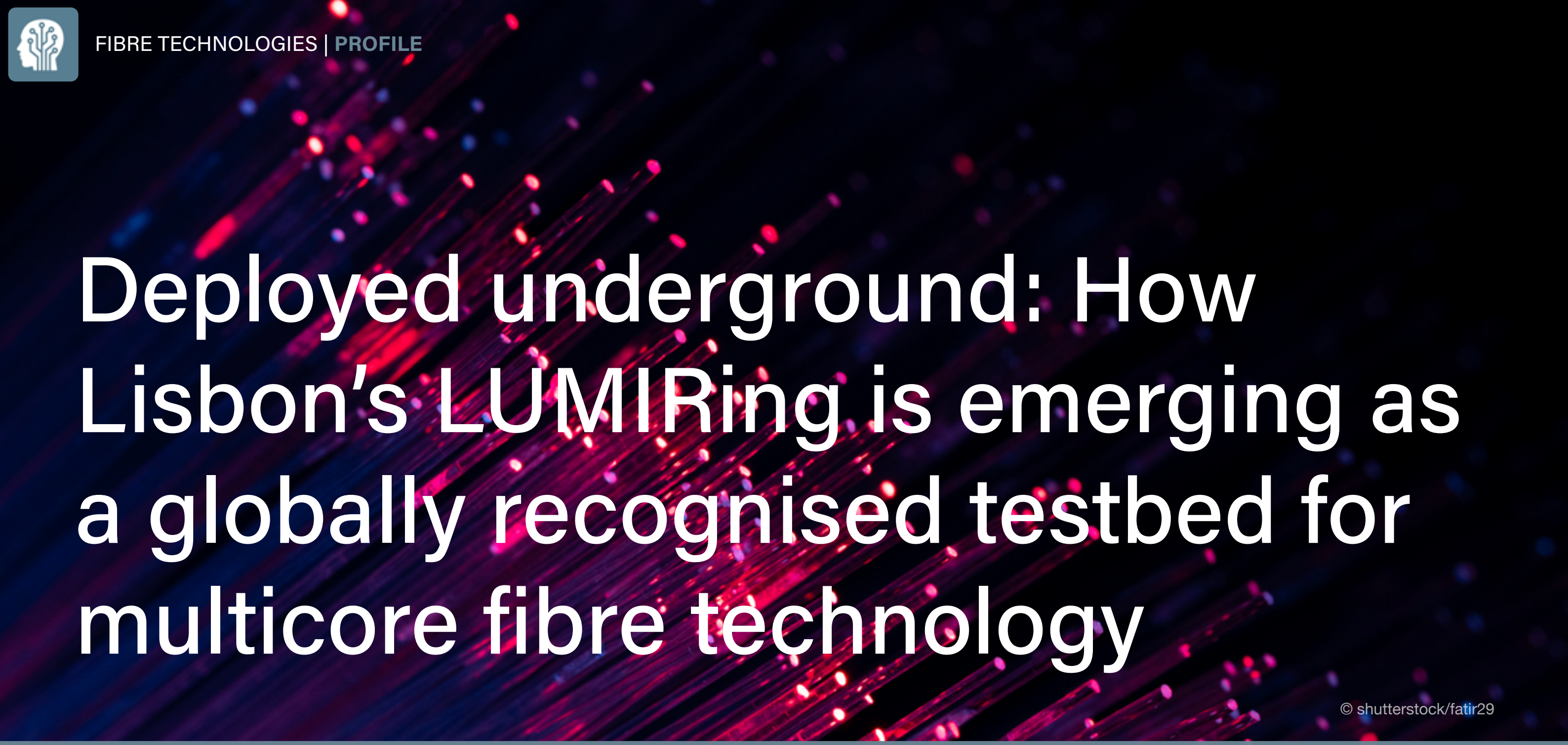

Deployed underground: How Lisbon's LUMIRing is emerging as a globally recognised testbed for multicore fibre technology

The LUMIRing project aims to advance multicore fibre technology by embedding a testbed into the subway system, addressing challenges of real-world deployment while positioning Portugal at the forefront of optical communications innovation

