HIGH FIDELITY SENSING BASED ON CP-OTDR: UNLOCKING NEW EMERGING APPLICATIONS

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ARAGÓN PHOTONICS

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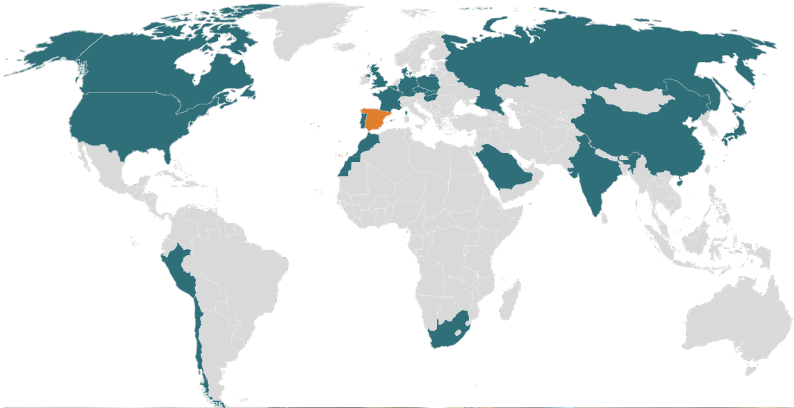
ARAGÓN PHOTONICS

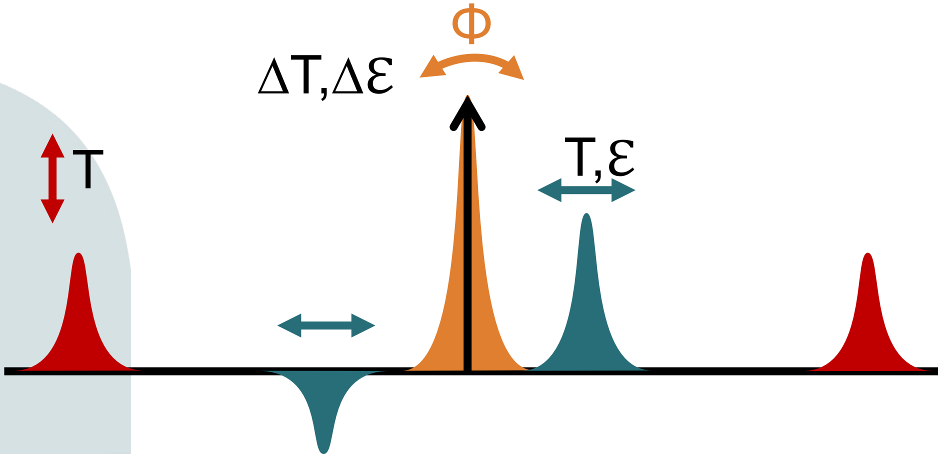
The Company
Overview

- Developer and manufacturer of **test and measurement equipment** in optics and photonics.
- Founded in Zaragoza in 2004 as part of **Grupo Fibercom**, with a solid relationship with **UNIZAR**
- **INNOVATION management**
  - Unique Patented Technologies
  - High-Value R&D Environment
- **PRODUCTION management**
  - In-House manufacturing
  - ISO 9001 Standard
- **SALES management**
  - Significant network of distributors and partners
- **Sustained growth** (1,5 – 2,0 M€)

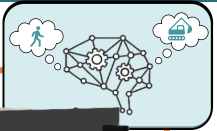


Line of Products

- Distributed sensing is based on the interaction between the light and the optical fiber
- Different physical states of the fiber induce different scatteringparemeters for the light
  - **Raman** → **DTS** (*Distributed Temperature Sensing*)
  - **Brillouin** → **DTSS** (*Distributed Temperature & Strain Sensing*)
  - **Rayleigh** → **DAS** (*Distributed Acoustic Sensing*).



