AOC Newsletter

Advanced Optical Communication Testbed

Published by AOC Testbed, a consortium project funded by the Department of Telecommunications, Government of India
https://www.aoctestbed.in/

Dear Readers,

The momentum behind multicore fibers (MCF) is undeniable, with the initiatives for the standardization at both ITU-T and IEC and the expanding OEM base for the MCF eosystem. As the MCF ecosystem evolves, the urgency to develop interoperability tests and cost-effective network components, such as FIFO, connectors, and transceivers, becomes paramount. The AOC testbed at IIT Madras, equipped with spare ducts, stands ready to support OEMs, researchers, and service providers in this endeavor.

Recently, the IIT Madras testbed has been at the forefront of groundbreaking Quantum Key Distribution (QKD) testing, exploring the coexistence of quantum and classical signals within adjacent fiber cores. Additionally, an RF-over-Fiber (RFoF) fronthaul demonstration over aerial MCF has been successfully completed, showcasing the testbed's versatility.

This edition of our newsletter shines a spotlight on the facilities available at the AOC Testbed, IIT Madras. We extend an invitation to the MCF community to leverage these state-of-the-art resources.

Stay connected with us at (https://www.aoctestbed.in/) to learn more.

Yours sincerely,
Deepa Venkitesh
Project Lead, AOC testbed project

September, 2025

Consortium Members

Academia

IIIT Delhi

IIT Delhi

IIT Madras

Industry

Quanfluence

SASMOS

SFO Technologies

SIGNALCHIP

SIGNALTRON

Sterlite Technologies

R&D

ERNET

Patents & Papers

18 Patents (Submitted)

62 Publications

1 Trademark

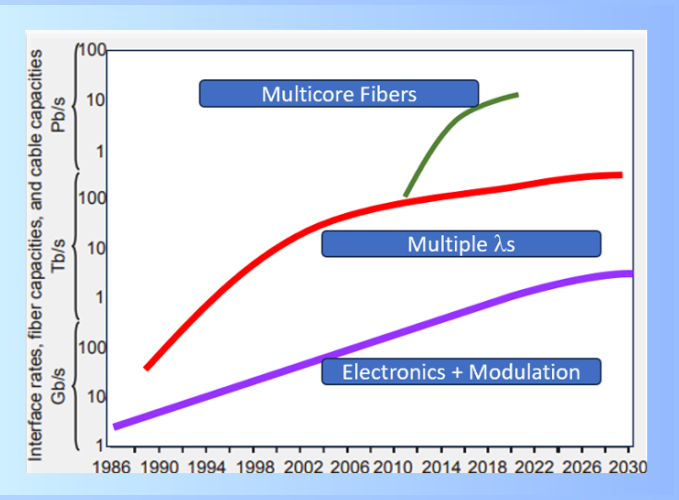
Multicore Fiber (MCF) – The Next Frontier in Optical Communication

Capacity scaling in optical communication has long been challenged by the need for energy-efficient innovations. As depicted in Figure, historically, this was initially propelled by the advancements in electronic signaling speeds, followed by parallelization techniques using multiple carrier wavelengths to meet growing demands. However, both approaches face fundamental limitations: transistor scaling is approaching atomic-scale barriers, while the next breakthrough lies in the Space Division Multiplexing (SDM) using Multicore Fiber (MCF), where multiple independent cores are fabricated within the standard 125 µm cladding, enabling linear capacity growth without altering existing cable infrastructure.

Multicore fibers (MCF) are gaining increased industry interest. Submarine networks started deploying MCF as cable size and weight are critical for the subsea industry.

Current Challenges:

- Lack of global standards (ongoing ITU-T SG15/Q5 efforts on 2–4 core MCF)
- Developing ecosystem (connectors, Fan-in/Fan-out, amplifiers, test equipment)
- Higher Total Cost of Ownership (TCO) until economies of scale are achieved
- Limited field trials beyond early testbeds



Capacity scaling trends over the years

P. J. Winzer, "The future of communications is massively parallel," J. Opt. Commun. Netw., vol. 15, no. 10, p. 783, Oct. 2023, doi: 10.1364/JOCN.496992.

