DESIGN AND PERFORMANCE OF EXPANDED BEAM, MULTI-FIBER CONNECTORS

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Introduction

Multiple embedded parallel optic modules facilitate the need for dense optical interconnect technology at the card edge demarcation point. With current architectures, this parallel optic demarcation occurs through multi-fiber bulkhead or blind-mateable connectors which employ traditional MT ferrules for the precision alignment. In order to obtain a low and stable insertion loss, the optical fiber tips from the mated pairs must come into physical contact with each other. This physical contact requires very tightly controlled termination, polishing and metrology procedures which drive the cost of traditional multi-fiber interconnects [1].

For interconnect densities beyond 24 fibers for multimode and 12 fibers for single mode, obtaining and maintaining physical contact of the fiber tips becomes unattainable with state of the art polishing and termination technology. As a result, the mated fiber tip interface of high fiber count MT ferrules becomes unstable, which can result in optical interference and amplifying return loss values higher than a simple unmated connector will generate. In addition to maintaining physical contact, particularly in the case of single mode ferrules, each fiber tip within the ferrule must be relatively pristine to ensure the signal is not attenuated through contamination blockage or loss of z-axis alignment (i.e., physical contact). While traditional, physical contact MT ferrules are suitable for demanding low-loss, high performance applications, they are not optimized for short reach, high-density, cost sensitive applications

Expanded Beam Lensed Multi-Fiber Ferrule Design Overview

A free space, expanded beam, collimated optical interconnect eliminates the need for fiber tip physical contact, which in turn, reduces the overall cost of multi-fiber optical cable assembly manufacturing. Light emitted by the fiber diverges from the fiber tip through the optical polymer to the lens. Over this distance, the beam diverges based on the NA of the fiber and the index of the polymer. The beam exiting the lens in nearly collimated. The same lens on the receiving ferrule focuses the light onto the fiber core. A cross section of the mated ferrule and ray trace schematic is shown in Figure 1. The ferrule design presented in this investigation is made with one, molded, monolithic component combining micro holes and lenses and expands the beam to a collimated spot over 3X the fiber core diameter. This design reduces the precision alignment at the mating plane, eliminating the need for costly stainless steel guide pins. The collimated free space transmission is also tolerant to z-axis alignment and reduces the need for high mating forces and costly polished end face topologies associated with physical contact connectors. Furthermore, the impact of debris occluding the power and causing z-axis separation is significantly reduced.

