

La rete in fibra come sensore:

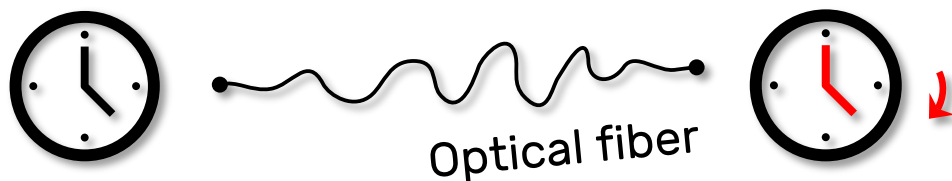
attività e prospettive
per un monitoraggio
geofisico globale

Cecilia Clivati

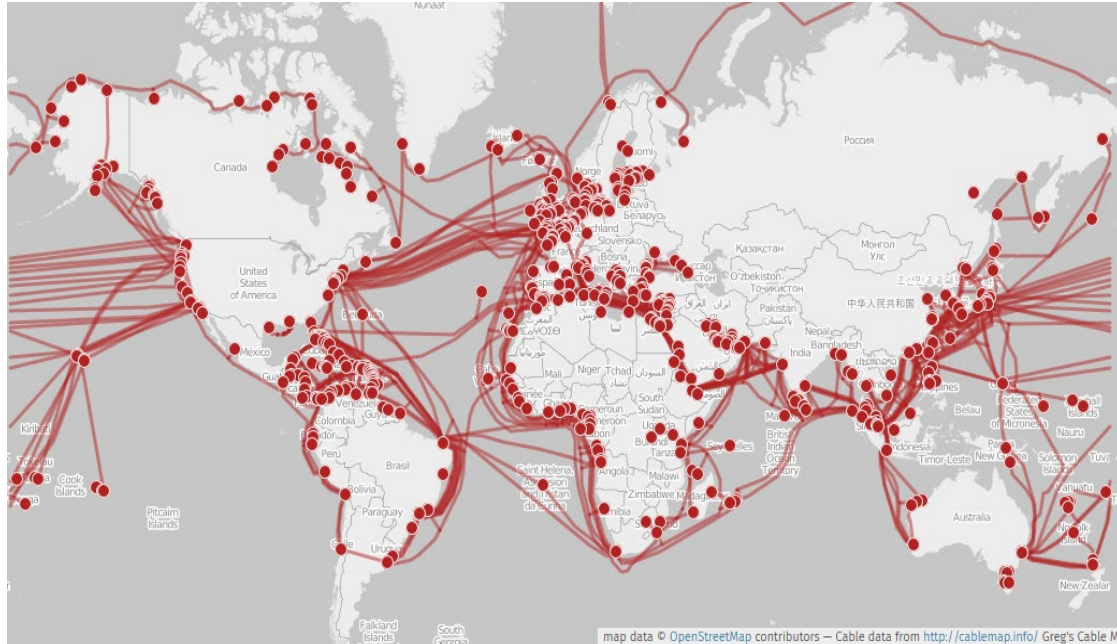
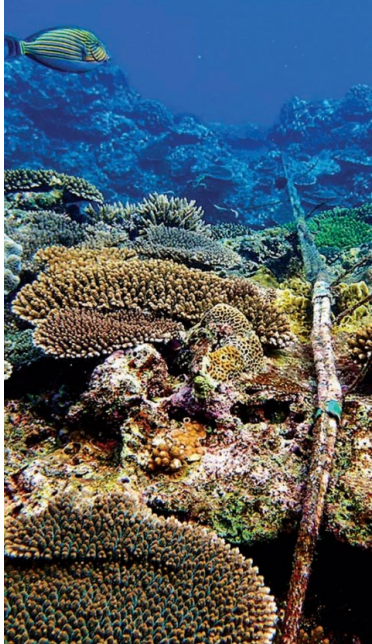
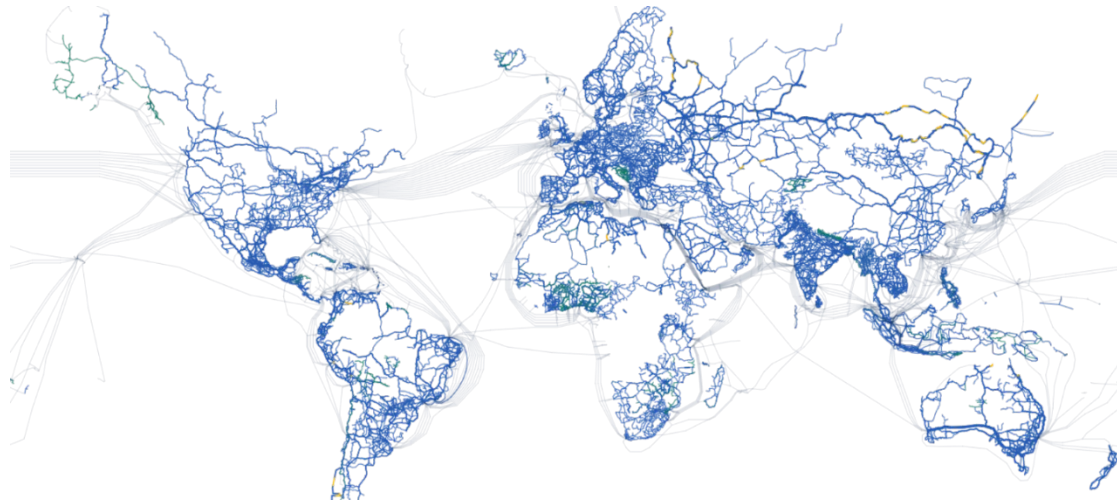
Ist. Naz. Ricerca Metrologica (INRIM)

The Italian Metrology Institute

- INRIM realizes and maintains in Italy the Units of the International System
- It realizes the Italian National Timescale UTC(IT) and distributes it to the users

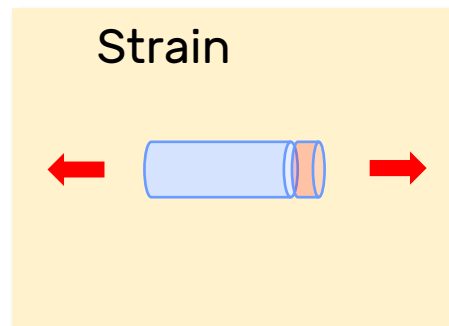
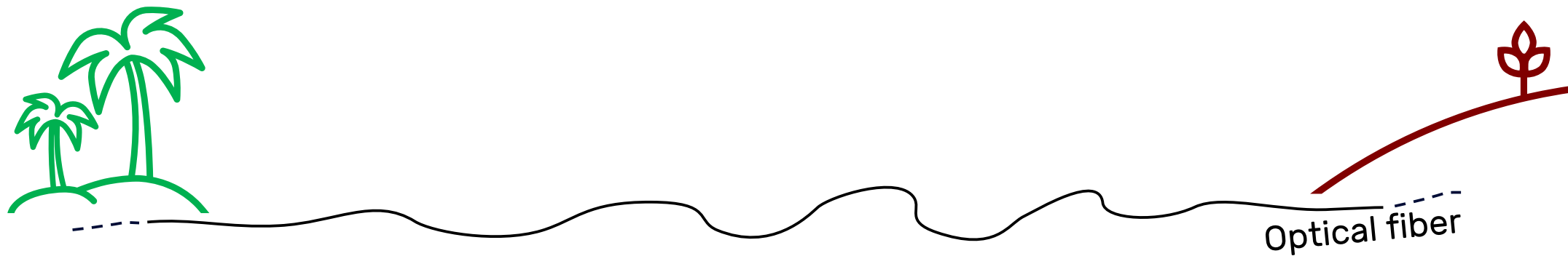


