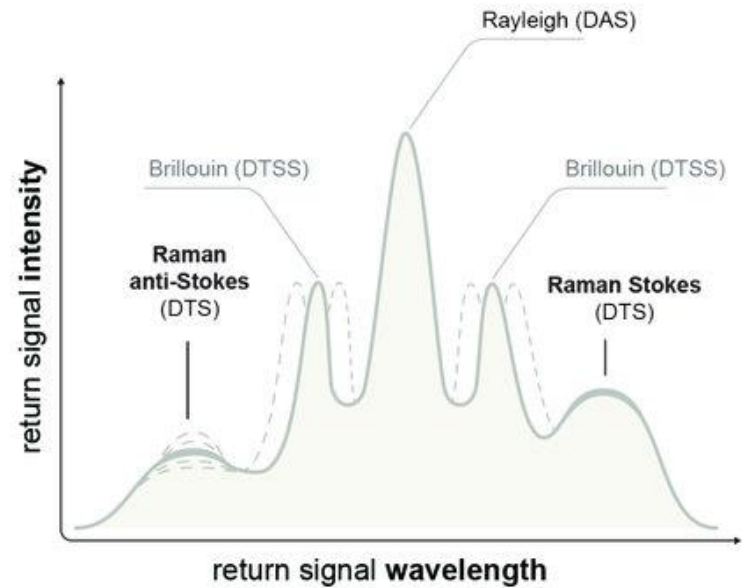
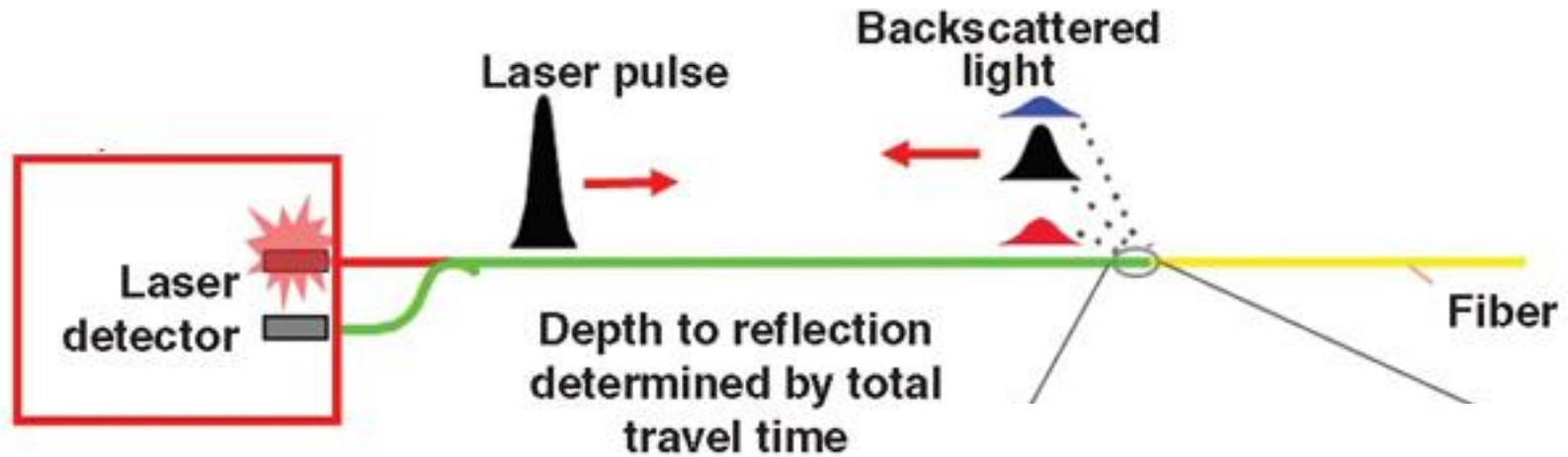


La Fibre optique comme capteur

Olivier Coutant (Isterre) / Diane Rivet (GéoAzur)

