

The Seismic Network for Accelerators

...hearing with thousand ears...

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WAVE workshop , May 13, 2025



1 DAS Network 2024

- DAS Interrogator
- DESY Campus
- Achievements
- PETRA

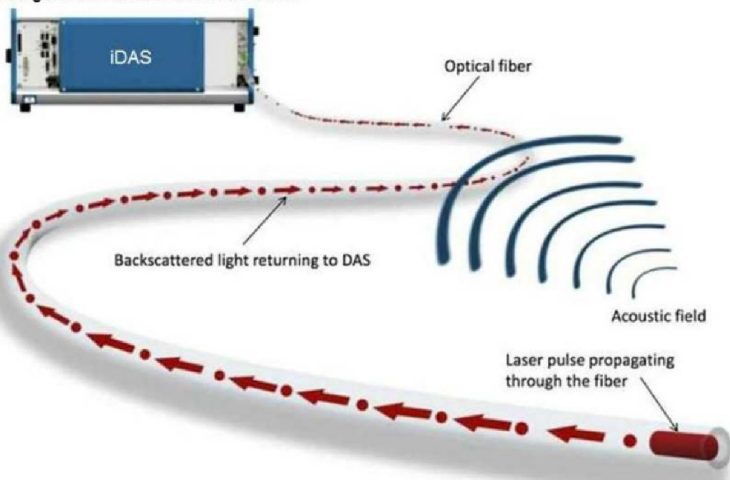
2 DAS Network 2025

- XFEL
- das-localize

3 New Ideas and What's next

DAS Principle

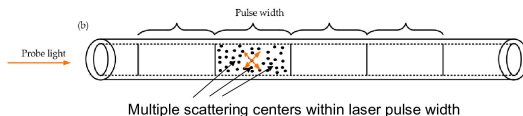
intelligent Distributed Acoustic Sensor



Phase-sensitive Optical Time Domain Reflectometry

Measurement principle...

Multiple scattering centers & measured waveforms



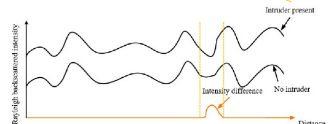
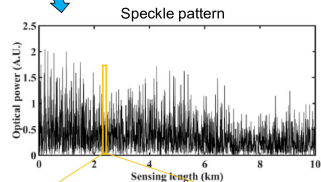
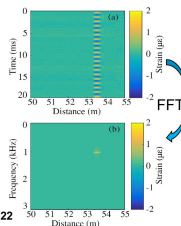
Intrinsically requires large data rates...

z: sampling of reflection $\sim 100 - 1000$ MSPS
(SNR & spatial resolution)

t: laser pulse rep. rate $\sim 1 - 100$ kHz
(SNR & noise frequency resolution)

→ Quickly ~ 1 Gbyte/sec

→ Data processing & analysis



Optics Letters · July 2020 DOI: 10.1364/OL.395922

DESY | Distributed fiber sensors | A. Lindner, N. Meyners, H. Schlarb | DESY | DIR-Meeting 04.02.2021

Sensors 2019, 19, 1709; doi:10.3390/s19071709

Typical Parameter set

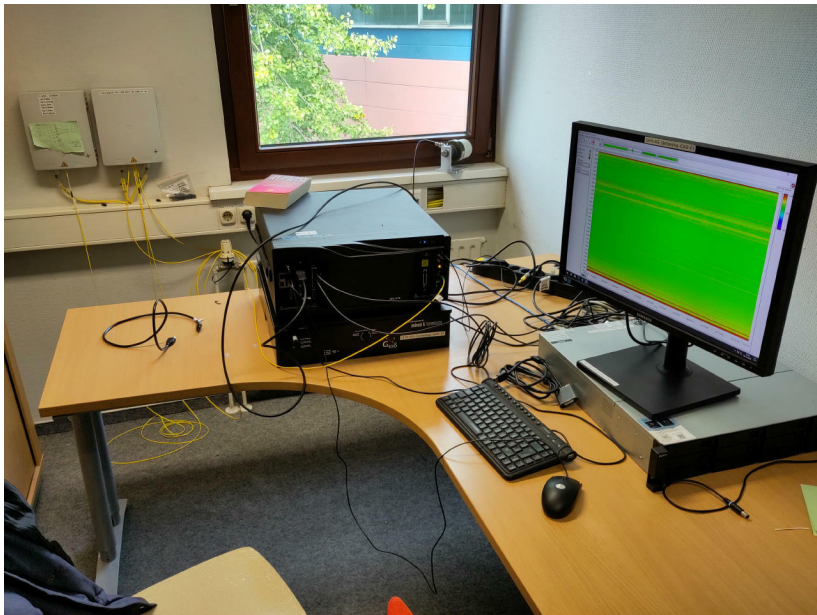
- Laser pulse width: 10 – 40 ns (at $\lambda = 1550$ nm)
- Fiber length: 15.6 km (with a single instrument)
- Spatial sampling/resolution: 1 m / 10 m (gauge length)
- Time sampling/resolution 1000 Hz (Laser pulse rate)
- Frequency resolution < 0.01 Hz (near DC) to 500 Hz

