Advancements in Fanout Technology for SDM Applications

V.I. Kopp, J. Park, J. Zhang, J. Singer, D. Neugroschl
Chiral Photonics, Inc., 26 Chapin Rd., #1104, Pine Brook, NJ 07058 USA
vickopp@chiralphotonics.com

Abstract: Real-world SDM deployment requires the development of a supporting ecosystem. Recent technological advancements allow for volume production of key components of this ecosystem, MCF fanouts, which meet demanding performance requirements.
OCIS codes: (060.2340) Fiber optics components

1. Introduction

Optical fiber networks based on a high-bandwidth-density SDM approach need to be ready in the next few years to avoid a capacity crunch [1]. The first generation SDM network, which will be based on uncoupled core multicore fibers (MCFs) [2], requires the development and adoption of multiple basic components. These include the MCFs themselves, MCF splicers, and fanouts. With these basic elements, even without fully integrated SDM components, many multicore fiber network functions, including Tx/Rx, switching, isolation, amplification, gain-flattening may be performed utilizing single-core components and devices. Fanout technology has matured as multiple vendors have developed commercialized MCFs [3] and MCF splicers [4, 5]. Here we describe advances in fanout technology for submarine, terrestrial, and sensing applications in performance, package size, and robustness, which have been made over the past decade.

2. Versatile all-glass fanout technology

The developed approach is based on fused glass technology utilizing a Vanishing Core fiber (VCF) as a bridge fiber between MCF and a single core fanout pigtail [6-8]. The approach enables fusion splicing of the fanout and MCF resulting in a monolithic glass structure from MCF to pigtail. In addition to the robust structure, this leads to very low back reflection, high power handling, as well as stable performance. The VCF approach is very versatile, allowing addressing both coupled and uncoupled MCFs having a wide range of core spacings from just a few microns to a few tens of microns, as well as different core counts from 2 to more than 20 with cores positioned on different lattices. Broadband performance is also achieved in these fanouts covering both the O- and C-bands with the same devices. Mode adaptation may also be implemented in the VCF-fanouts. In the C-band, for example, a VCF-fanout with standard SMF-28 pigtails having

