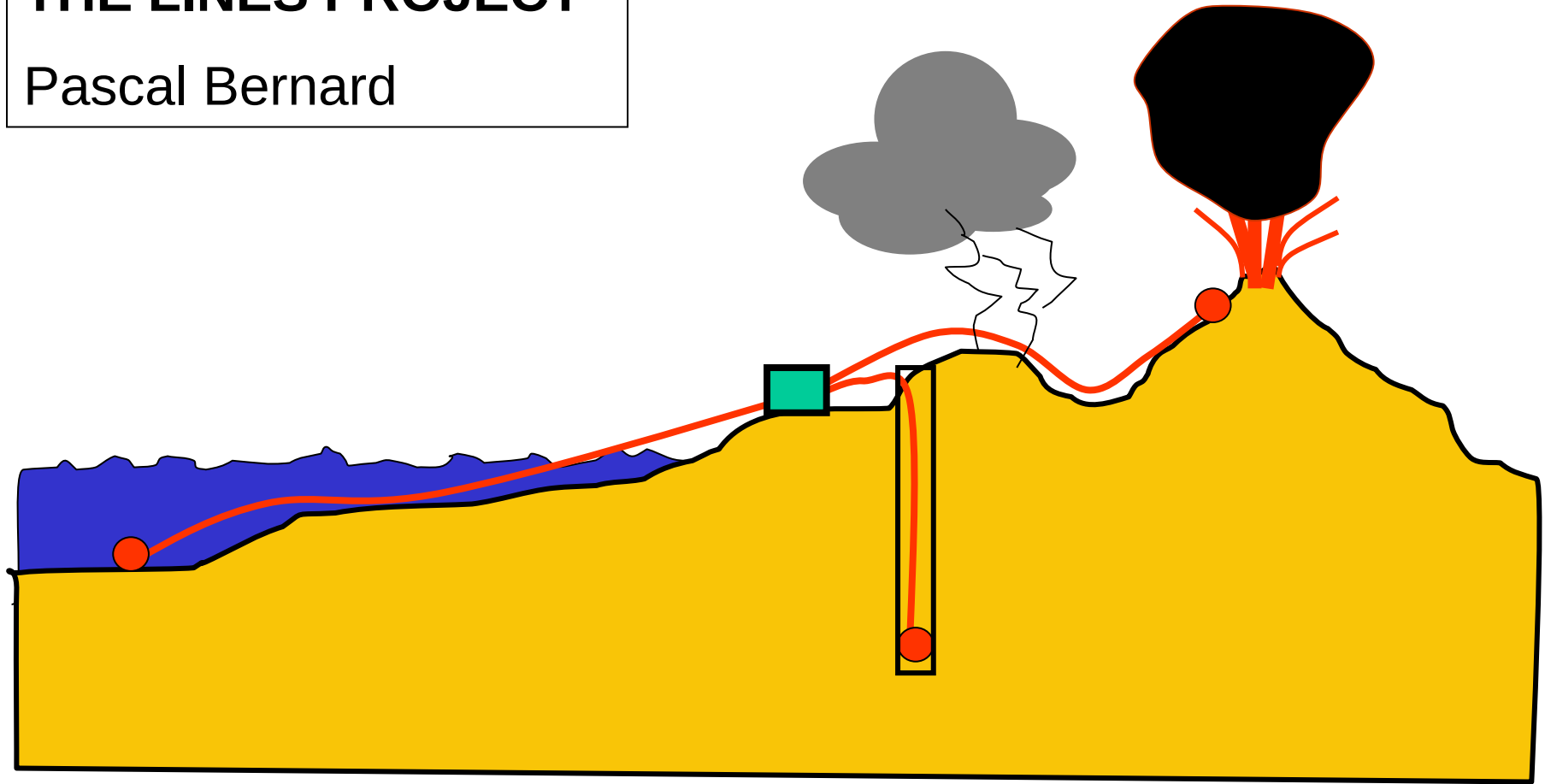


THE LINES PROJECT

Pascal Bernard



HIGH RESOLUTION GEOPHYSICAL MONITORING IN CHALLENGING CONDITIONS

Far offshore, deep boreholes, volcanoes, mountains, landslides...

LINEs project:

Development of high-resolution opto-mechanical geophysical sensors

Seismometer, tiltmeters, strainmeters, etc...

For monitoring telluric hazard

Géosciences Montpellier: J. Chery, F. Boudin

borehole and long base tiltmeter

IPGP (Paris) – P. Bernard, A. Nercessian, C. Brunet

Seismometry

OSE-LAAS (Toulouse) H-C Seat, M. Cattoen

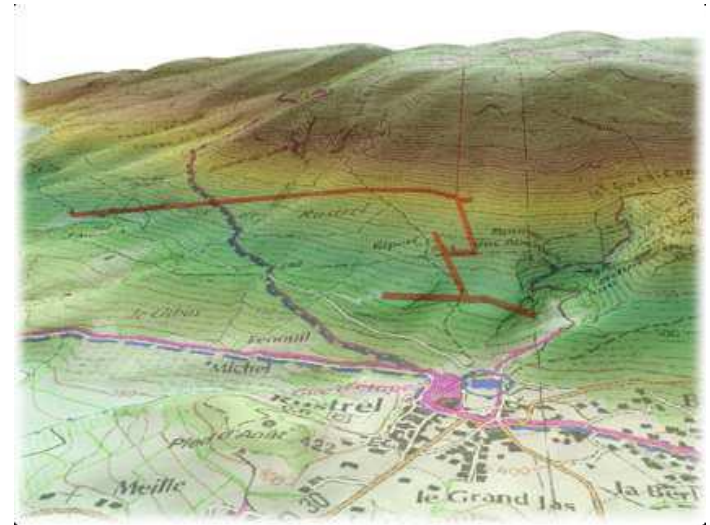
opto-electronics

ESEO (Angers) – G. Plantier, A. Sourcie

Signal processing

LSBB (Nice) - S. Gaffet

Site for underground tests

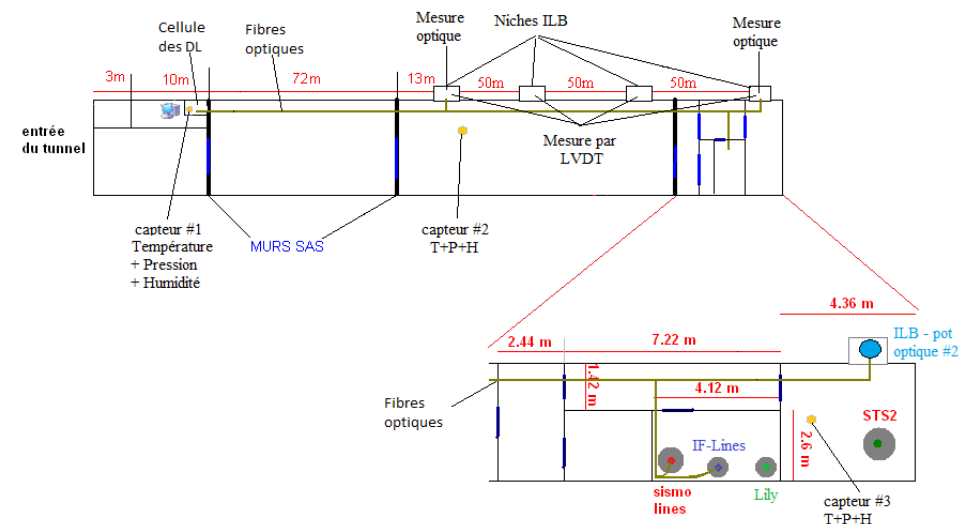


Since 2012

3 prototypes at

Laboratoire Souterrain à Bas Bruit de Rustrel (LSBB)