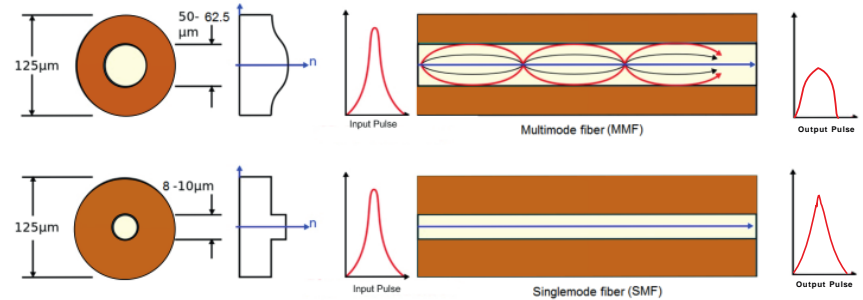
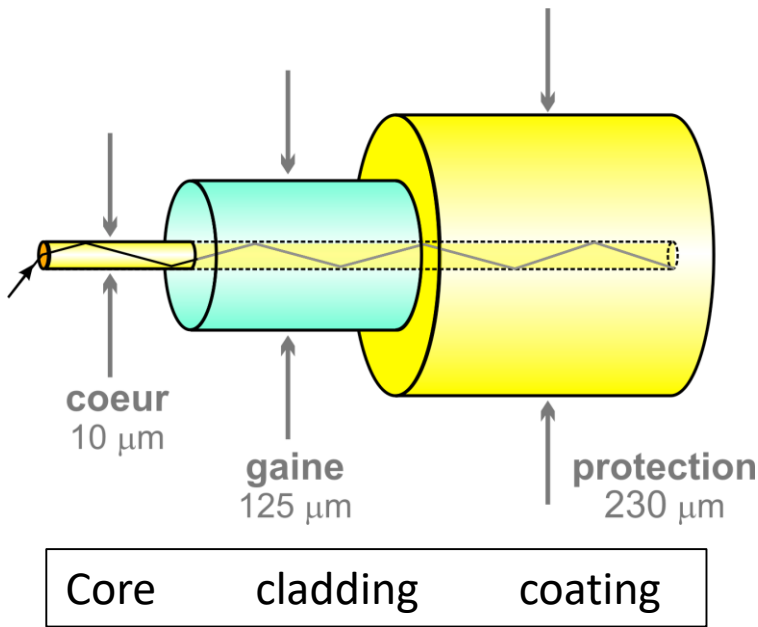
Principe de la mesure