Line of Products



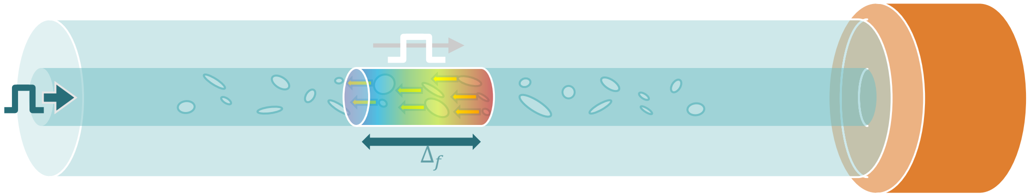
2022	2023	2025
HECTOR →	HECTOR-XS	
HDAS 1.0 →	HDAS 2.0 →	**HDAS 3.0**
FINEST →	BLAST →	BLAST HR

- Upcoming 3.0 Version of the Hi-Fi Distributed Acoustic Sensor (HDAS)
- Geophysics market oriented:
  - **Hardware:**
    - Reach*: **> 100 km**
    - Spatial Res.: **< 5 m**
    - Freq. Stability: **< 10^{-4} Hz**
  - **Software:**
    - Real time:
      - Event Detection
      - Pattern Classification
      - Alarm definition

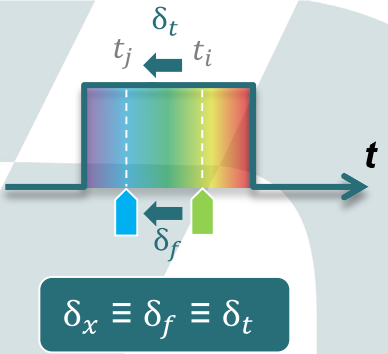
* Without assisted amplification.

CP-ΦOTDR Technology

- A frequency swept is done inside the pulse → Chirped pulse



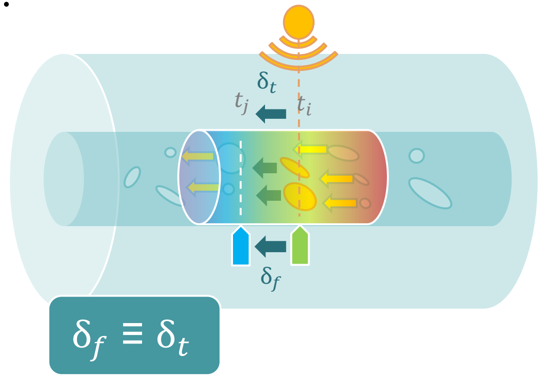
- If a perturbation occurs over the fiber, the phase of the perturbated points will change, varying the interference of the backscattered light.



- This phase change is equivalent to a frequency drift inside the chirped pulse.

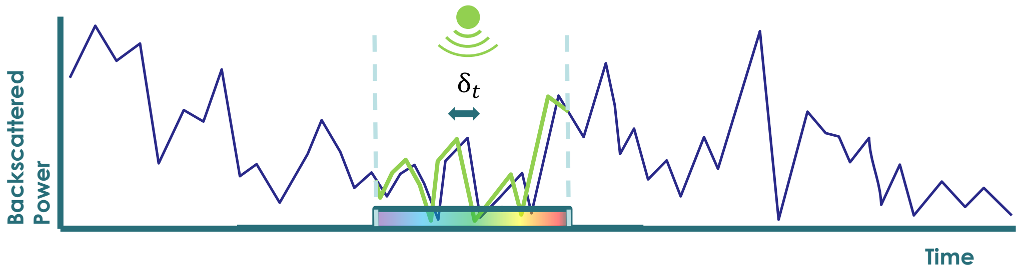
$$\Phi_i = \frac{4\pi\,(nL_i)}{c} f$$

- The frequency drift is equivalent to a time delay.