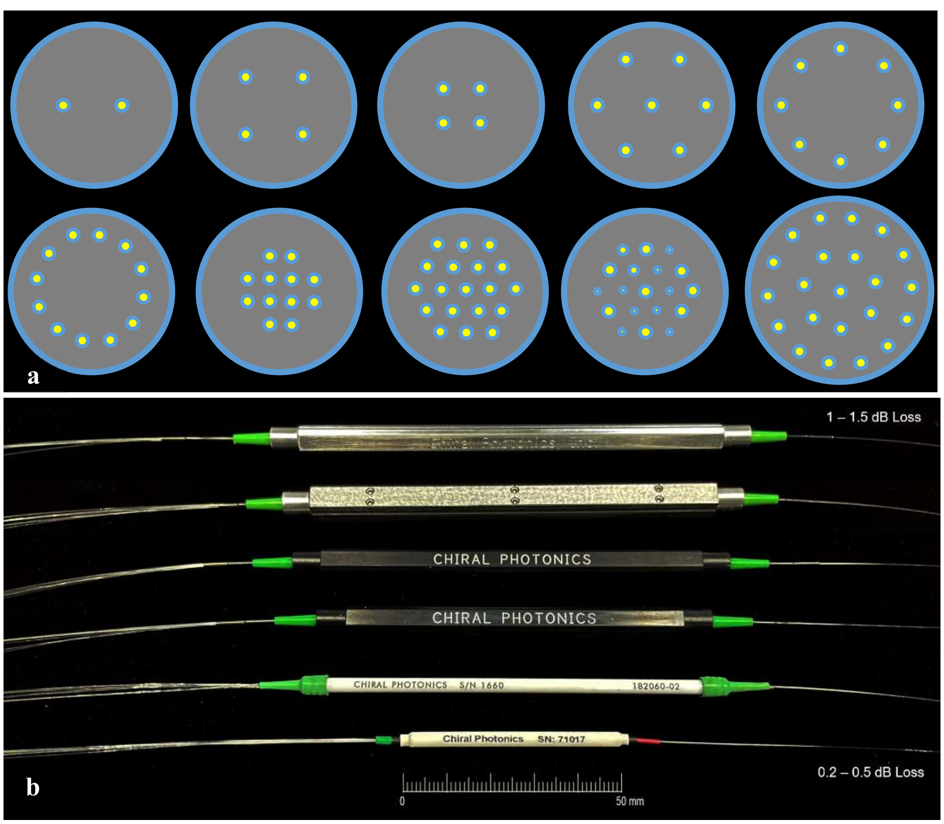


Fig. 1. (a) Various types of MCFs which have been addressed by the VCF-fanouts. (b) Evolution of MCF fanout technology over last decade 2013 - 2023.

10-micron mode field diameters (MFDs) may be fusion spliced with low loss to an MCF with the MFDs ranging from 4 to 12 micron. VCF fanouts addressing even heterogeneous MCFs with MFDs varying in the same MCF have been demonstrated. A near-field MFD measurement setup was utilized to fine-tune the VCF geometry and achieve the optimized fanout performance shown below [9]. Figure 1a shows some examples of MCFs, which have been addressed by the VCF approach, and Fig. 1b summarizes the evolution of this approach over the last decade, showing the reduction in package size, as well as the improvements in insertion loss (IL). The statistics of fanout performance shown below corresponds to three MCF configurations with 2, 4, and 7 cores for which fanouts have been fabricated in sizable volumes.

3. Fanout performance

A fully automated measurement setup based on a Keysight N7778C tunable laser source allows for the characterization of single fanouts in production. The performance of the last 500 2-core fanouts is shown in Fig. 2. Since bi-directional

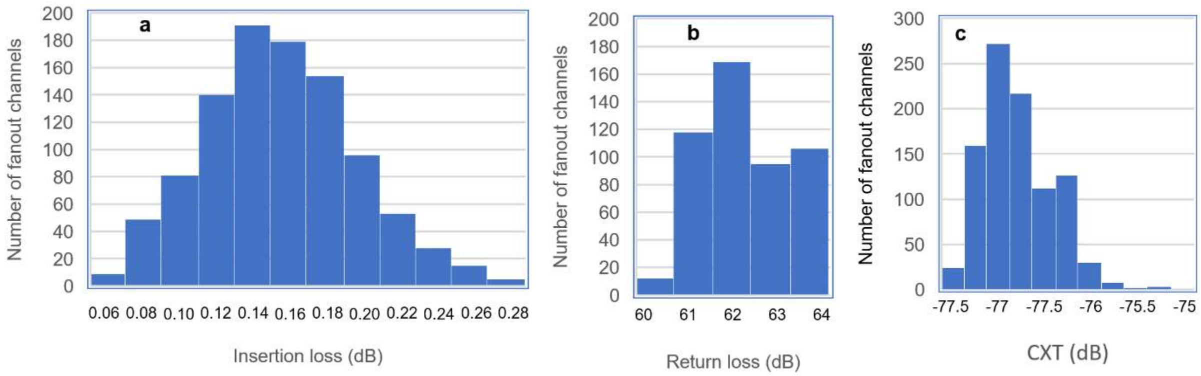
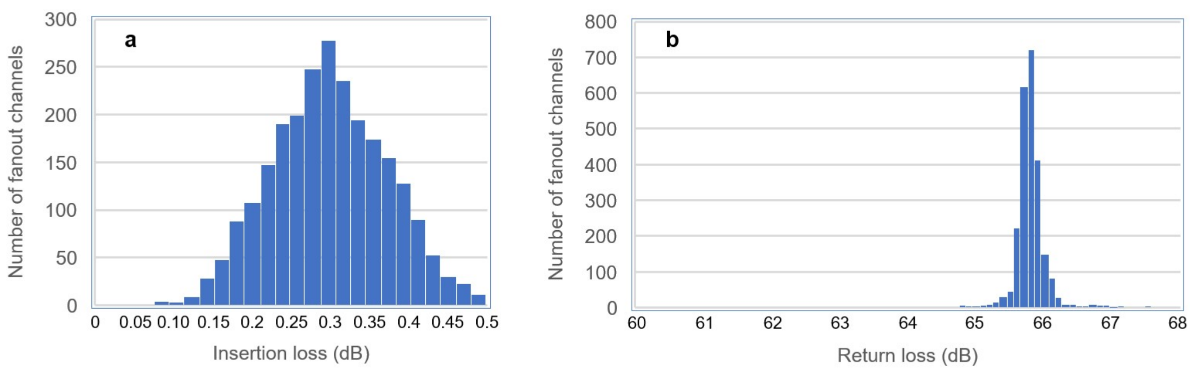