Optical Networks today

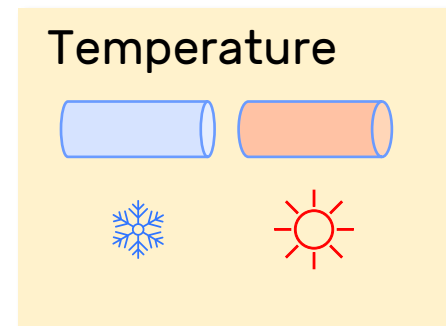
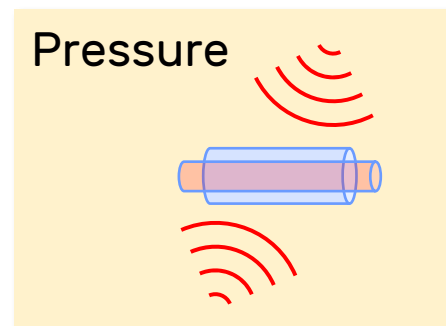


<http://cablemap.info>
<https://bbmaps.itu.int/bbmaps/>

The fiber as a sensor



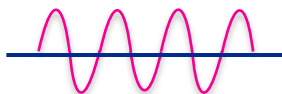
Change in fiber length



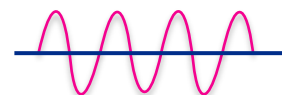
Change in glass density

The fiber as a sensor

Launched optical field



Transmission disturbances



Phase



Polarization

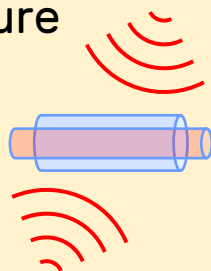


Optical fiber

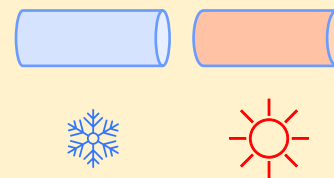