CP-ΦOTDR Technology

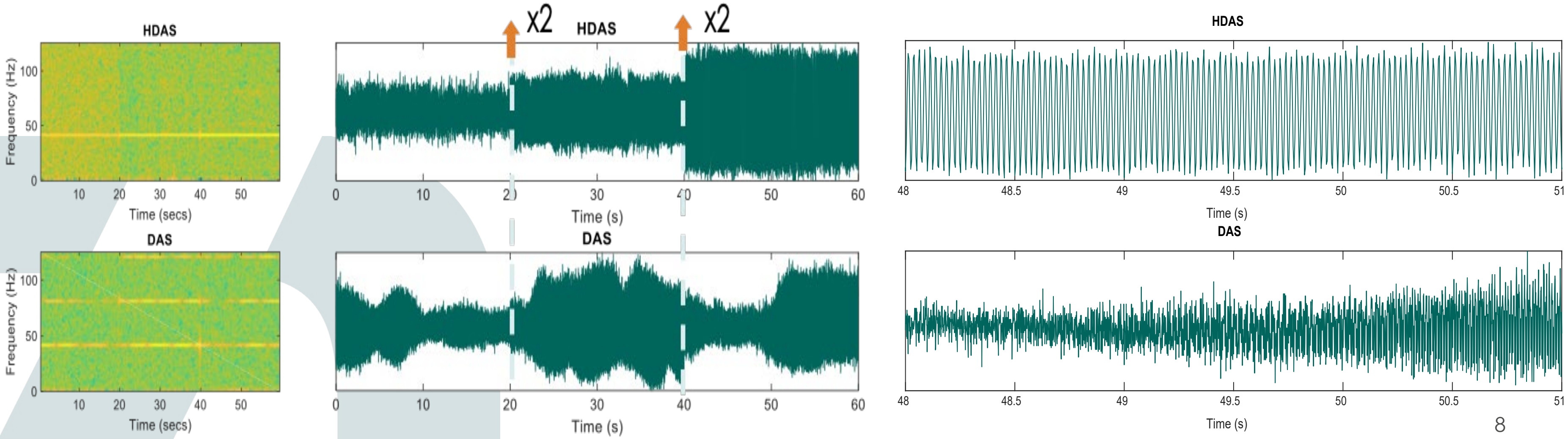
- Perturbations over the fiber are then measured as time delays over the portion of the trace illuminated by the pulse.



- This form of measurement provides high fidelity along the fiber.
- Many advantages when compared with other technologies

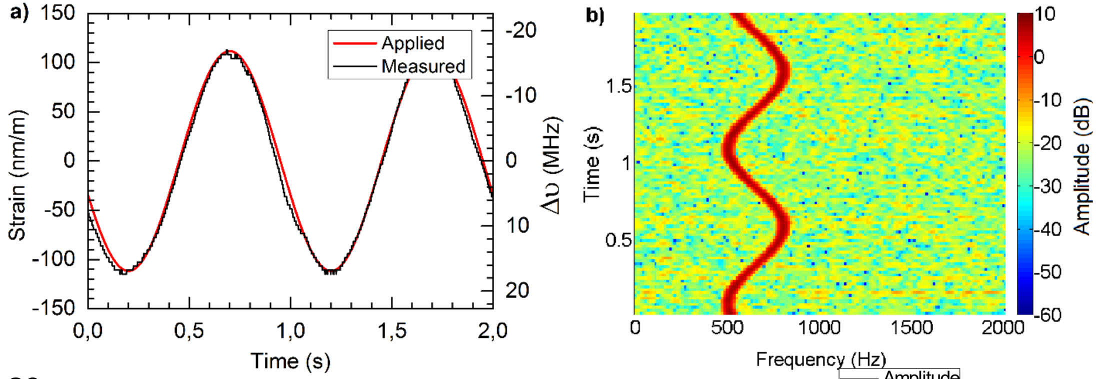
CP-ΦOTDR Technology

- Linear Response: No distortion. High Fidelity.
- Quantitative measurement: Reliable measurement of strain and temperature changes.
- Homogenous SNR along the fiber with high stability and no fading points.