- 1 seismometer
- 1 borehole tiltmeter
- 1 long base hydrostatic tiltmeter



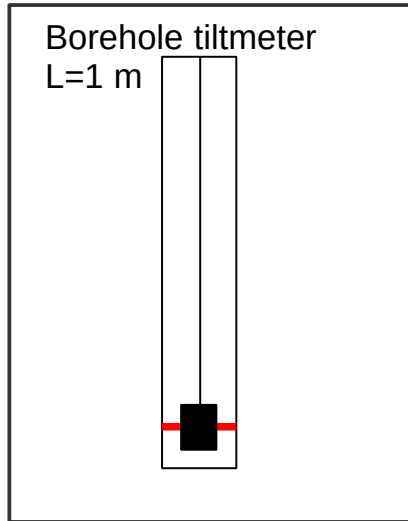
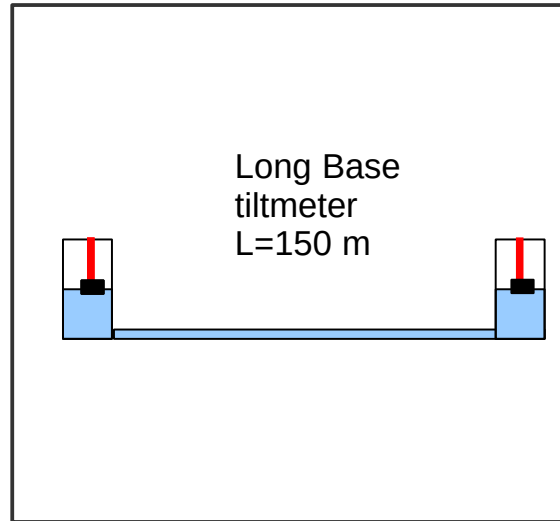
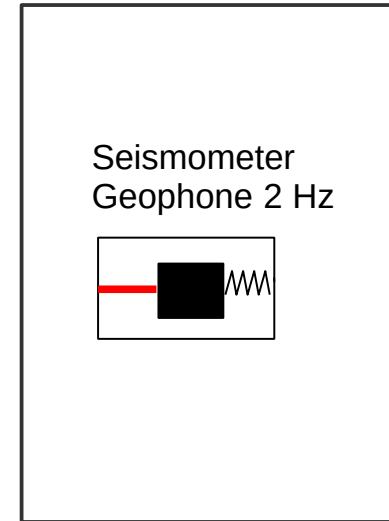
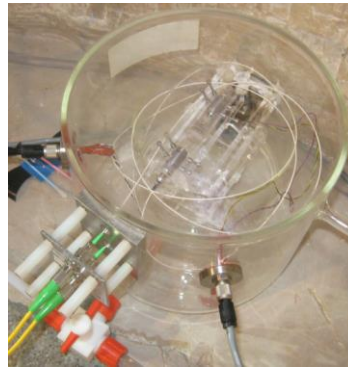
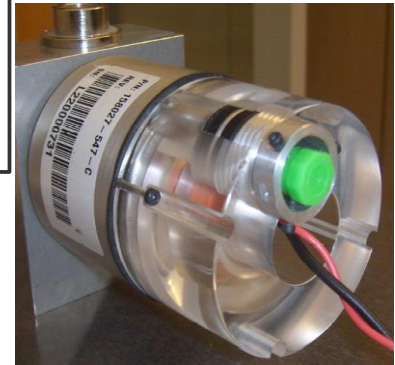
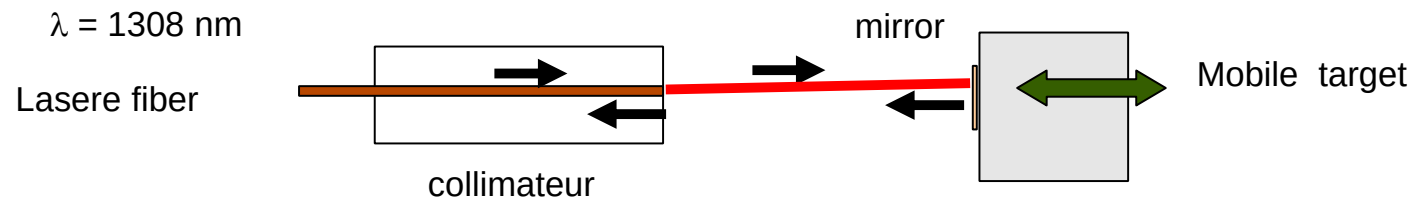
Optical interferometry for measuring displacement

Reaches the best accuracies of commercial instruments (**<0.1-1 nm**),
with the advantages

- + the optical fiber between mechanical sensor and optical system can be several km long
- + better stability with time (no electronic drift at the sensor)
- + long fiber insensitive to EM perturbations (lightning, telluric currents, industrial environment, high voltage power lines...)
- + small size mechanical sensor
- + sensor less sensitive to high temperature (no electronic component)
- + sensor simple, robust, and unexpensive

**Application for natural hazard monitoring in difficult environment:
far offshore, deep borehole, mountain/volcanoes,...**

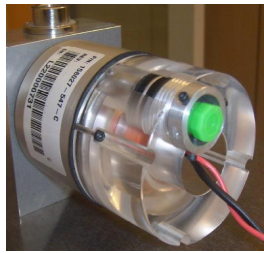
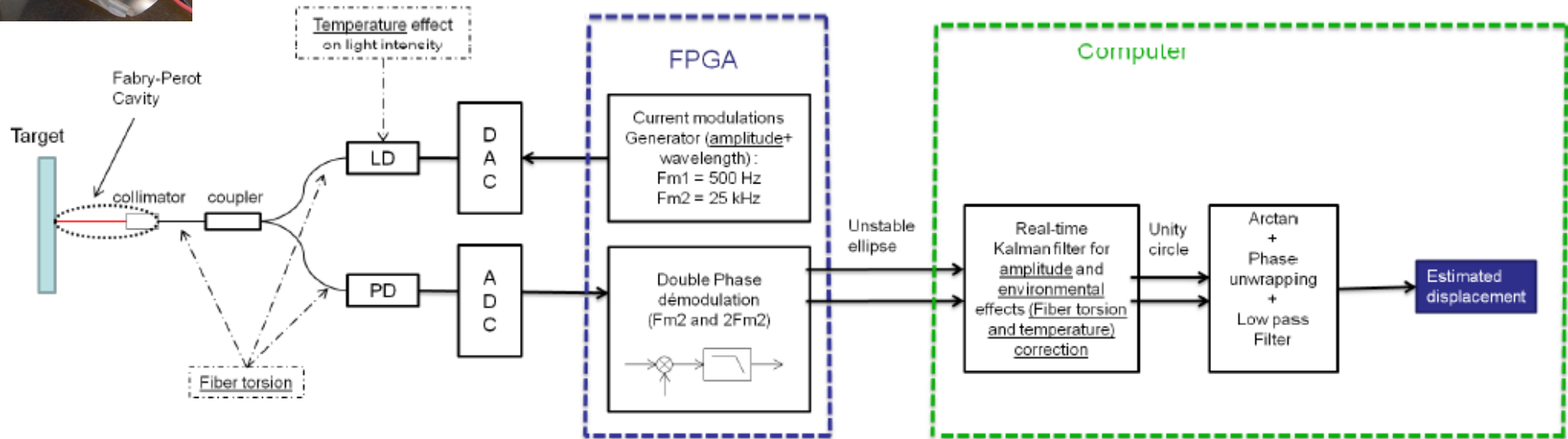
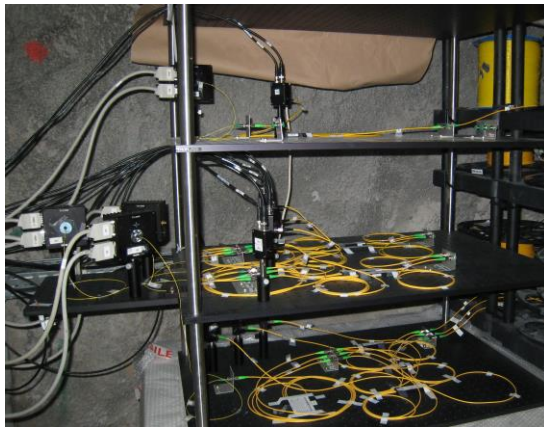
Prototypes of the LINES sensors