Fig. 2. Distributions of C-band average insertion loss (a), return loss (b), and counter-propagating crosstalk (c) for last 500 fabricated 2-core fanouts, fusion spliced to 2-core MCF.

propagation is the most important application of the 2-core MCF, only counter-propagating crosstalk (CXT) is shown for these fanouts, but the co-propagating crosstalk (XT) is also low, below -40 dB for all fabricated devices. As shown in Fig. 2a-c, the average IL is 0.16 dB, maximum IL is 0.3 dB, return loss (RL) is larger than 60 dB and CXT is below -75 dB. This performance, combined with a robust Telcordia and subsea qualified package, makes these fanouts suitable for subsea network applications.



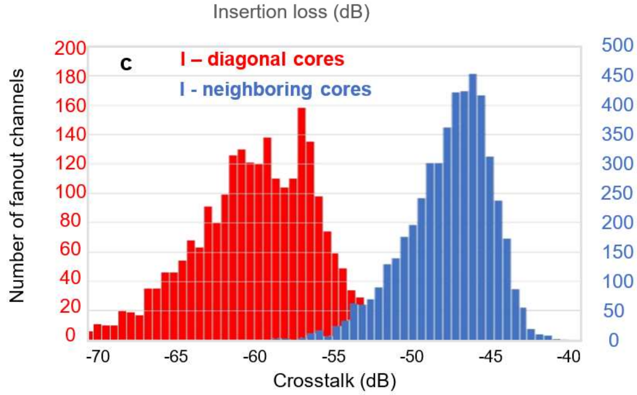


Fig. 3. Distributions of C-band average insertion loss (a), return loss (b), and crosstalk (c) for 612 fabricated 4-core fanouts, fusion spliced to 4-core MCF.

The performance of 612 four-core fanouts for a terrestrial application is shown in Fig. 3 [10]. For these 4-core fanouts the average IL is 0.3 dB and maximum IL is 0.5 dB. Since bi-directional propagation, in which neighboring cores are used for counter-propagation, is the most beneficial for 4-core MCFs, Fig 3c shows the XT separately for neighboring and diagonal cores. The diagonal cores, which are used for co-propagating light show less than -50 dB crosstalk. The combination of acceptable IL, RL, and XT values as well as Telcordia qualification, makes these fanouts suitable for datacom applications in areas, such datacenters and urban metro, where fiber congestion presents a major challenge.

Seven-core fanouts fusion spliced to 7-core fibers, at present, are mostly used for 3D shape-sensing applications. In this application, the 7-core MCFs have smaller MFDs of ~ 6 microns. The fabricated fanouts have a built-in mode field converter providing mode matching for both 10-micron-core pigtails and 6-micron-core MCF. The performance

