Latest Trends and Future Prospects of SDM Optical Fiber Research

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1. Introduction

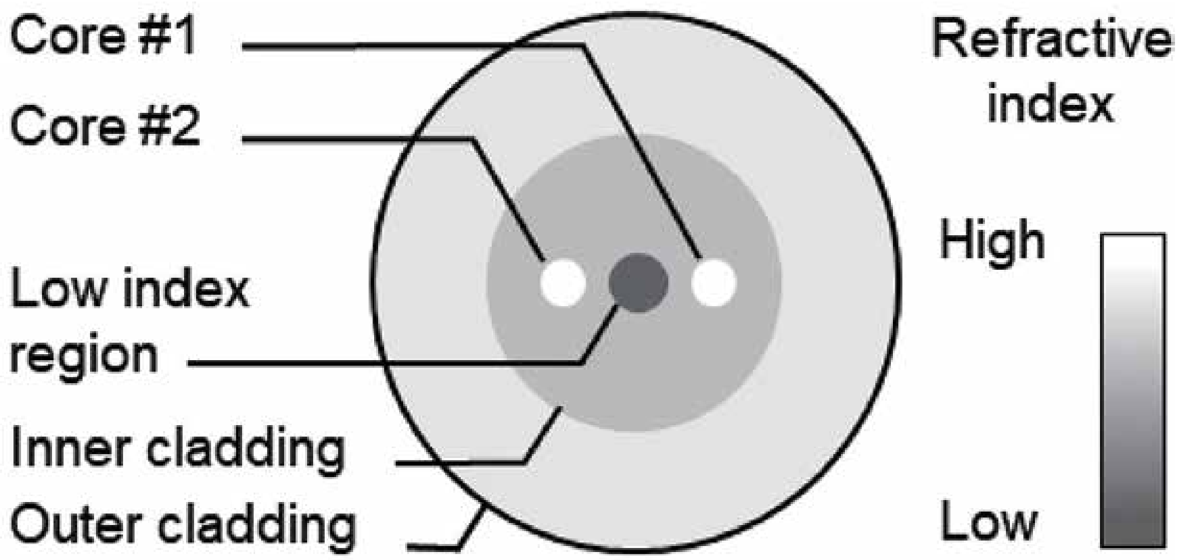
As a result of the development of wavelength division multiplexing and digital coherent transmission technologies against the backdrop of exponential growth in demand for communication capacity in optical communication networks, the per-core information transmission capacity of widely used single-mode fibers (SMFs) is approaching its physical limit, pointing to the increasing importance of spatial division multiplexing (SDM) as a means to further expand transmission capacity. This paper describes the research trends in SDM optical fiber for submarine communications, where the commercialization of SDM optical fibers has begun, and for terrestrial communications, where field verification is progressing toward the widespread use of SDM optical fibers.

2. SDM optical fiber for submarine communications

In submarine cables, which often use advanced transmission technologies, the transmission capacity per core is already nearing its limit. Additionally, under the constraints of power supply to submarine optical repeaters, SDM is effective in maximizing transmission capacity. Therefore, the need for SDM is high[1], and multi-core optical fibers within cables are becoming widespread as the first generation of SDM. As a result of the shift to multiple fibers, 48-fiber cables have been commercialized as cutting-edge optical submarine cables[2]. However, further increase in the number of fibers is likely to be difficult due to the structural limitations of submarine cables. Therefore, multi-core fiber (MCF), which has multiple cores in a single optical fiber, shows promise as the second-generation SDM technology[3]. Activities for its commercialization for submarine communications have in fact progressed. In 2023, two-core fiber (2CF) for optical submarine cables was commercialized[4], and construction of optical submarine cables using 2CF was announced[5].

Since MCFs have multiple cores, complexities not found in SMFs may arise, such as in managing core layouts for connections and in managing crosstalk between cores in installation environments. In addition to the optical properties of the MCF itself, it is also important to reduce the above complexities in order to promote the smooth uptake of MCF. In the 2CF for submarine communications[6,7] (Figure), measures to reduce complexity have been adopted, such as (a) the mirrored symmetric core layout eliminates the need for end-to-end management by eliminating the polarity of the MCF, and (b) core identification by core shift eliminates the need for identification markers. Likewise, optical performance equivalent to that of conventional SMF for submarine communications has been demonstrated.