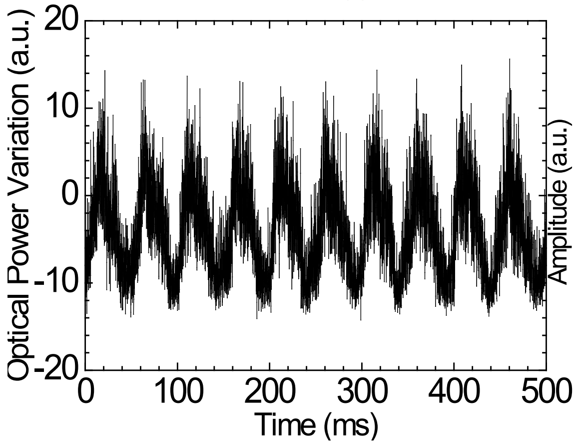


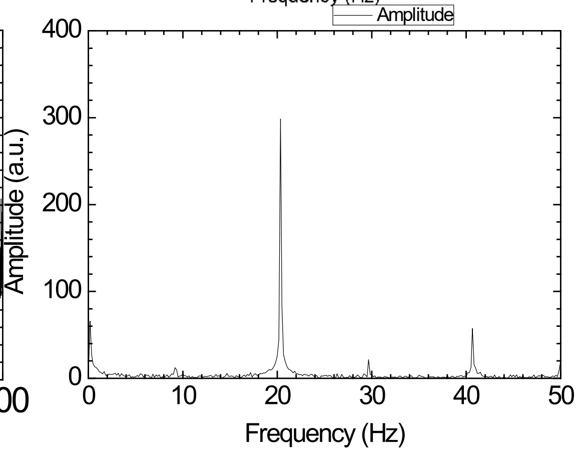
CP-ΦOTDR Technology

- CP-ΦOTDR



- Traditional ΦOTDR





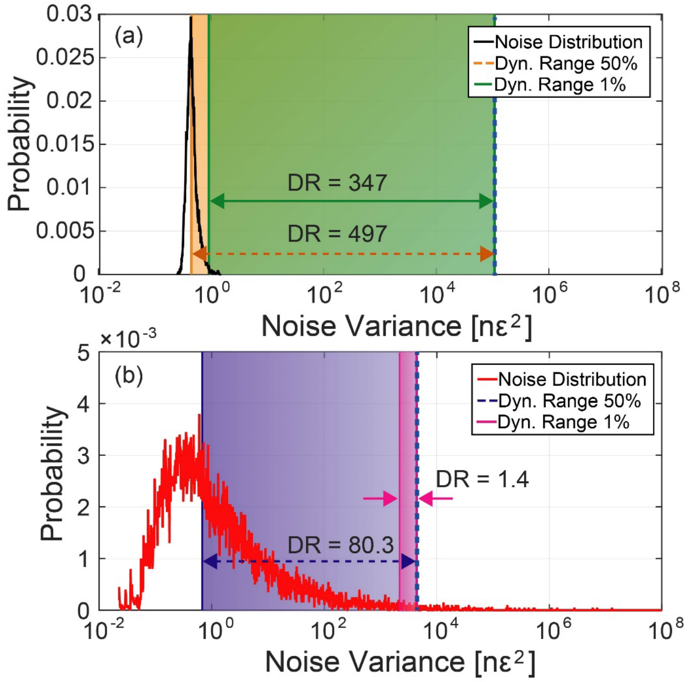
CP-ΦOTDR vs ΦOTDR

Chirp-Pulse ϕOTDR

- Shift of Zero-Intensity Point can be measured
- Almost Constant SNR along fiber (3dB variation, for constant optical SNR)
- Linear mesaurement – High Bandwidth

Phase-Measuring ϕOTDR

- Phase of Zero-Intensity Point cannot be measured
- High SNR variability & Fadding ("Dead Zone") (>30dB at 1% heigth, for constant optical SNR)