THE GLOBAL telecommunications sector is facing unprecedented demand for data transmission, driven by cloud computing, artificial intelligence (AI), high-definition video streaming, and the Internet of Things (IoT). Conventional optical networks based on single-core fibers (SCFs) are approaching their capacity limits, motivating the adoption of Space-Division Multiplexing (SDM) as a key technology for future optical infrastructures. Among SDM solutions, Multicore Fiber (MCF) enables multiple spatial channels within a single optical fiber, significantly increasing transmission capacity. However, widespread deployment requires overcoming challenges such as operation in harsh urban environments, precise fiber splicing, and minimising inter-core crosstalk.

The LUMIRing (Lisbon Underground Multicore Fiber Ring) project, coordinated by Iscte – Instituto Universitário de Lisboa, addresses these challenges through a pioneering real-world deployment of MCF technology. By integrating a state-of-the-art multicore fiber testbed into Lisbon's underground metro infrastructure, LUMIRing bridges the gap between laboratory research and operational networks. Inaugurated in November 2025, it is the longest and most comprehensive terrestrial-deployed MCF testbed reported to date, establishing Portugal and its international partners at the vanguard of next-generation optical communications.

Project background and core mission

The LUMIRing project was created to validate, characterise, and operate a real-world MCF infrastructure under practical deployment conditions. Led by Principal Investigator Adolfo V. T. Cartaxo of the Department of Information Science and Technology, Iscte – Instituto Universitário de Lisboa, the project aims to demonstrate the feasibility of MCF technology beyond controlled laboratory environments.

To achieve this, LUMIRing deployed an experimental MCF testbed along the Yellow Line of the Lisbon Underground (Metropolitano de Lisboa). Subway tunnels provide a demanding environment for optical fibers due to continuous vibrations from train traffic, temperature variations, and high humidity. Demonstrating reliable MCF operation under these conditions provides valuable evidence for future deployment in operational optical networks worldwide.

The project followed a structured implementation strategy with three main phases. The first focused on acquiring and specifying specialised fibers, subway cables, and optical components, requiring close collaboration with international manufacturers because of the limited standardisation of MCF technologies. The second phase involved installing the MCF cable along the metro line, followed by an extensive splicing campaign to ensure operational readiness. The third phase is dedicated to the continuous characterisation of the deployed infrastructure, including measurements of attenuation, inter-core crosstalk, chromatic dispersion, polarisation mode dispersion, and high-capacity transmission experiments.

Throughout all phases, project management, dissemination, and exploitation activities have been conducted in parallel to maximise the visibility of the LUMIRing testbed, foster international collaborations, and accelerate the adoption of MCF technologies for next-generation optical communication networks.

Technical specifications of the LUMIRing testbed

The scale and engineering diversity of the LUMIRing infrastructure distinguish it from existing terrestrial optical testbeds. Its cable architecture is specifically designed to support both conventional SCF experiments and advanced MCF research across multiple optical bands.

The deployed cable contains 144 optical fibers arranged in 12 dry loose tubes, each holding 12 fibers. It combines 74 MCF strands, representing five different fiber architectures, with 70 standard single-mode SCF strands. Together, the MCF deployment provides more than 1,800 km of cumulative multicore infrastructure, while the SCFs contribute over 1,700 km, enabling direct performance comparisons between conventional and multicore technologies.

The five MCF variants (MCF-A to MCF-E) all have a standard 125 μm cladding diameter, ensuring compatibility with existing optical infrastructure, installation procedures, and handling tools. Core pitches range from 37 μm to 41 μm. MCF-A and MCF-B contain seven cores, whereas MCF-C, MCF-D, and MCF-E have four cores. Three variants use trenched core designs, while two are non-trenched, allowing systematic evaluation of crosstalk mitigation techniques. Trenched fibers confine light more effectively, significantly reducing inter-core crosstalk; for example, MCF-C achieves approximately −59 dB/km at 1550 nm.