Strain



Pressure



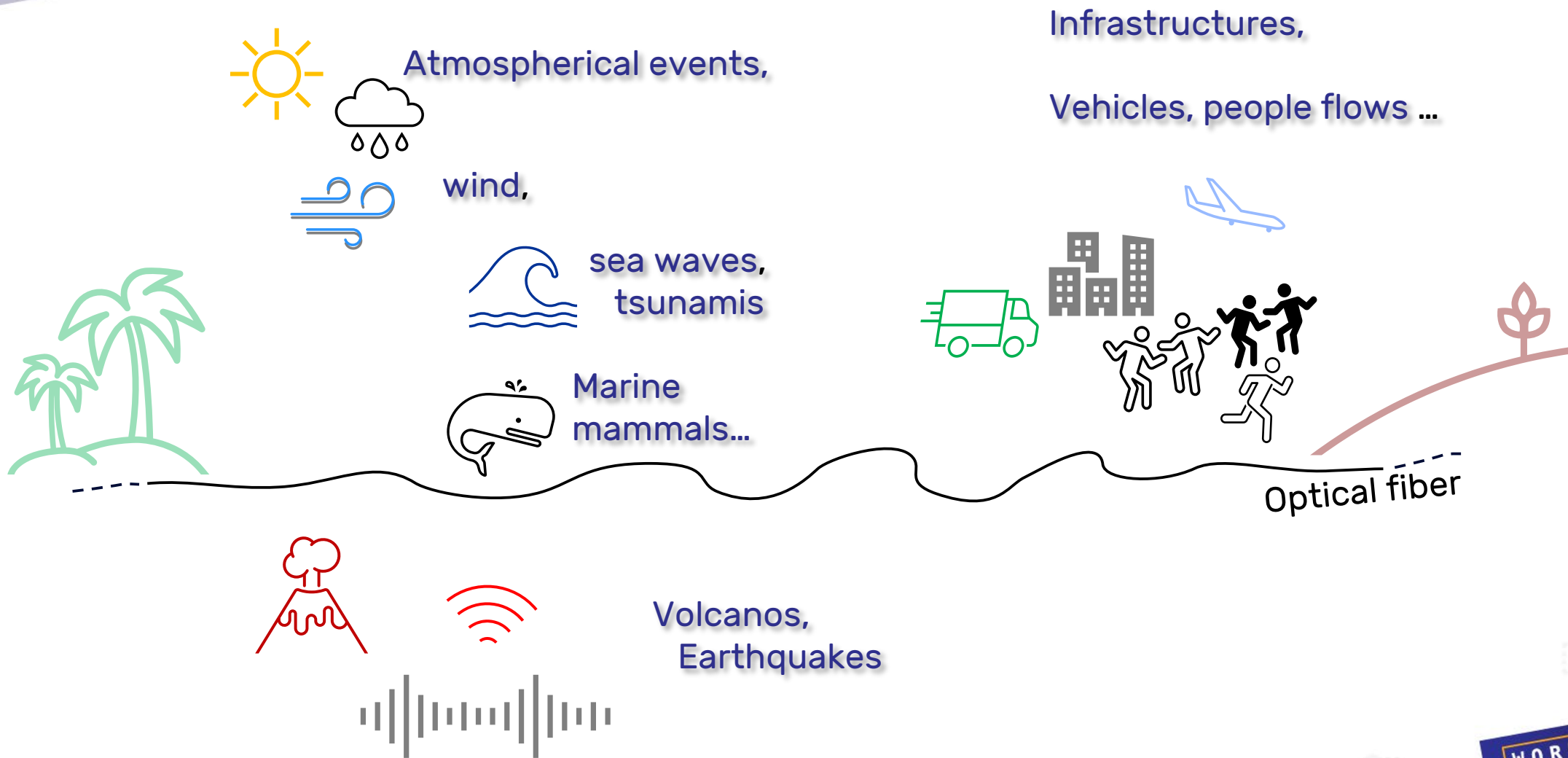
Temperature



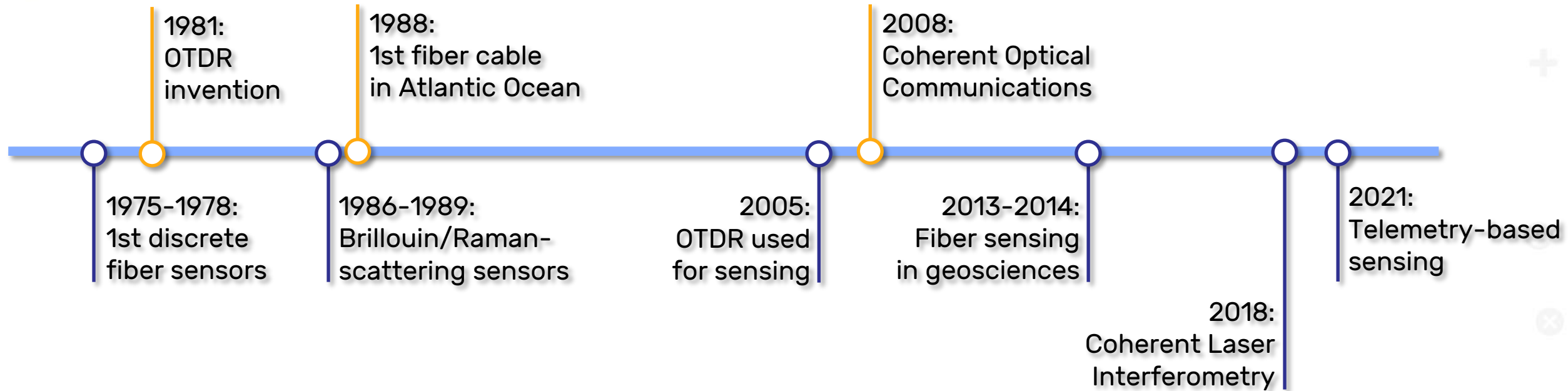
Change in fiber length

Change in glass density

The fiber as a sensor

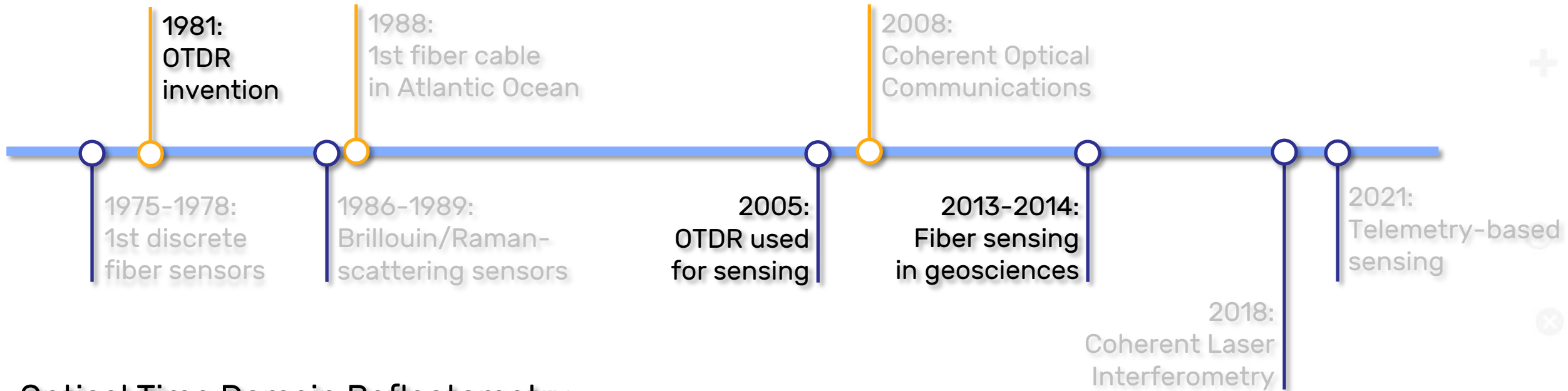


Distributed Fiber Optic Sensing

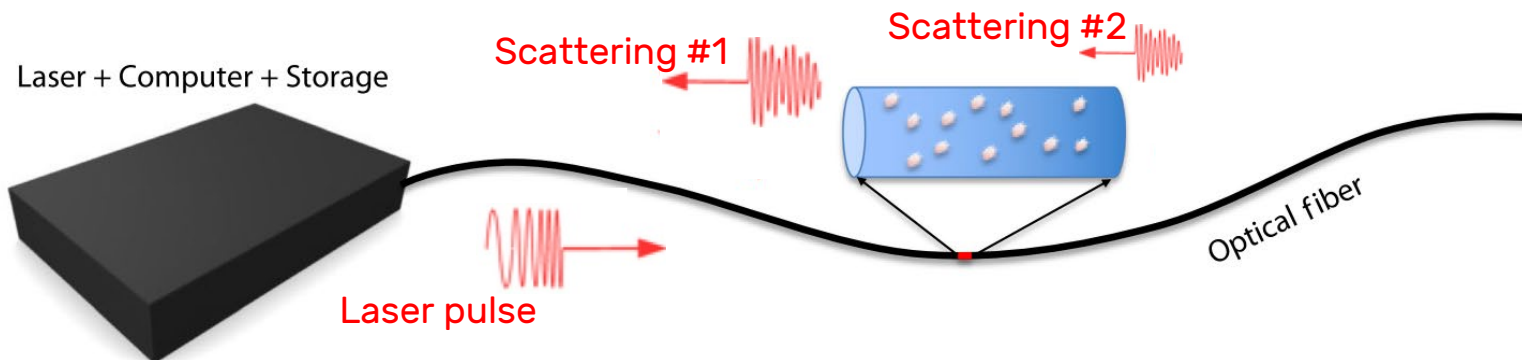


E. Ip, proc. of the IEEE, 110, 1853 (2022)
Z. Zhan, Seism. Res. Lett. 91, 1 (2020)

Optical Time-Domain Reflectometry

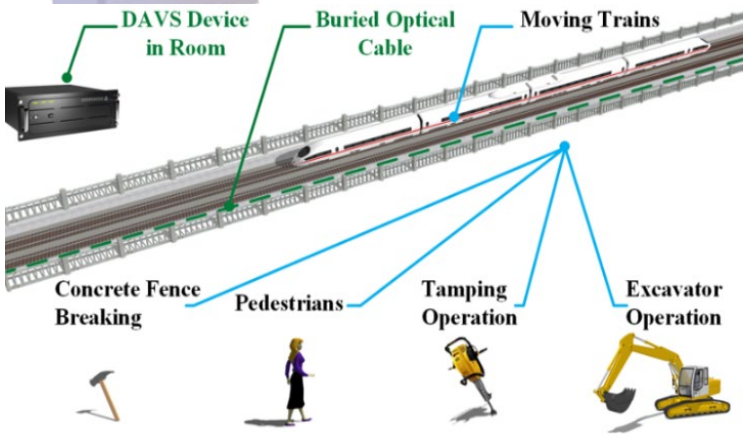


Optical Time Domain Reflectometry:

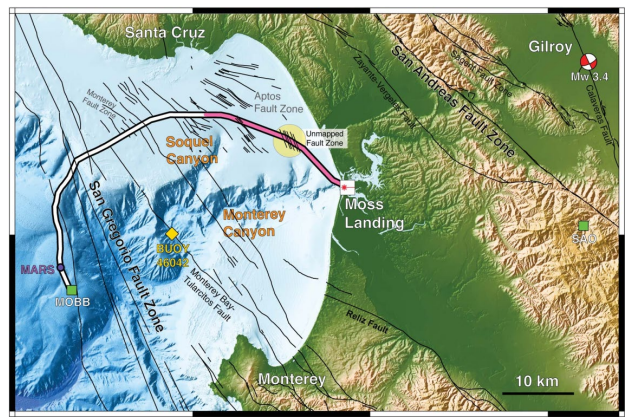


- Point-by-point acoustic map along cable

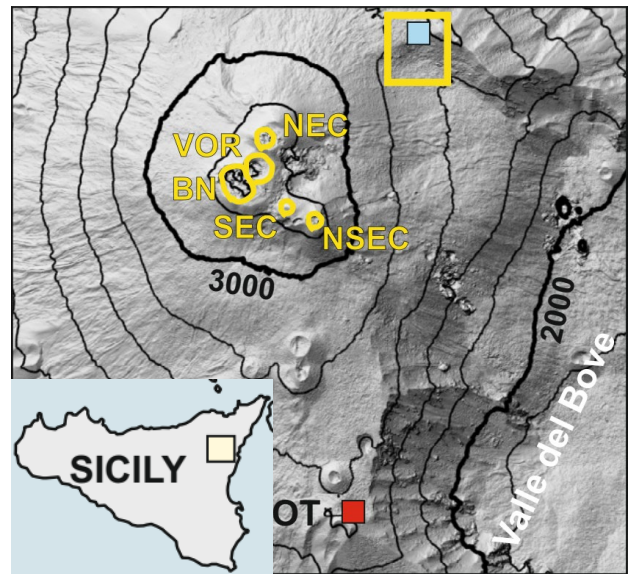
Optical Time-Domain Reflectometry



Z. Wang et al.,
Opt. Expr. 27, 23682 (2019)



N. Lindsey et al.,
Science 366, 1103 (2019)

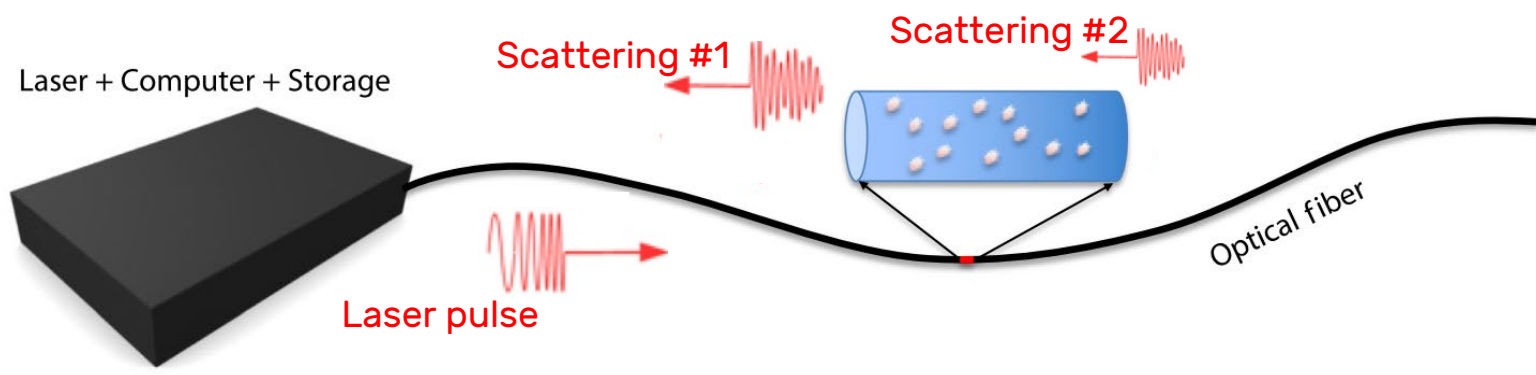


P. Jousset, G. Currenti et al.,
Nat. Comm. 13, 1753 (2022)



F. Walter et al.,
Nat. Comm. 11, 2436 (2020)

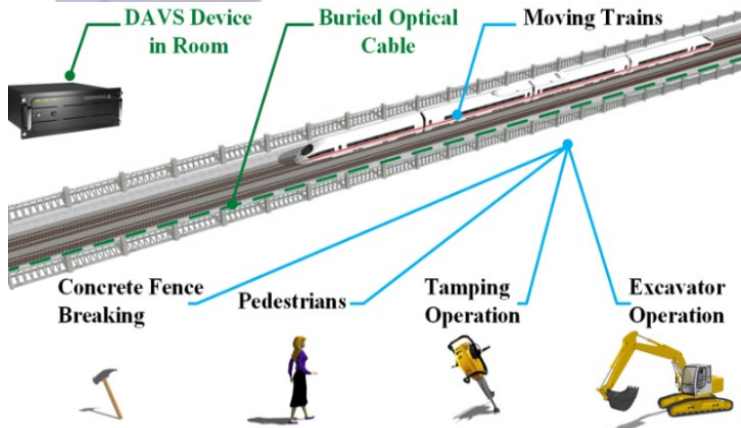
Optical Time Domain Reflectometry:



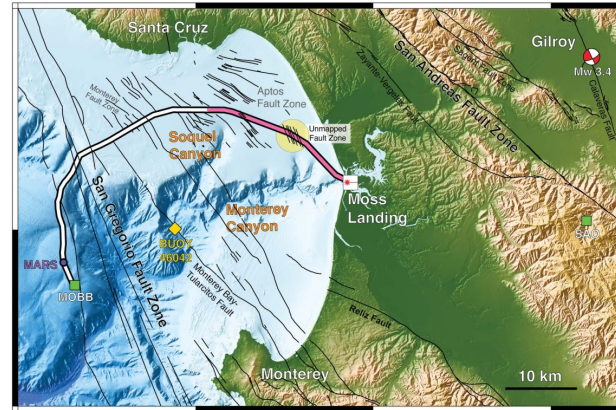
- Point-by-point acoustic map along cable