Fabry-Pérot cavity : **Interference** of the 2 reflected beams

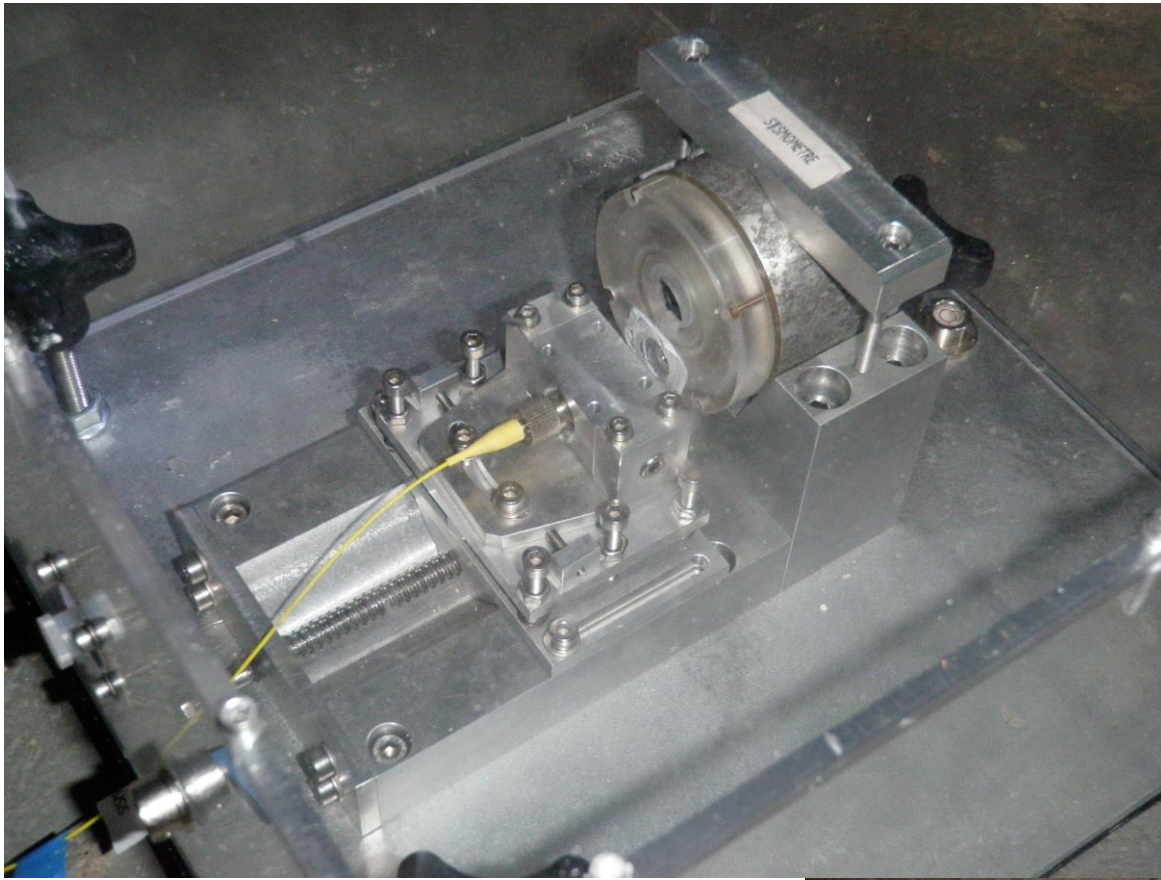
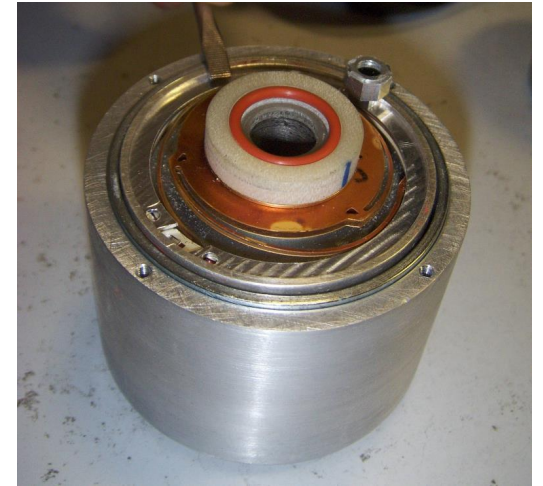
Principle of the instrument: analyse phase of two beams in quadrature $\pi/2$

Current generation and modulation + laser diod + fiber + optomechanical sensor + fiber + photodiod + demodulation + real-time calculation of target displacement on computer



OPTICAL SEISMOMETER

with 3 km fiber

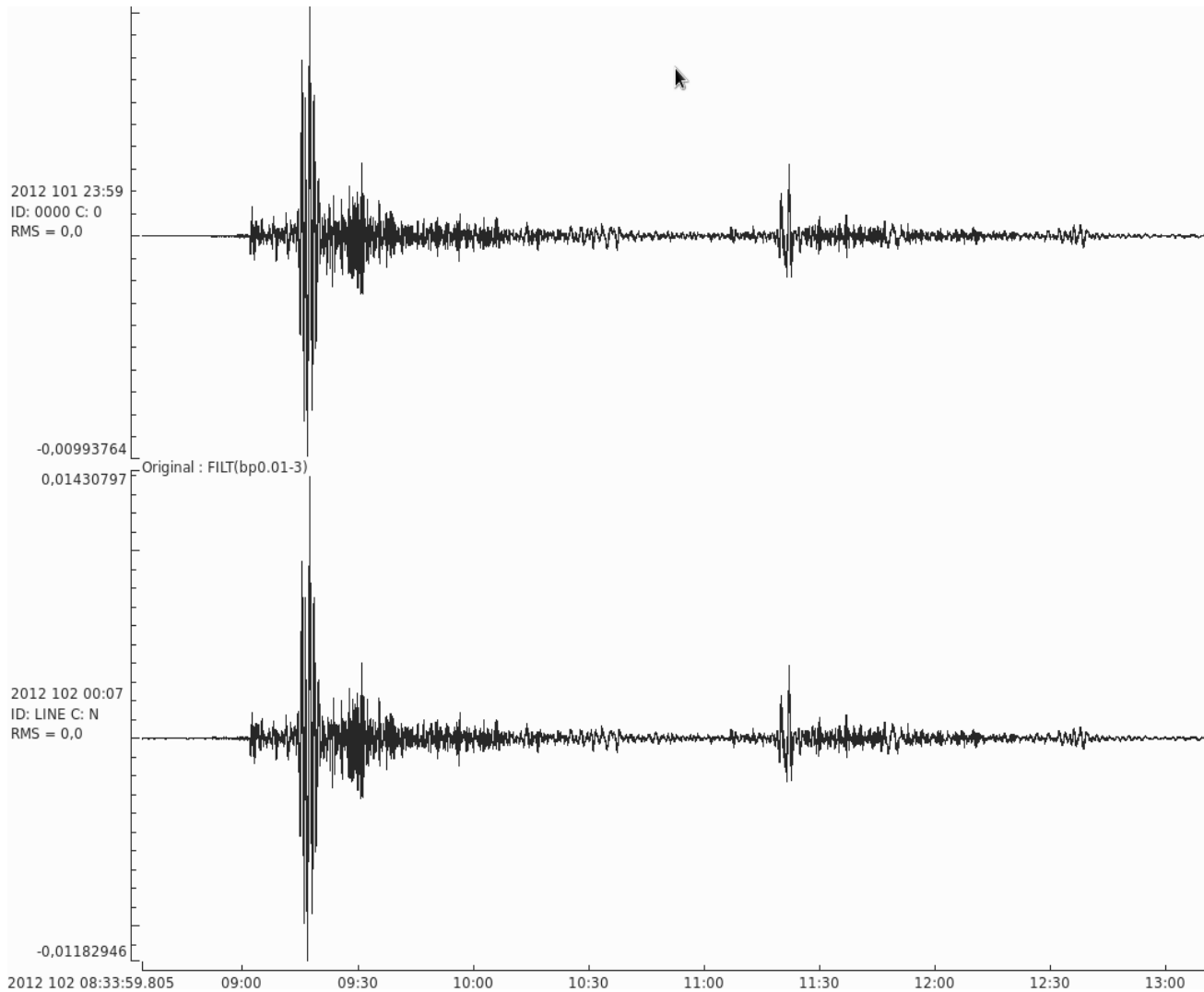


Geophone 2 Hz
+ fiber optics ar LSBB



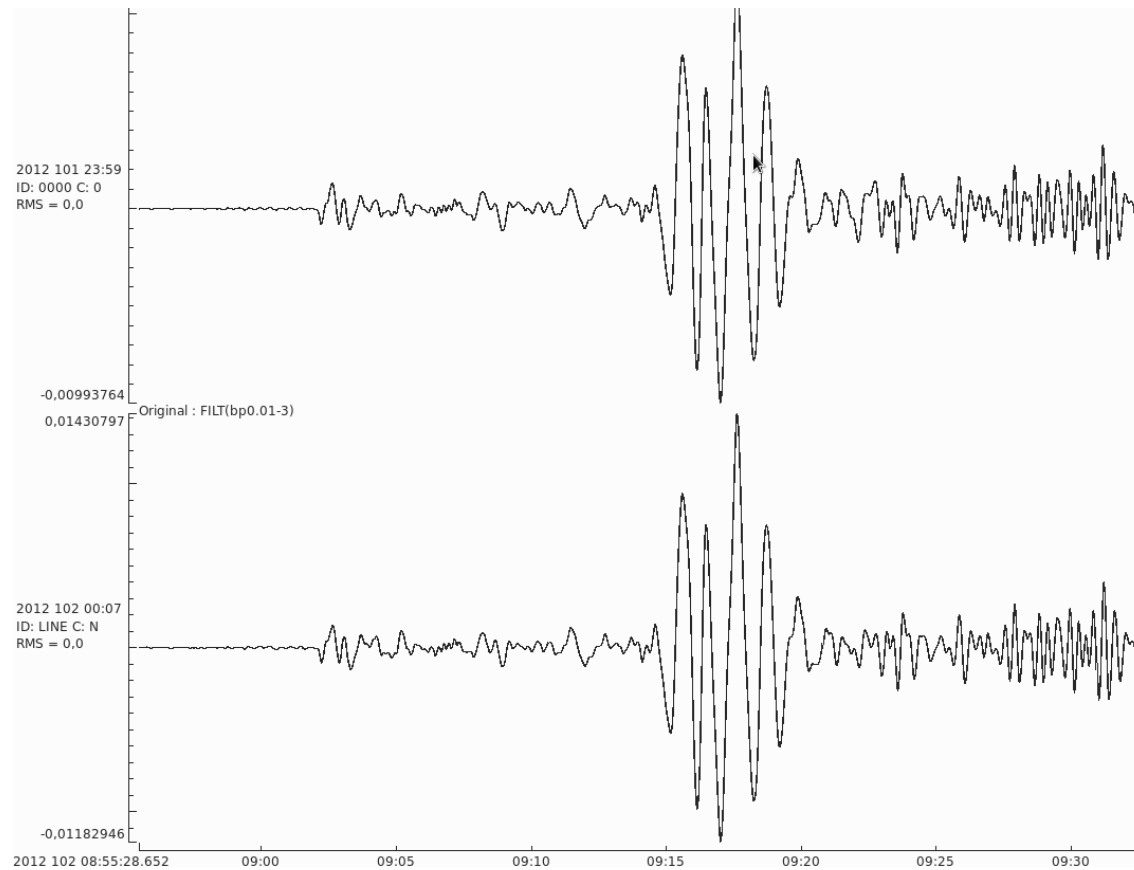
N displacement (m) for the Sumatra M=8.7 earthquake at LSBB