What is the data about?

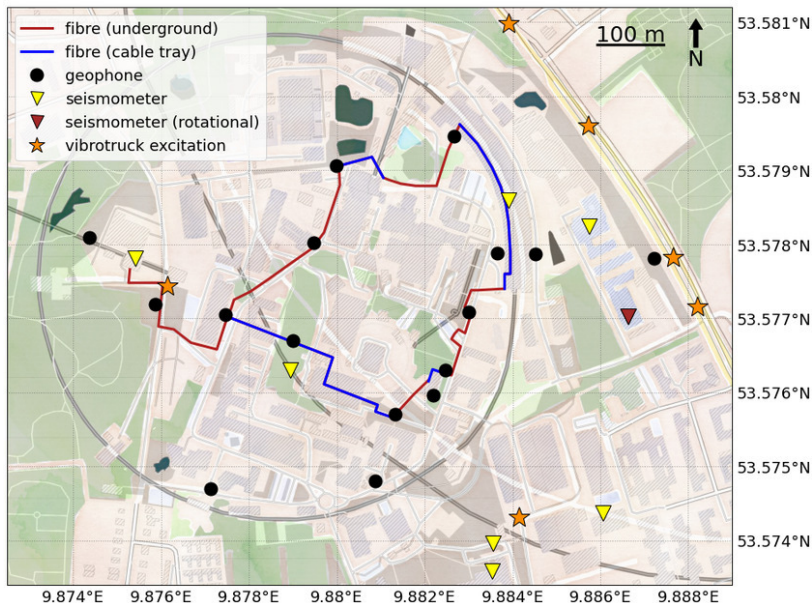
Observables

- strain / nano strain (change in optical length)
- strain rate
- noise (seismic and acoustic)
- temperature / temperature change (from slow drifts)

