SPARKLE

Transforming Ocean Cables into Seismic Sentinels: **Sparkle's Experience**

How submarine fiber-optic infrastructure is being repurposed for real-time earthquake and tsunami monitoring

The world's ocean floors are crossed by approximately 1.5 million kilometers of submarine fiber-optic cables. Originally designed for digital communications, this vast network is now emerging as an unprecedented tool for monitoring earth's natural phenomena. Sparkle is at the forefront of this transformation, converting existing submarine infrastructure into sophisticated early warning systems for earthquakes and tsunamis.

From Communication to Detection

In this pioneering context of submarine telecommunication infrastructure, Sparkle is actively collaborating with major academic and scientific institutions to investigate ways of transforming underwater cables - while maintaining their primary role as data conduits - into distributed environmental sensors capable of detecting seismic activity across ocean basins.

The main methodologies being studied are Distributed Fiber-Optic Sensing (DFOS) which repurposes existing cables by detecting minute changes in light transmission caused by environmental disturbances and Science Monitoring and Reliable Telecommunications (SMART) that integrates dedicated sensors directly into new cable installations or subsea repeaters.

The Mediterranean as a Natural Laboratory

Since 2022, Sparkle has collaborated with INGV (Italian National Institute of Geophysics and Volcanology) and Google to explore the seismic sensing potential of the MedNautilus submarine cable system. Spanning more than 7,000 kilometers from Sicily across the Eastern Mediterranean and reaching depths of 4,000 meters, this network has become a living laboratory for seismic detection without disrupting internet communications. Sparkle has now also extended its work to BlueMed, its new cable connecting Italy with France, Greece and several countries bordering the Mediterranean.

Sparkle's commitment to advancing this field is further demonstrated by its involvement in the €4 million EU-funded ECSTATIC project, which brings together 14 academic and industrial partners - including the University of L'Aquila, the University of Padua, and Infinera (now Nokia) - to improve telecommunications network sensing capabilities. Sparkle contributes extensive historical data from previous experiments to this second-generation research initiative.

Current activities focus on the Tyrrhenian segment of Sparkle's BlueMed submarine cable system, connecting Genoa to Palermo, along with the MedNautilus cable,

"THROUGH ECSTATIC, **SPARKLE IS DEVELOPING ADVANCED SENSING METHODOLOGIES** BASED ON INTERFEROMETRY AND POLARIZATION"

to validate new technologies for seismic early warning, predictive maintenance, and network integrity monitoring. Data processing and storage take place at Sparkle's Network Operations Centre in Catania, creating an integrated monitoring ecosystem.

Through ECSTATIC, Sparkle is developing advanced sensing methodologies based on interferometry and polarization, enhanced by artificial intelligence and machine learning algorithms for accurate, real-time detection of vibrations, seismic events, and network conditions.

The first results are very encouraging. By analyzing changes in the state of polarization (SOP) of optical signals on the link connecting Catania to Haifa and Tel Aviv, algorithm to process SOP data (Jones Matrix) has been developed. This enabled

clear detection of the magnitude 5.8 earthquake that struck the Dodecanese Islands on 2 June 2025 [1]. The same approach also identified a precursor signal to the magnitude 8.8 megathrust earthquake that struck the Kamchatka Peninsula in Russia on 29 July 2025 [2].

This technology demonstrates remarkable robustness, producing identical results across different fibers within the same cable and remaining unaffected by random polarization coupling or signal propagation direction.

Global Impact and Future Prospects

As climate change intensifies the need for comprehensive environmental monitoring, fiber-optic sensing technologies provide unprecedented opportunities for long-term observation of deep-sea temperature variations - data currently limited by the high cost and sparse distribution of conventional sensors.

Leading cable manufacturers are now offering turnkey fiber-sensing solutions that support climate research, providing geologists and oceanographers with powerful new tools. At the same time, growing national security concerns are accelerating interest in real-time surveillance of strategic underwater assets.

In addition, Sparkle is also involved in two research programs by the Polo nazionale della dimensione subacquea (PNS, the Italian National Hub for the Underwater Domain) aimed at developing next-generation underwater technologies. Backed by over €9 million in public funding, and carried out in collaboration with universities, research institutes, startups, and defense companies, these initiatives aim to create intelligent underwater infrastructure for real-time surveillance, environmental monitoring, and contact detection.

Sparkle is also contributing to global governance efforts through its support of the United Nations' One Ocean Finance project, which aims to regulate and enhance subsea fiber-optic cable infrastructure for humanitarian and disaster-prevention purposes.

Looking Ahead

Having secured €1 million in institutional research funding, with increased investment planned for 2026, Sparkle continues to build on a legacy that began more than a century ago, when it - then operating as Italcable - laid the first transoceanic cable between Italy and Argentina.

Today, that heritage extends far beyond connectivity. Submarine cables are evolving into sentinel systems that protect coastal populations from natural disasters while advancing our understanding of Earth's most remote and dynamic environments. As fiber-optic sensing matures and artificial intelligence enhances detection capabilities, the ocean's communication highways are becoming humanity's global early warning network against nature's most powerful forces.

References

[1] Geophysical sensing using Jones matrices extracted from submarine optical cable transceivers – Antonio Mecozzi (UNIAQ), Cristian Antonelli (UNIAQ), Danilo Decaroli and Alberto Marullo (SPARKLE), Luca Palmieri (UNIPD), Luca Schenato (UNIPD), Siddart Varughese (NOKIA), Pierre Mertz (NOKIA), Antonio Napoli (NOKIA) - OPTICA – September 2025

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[2] Observation of a precursor to the Kamchatka earthquake by monitoring an optical fiber link in the Mediterranean Sea. Antonio Mecozzi (UNIAQ), Cristian Antonelli (UNIAQ), Danilo Decaroli and Alberto Marullo (SPARKLE), Luca Palmieri (UNIPD), Luca Schenato (UNIPD), Siddart Varughese (NOKIA), Pierre Mertz (NOKIA), Mohammad M. Hosseini (NOKIA), Antonio Napoli (NOKIA) – ECOC 2025 – September the 28th - October the 6th 2025