4 hours, frequency 0.01 – 3 Hz



N displacement (m) for the Sumatra M=8.7 earthquake at LSBB

30 minutes , frequency 0.01 – 3 Hz



STS2

GAS

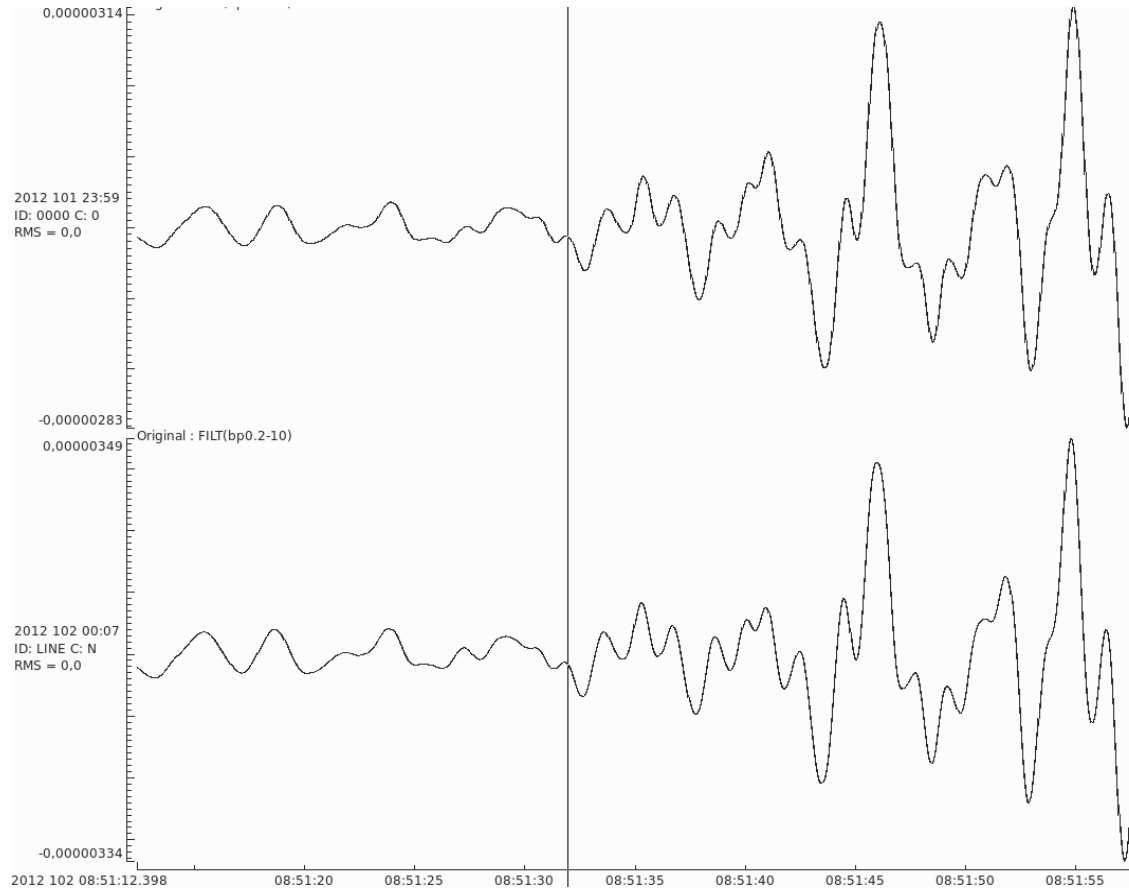
LASER
SEISMOMETER

3 km long fiber

Geophone 2 Hz

N displacement (m) for the Sumatra M=8.7 earthquake at LSBB

50 seconds, frequency 0.1 – 10 Hz



STS2

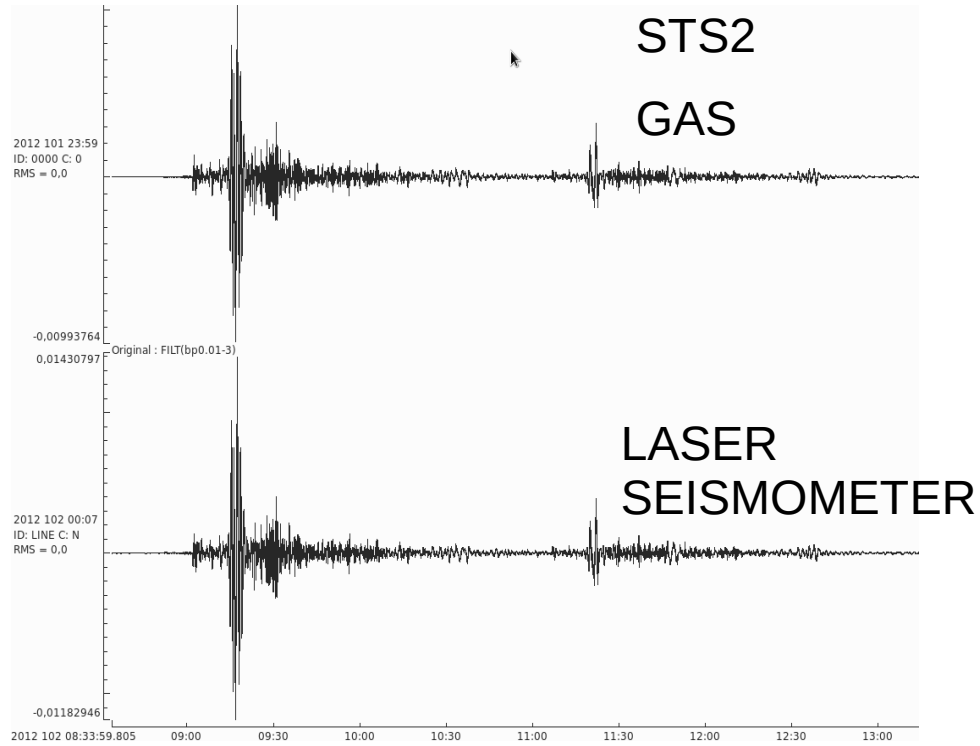
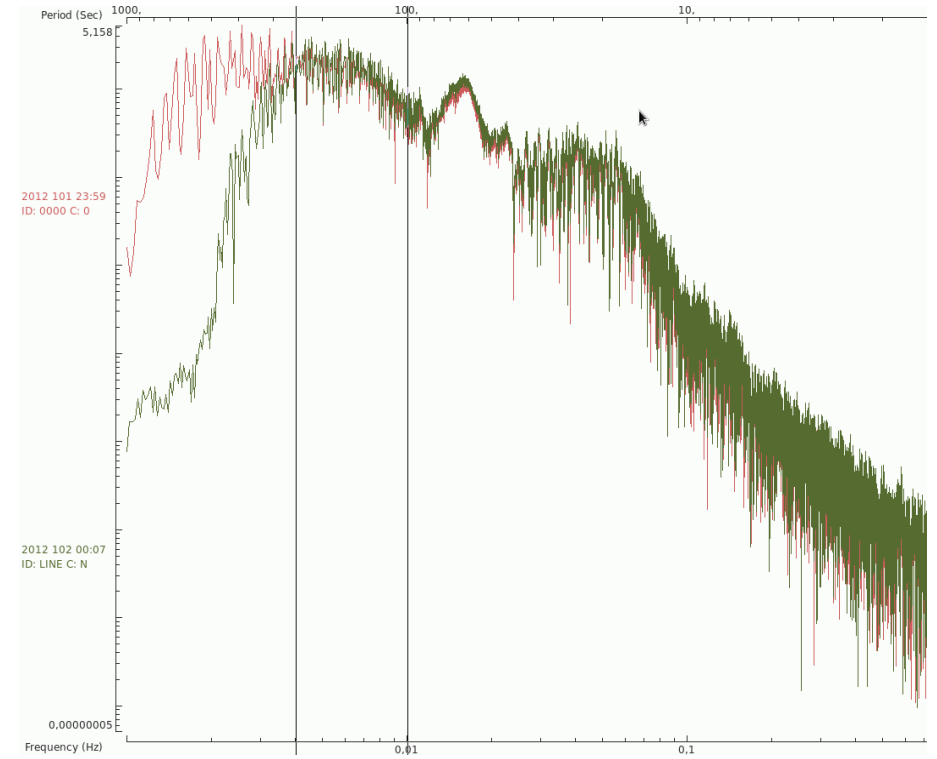
GAS