Unlock the Future of Optical Transmission with Our Multicore Fiber Testbed:

Multi-Core Fiber (MCF) technology integrates several optical cores within a single cladding. This design makes it possible to transmit multiple independent data streams at the same time, significantly boosting the overall capacity of the fiber.

The MCF-based AOC testbed, the first of its kind infrastructure, is established at IITM to support end-to-end evaluation of high-capacity fiber transmission technologies under real deployment conditions. The testbed supports advanced transmission formats such as 56 GBaud / 64QAM / PAM4, and has been deployed in both underground ducts and aerial installations to mimic real-world conditions.

As part of the project, MCF fibers and cables are manufactured and installed by Sterlite Technologies Limited (https://stl.tech/) in the IITM campus. Our testbed enables comprehensive evaluation of Multi-Core Fiber transmission, facilitating in-depth research into the performance and advantages of spatial division multiplexing. This includes evaluating cross-talk, loss, and system-level behavior in MCFs under realistic deployment scenarios.

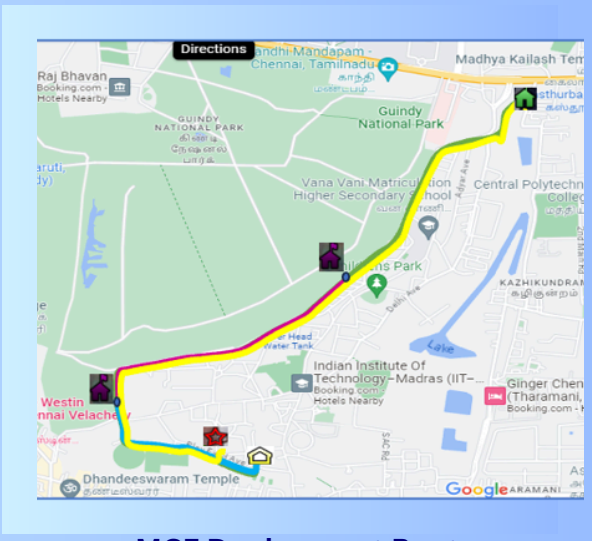
Real World Fiber Deployment:

Complete ecosystem for high-speed data transmission using Multicore Fiber (MCF):
Use-case demonstration for both Analog RFoF and Digital high-speed communication in the field.

Indigenous product development:
MCF field deployment with fan-in/fan-out modules, optimized modulation and pulse shaping, and custom DSP algorithms.

You can now view the AOC fiber route on Google Maps to better understand the layout of the deployed infrastructure across the IIT Madras campus.

Click here to view map



MCF Deployment Route
----- Areial Deployment
----- Underground Deployment

Ready for Industry Engagement:

Our testbed infrastructure includes fiber ducts that researchers and vendors can utilize to lay their own fiber and conduct experiments. This flexibility allows for seamless integration of external components and systems, promoting real-world testing and validation. By providing this infrastructure, we support a collaborative environment where innovation can thrive, and customized solutions can be developed and tested effectively.

What We Offer:

MCF Access Link:

- Deployed with fan-in/fan-out and other components
- Bring Your Own Components for testing in a customizable and collaborative optical setup

Blazing Throughput:

- Achieving 7.1 Tbps net data rate with FEC BER using optical frequency comb source
- Optimal modulation and pulse shaping schemes under evaluation Advanced DSP Development
- Custom-built algorithms for multi-core coherent signal recovery and crosstalk mitigation

Field Deployment: Real Conditions, Real Results:

- Underground and aerial installation completed across IIT Madras campus
- Testing of OOK, PAM4, and coherent formats in progress
- RF-over-Fiber (RFoF) fronthaul demo over aerial MCF route

Underground MCF Deployment:

We deployed a 4-core multicore fiber (MCF) cable using trenching, with ducts laid from the lab to the main gate. This infrastructure forms a critical part of the AOC testbed, enabling reliable and scalable optical transmission experiments on campus.

The deployment done by STL, included underground chambers and route markers along the path to support identification and maintenance. The MCF was installed in a single length, enabling end-to-end blowing without splicing, ensuring seamless performance. A total of 12 MCFs were deployed, allowing loop-back configurations for an effective 48 km transmission distance. The cable is terminated inside the lab, and the ODCs are properly earthed at their location.

