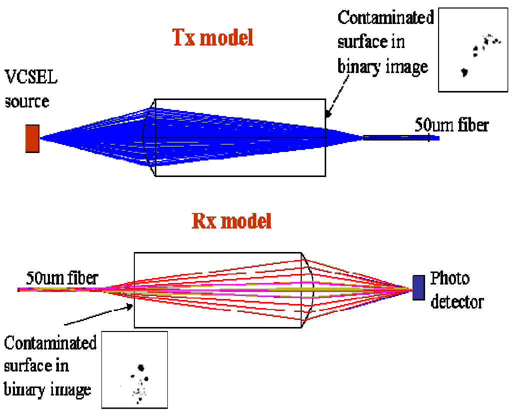

Figure 3: ZEMAX Model of Tx and Rx

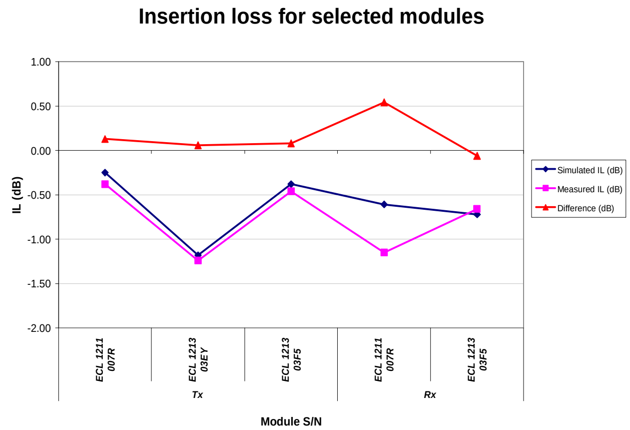

Figure 4: Comparison of Modeled and Measured IL

Once the source profile is determined, the ray tracing is carried out to calculate the power coupled into the 50um multimode fiber in the case of the transmitter and the power captured by a detector in the case of the receiver. The calculation is made with and without the presence of binary images processed according to the previously described method. A comparison of the coupled power with or without the images quantifies the effects of contamination on insertion loss. The simulation data are compared with the experimental data as shown in the graph in Figure 4. The results show that a good agreement is achieved between the two and the modeling accurately accounts for the insertion loss increase caused by the lens surface contamination.

5. Conclusions

Multimode transceivers present additional challenge in optical modeling compared to the single mode device, as such laser source characteristics can vary significantly by designs and operating conditions. Common features do exist across many designs, such as VCSEL radial symmetry, circular waveguide properties that support several lowest order modal groups, etc. A generic form of source can be extracted. A comparison of experimental and simulation results show that consistency between the two is demonstrated in many cases and the modeling methodology shows promise as a more simplified approach for developing inspection criteria for various transceiver designs.

[1]. Hisato (Scott) Takahashi, Yutaka Sadohara, Carla Gleason, Tatiana Berdinskikh, Thomas Mitcheltree, Steve Lytle "Contamination Influence on Receptacle Type Optical Data Links", in Photonic Applications in Biosensing and Imaging, Vol.5970 of the SPIE Proceedings Series (The International Society for Optical Engineering, 2005), pp.32-42.
[2]. Christine Chen, Yutaka Sadohara, Tatiana Berdinskikh, David Fisher, Sun-Yuan Huang, Brian J. Roche, Beth Coviello "Modeling and Experimental Analysis of Contamination Effects on Lens-Based Optic Modules, Douglas H. Wilson", Proceedings of OFC/NFOEC2009, San Diego, Mar 22-Mar 26, 09, JThA, pp.1-3.