LASER
SEISMOMETER

3 km long fiber

Geophone 2 Hz

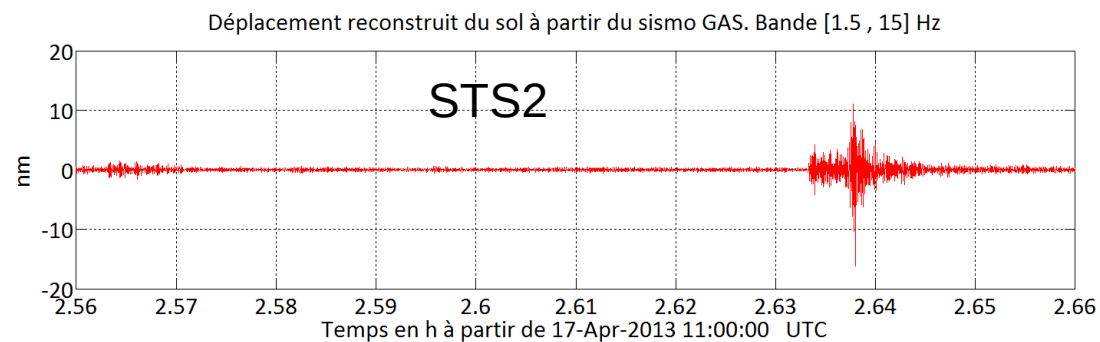
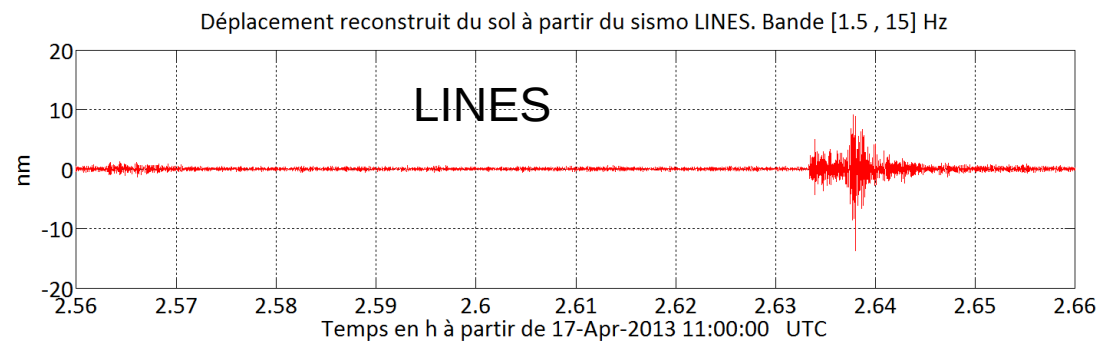
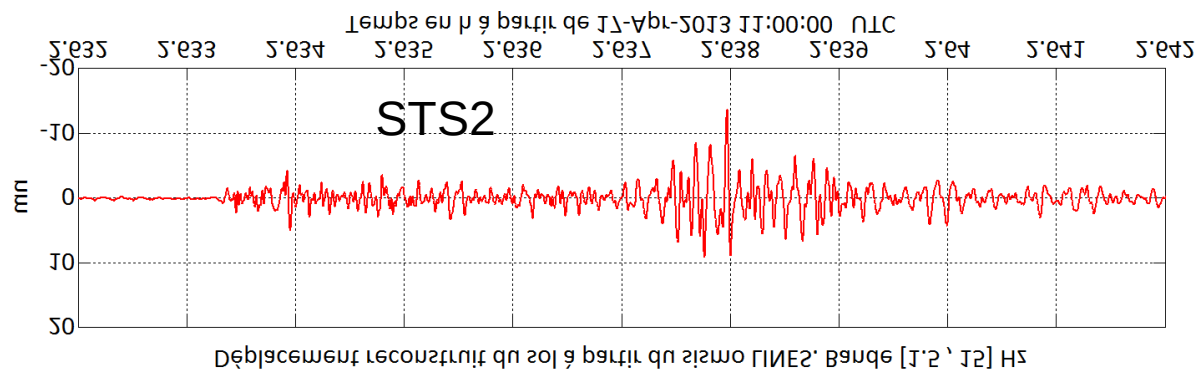
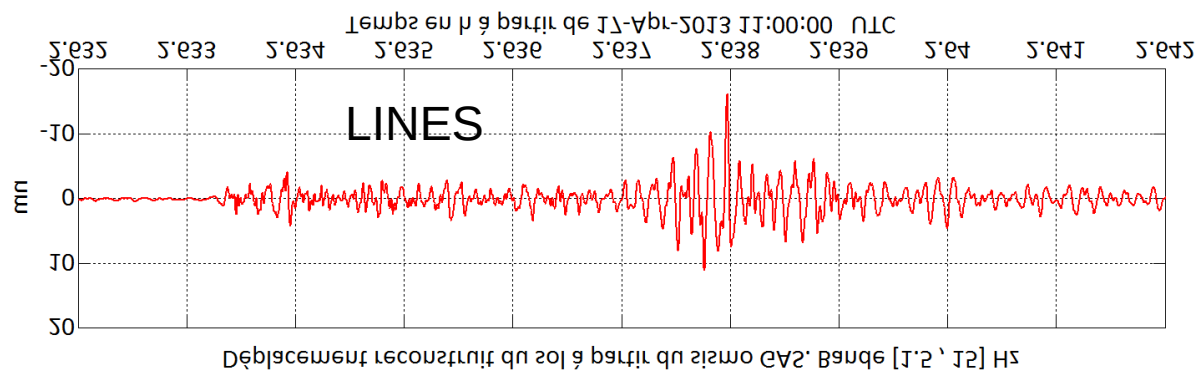
N displacement (m) for the Sumatra M=8.7 earthquake at LSBB





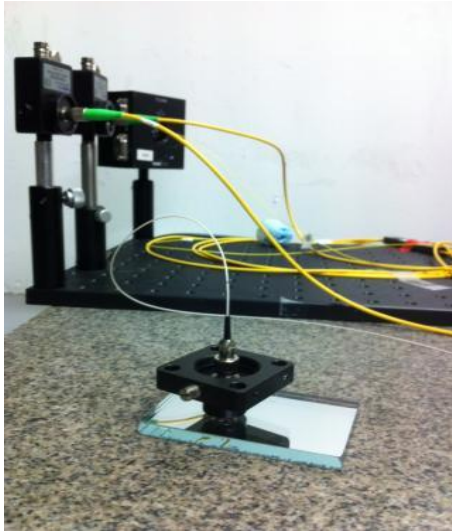
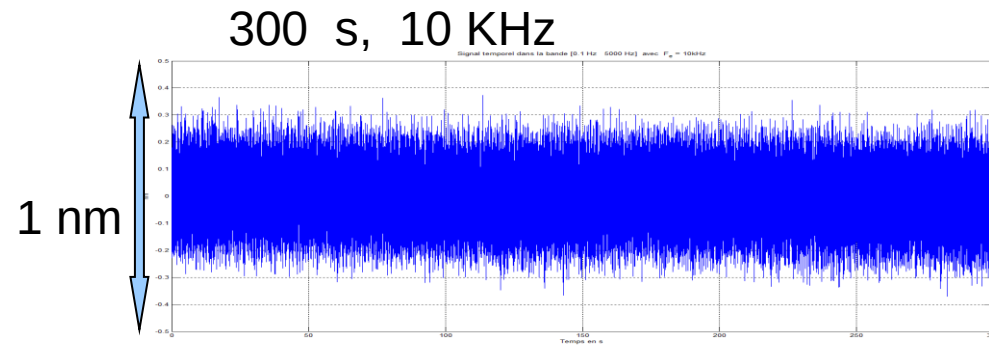
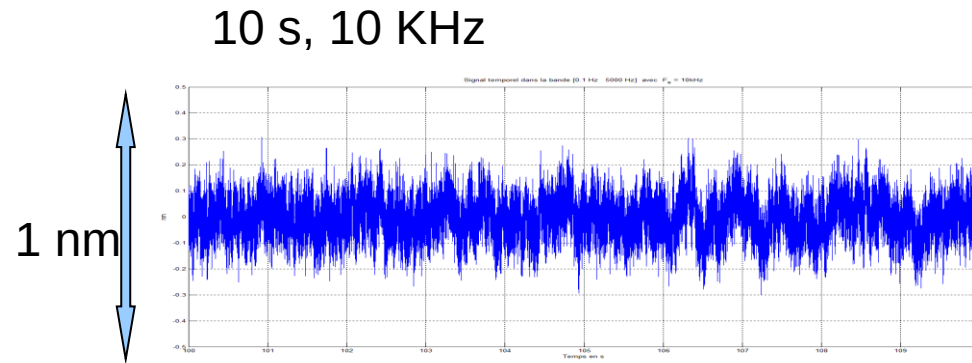
M=2.5, d=100 km