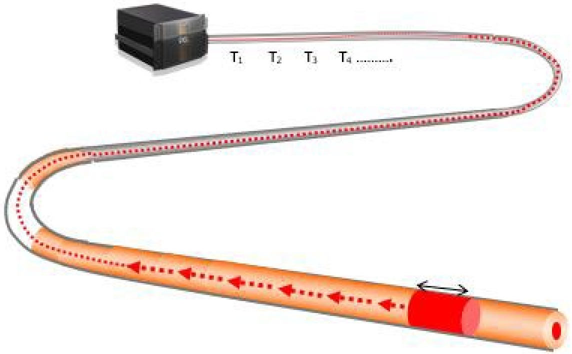
Main Advantages

- Low cost/complexity setup
  - Direct Detection (no polarization issues)
  - Current modulated laser (No AOM, AWG, etc)
  - Low laser requirements (linewidth, freq. Drift)
- Signal measured as local effect
  - Perturbations are not accumulated in the signal along fiber
  - No Averaging issues
- Linear Signal (no harmonic distortions) for strain and temperature
  - Long term stability if accumulated errors are handled
  - Measures Time-Delays (Robust again RIN / ASE noise)
- High sensitivity and stability:
  - 3.6 $p\varepsilon/\sqrt{Hz}$ demonstrated limit
  - 3mK over 1 month measurement
  - Steady SNR and no fading ("dead zone") points

Geophysics Solutions

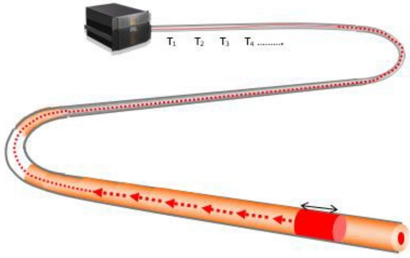
- HDAS:
  - 2D F-K Spectrum:
  - (F,K) Wavelength & frequency
  - Seismic Wavelengths ~ km
  - Isolate seismic features

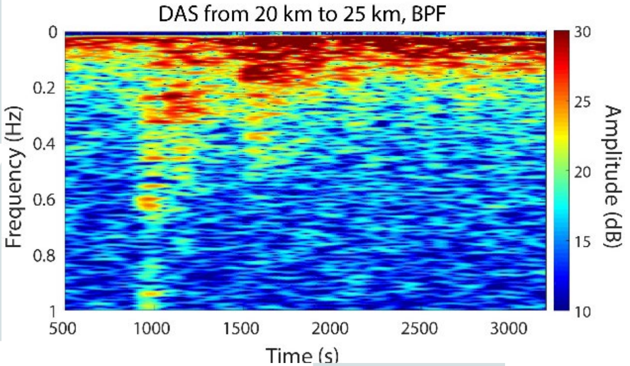
- Point Seismometer:
  - 1D BandPass Filtering:
  - Higher Sensitivity
  - No wavelength info
  - Filter noise by frequency