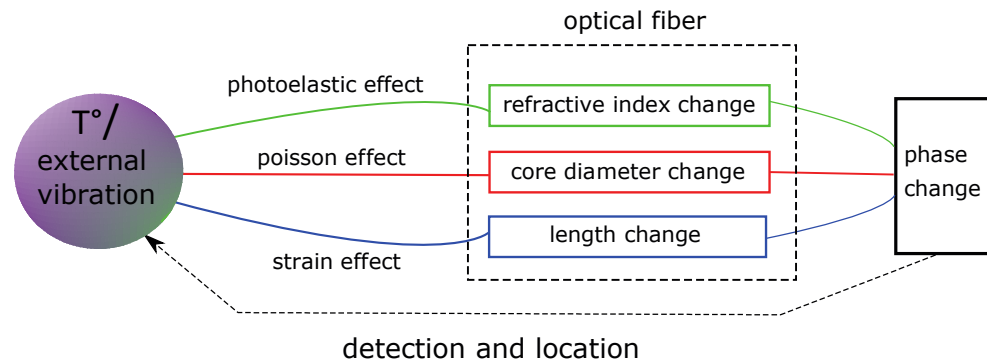
Rayleigh: diffraction élastique

Brillouin, Raman: diffraction anélastique
décalage en longueur d'onde

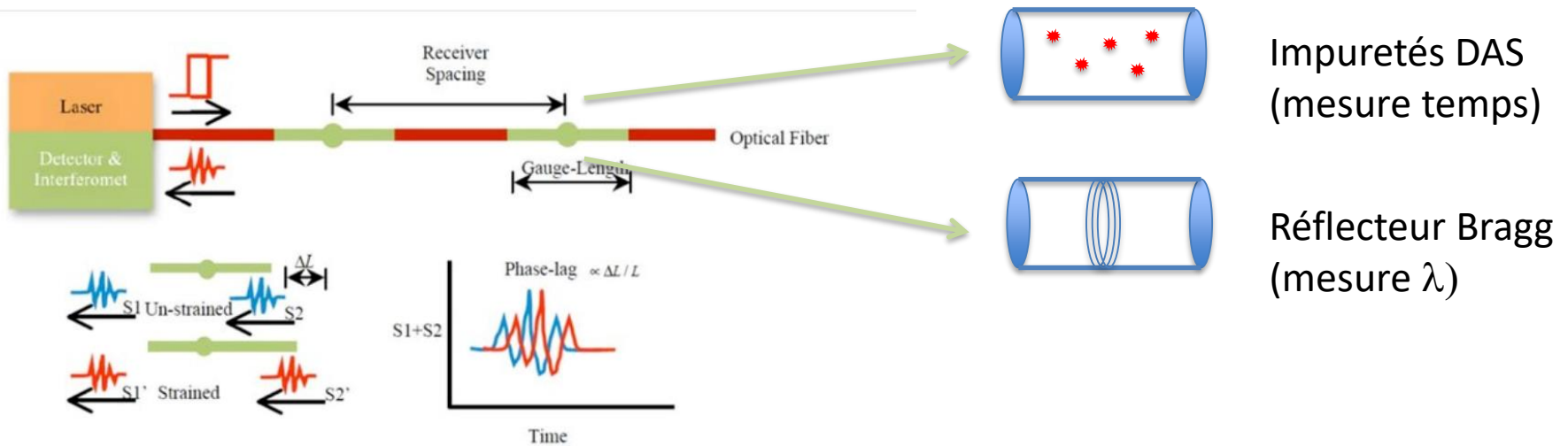
A quoi la fibre est-elle sensible?



Diffraction Rayleigh



A quoi la fibre est-elle sensible?



