## Laser interferometry on optical data networks:

## from integrated fiber sensing to quantum communication

Detailed topic description

Optical fibers are not only the backbone of global telecommunications but also a versatile tool for cutting-edge scientific applications. Beyond their role in data transmission, they can be used to monitor environmental changes, exchange quantum cryptographic keys for secure communication, and distribute precise time and frequency signals as an alternative to GPS, enabling advanced research and smart and resilient telecommunications at a time.

At the Italian Metrology Institute (INRIM), we have developed low-noise techniques to measure tiny deformations in optical fibers, induced by environmental changes such as seismic activity, down to nanometer precision. Using narrow-linewidth lasers, these methods have already been applied to improve quantum key distribution (QKD) [C. Clivati et al., Nat Comm. 13, 157 (2022)], compare distant atomic clocks [C. Clivati et al., Phys. Rev. Appl. 18, 054009 (2022)], and detect earthquakes through subsea and urban fiber networks [S. Donadello et al., Commun. Earth Environ. 5, 178 (2024)].

As part of this research, your work could contribute to a range of pioneering topics, with the flexibility to align with your specific research interests. You will have the opportunity to collaborate with leading international institutions and companies in the field. Potential PhD research areas include:

- Distributed Fiber Sensing: Design and develop novel opto-electronic interrogators based on narrow-linewidth lasers and advanced digital electronics; model the fiber response to various perturbations; explore innovative probing strategies to localize deformations and adapt to network architectures (e.g., fiber-to-the-home). You will also have the chance to apply machine learning for advanced data analysis and pattern recognition, useful for the development of intelligent alerting. These activities will be carried out within the <u>SENSEI</u> <u>project</u>.
- 2. **Quantum Key Distribution (QKD)**: Demonstrate secure quantum key exchange over regional distances by utilizing advanced laser sources and opto-electronics qubit encoders, as part of the European Quantum Communication Infrastructure (QCI).

This research offers a unique opportunity to push the boundaries of both telecommunications and quantum technologies, positioning you at the forefront of groundbreaking developments in the field. The activity will be carried out at INRIM.