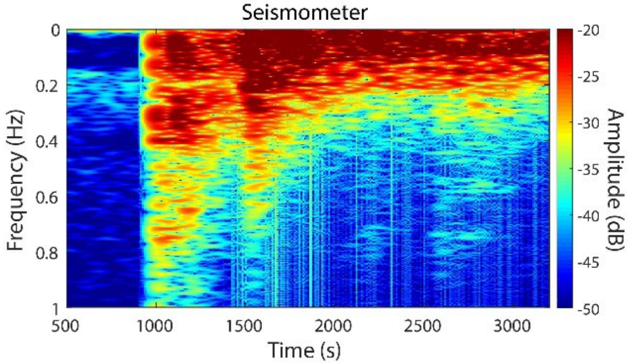
Geophysics Solutions

- DAS:
  - Distributed Mapping
  - Lower Sensitivity





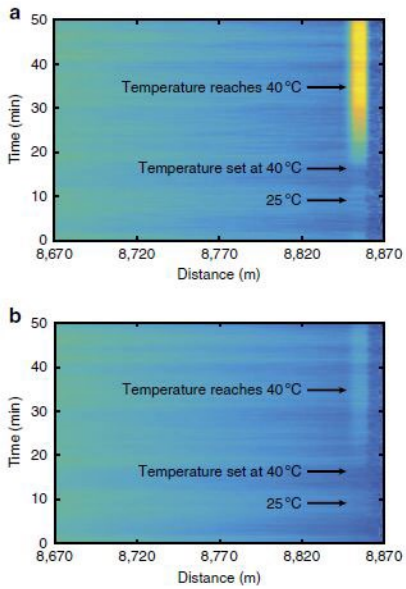
- Point Seismometer:
  - 1 Point Sensor
  - Higher Sensitivity

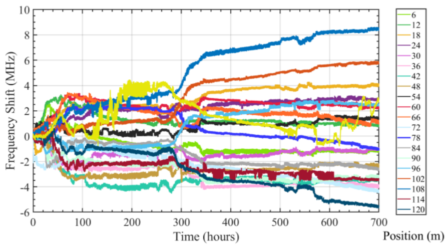


- Optical Fiber as a dense array of seismographs
  - 50km of fibre = 10 000 seismometers
  - 10 000 coherent channels >> 10 000 individual sensors

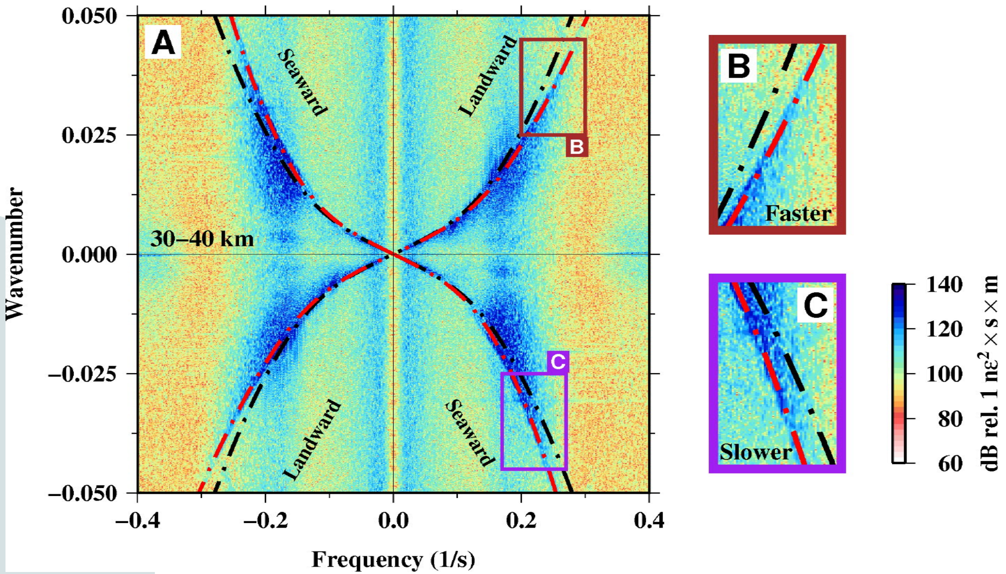
- Advantages of 2D signal processing
- Coherent Averaging: SNR ~ √N
- 2D / 3D Image processing: White noise removal
  - (F,K) Wavelength & frequency: Isolate seismic features

- Long-term performance <10^{-4}Hz stability
  - Isolating seismic features (wave propagation, etc.) Not previously available