Underground MCF deployment

Aerial MCF Deployment:

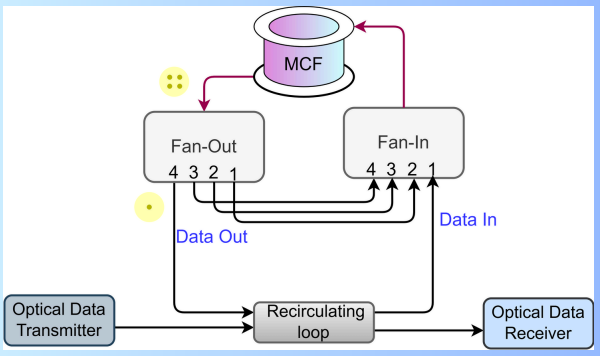
A dedicated aerial fiber network has also been established as part of the AOC testbed at IIT Madras. Along this aerial route, 17 poles have been installed, each fitted with a 1-meter muff and a concrete base, with proper earthing completed at every pole. Aerial cable accessories have been mounted on all poles to support the installation. Optical Distribution Cabinets (ODCs) are installed at the aerial start and end points.

An additional duct runs from the lab to the aerial start point, within which a 72F single-mode fiber (SSM) cable has been deployed. Similar to the underground installation, the cable is in a single length with no joints, ensuring seamless transmission. This setup enables loop-back configurations with an effective transmission distance of 13.2 km, allowing comparative analysis between different deployment environments.

Areial MCF deployment

End-to-End Transmission Setup Using Multicore Fiber (MCF):

The illustration showcases an end-to-end optical transmission setup using a 4-core Multicore Fiber (MCF). Data from the optical transmitter is split into four channels using a Fan-Out, transmitted through individual cores of the MCF, and recombined at the other end using a Fan-In before reaching the optical receiver. This setup demonstrates parallel data transmission over MCF, enabling high-throughput optical communication while supporting core-wise signal monitoring and performance evaluation.



4-Core MCF transmission

Recirculating Loop Developed at AOC Testbed, IITM

Recirculating Loop:

A new milestone has been achieved at the AOC Testbed, IIT Madras, with the development of a prototype recirculating loop system that enables emulation of long-distance optical links within a controlled laboratory setting.

This innovative system allows data to be transmitted through a single optical fiber multiple times, effectively reproducing realistic signal degradation caused by amplifier noise and fiber impairments. Using just 50 km of laboratory fiber, the team has demonstrated an equivalent transmission distance of over 3000 km.

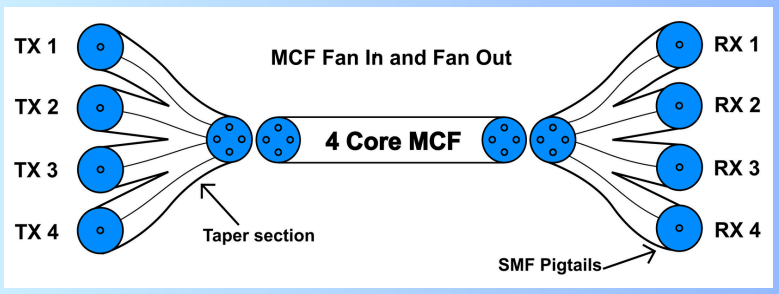
The recirculating loop has quickly become a vital instrument for ongoing experiments at the AOC Testbed. Its capabilities have already started attracting significant interest from both industrial and academic partners, who are keen to use the system for advanced long-distance optical transmission studies.

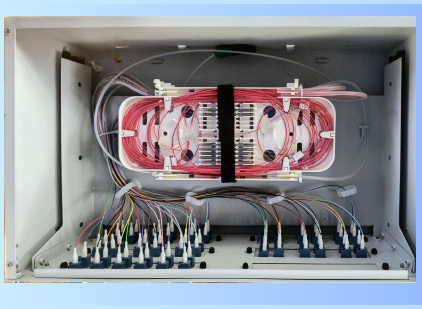
Recirculating Loop

Fan-In/ Fan-Out:

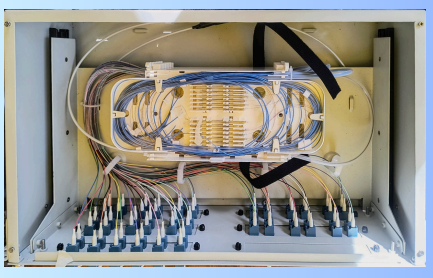
4 fiber Fan-In Fan-outs are housed in Optical Distribution Cabinets (ODC) at the termination points, facilitating connectivity with standard single mode fibers.