DAS Interrogator

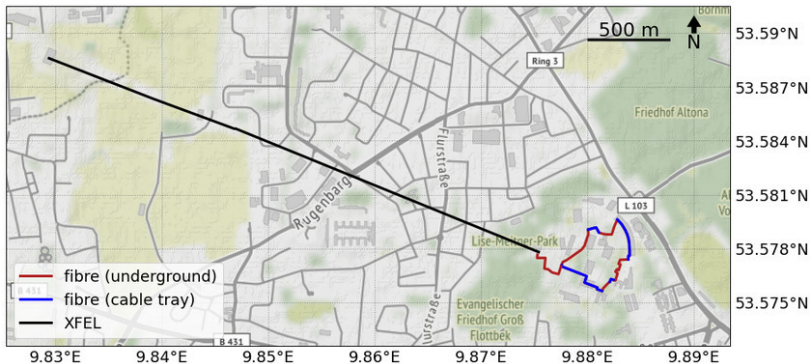


DESY Campus



DESY Campus

DAS sensing: DESY Campus and XFEL

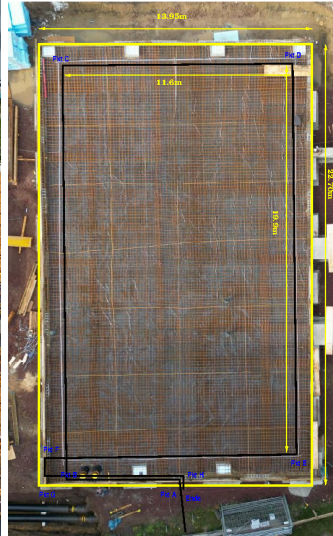


DAS Network Achievements 2024 Campus Bahrenfeld/DESY

- ① Extension of the fiber in foundation of Hall 54b.
- ② 2.5 km extension of the fiber in PETRA ring tunnel.
- ③ The Interrogator has moved from Bld. 35 to Bld. 55A.
- ④ We made a full new geo referencing of the fiber path.
- ⑤ Improved the algorithms for offline-analysis.
- ⑥ Quick data path for live visualization.
- ⑦ Databrowser and live visualization on a Server. (for outreach)
- ⑧ New Cross Spectral Density analysis of the signals.
- ⑨ ErUM-WAVE collaboration.
- ⑩ The fiber cable in concrete founding was destroyed.
- ⑪ Investigations/Setup in MOCKUP tunnel for fiber and installation types.