The extensive deployment of MCF-D, comprising 28 strands and more than 700 km of cumulative fiber, enables long-haul transmission experiments by looping optical signals through multiple cores and strands. This configuration allows researchers to emulate transcontinental transmission distances within the LUMIRing, providing a unique platform for evaluating next-generation optical communication systems.

Deployment, cable engineering, and splicing operations

Deploying the LUMIRing infrastructure in the Lisbon Underground required specialised cable engineering and meticulous field operations to ensure reliable performance under demanding real-world conditions.

The multicore cable was custom-designed for the harsh subway environment through an international collaboration. Its design includes 12 dry loose tubes housing 144 optical fibers, protected by corrugated steel armouring against moisture and mechanical damage, and a Low Smoke Zero Halogen (LSZH) outer sheath with a B2ca-s1a,d1,a1 CPR fire rating to meet strict subway safety requirements.

The LUMIRing testbed forms a 25.5 km ring along Lisbon Underground's Yellow Line, incorporating nine splicing locations and five main access points, including the Optical Communication Laboratory (LCO) at Iscte, which serves as the network's monitoring and experimentation hub.

Pulling and installation of multicore fibre cable in the tunnel of the Yellow Line of the Lisbon Metro

A major achievement was the MCF splicing campaign. Unlike conventional fiber splicing, MCF requires precise alignment of multiple cores in all spatial and rotational axes. Using specialised equipment, the project team completed nearly 1,000 MCF splices and 700 SCF splices, establishing the largest terrestrial MCF splicing campaign reported to date. The experience provides valuable benchmarks for large-scale installation, splice-loss optimisation, and the large-scale deployment of next-generation optical communication networks.

LUMIRing Hub: This image showcases the LCO cabinets, featuring access to the cores of MCFs on the right and optical amplifiers designed for long-haul transmission on the left.

Connectivity infrastructure and experimental flexibility

The value of a testbed depends on its flexibility. To enable rapid experiment reconfiguration without modifying or risking damage to the underground cable infrastructure, LUMIRing incorporates an advanced connectivity interface at its access points.

This flexibility is provided by strategically deployed Fan-In/Fan-Out (FIFO) devices, which separate the multiple cores of an MCF into individual SCF pigtails compatible with conventional laboratory equipment. A total of 162 FIFO devices have been installed across the network, supporting all deployed MCF types.

The FIFO infrastructure is distributed across all MCF variants, ensuring comprehensive access to the deployed multicore network. Through simple patch-panel reconfiguration at the LCO, researchers can interconnect different cores and fiber sections without altering the field installation. This capability allows the creation of customised optical paths ranging from short, low-latency metropolitan links to long-haul transmission loops that emulate regional or national backbone networks.

By combining extensive multicore deployment with highly reconfigurable access, LUMIRing offers an exceptionally versatile experimental platform for evaluating next-generation optical communication systems under realistic operating conditions.

National and international contributions

The impact of LUMIRing extends beyond its technical achievements, strengthening Portugal's research ecosystem while establishing an international benchmark for MCF technologies.

LUMIRing has become a reference platform for education, research, and innovation in optical communications. It provides students, researchers, and engineers with hands-on access to a world-class MCF testbed, helping develop expertise in SDM networks. The project has also strengthened collaboration with Portuguese partners, including Metropolitano de Lisboa, Telcabo, and the Instituto de Telecomunicações (IT), advancing capabilities in infrastructure deployment, and large-scale transmission experiments.

Internationally, LUMIRing has built strong partnerships with Heraeus Covantics, Tratos, and Chiral Photonics, whose technologies have been instrumental in deploying the testbed. Featuring 74 MCF strands, five fiber architectures, and more than 1800 km of cumulative multicore infrastructure, LUMIRing is the largest terrestrial-deployed MCF testbed reported to date and a unique platform for validating SDM technologies under real operating conditions.

Its importance was recognised at the **Optical Fiber Communication Conference (OFC) 2026**, where companies including Sumitomo Electric and Google highlighted LUMIRing as a key platform for assessing the maturity of MCF technologies. The project has also been invited to contribute to the **ITU-T (International Telecommunication Union Telecommunication Standardisation Sector)**, supporting the development of future international standards for MCF deployment.