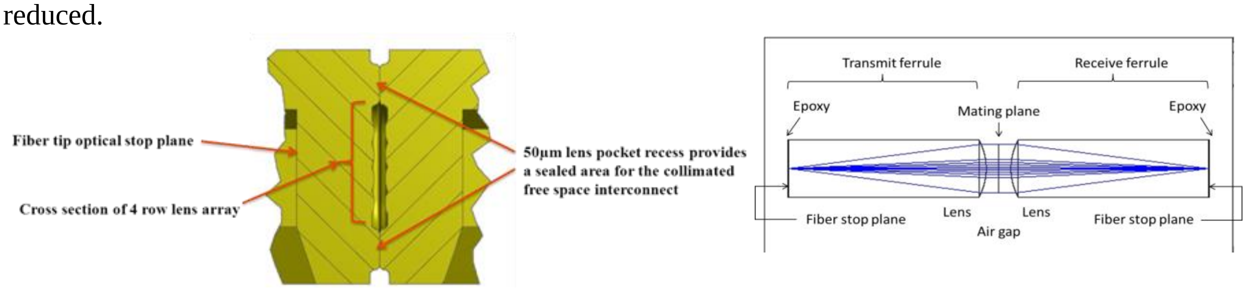

Figure 1. Mated, Free-Space, Lensed, Multi-Fiber Ferrule

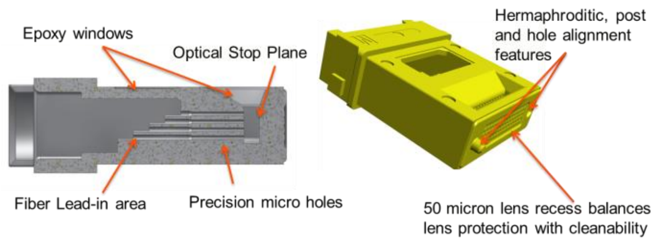

Figure 2. Lensed Multi-Fiber Ferrule Design

The expanded beam ferrule was designed with the same outer length, width, height and shoulder footprint as a traditional, physical contact MT ferrule and is highlighted in Figure 2. This aspect of the ferrule design allows for use with existing MT based connector solutions such as the MPO connector or other MT ferrule based connector solutions.

Results for Single Mode Expanded Beam Connectors

A ray-tracing, Monte Carlo simulation model was initially established to predict loss of the single mode expanded beam ferrules. For the empirical study, the ferrule produced and tested had a single row of 16 single mode fibers with an approximate collimated beam of 90 microns. Ten randomly mated expanded beam ferrule pairs were tested in a manner similar to standard fiber connector testing which uses conventional return loss and insertion loss test equipment, results shown in Figure 3. These ferrules were manufactured in accordance with the typical single-mode alignment tolerances associated with the optical model [3].

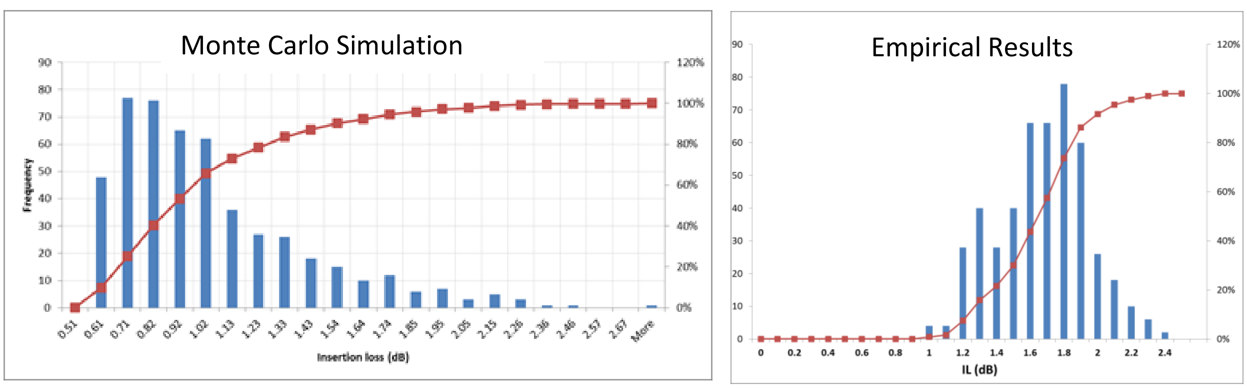

Figure 3. Insertion Loss Simulation and Empirical Results

Conclusion

A multi-fiber, molded, monolithic, expanded beam ferrule had been designed, manufactured and tested to confirm the viability of low cost, no-polish, debris insensitive ferrule for single mode applications. This interconnect technology is ideal for passive interconnects at the equipment, card-edge interface with embedded optic technology where cost, density, debris sensitivity and coupling force are of concern. Parts were manufactured to the specifications assumed in the optical simulations. Empirical data from randomly mated connector pairs was collected and confirmed to closely match the predicted results from the optical Monte Carlo simulation.

References

[1] Childers, D., Hughes, M., "High density, low cost, no-polish optical ferrule," *Optical Interconnects Conference 2013*, Santa Fe, NM.

[2] Childers, D., Childers, E., Graham, J., Hughes, M., "Next generation, high density, low cost, multimode optical backplane interconnect," *Photonics West 2012*, San Francisco, CA.

[3] Childers, D., Hughes, M., Satake, T., "New, single-mode, multi-fiber, expanded beam, passive optical interconnect," *Photonics West 2014*, San Francisco, CA.