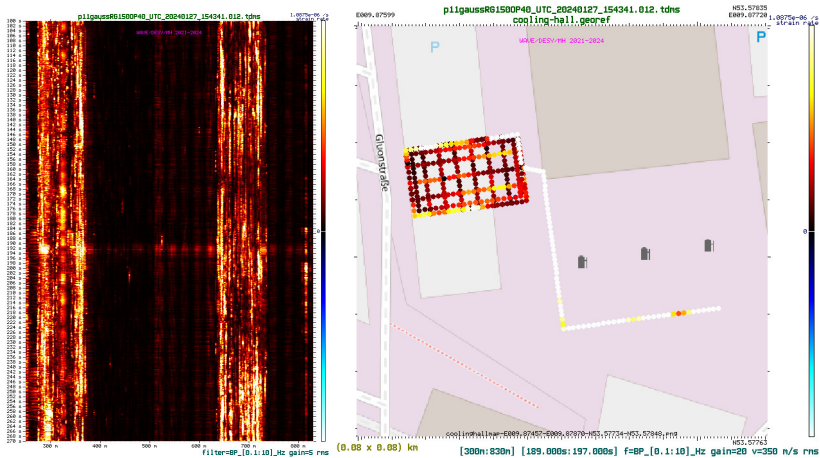
Achievements

Fiber cable in Foundation of Building 54b



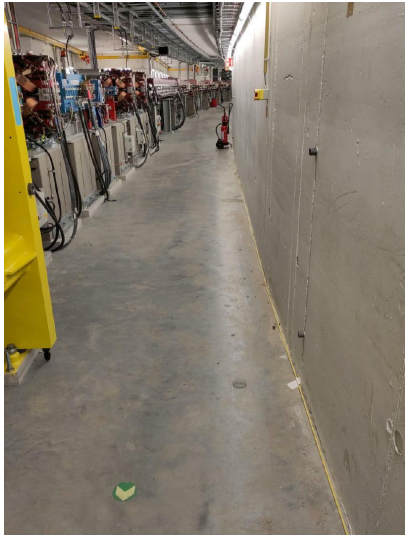
Achievements

Sinkhole Event 27 Jan 2024 Jänisch-Park



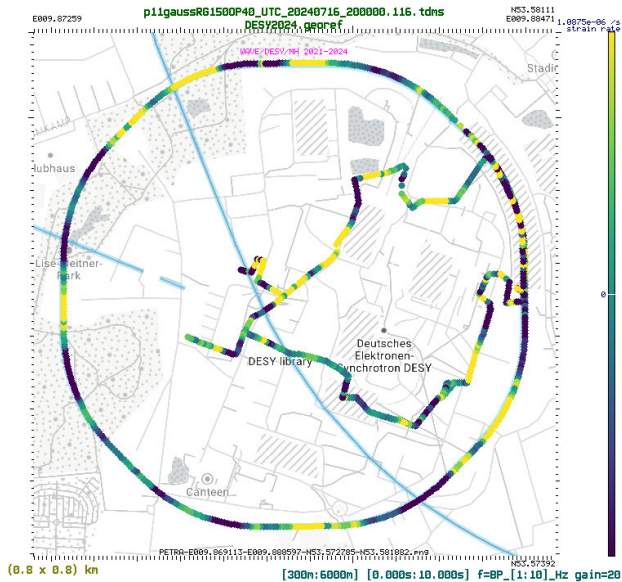
PETRA

Fiber cable in PETRA

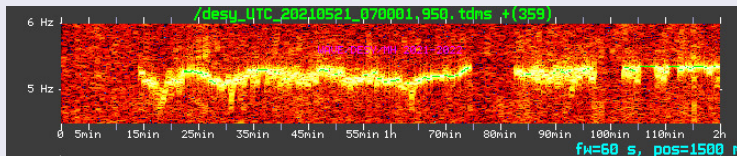


PETRA

New fiber cable in PETRA



Soved: 5.2 Hz seen at PETRA

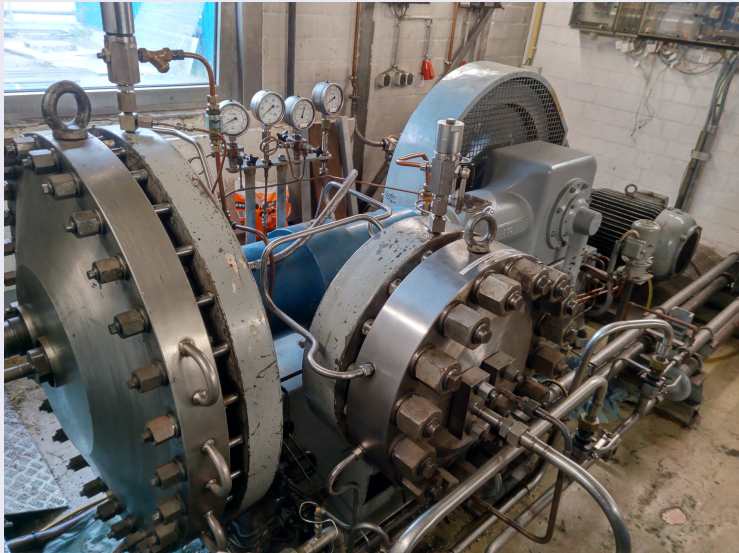


long time unsolved puzzle:

- Disturbs the PETRA closed orbit (feedback),
- very narrow bandwidth
- irregular occurrence,
- seen everywhere on the campus.

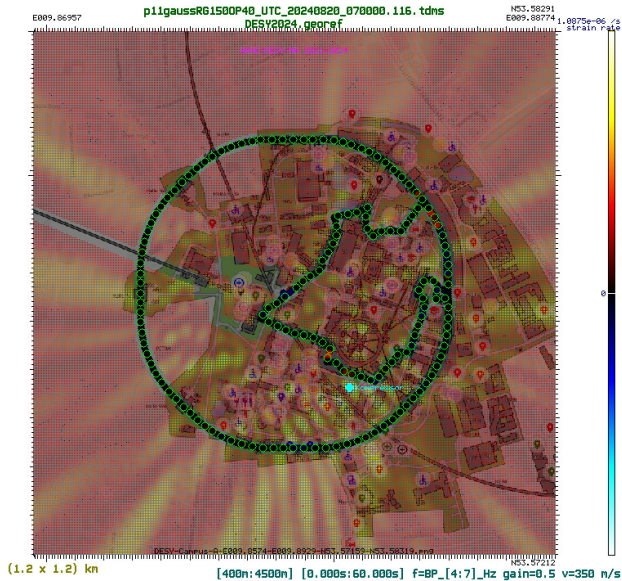
→ disturber has been found.