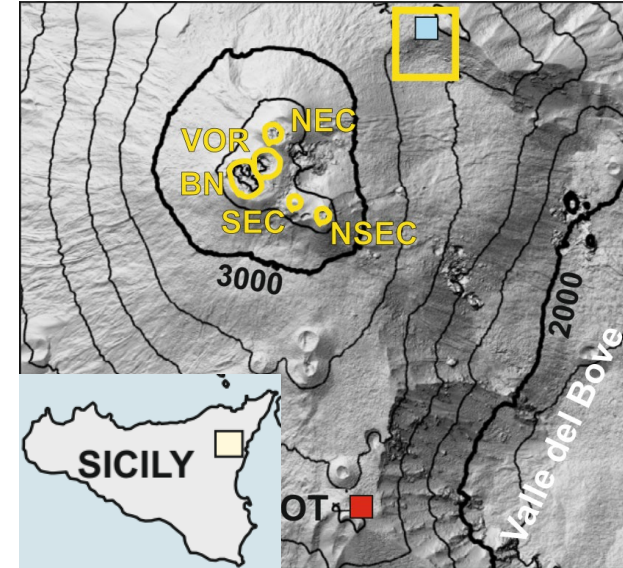
Optical Time-Domain Reflectometry



Z. Wang et al.,
Opt. Expr. 27, 23682 (2019)



N. Lindsey et al.,
Science 366, 1103 (2019)

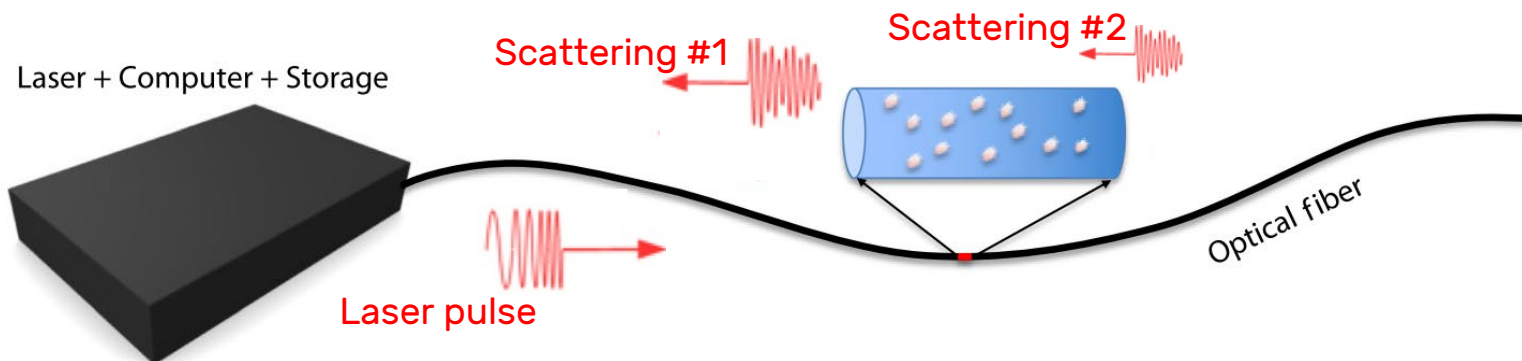


P. Jousset, G. Currenti et al.,
Nat. Comm. 13, 1753 (2022)



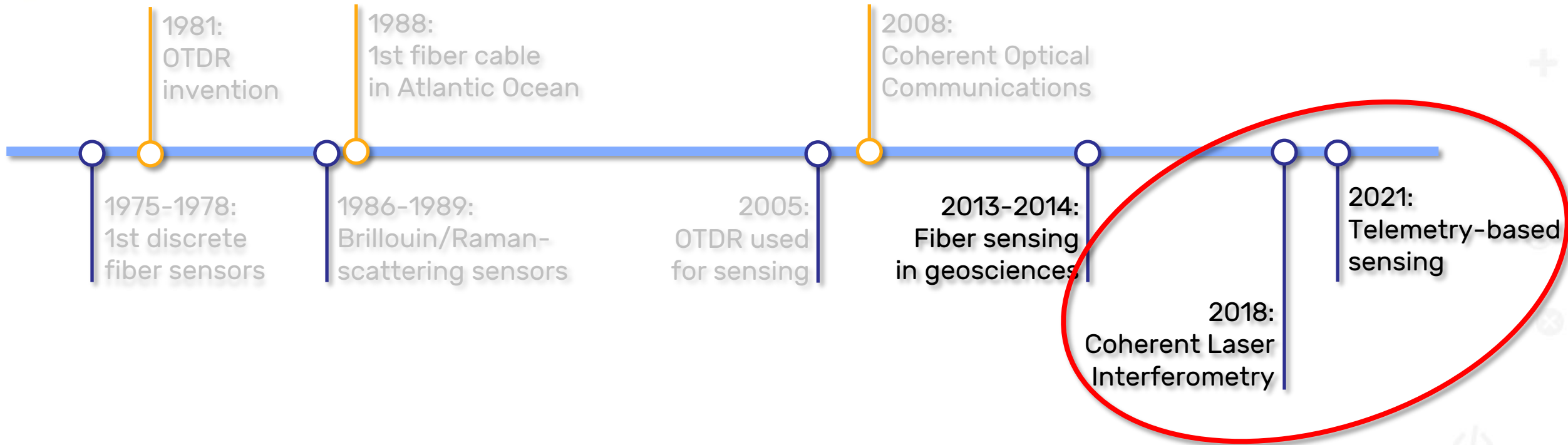
F. Walter et al.,
Nat. Comm. 11,
2436 (2020)

Optical Time Domain Reflectometry:

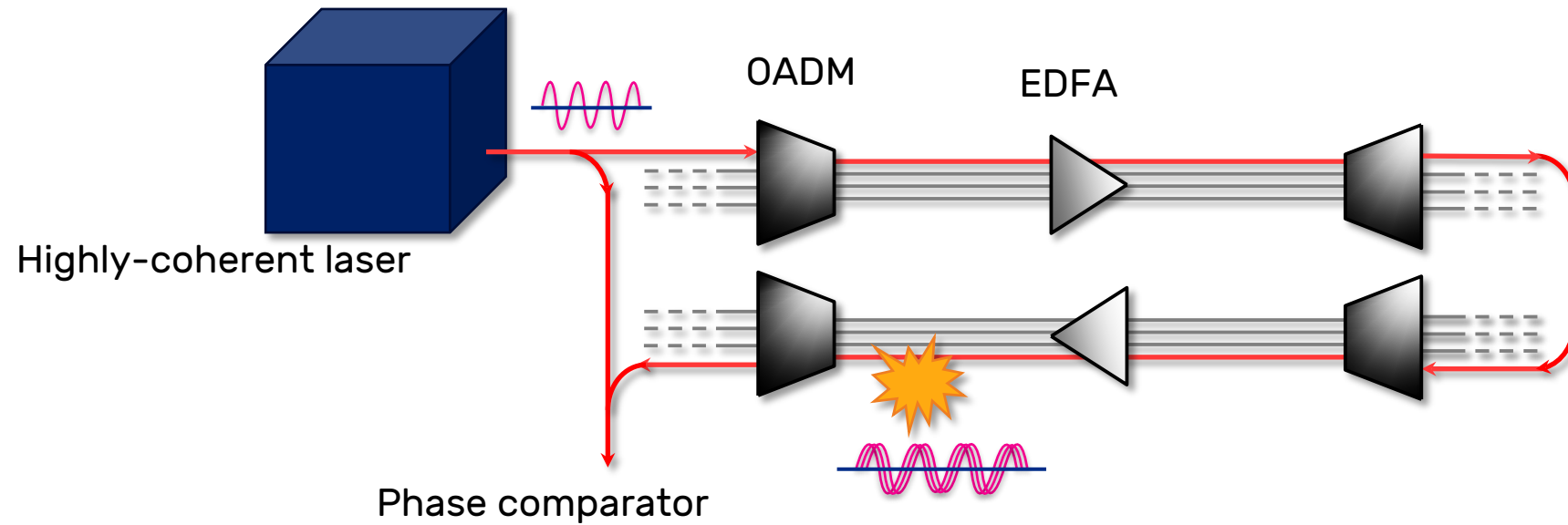


- Point-by-point acoustic map along cable
- Not compatible with data traffic
- \$\$\$, not scalable