Sensibilité ramenée à une déformation

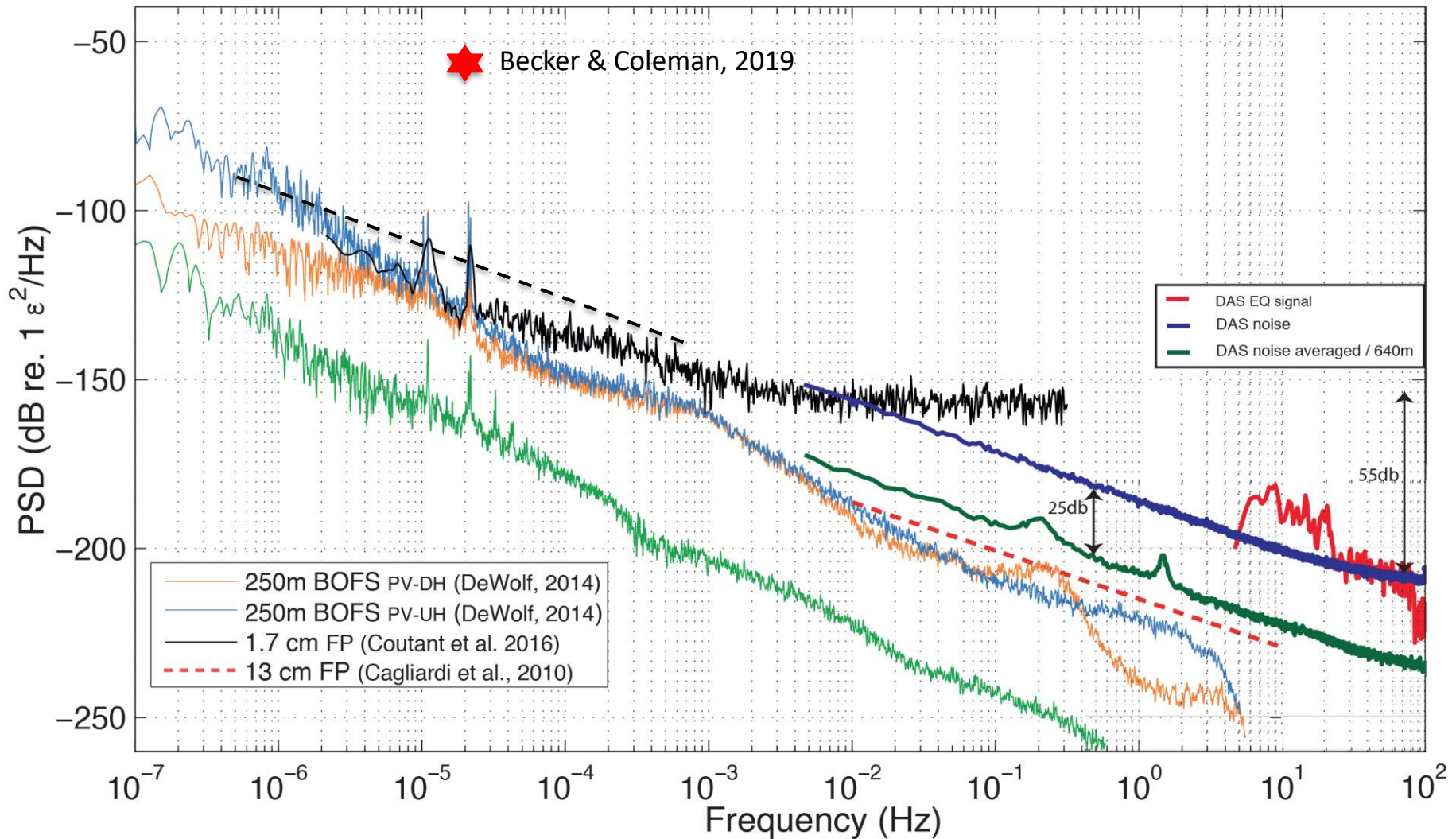
Température (indice)	$7.8 \mu\epsilon / ^\circ\text{C}$
Déformation (élongation+indice)	$\dot{\epsilon}_{mes} = 0.78 \dot{\epsilon}$
Pression (indice)	$0.3 \mu\epsilon / \text{bar}$