Trench type fiber installations, connectivity solutions with termination boxes, FAN-IN-FAN-OUT and other components





Fan In



Fan Out

Optical Distribution Cabinet (ODC)

Behind the Scenes: Building the MCF Testbed

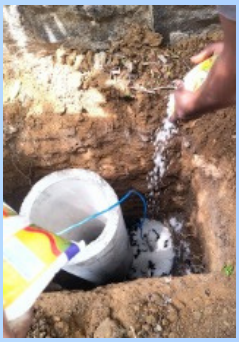
Trenching and ducting

Chamber installation

On site at the MCF Testbed

Route marker

Aerial Pole installation



Salt and charcoal in earth pit

MCF splicing on field

Updates from the MCF Testbed

1. Quantum Key Distribution (QKD) testing on MCF fibers:

IIT Madras, in collaboration with ERNET India, C-DOT, and MAQAN partners, is developing a secure, Software Defined Network (SDN) enabled Quantum Key Distribution (QKD) network under the AOC Testbed. This initiative establishes field-deployable QKD systems for secure communication across metro-area optical networks.

Field Deployment:

The QKD system is being tested in real-world conditions to validate the performance of quantum-secure communications.

- The Multicore Fiber (MCF) testbed at the IIT Madras campus has been used for Quantum Key Distribution (QKD) testing from July 24 to August 6, 2025, which focused on the demonstration of coexistence of quantum and classical signals in adjacent fiber cores.

2. Smarter MCF for Faster Networks:

Math-model simplifies cross-talk in optical fibers:
Researchers at IIT Madras have developed a new mathematical model to tackle signal distortions in multi-core optical fibers. Using the Kronecker product, the team has shown a simpler way to handle cross-talk and polarization mixing between fiber cores. This approach reduces processing complexity by nearly 75%, paving the way for more efficient high-capacity communication systems.

Index modulation boosts multi-core fiber capacity:
A team at IIT Madras has shown that index modulation can be used to boost the efficiency of multi-core optical fibers. By selectively turning fiber cores on and off to encode extra information, an 11% improvement in data capacity can be achieved without adding processing complexity. This approach opens new possibilities for faster and more efficient communication networks.

3. Expanding Sensing Horizons with Multi-Core Fibers (MCF):

Multi-Core Fibers (MCFs) are emerging as a promising platform for distributed sensing. It can detect acoustic and vibration events by analyzing Rayleigh backscattering, while Raman backscattering enables simultaneous temperature monitoring. This dual functionality makes MCFs attractive for infrastructure monitoring and security applications. Additionally, the spatial diversity across multiple cores helps mitigate signal fading, improving the signal-to-noise ratio compared to conventional single-mode fiber implementations. As research advances, MCF-based sensing could significantly enhance the performance and reliability of distributed acoustic and temperature sensing systems.

Products Ready for Commercialization through ToT:

The products being developed as part of the AOC project can be commercialized by OEMs through Transfer of Technology (TOT). Some of the products are listed below.
Please reach out to us at **aociitm@ee.iitm.ac.in** for further information on the specifications.

1. Optical Power Meter
2. Recirculating Loop
3. Optical phase conjugator
4. Optical frequency comb
5. Modulator bias controller
6. Optical parametric amplifier
7. FSO

"Partner with us to shape tomorrow's broadband infrastructure— test, validate, and scale your MCF solutions in a real-world environment. Collaborate today. Innovate for tomorrow."

For more information and opportunities, visit **https://www.aoctestbed.in/**
Contact us at **aociitm@ee.iitm.ac.in**

Visit us IMC 25
Hall 1, Booth: M1