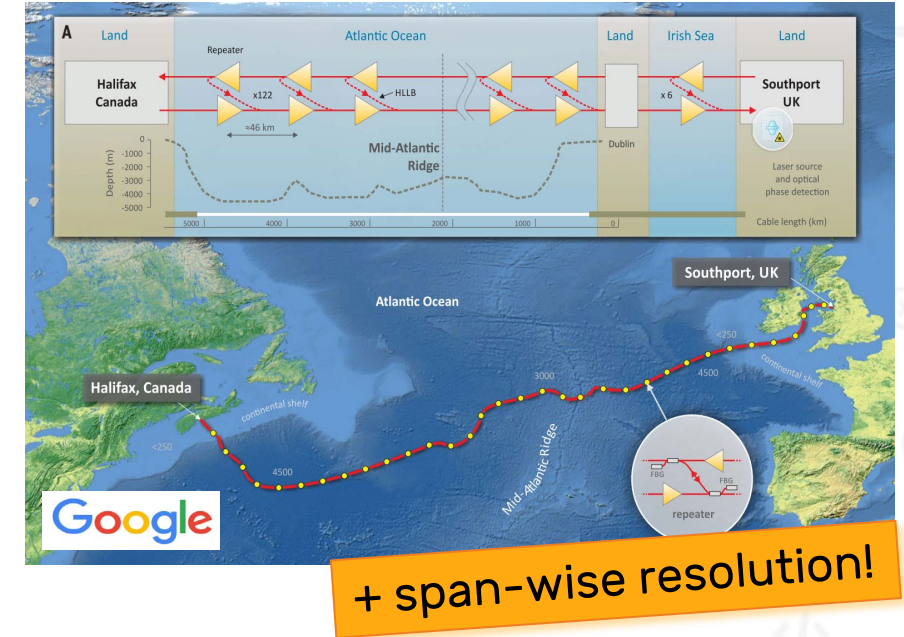
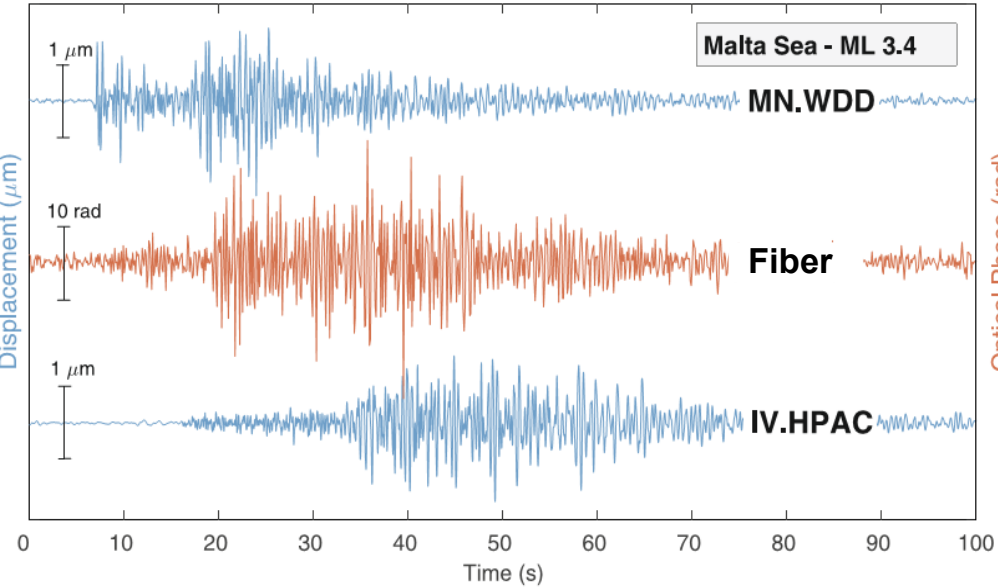
Sensing while carrying data



Coherent laser interferometry



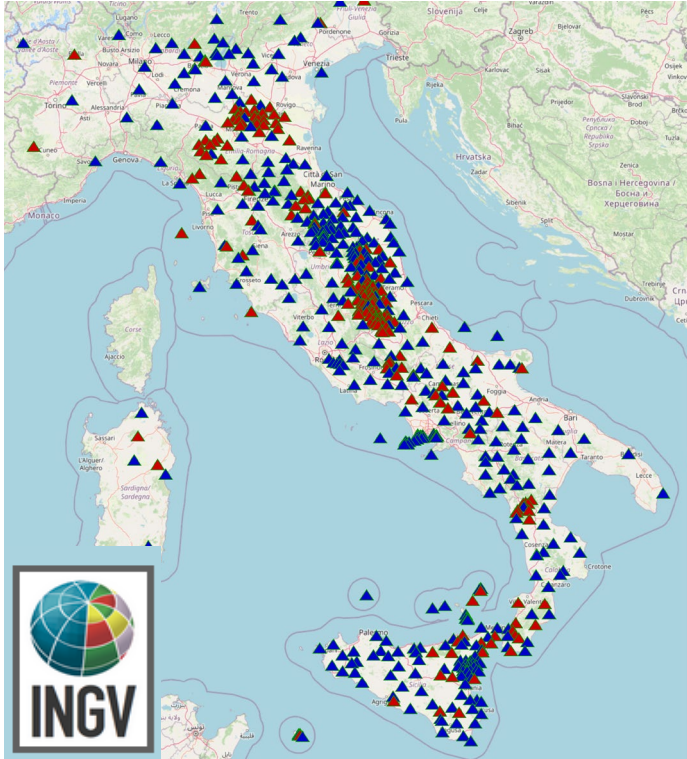
Accessing remote areas with coherent laser interferometry



- Fully-compatible with data networks
- Gives access to unexplored areas
- Poor resolution (100 km), work in progress