A quoi la fibre est-elle sensible?

- Les fibres monomode atténue la lumière avec la distance, **utilisable jusqu'à 50km**
- À 50km, le pas d'échantillonnage min est de $2 * 50 \text{ km} / 2.e5 \text{ km/s} = 50\text{msec} \Leftrightarrow \text{2kHz}$
- Longueur de gauge typique **10/20m**
- Un capteur tous les mètres sur 1 km @ 2KHz
1 journée ~ 1To de données

Niveau de bruit

La résolution est inversement proportionnelle à la longueur de mesure



Exemple: enregistrement « Large-bande », moyenne sur 1200m

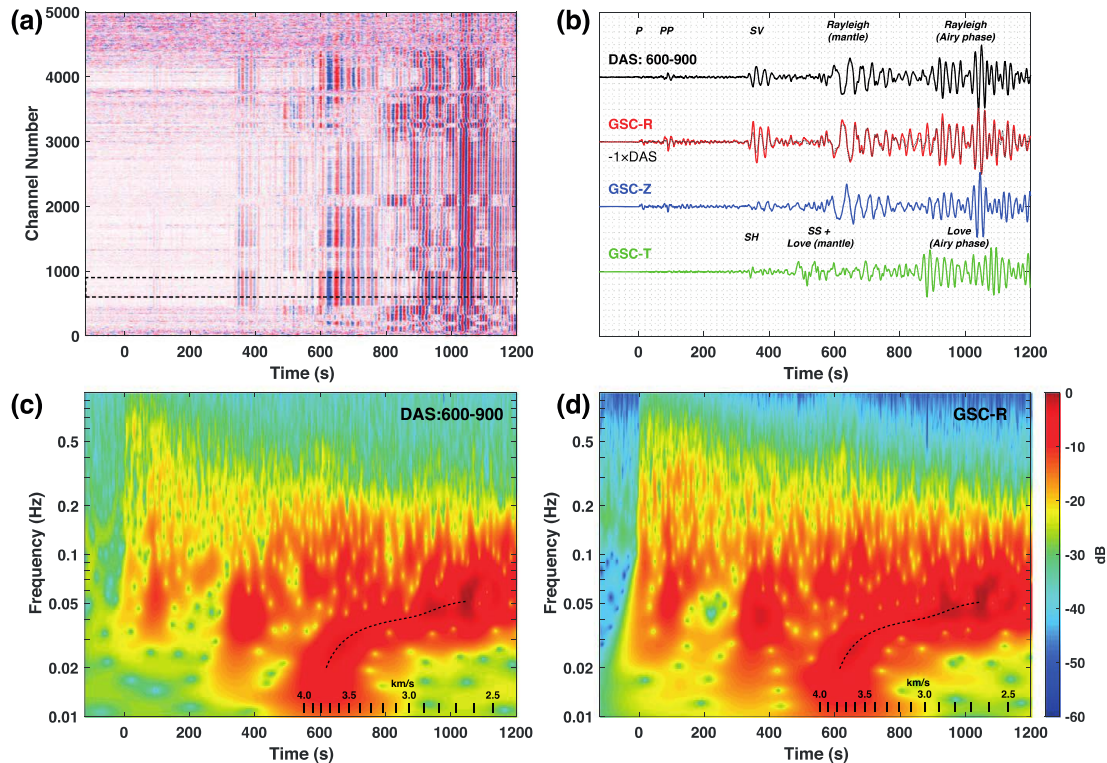


Figure 2. Data from the 2018 M7.5 Honduras earthquake recorded on DAS channels and GSC broadband seismometer. (a) Waveform data of all ~5,000 DAS channels from the Goldstone Optical Fiber Seismic experiment. The channel spacing is 4 m. (b) Comparison between selected DAS strain and GSC particle velocity. The GSC waveforms are rotated into vertical, radial, and tangential components after removing the instrument response. Waveforms are band-pass filtered between 0.01 and 2 Hz. Amplitudes are normalized to unity by the peak amplitude of DAS strain and radial GSC velocity, respectively. The selected DAS strain is stacked from channels 600–900. For better comparison, polarity-reversed DAS strain (dash line) is also plotted, overlying the radial GSC velocity. (c, d) The spectrograms of the stacked DAS strain and radial-component GSC velocity, respectively. The dash line tracks the Rayleigh wave group velocity dispersion. The group velocity scale is shown at the bottom. DAS = distributed acoustic sensing.

GRL, 2019, The Potential of DAS in Teleseismic Studies: Insights From the Goldstone Experiment

C Yu , Z Zhan , N. J. Lindsey , J. B. Ajo-Franklin , and M. Robertson, UC Berkeley