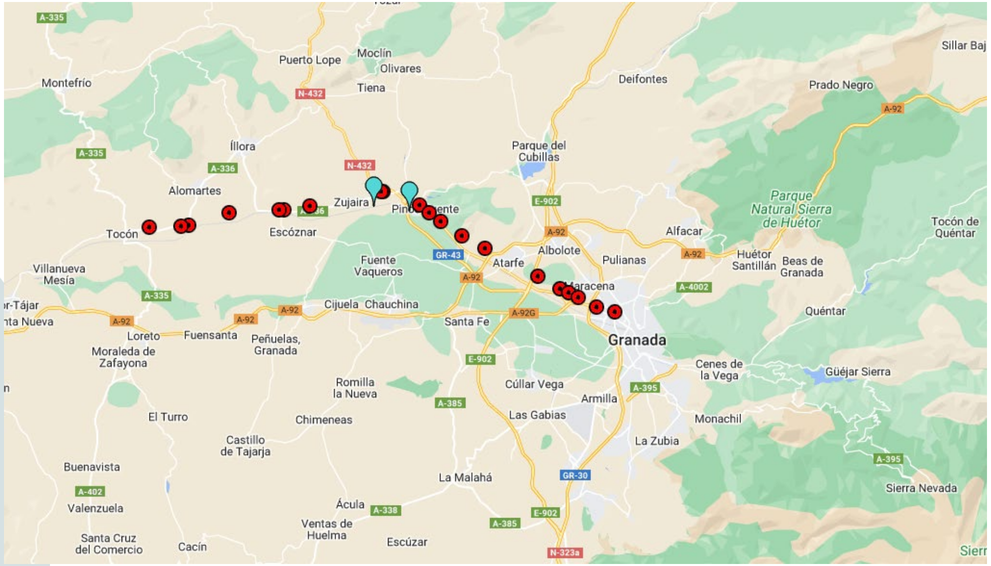


- Application in submarine cables
  - Strong landward-propagating / weak seaward-propagating ocean waves
  - Asymmetrical dispersion due to an ocean current



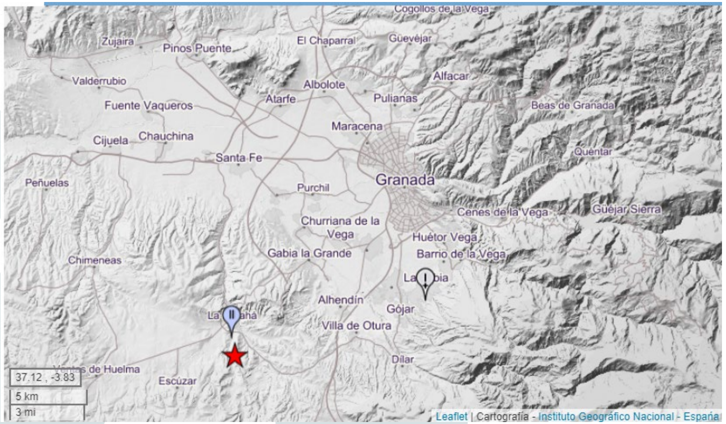
Regional Earthquake Detection

- Earthquake detection
  - Fiber deployed in Granada, Spain
  - 36KM / 100HZ / HIGH SENSITIVITY / 10M-20M

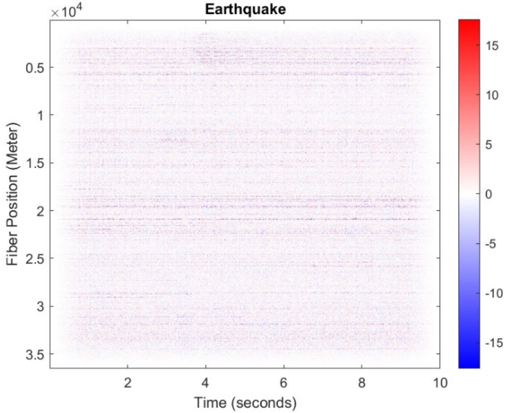


Regional Earthquake Detection

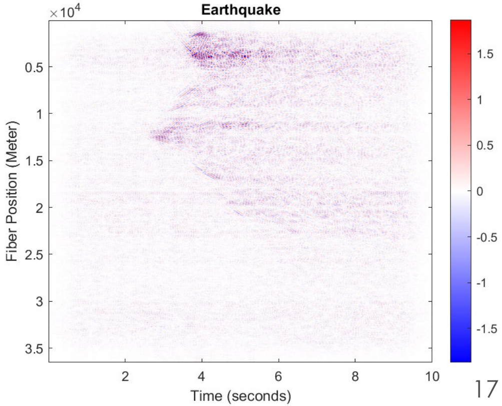
- Regional Earthquake detection
  - Granada
  - 02/07/2022 17:20:02
  - mgLb 2.1 / Low Magnitude
  - Automated alarm algorithm development



