Coherent laser interferometry for seismic monitoring over the deployed optical fiber network

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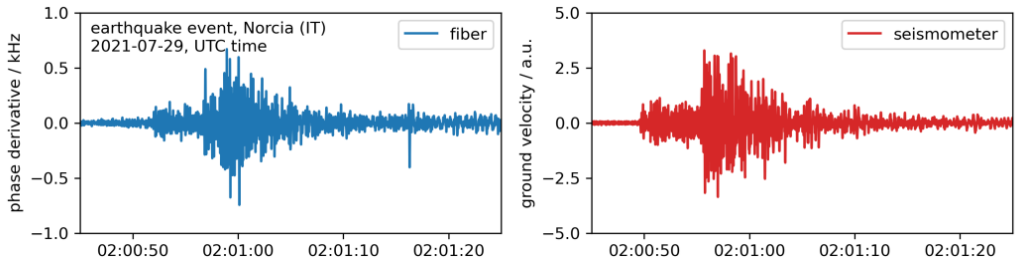
Optical fiber sensing represents a great opportunity for geophysical sciences and seismic monitoring, in view of its possible integration with traditional sensor networks and application in early warning systems. Earthquakes cause deformations in optical fibers, which can be detected through optical phase measurements. Coherent interferometry with ultrastable lasers is a particularly promising detection technique, thanks to its high sensitivity, long-reach, and compatibility with existing telecommunication infrastructures[1]. Advancements in laser integration technologies are making it possible to develop small-form-factor interrogators, suitable for large-scale implementation in global networks.

We describe the implementation of this technology over a commercial optical fiber network in a highly seismic region of central Italy[2], in coexistence with standard internet services. Our setup employs self-heterodyne interferometry detection, with a laser source stabilized to an optical cavity using the Pound-Drever-Hall technique. We successfully detected approximately one hundred earthquakes over an observation period of two years, distinguishing earthquakes from typical noise sources, such as acoustic interferences or anthropic activity. Our detection capability extends from local events with magnitude M=2 to distant teleseisms, demonstrating the technique robustness. We present the first characterization of the seismic event detection probability as a function of magnitude and epicenter distance. Furthermore, our analysis reveals a correlation between the event magnitude and signal spectral features.

Our findings highlight the compatibility of coherent interferometry with deployed telecommunication fibers and its efficacy in seismic monitoring, offering a quantitative perspective for the application of the technique in view of developing scalable sensing networks on a wide scale.



[1] G. Marra et al., "Ultrastable laser interferometry for earthquake detection with terrestrial and submarine cables", *Science*, 361(6401), pp. 486–490, 2018.
[2] S. Donadello et al., "Earthquake observatory with coherent laser interferometry on the telecom fiber network", ArXiv:2307.06203, 2023. Submitted to *Communications Earth & Environment*.