Exemple: détection d'une zone de faille

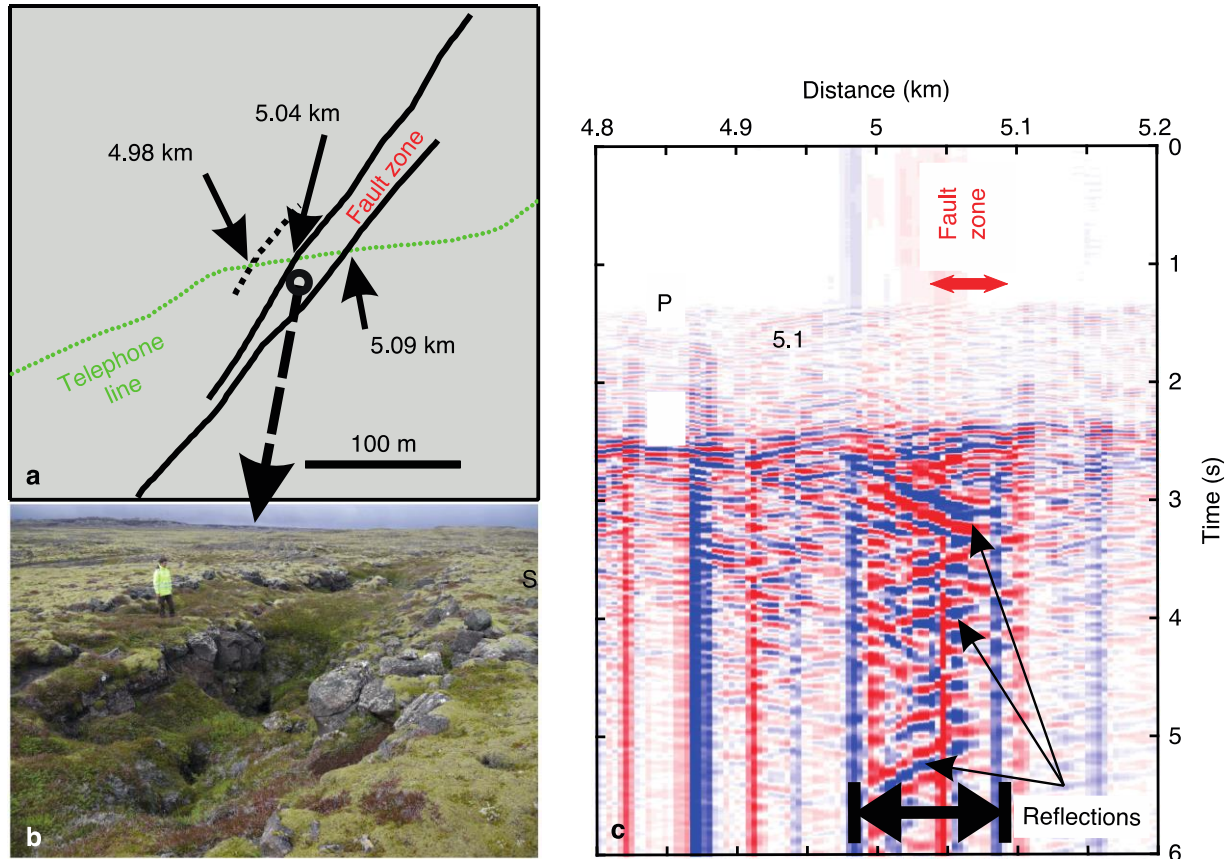


Fig. 7 Structure of a fault damage zone within an active geological rift. The road and the cable (distance ~5 km) cross several faults, e.g. a clearly visible fault zone with more loose material in the field (between 5.04 and 5.09 km). b The fault damage zone is visible by the ~5060 m wide depression area (picture taken at ~100 m SW of the road, looking towards SW). Note that at the cable location no depression area is visible. The depression is only the surface expression at the position of the picture (Picture Martin Lipus, GFZ). c Short record (6 s) of strain phases from a local earthquake (Fig. 5) trapped in the fault damage zone. Phases are reflected until ~4.98 km, which may indicate a hidden fault with surface expression. Waves inside and outside the fault zone have different apparent velocities.

Nature Comm., 2018, Dynamic strain determination using fibre-optic cables allows imaging of seismological and structural features P. Jousset et al. (GFZ)

Exemple d'enregistrement DAS terrestre (FebusOptics & ISTerre)

We have tested during 5 days in September 2018 the DAS interrogator from Fiber-Optics on a commercial telecommunication fiber operated by Fibrea-Covage in the Maurienne Valley, French Alps. The cable runs along the «La Chapelle» active seismic swarm, from the valley to the St François Longchamp ski resort. Several earthquakes were recorded, we show the sections for two events of magnitude 1.2 and 1.4. (g. 1). The Fibrea fiber cable infrastructure (g. 2) is theoretically not favorable to the coupling efficiency between the ground and the optical fiber.