Before



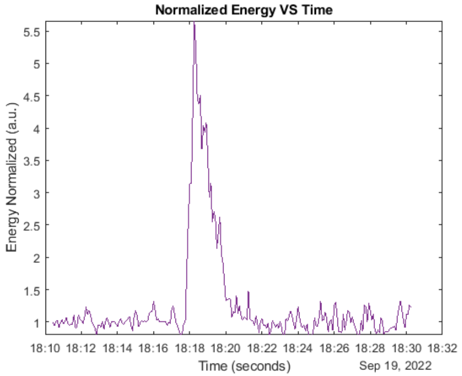
During

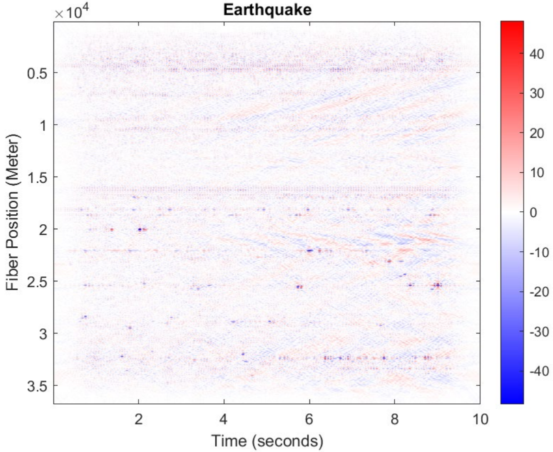


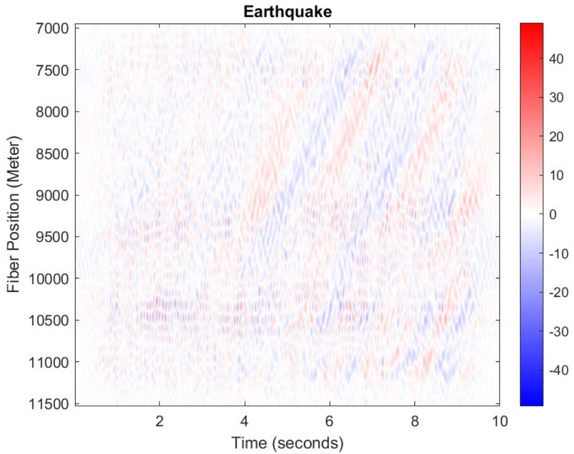
Teleseismic Detection

- Telesemic Earthquake detection
  - Mexico
  - 2022-09-19 18h17m50s
  - 7,7 Mw/ HighMagnitude
  - >9400 km
  - Automated alarm algorithm development

Energy Threshold







Projects, Partners & Collaborators

- **National (Spain):**
  - <u>*“Retos de la Sociedad”:*</u>
    - (2019) **MODITI**: UNIZAR-GTF / UNIZAR-VivoLab
    - (2022) **TREMORS**: REPSOL / UAH-GRIFO / CSIC-ICM
  - <u>*“Líneas Estratégicas”:*</u>
    - (2021) **PSI**: UAH-GRIFO / CSIC-ICM / AFR-IX
    - (2022) <u>**DigiVolCan**</u>: INVOLCAN / ITER / UGR / ULL
- **Europe:**
  - <u>EIC TRANSITION:</u>
    - (2022) **SAFE**: UAH-GRIFO / TELXIUS / CNRS-GEOAZUR / IPMA

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