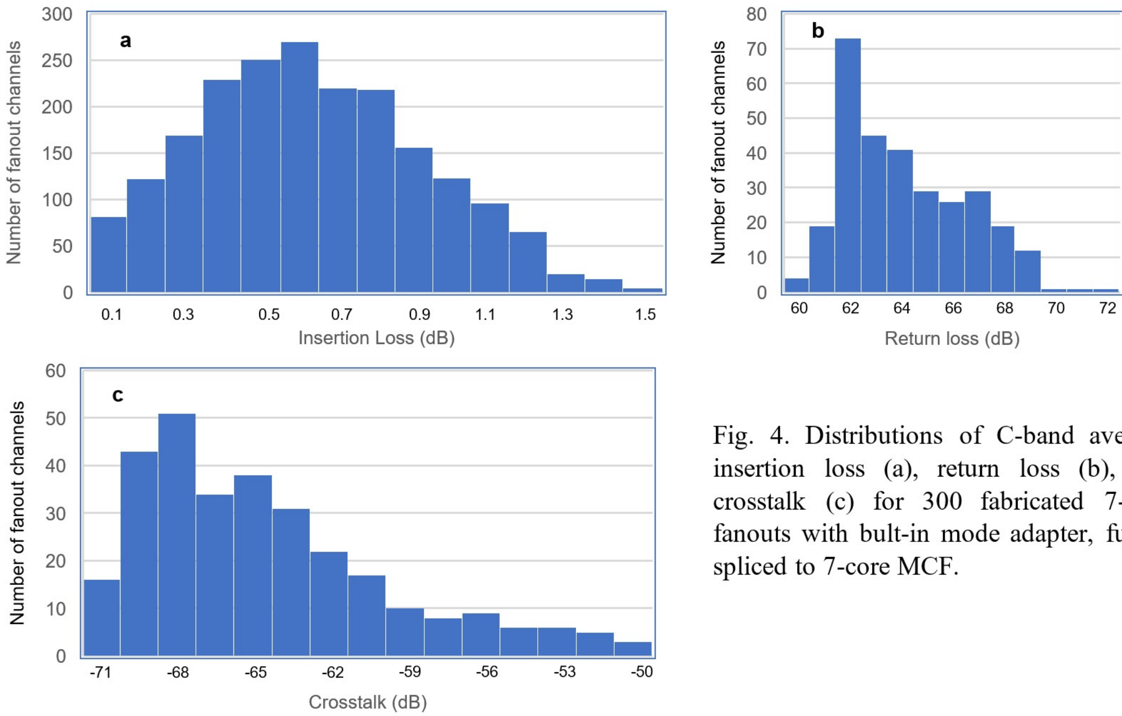


Fig. 4. Distributions of C-band average insertion loss (a), return loss (b), and crosstalk (c) for 300 fabricated 7-core fanouts with bult-in mode adapter, fusion spliced to 7-core MCF.

of the last 300 7-core fanouts is presented in Fig. 4. The insertion loss shown with an average and maximum values of 0.7 and 1.5 dB, together with less than -50 dB XT, and larger than 60 dB return loss make these fanouts appropriate for 3D shape sensing applications.

4. Conclusion

Fanouts for 2-, 4-, and 7-core multicore fibers, key components for multicore SDM networks, have been developed to meet stringent requirements of terrestrial, submarine, and sensing applications. With already developed and commercially available MCFs and fusion splicers, these advances create an ecosystem that enables the wide adoption of MCF networks.

6. References

[1] P.J. Winzer, Journal of Optical Communications and Networking **15**, 783 (2023).
[2] S. Grubb, "Perspective and requirements for SDM fiber cables for submarine networks" presented at the "Revolutionary vs. Evolutionary SDM Fibers: Extra Gain at Elossra Complexity?" workshop, OFC 2023.
[3] https://sumitomoelectric.com/press/2023/09/prs049; https://fibercore.humaneticsgroup.com/products/multicore-fiber; https://www.ixblue.com/wp-content/uploads/2022/09/ixblue-multicore-fiber-offering.pdf
[4] W. Zheng, OFC2013, **OM3I.4** (2013).
[5] T. Kremp, Y. Liang and A. H. McCurdy, ECOC2022, pp. 1-4.
[6] V.I. Kopp, J. Park, M. Wlodawski, J. Singer, D. Neugroschl, A.Z. Genack, IEEE Summer Topicals, **TuC2.2** (2013).
[7] V.I. Kopp, J. Park, J. Singer, D. Neugroschl, and A. Gillooly, OFC2020, **M2C.3** (2020).
[8] V.I. Kopp, J. Park, J. Singe r, D. Neugroschl, T. Suganuma, T. Hasegawa, T. Ohtsuka, and H. Tazawa, OFC2022, **Th1E.2** (2022).
[9] V.I. Kopp, J. Park, J.Singer, D.Neugroschl, K.Takenaga, and U.Nasir, Optica Open, https://doi.org/10.1364/opticaopen.**22179329**.v1.
[10] V.I. Kopp, J. Park, J. Zhang, J. Singer, D. Neugroschl, T. Oda, O. Mukai, and U. Nasir, Opt. Express **31**, 5794-5800 (2023).