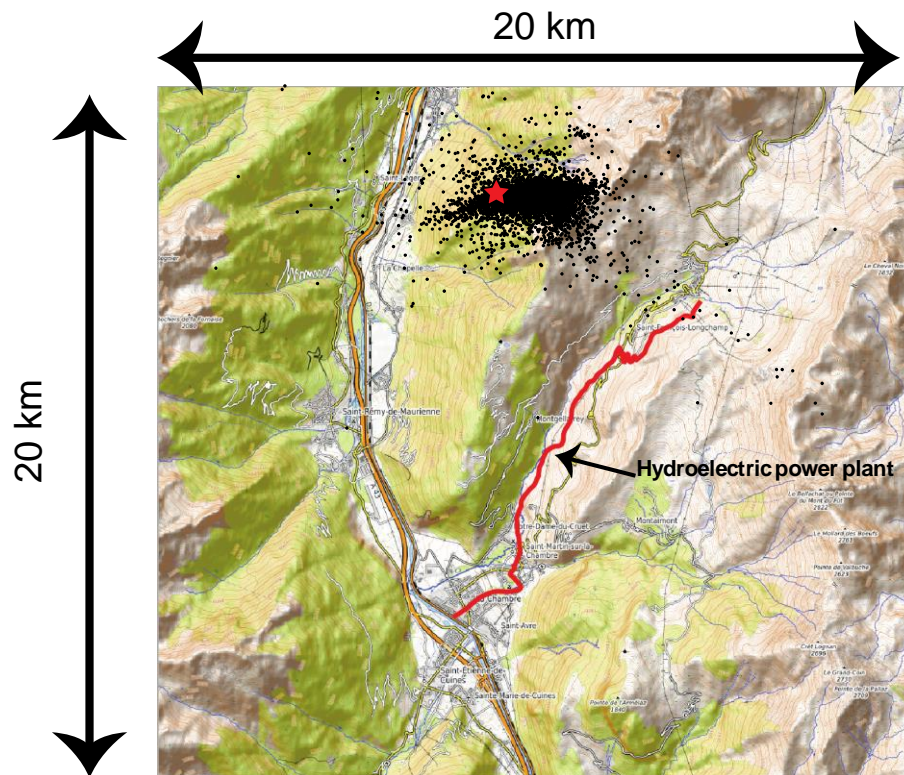


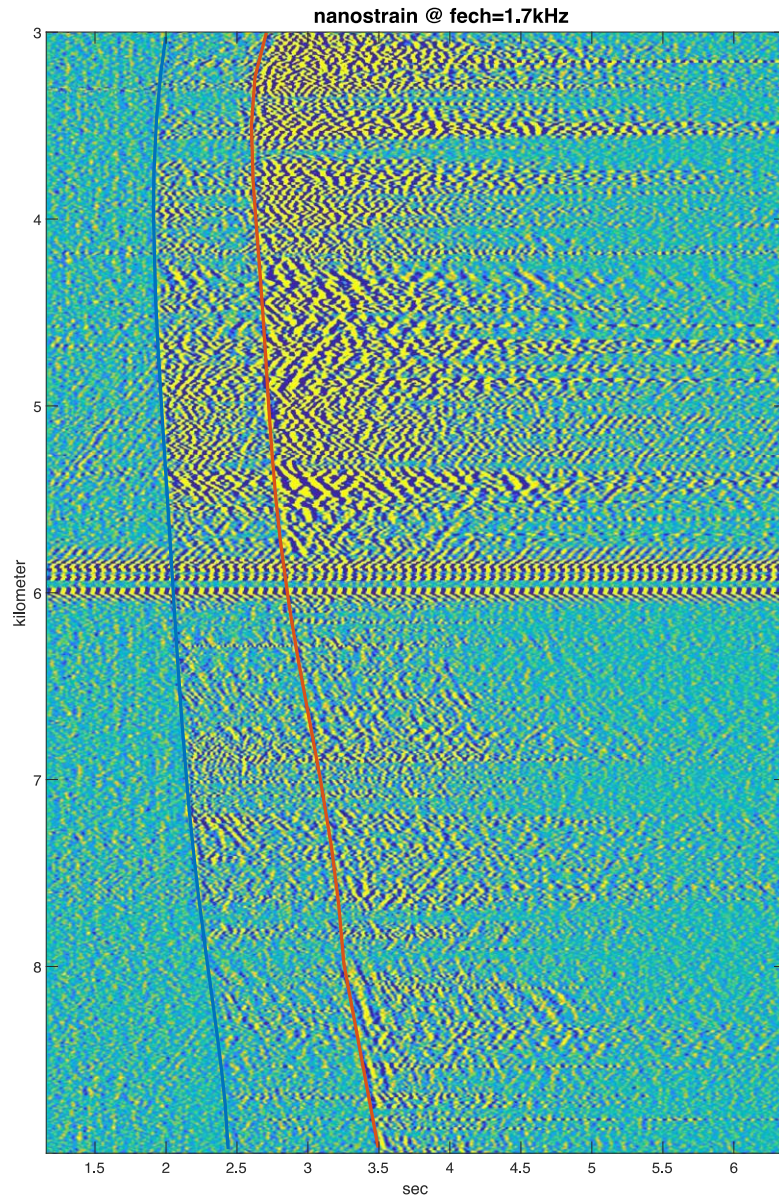
Figure 1: Telecom fiber location (red) and seismic swarm EQs locations (dots & star)