G. Marra et al., Science 361, 6401 (2018)
G. Marra et al., Science 376, 874 (2022)

Coherent laser interferometry on land



- Fibers complement & enhance the existing sensor networks



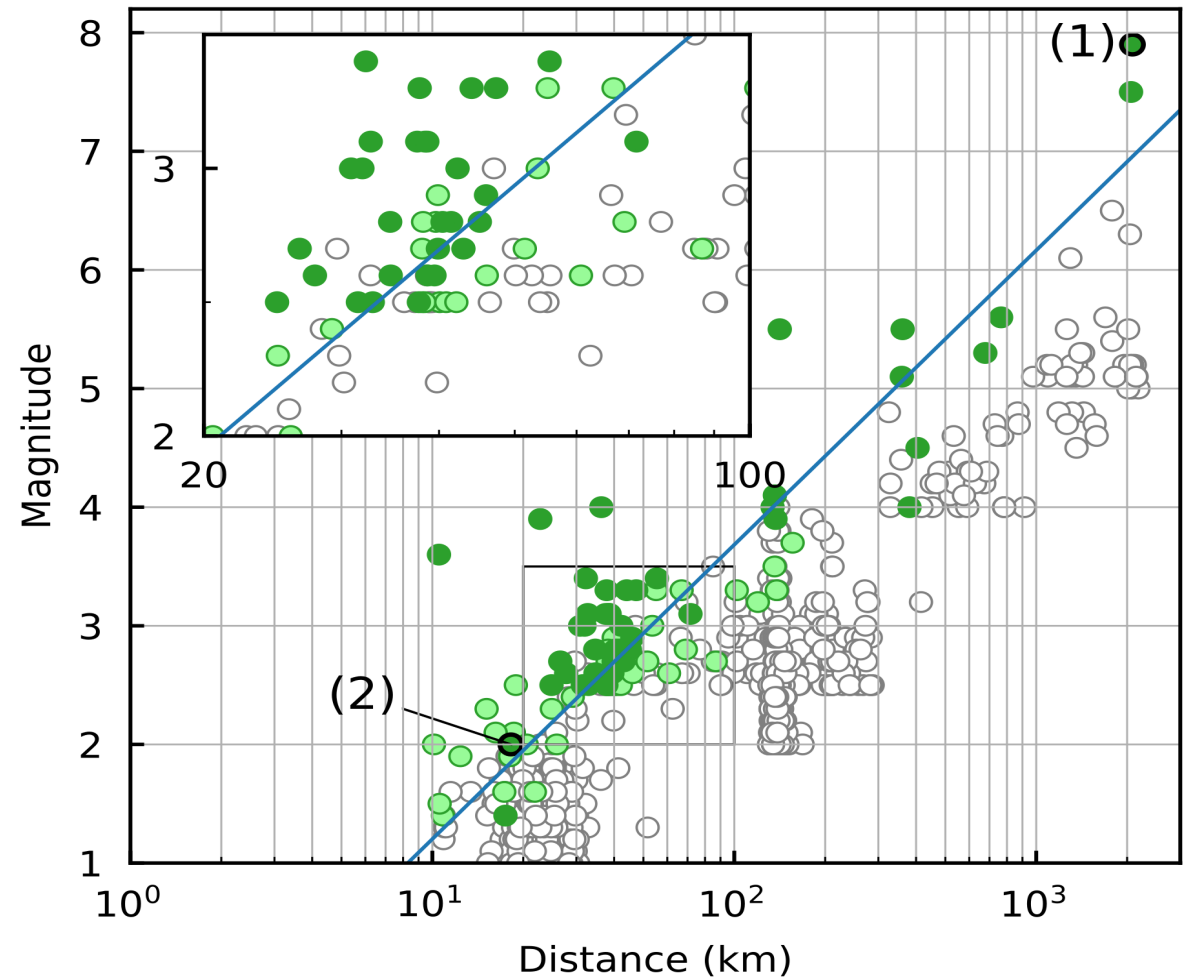
Laser interrogator
in network shelter

The link:
32-km long,
100 Gb/s QPSK



Coherent laser interferometry on land

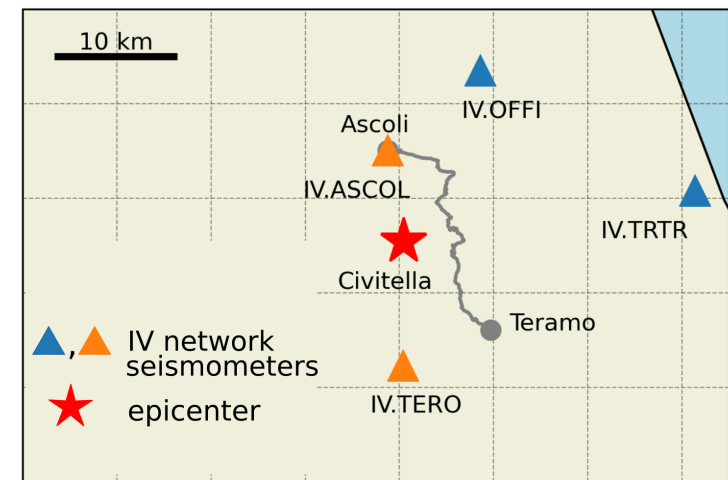
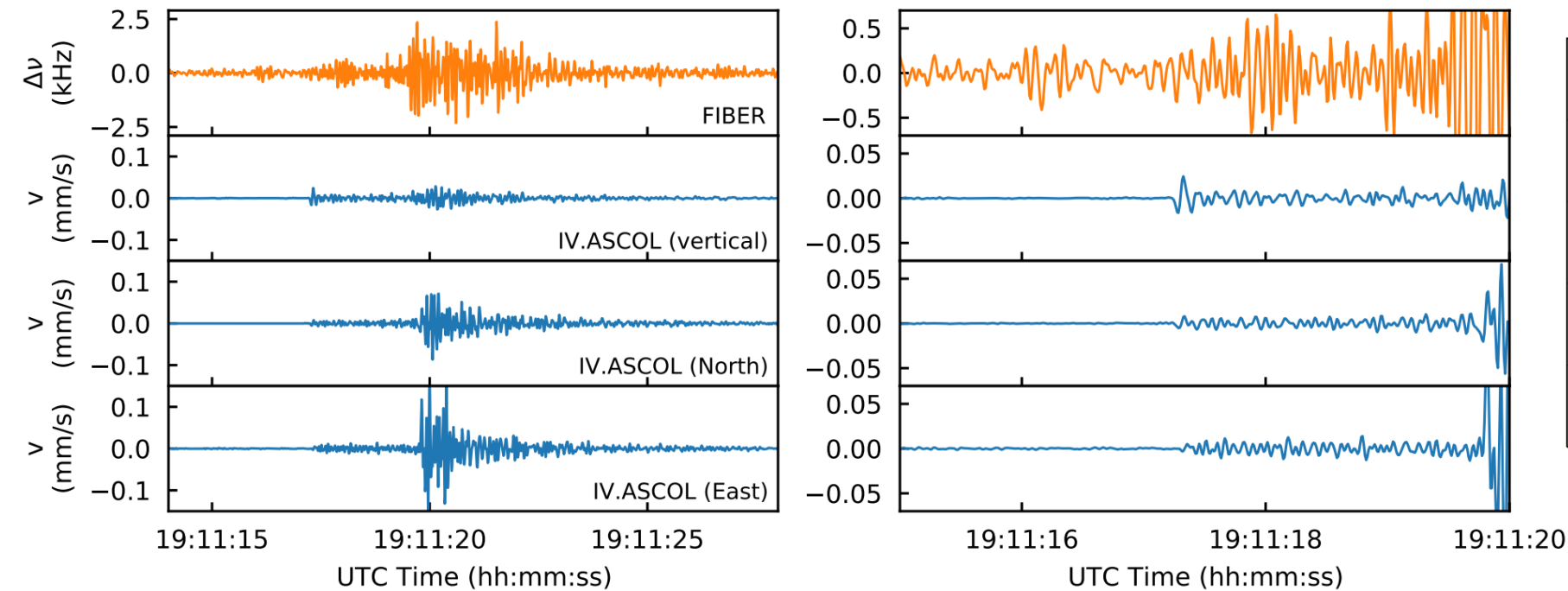
- 2-year-long acquisition
- No disturbance to data traffic
- Very rich dataset of events
- Detection probability related to distance and magnitude
- Very weak events are detectable!