Figure : Structure of 2CF for submarine communications



3. SDM optical fiber for terrestrial communications

SDM optical fibers such as MCF will be required in the future to expand transmission capacity under the constraints of the conduit space in terrestrial communication networks, where multi-vendor implementation and standardization are also crucial. In this regard, inter-connection between multiple vendors using four-core fiber[8] and documentation of SDM technology[9] for ITU standardization have been carried out.

In 2019, a field test bed for MCF was built for the first time in the city of L'Aquila, Italy[10], which demonstrated transmission performance in a terrestrial environment and verified application technologies leveraging the characteristics of MCF, such as optical frequency clock transmission[11], which uses the correlation of phase fluctuation between cores to improve accuracy. In addition, high-density optical cables have been used for connections within and between data center buildings. In particular, the use of 12-core fiber is expected to increase cable density and reduce connection time per core[12].

4. Conclusion

Development of SDM optical fiber is progressing, along with progress in its commercialization for submarine communications and in its field verification for terrestrial communications. Further growth of optical communication networks is anticipated with the progress in the development and mass production of transmission equipment and related technologies for connection and amplification.

References

[1] M. A. Bolshtyansky, et al., "Single-mode fiber SDM submarine systems," J. Lightwave Technol. 38, 1296-1304 (2020).

[2] NEC press release, "NEC qualifies 24 fiber pair subsea telecom cable system-Fully qualified end-to-end solution for larger capacity and better connectivity-," issued on Mar. 19, 2021.

[3] H. Takeshita, et al., "Demonstration of uncoupled 4-core multicore fiber in submarine cable prototype with integrated multicore EDFA," J. Lightwave Technol. 41, 980-988 (2023).

[4] Sumitomo Electric press release, "Sumitomo Electric launches world's first mass-produced ultra-low loss, multi-core fiber," issued on Sep. 22, 2023.

[5] Google blog, "Boosting subsea cables with multi-core fiber technology," issued on Sep. 13, 2023.

[6] T. Suganuma, et al., "2-core fiber for practical spatial division multiplexing," SubOptic 2023, TU3C-2 (2023).

[7] T. Suganuma, et al., "First 0.15-dB/km uncoupled 2-Core fibre for transoceanic cable," ECOC 2023, Th.A.6.3 (2023).

[8] T. Matsui, et al., "118.5 Tbit/s transmission over 316 km-long multi-core fiber with standard cladding diameter," OECC 2017, doi: 10.1109/OECC.2017.8115049.

[9] C. Kito, et al., "ITU-T standardization activities for spatial division multiplexing optical fibers and maintenance of outdoor optical facilities," NTT Technical Review 21 (2), 45-48 (2023).

[10] T. Hayashi, et al., "Field-deployed multi-core fiber testbed," OECC/PSC 2019 PDP3 (2019).

[11] N. Hoghooghi, et al., "Towards international clock comparisons on a telecom network: ultrastable optical frequency transfer over deployed multi-core fiber," OFC 2024, Th4A.5 (2024).

[12] T. Hayashi, et al., "Ultra-High-Density Microduct Cable with Uncoupled 12-Core Fibers with Standard 250-µm Coating," OFC 2023, Tu2C.2 (2023).

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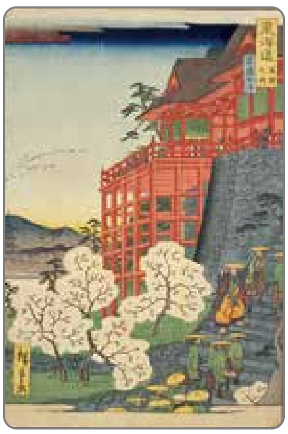

Kiyomizudera Temple, Kyoto, from Famous Views of Tokaido Road

Utagawa Hiroshige (1797-1858)

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