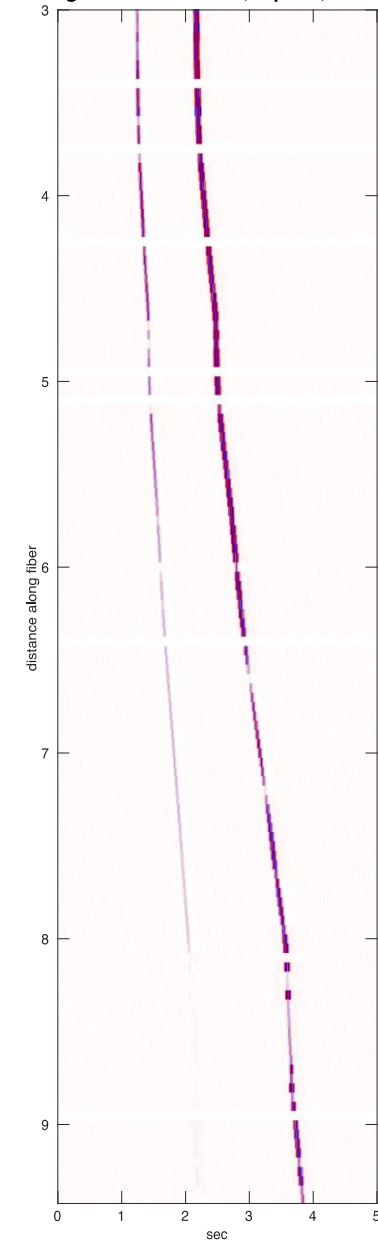
Figure 2: Fiber loose cable inside the PEHD tube (Courtesy of Fibrea-Covage)



Enregistrement d'un mag 1.5: observation / modélisation de l'élongation en milieu homogène



Elongation for strike=0, dip=20, rake=80



Perspectives

- **Acteurs industriels coté interrogateur**
 - Silixa (UK)
 - OptaSense (US)

 - FebusOptics (Fr)
 - Schlumberger; Halliburton; Fotech(UK); BandWeaver (China); ApSensing, NBG (RFA); Ziebel (US)....

Le nombre d'offres instrumentales explose

Prix 100k€ à 240k€

Tous les interrogateurs se valent-ils?

Perspectives

- **Acteurs industriels coté fibre**

En France relativement peu de fibre « noires »,
mais déploiement du réseau THD

Accès à la fibre via

- les opérateurs (SFR, Covage),
- les délégataires de service public,
- les collectivités (ex: département de l'Isère)



Déploiement de la fibre optique

- Réalisé
- 2016-2017
- Projet 2019

fibrea

CRÉATEUR DE RÉSEAUX FIBRE OPTIQUE
NEUTRES ET OUVERTS EN SAVOIE

Perspectives

- Applications en géophysique et environnement: surveillance en vallées Alpines
 - Sismicité
 - Crues
 - Glissements de terrain
 - Avalanches
 -
- Imagerie passive entre fibres
- Monitoring des structures
- Fibres sous-marines
- ...

Projets en cours:

ANR SEAFOOD (Seafloor Fiber Optic Observatory for Distributed measurements), ANR 2018, A. Sladen

ANR MONIDAS 2019->2023

Partenaires:

Febus-Optics: construction d'un DAS

ISTERRE : vallées Alpines

IPGP: cible Stromboli

Géoazur: cible sous marine

EOST: exploitation géothermique

- Quels traitements pour réduire les flux de données?
- Meilleure caractérisation du couplage fibre/sol