S. Donadello et al., (2023), arXiv:2307.06203

Detecting weak, local earthquakes

Civitella (TE), Feb. 19th, 2022
magnitude 2.0, distance 18 km



S. Donadello et al., (2023), arXiv:2307.06203

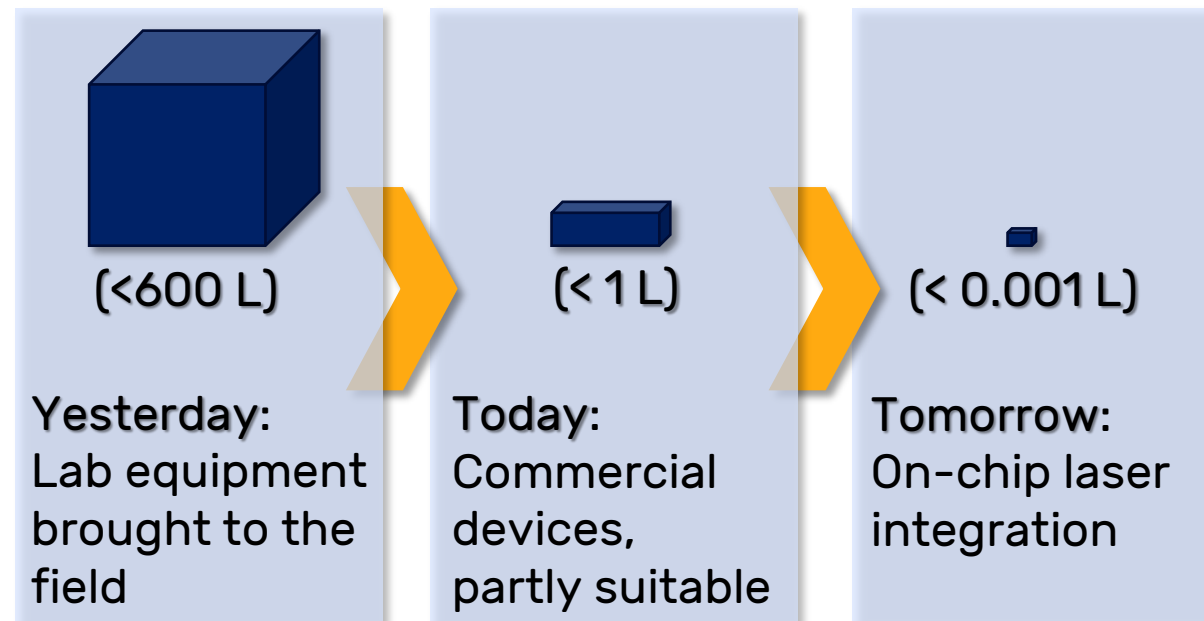
Besides earthquakes

- Periodical resonances:
aerial cables shaken by wind
- Strong day/night variations:
human activities
- Impulsive events:
vehicles on road joints

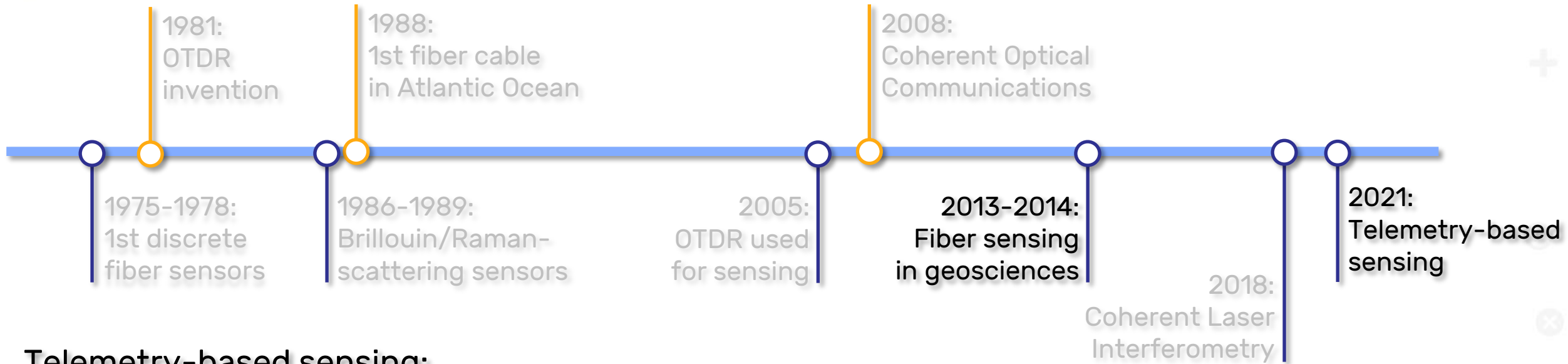


Integration and scalability

- Weak event detection on a pervasive network helps seismic monitoring
- Scalable, \$\$ (↘), reaches remote regions
- Laser interrogator is complex and bulky



Sensing while carrying data /2



Telemetry-based sensing:



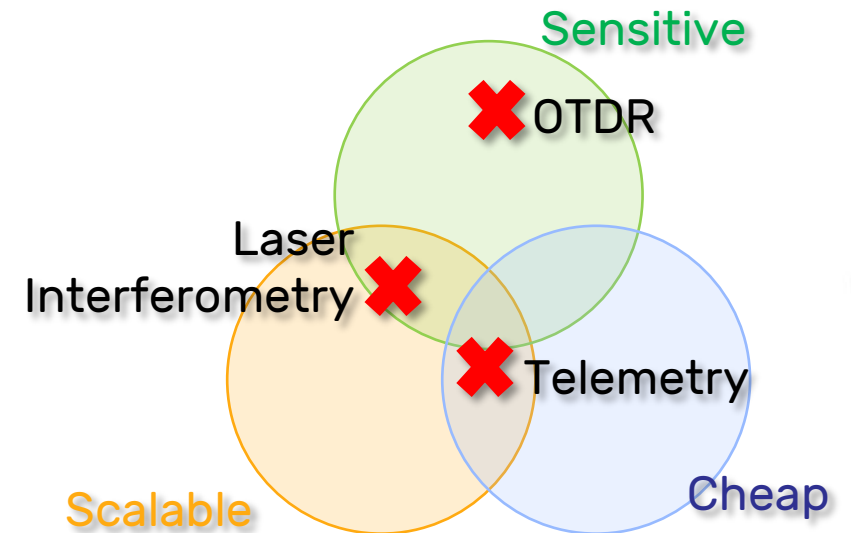
- In coherent communication, huge amount of info computed (State of polarization, Phase, Dispersion, GVD ...)
- «Re-use» them for sensing
- Takes advantage of laser integration

Z. Zhan et al., Science 371, 931 (2021)

E. Virgillito et al., ICTON 2023, Mo.D1.3 (2023)

Concluding remarks

- Each technique (OTDR, laser interferometry, telemetry...) has peculiar strengths and optimal field of application
- Fiber offers great opportunities for global monitoring
- Earthquakes, volcanic, tsunami early warning
- Mobility management, infrastructure monitoring in smart cities
- A complement, not an alternative, to traditional sensing



Thank you

Cecilia Clivati
INRIM, Torino
c.clivati@inrim.it
www.inrim.it