Filter 1-15 Hz



Recording at High frequency

Instrumental Noise 0.1- 5 KHz: Tests with fixed target

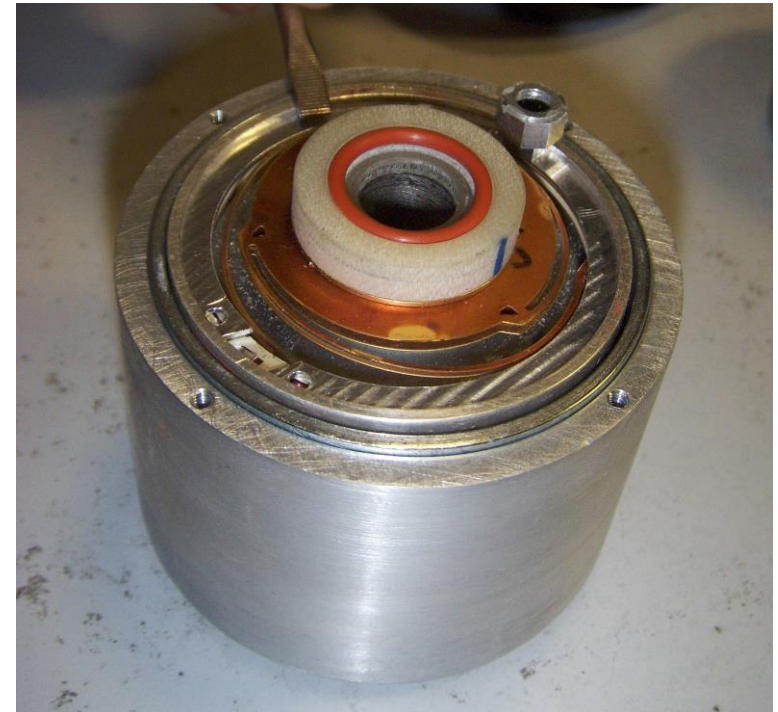


real-time acquisition and processing at 10 KHz
has been validated at LSBB

Geophone LINES

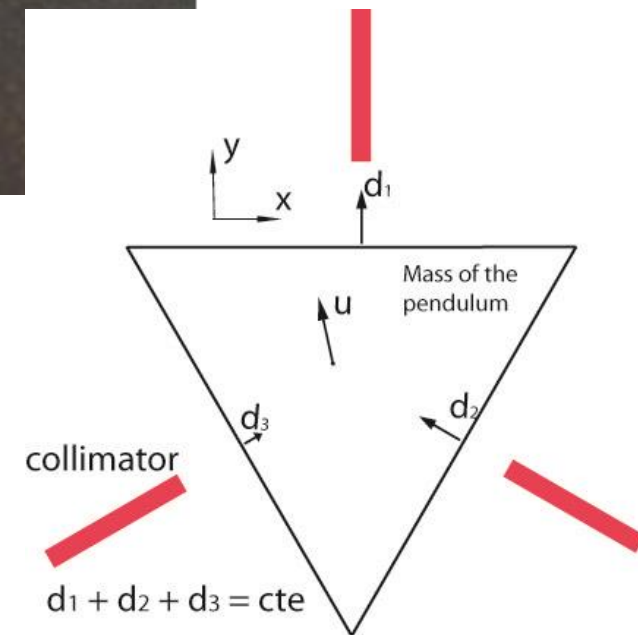
In development:

**3 component prototype for
offshore and borehole installations**



BOREHOLE TILTMETER

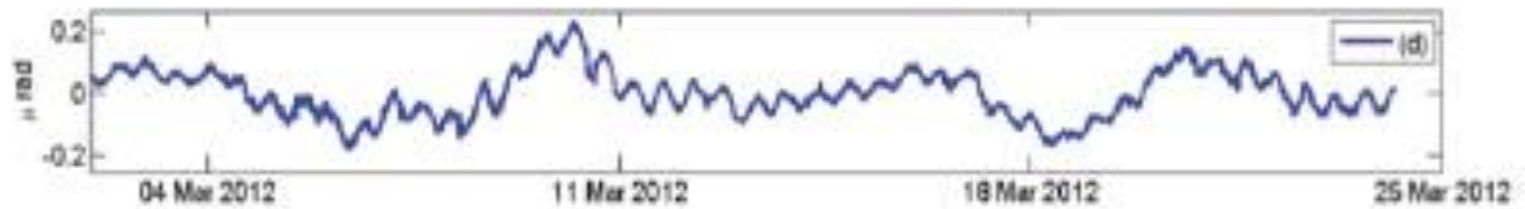
Borehole tiltmeter: pendulum & optics



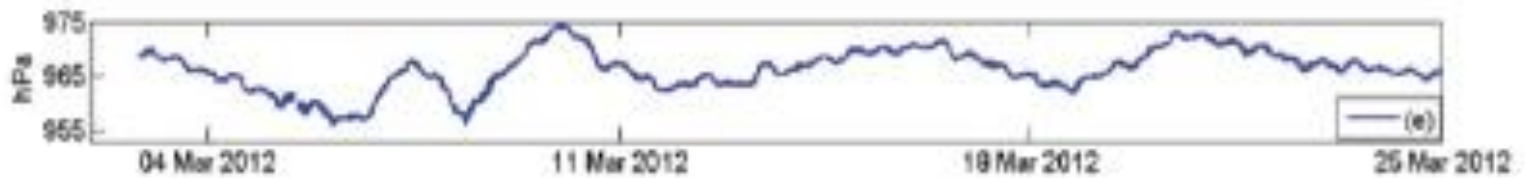
Tilt
Optical
Borehole Tiltmeter

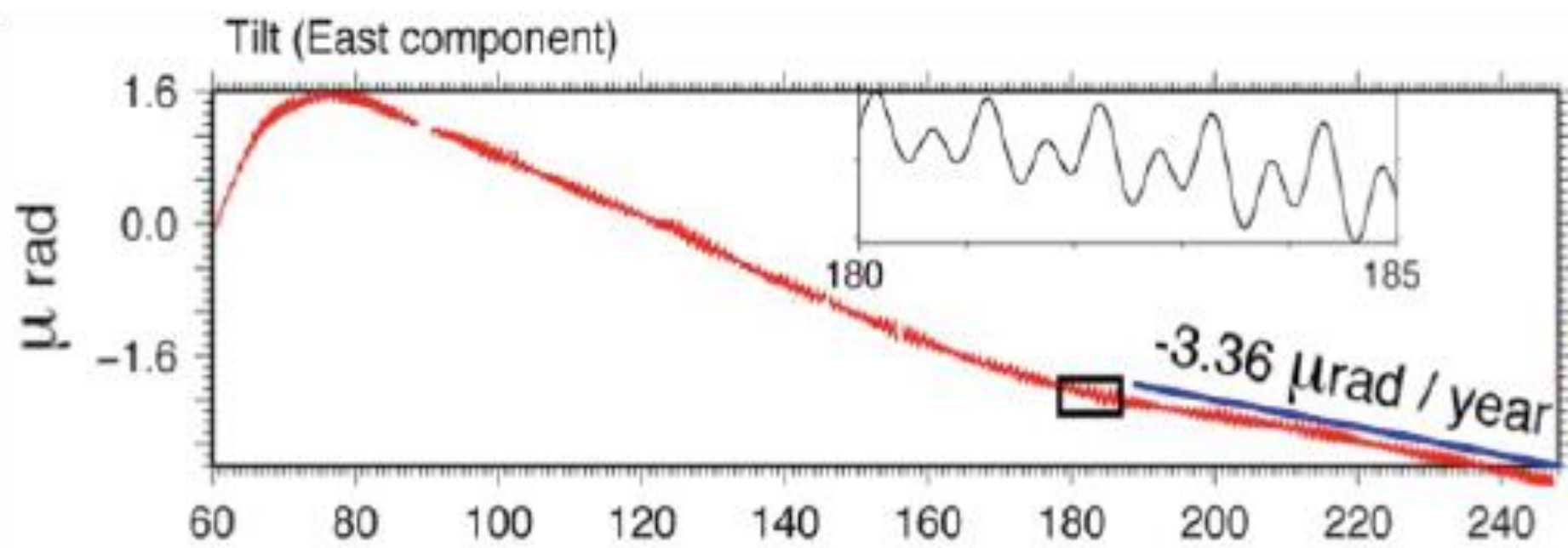


Tilt Lily



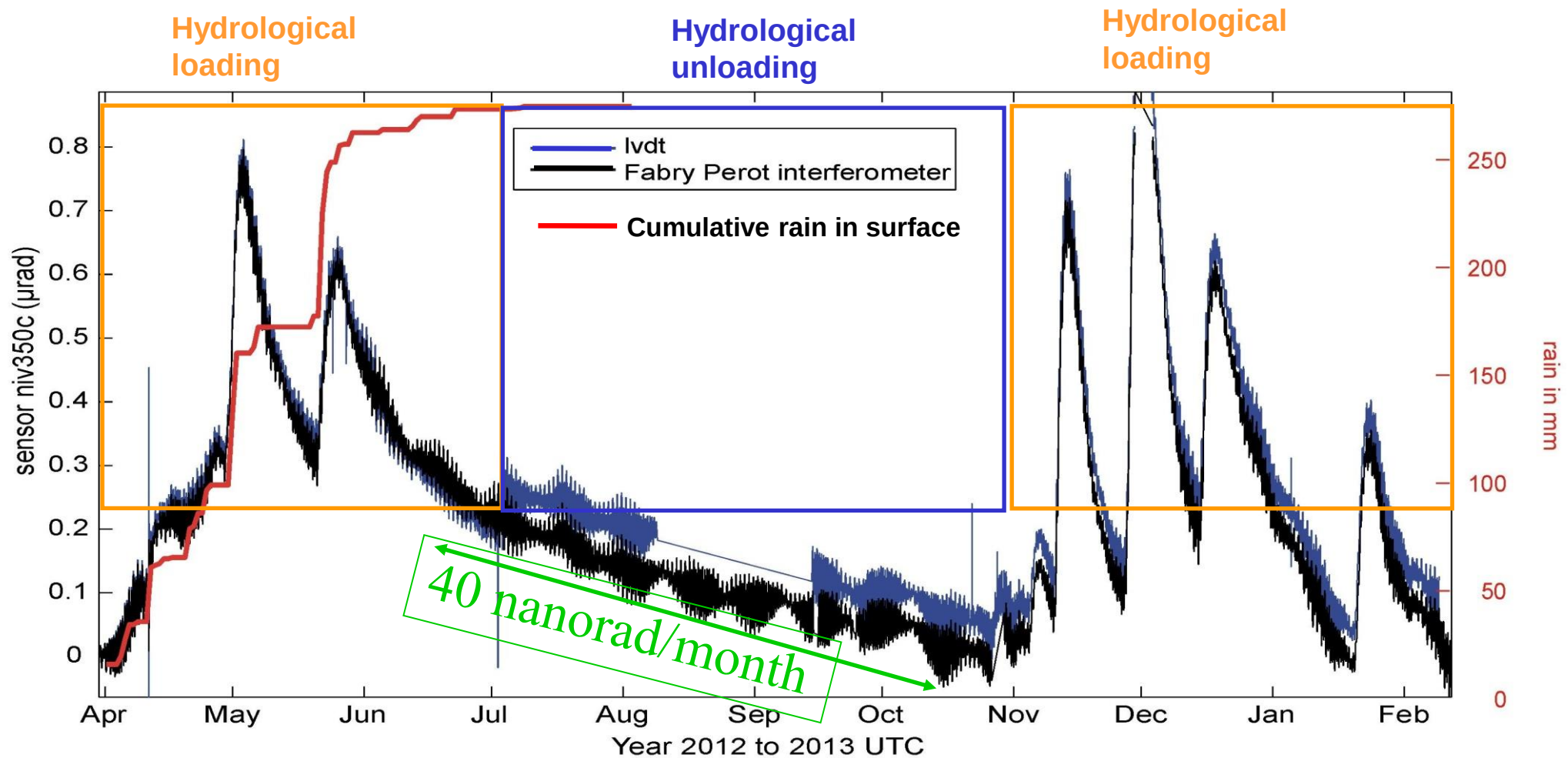
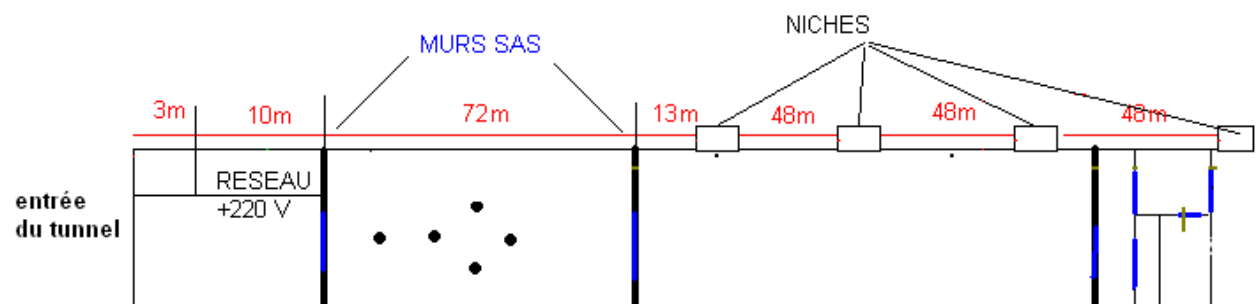
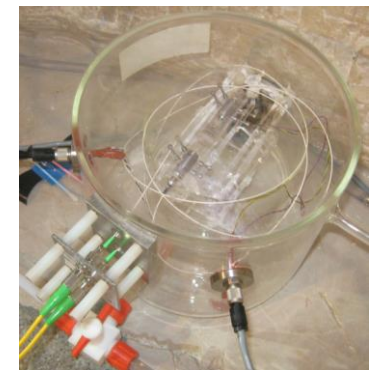
Atmospheric
pressure

