Distributed Acoustic Sensing (DAS) for high resolution and high scale geophysical imaging

Fibre optics basics - DAS principles

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IR0000032 – ITINERIS, Italian Integrated Environmental Research Infrastructures System
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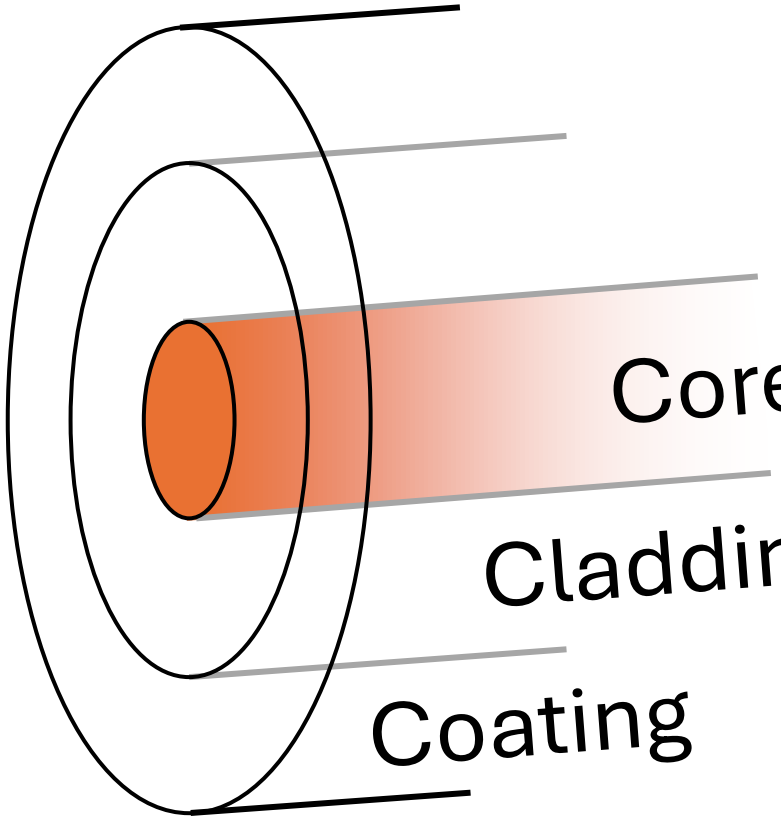
Optical fibre structure