Global positioning and industrial integration

A cornerstone of LUMIRing's long-term sustainability is its open and collaborative approach. Rather than operating as a closed academic facility, Iscte has established LUMIRing as an international hub that brings together companies, research institutes, and technology providers working on MCF technology.

The project has built a growing network of collaborations with organisations specialising in MCFs, optical components, network analytics, and photonic integration. By providing a unique real-world testbed, LUMIRing enables external partners to validate and demonstrate new technologies under operational conditions.

By connecting stakeholders across the entire optical communications value chain–including fiber and cable manufacturers, component suppliers, deployment companies, and instrumentation developers–LUMIRing accelerates the transition from laboratory research to practical deployment. This collaborative ecosystem allows innovations to be rapidly tested and validated in a live underground network, fostering technology transfer and supporting the development of future optical communication systems.

Challenges overcome and key lessons learned

Deploying advanced MCF technology within an operational metro network presented significant technical and logistical challenges, generating valuable lessons for future optical network deployments.

Installation activities could only be carried out during short overnight maintenance windows, when metro services were suspended, and power was disconnected. This required precise coordination between manufacturing, logistics, and deployment teams, as any delay could postpone operations for weeks.

A major technical challenge was MCF splicing. Initial field tests revealed alignment inaccuracies that resulted in excessive splice losses. Through close collaboration with industrial partners and iterative optimisation of splicing procedures, the project team reduced these losses to commercially acceptable levels, establishing practical guidelines for large-scale MCF installation.

The project highlighted two key lessons. First, successful real-world deployment of MCF requires multidisciplinary expertise and close cooperation between academia, industry, and infrastructure operators to address environmental, mechanical, and regulatory constraints. Second, the project exposed a global shortage of specialists in space-division multiplexing technologies. Expanding education, hands-on training, and collaborative testbeds such as LUMIRing is therefore essential to develop the skilled workforce needed for the widespread adoption of next-generation networks.

Next steps on the horizon

As LUMIRing enters its operational phase, its roadmap focuses on three priorities: conducting advanced transmission experiments, including long-haul, multi-band (O, C, and L), distributed sensing, and quantum key distribution (QKD) trials; expanding contributions to ITU-T standardisation activities to support international MCF standards; and accelerating industrial adoption by demonstrating that MCF is a mature, scalable technology fully ready to power the global networks of tomorrow.

Acknowledgements and institutional support

The monumental success of the LUMIRing project was made possible through the generous financial backing of prominent regional, national, and international funding bodies, alongside an elite network of industrial and academic collaborators.

Funding bodies

The project acknowledges the vital support of **CCDR LVT (Comissão de Coordenação e Desenvolvimento Regional de Lisboa e Vale do Tejo), LISBOA 2030 – FEDER, and Fundação Calouste Gulbenkian.**

Funded by the European Union

Key project partners

The operational ecosystem relies on a tightly integrated network of specialized partners:

Iscte - Instituto Universitário de Lisboa (Portugal): Project Lead, Host Institution, and LCO operating Entity.

Metropolitano de Lisboa (Portugal): Subway Infrastructure Provider.

Heraeus Covantics (Germany): World-class Multicore Fiber Manufacturer.

Tratos (Italy): specialised Armored Cable Manufacturer.

Telcabo (Portugal): Telecommunications and Energy Networks Service Provider.

Instituto de Telecomunicações (Portugal): Elite Domestic Telecommunications Research Institute.

Through this unprecedented synergy of regional funding, academic leadership, and global industrial excellence, the LUMIRing project has successfully transformed the historic tunnels of Lisbon into the literal birthplace of tomorrow's high-capacity global internet.

Further information and contacts

For researchers, operators, and prospective international partners wishing to explore collaboration opportunities or review the open characterization data, the project maintains an active digital presence and open-door policy:

Official Website: https://lumiring.iscte-iul.pt/

Central Office: Department of Information Science and Technology, Iscte - Instituto Universitário de Lisboa, Building 2, 6th Floor, Room D6.27, Avenida das Forças Armadas, 1649-026 Lisbon, Portugal.

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