The 1965 Helium-Compressor



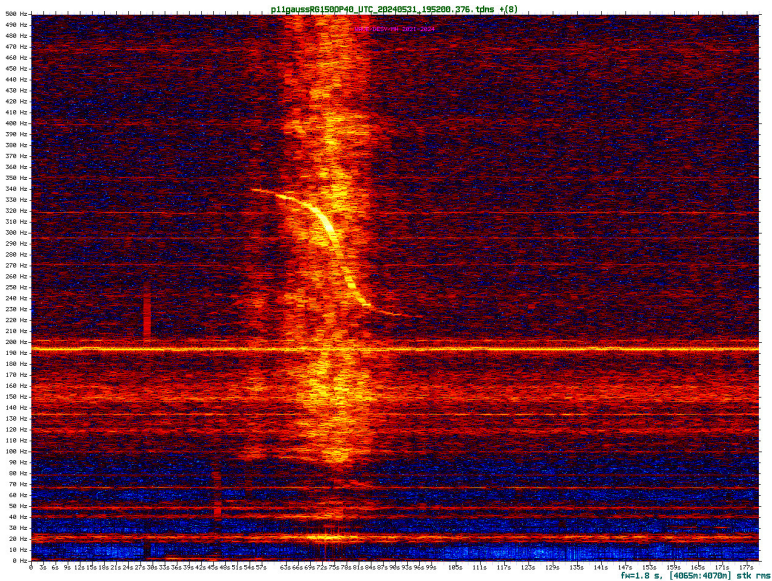
PETRA

Reconstruction of waves from data

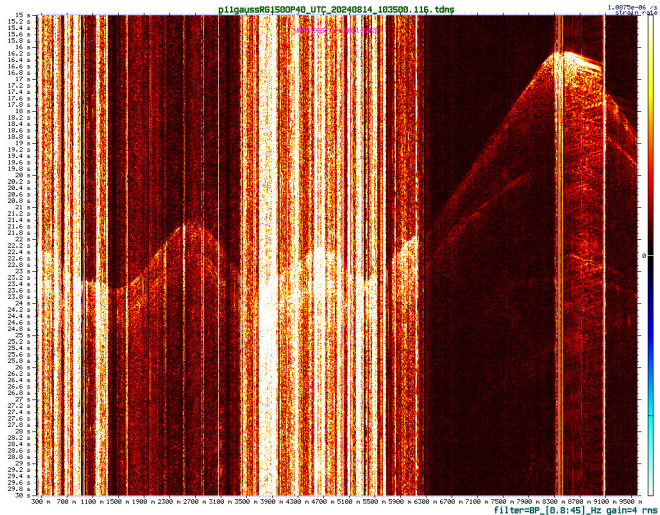


PETRA

Airplane signatures

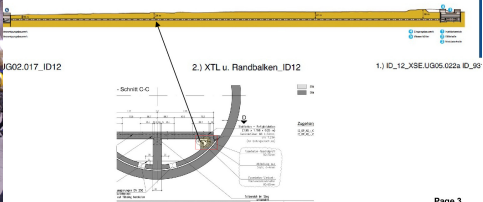
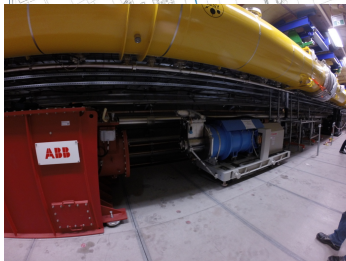
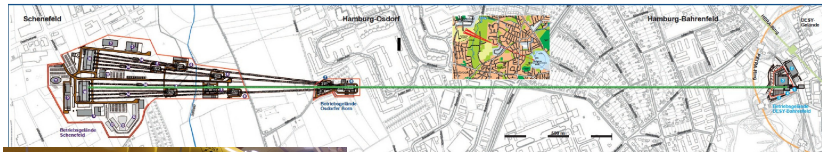


Thunderstorms



The Movies

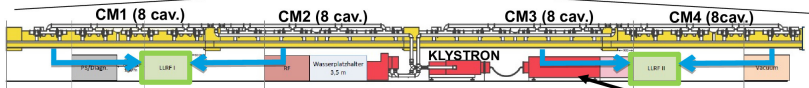
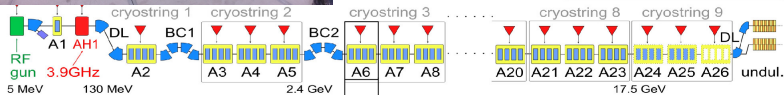
- Lightning 1 (lighteningwave1b.webm)
- Lightning 2 (lighteningwave2.webm)