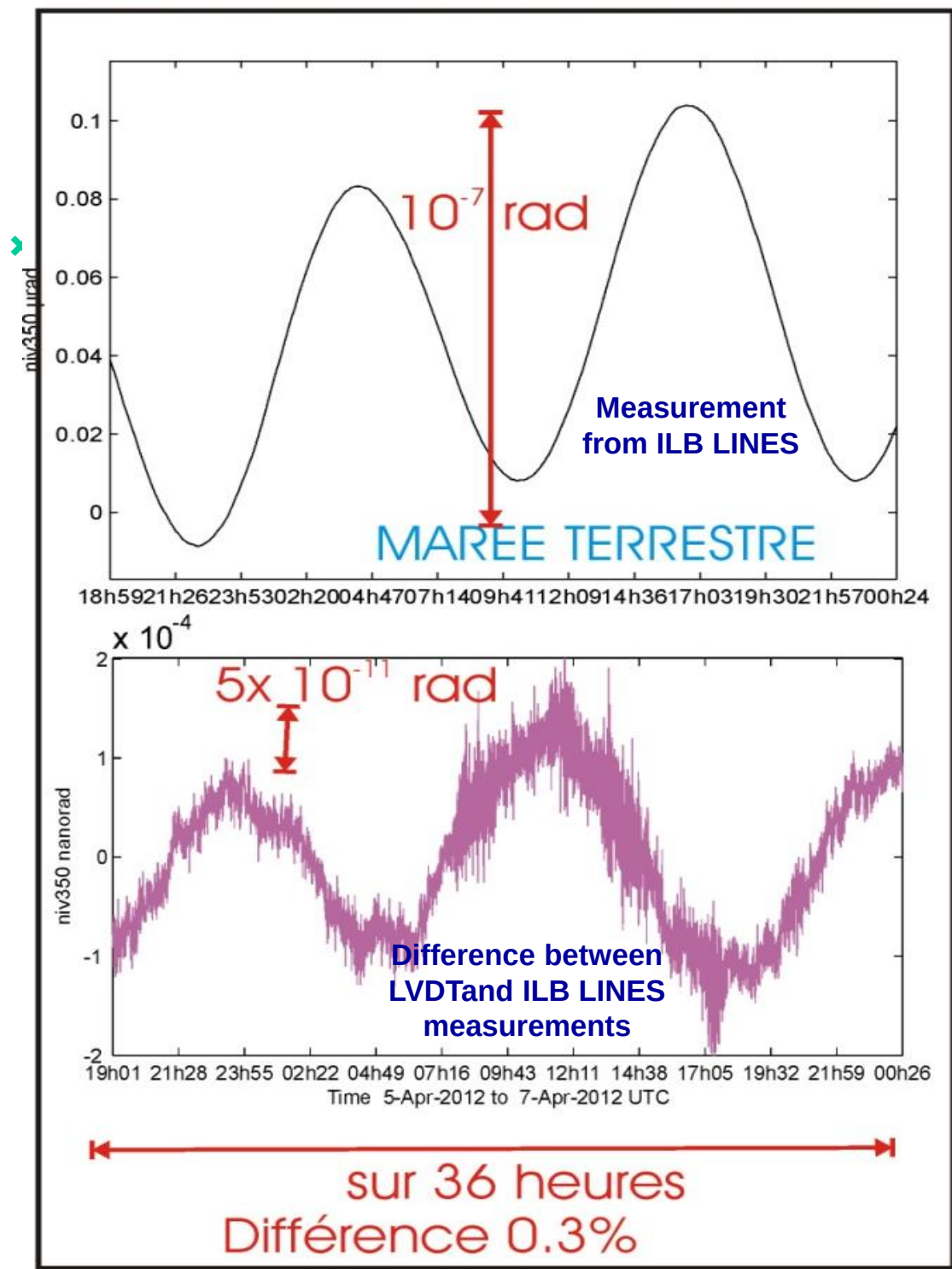


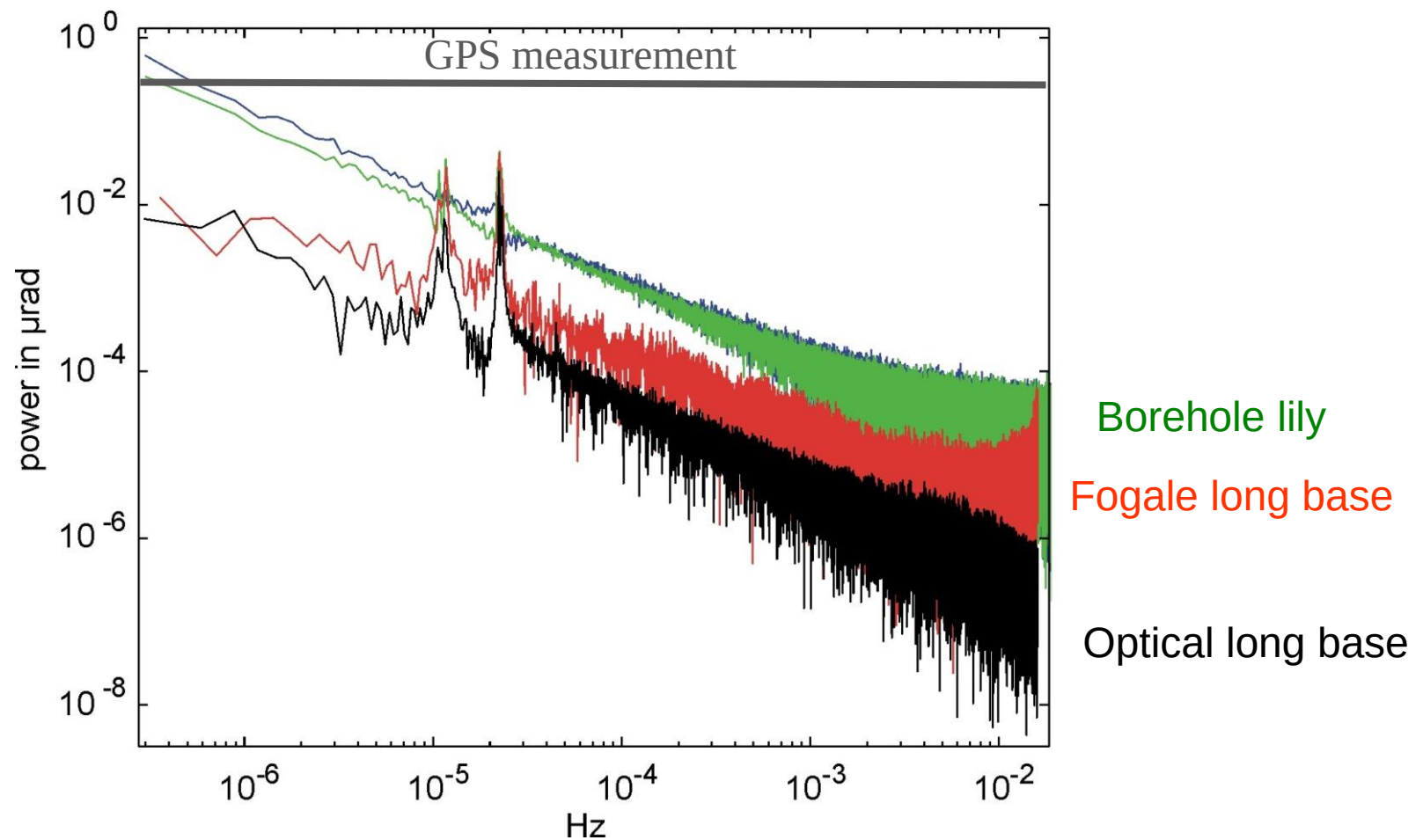


LONG BASE TILTMETER

Comparison between optical and LVDT measurement





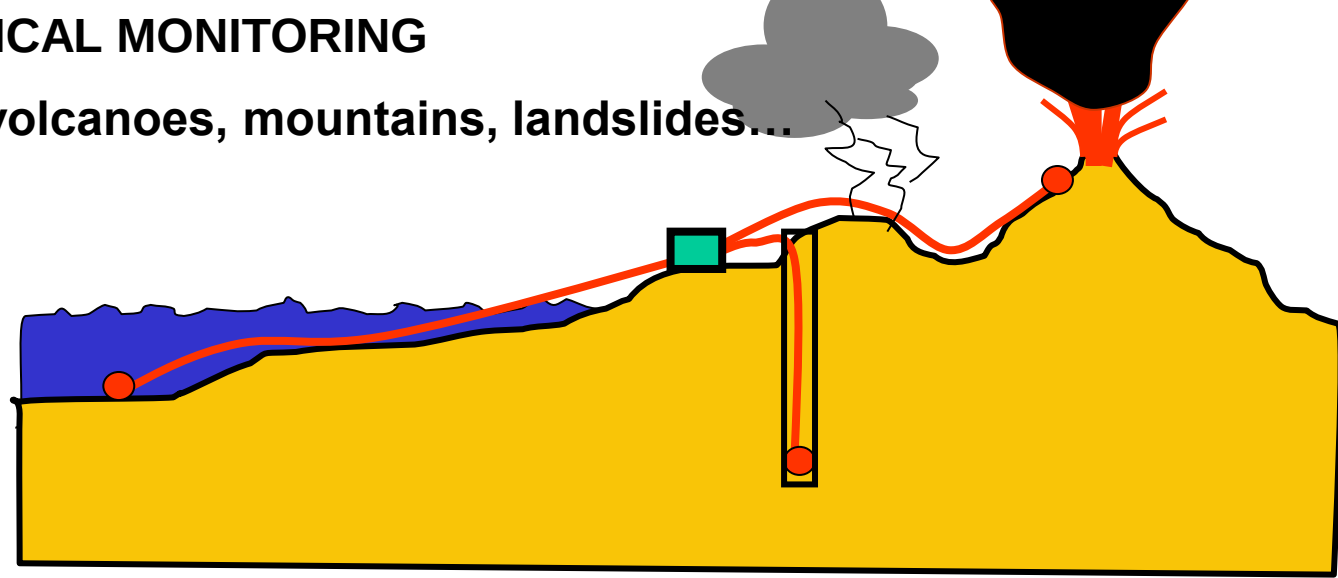


- ILB 140 m Fogale capacitive sensor used by the CERN
- ILB 150 m optical sensor LOSE used in LSBB site
- best commercial borehole tiltmeter (example LILY)
- GPS measurement

HIGH RESOLUTION GEOPHYSICAL MONITORING

Far offshore, deep boreholes, volcanoes, mountains, landslides...

LASER INSTRUMENTATION



- Optical noise < 10^{-10} m

- Seismometer:

- 2 Hz geophone resolves earth noise up to 5 s
- can work at 10 KHz
- 3 km fiber (rolled, equivalent to 10 km unrolled)

- Tiltmeter:

- long base tiltmeter (150 m long) , resolution better than 10^{-10} radians
- borehole tiltmeter (1 m long), 10^{-9} radians

Applicability for :

- monitoring natural hazards
- Industry: exploration and monitoring of reservoirs, geothermy, deep mines, ...