Page 3

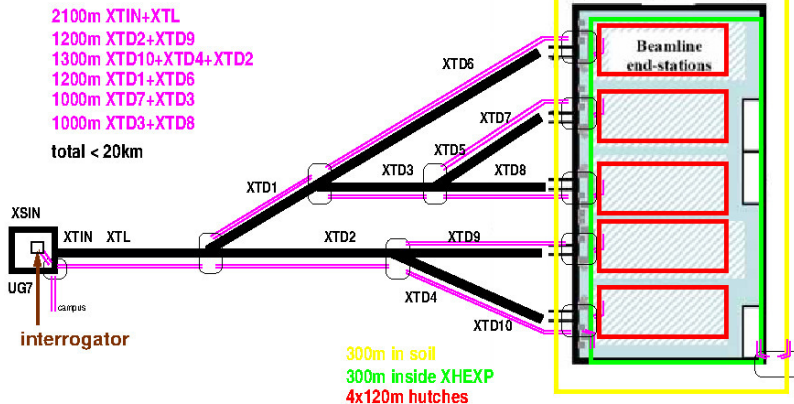
LINAC3

▼ Klystron ◼ Cryomodule ◼ RF station



Proposal for XFEL

proposed fiber layout



Work to be done

Hardware Installation

- Install cables,
- get and set up interrogator.
- Geo-Referencing of the new fibers.
- integrate into science city network.

Software

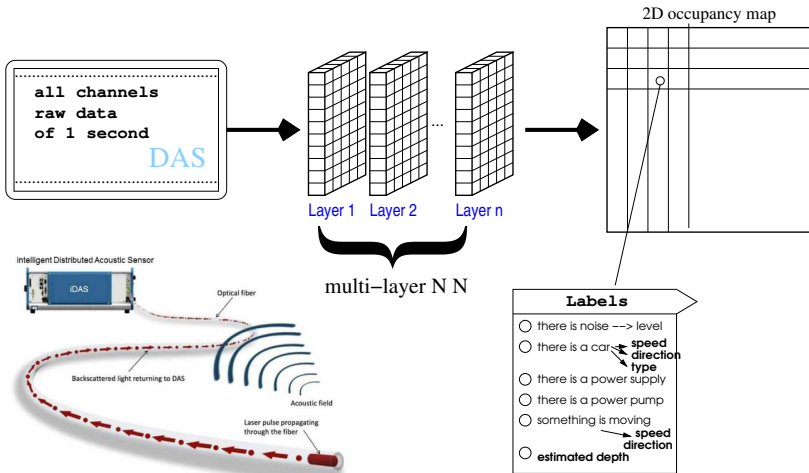
- Data flow handling, processing, storage.
- Visualization of the data.
- Integration into accelerator control systems.

→ Nearly all software and algorithms in house developpment.

das-localize

Algorithmic project

(das-localize)



My vision for 2025:

- ① equip all (photon) tunnels of XFEL with cables on the tunnel floor (July)
- ② Interrogator needs to move again(!) from Bld. 55A to Bld. 3.
- ③ Redo geo referencing of the new fiber cables paths.
- ④ Buy another Interrogator for XFEL (Sept).
- ⑤ Project: das-localize/ErUM-SESAM: localization and classifications of noise sources on a course grid using NN.
- ⑥ Project: Orbit and optics simulations for PETRA-IV using DAS data.
- ⑦ Project: **Wave field reconstruction** and prediction using DAS data (ErUM-WAVE), for which **properties of fiber** sensor needs to be measured, coupling factors, sensitivities, **comparisons with seismometer** data and cross-calibration, different fiber types, eliminating temperature effects, → Eriks Talk.

Whats Next?

... to form the seismic network for Hamburg:

Hardware

- Fiber cables in all new buildings + soil fibers around.
- Fibers in all accelerator tunnels + experimental halls (on the floor)
- additional fiber in (around) HERA ring tunnel (6.5 km)
- indoor-fiber in labs with cryo-electron microscopes (FS).

Software

- real-time data processing and live disturbance visualization with ML
- wave predictions everywhere (ErUM WAVE) and localizations.
- Automatically **identify**, **classify**, and **localize** disturbances. Quantify and estimate impact on experiments.

New Ideas

Hardware

- "Dual-Use" of the DAS fiber: We can measure ionizing radiation in the accelerator tunnels using the fibers with a stationary OTDR Measurement device which we can permanently operate at one of the fibers in the tunnel and automatically readout.