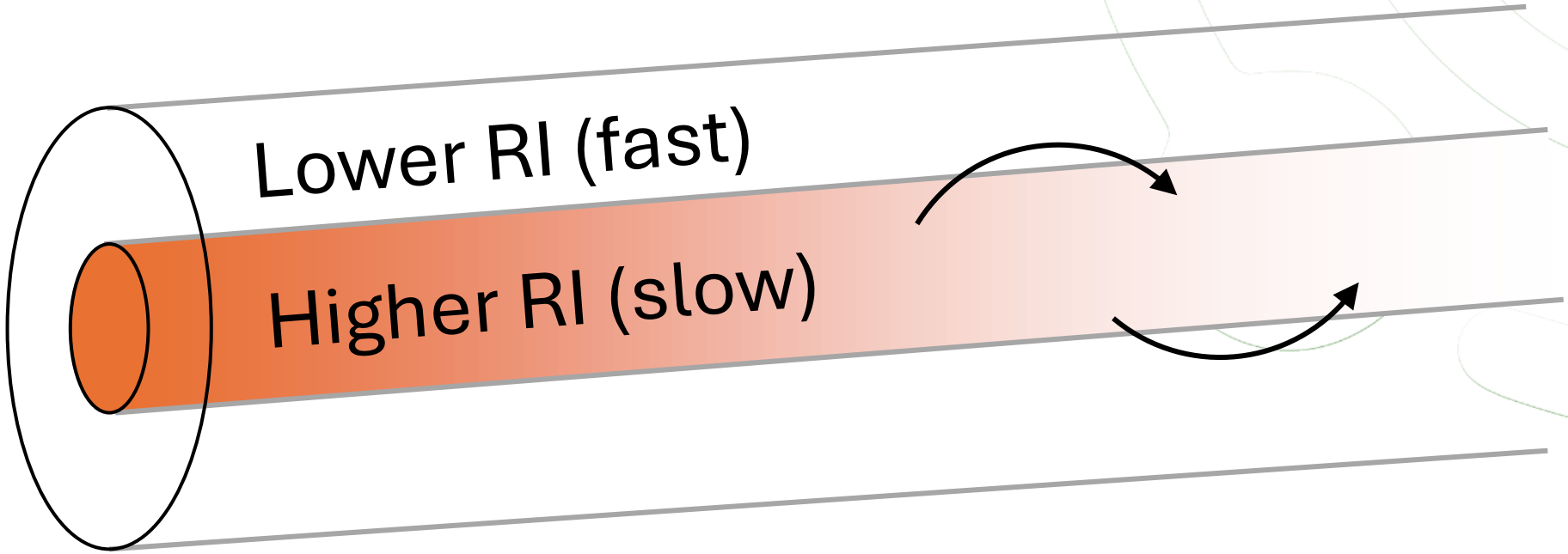
SMF: 10 µm, MMF: 50 µm

125 µm

250 µm

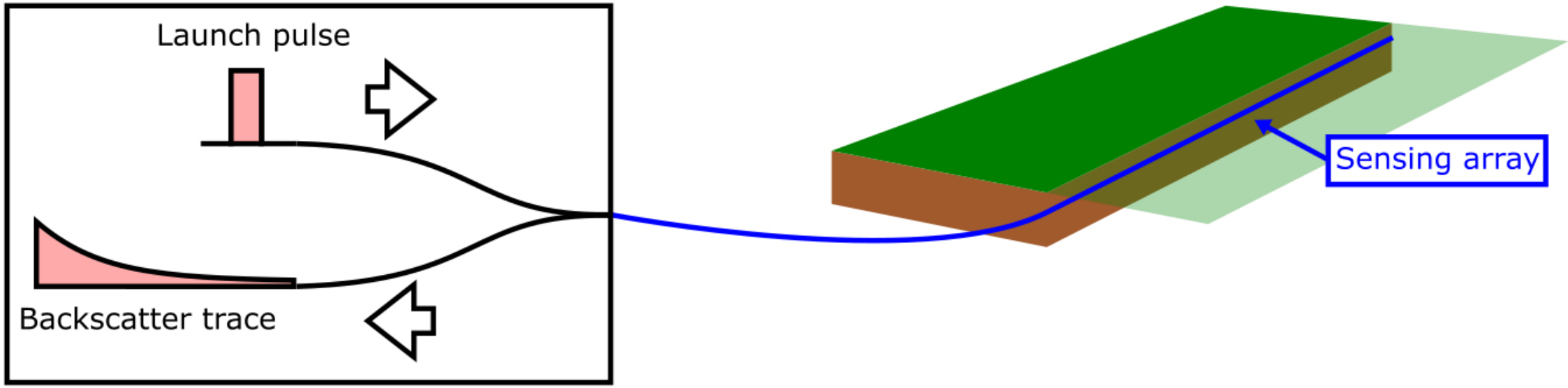
Optical fibre structure

Waveguide effect confines light to core

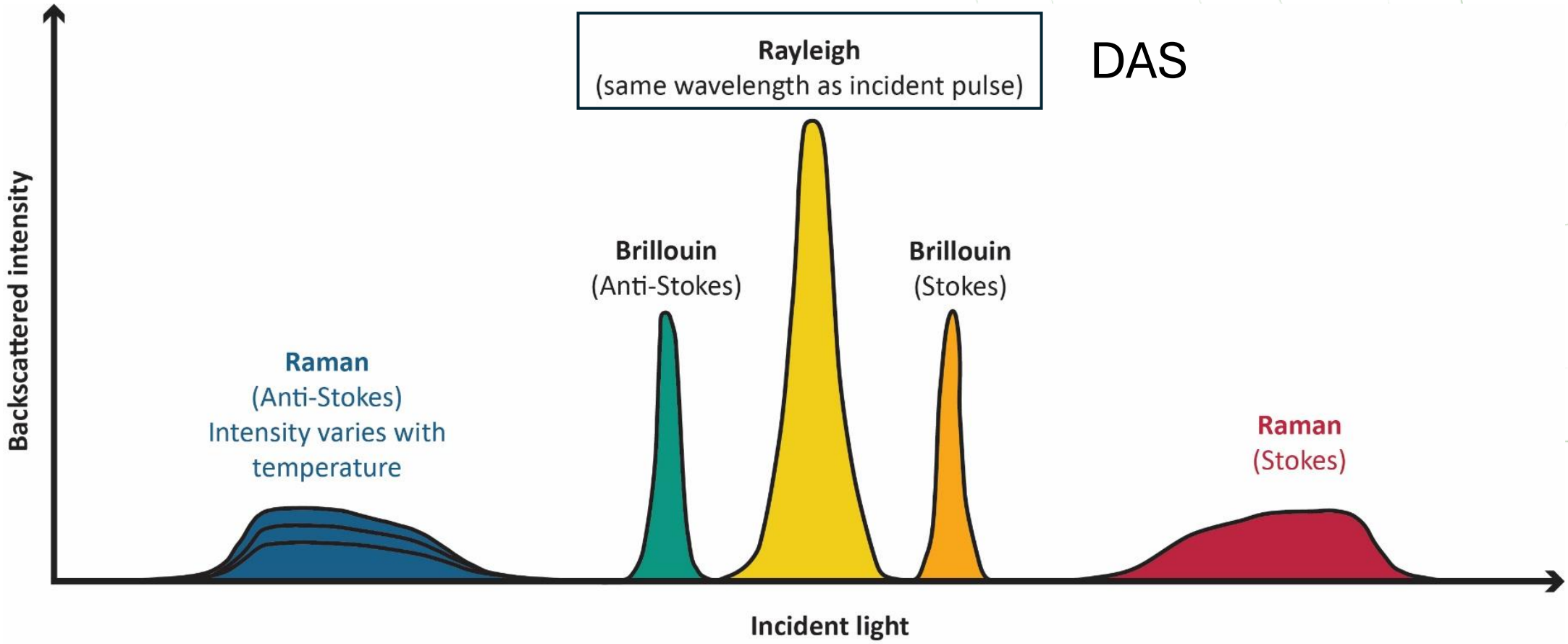


Typical propagation RI (group index) = 1.46
Rule of thumb: Speed of light ≈ 2×10^8 m/s

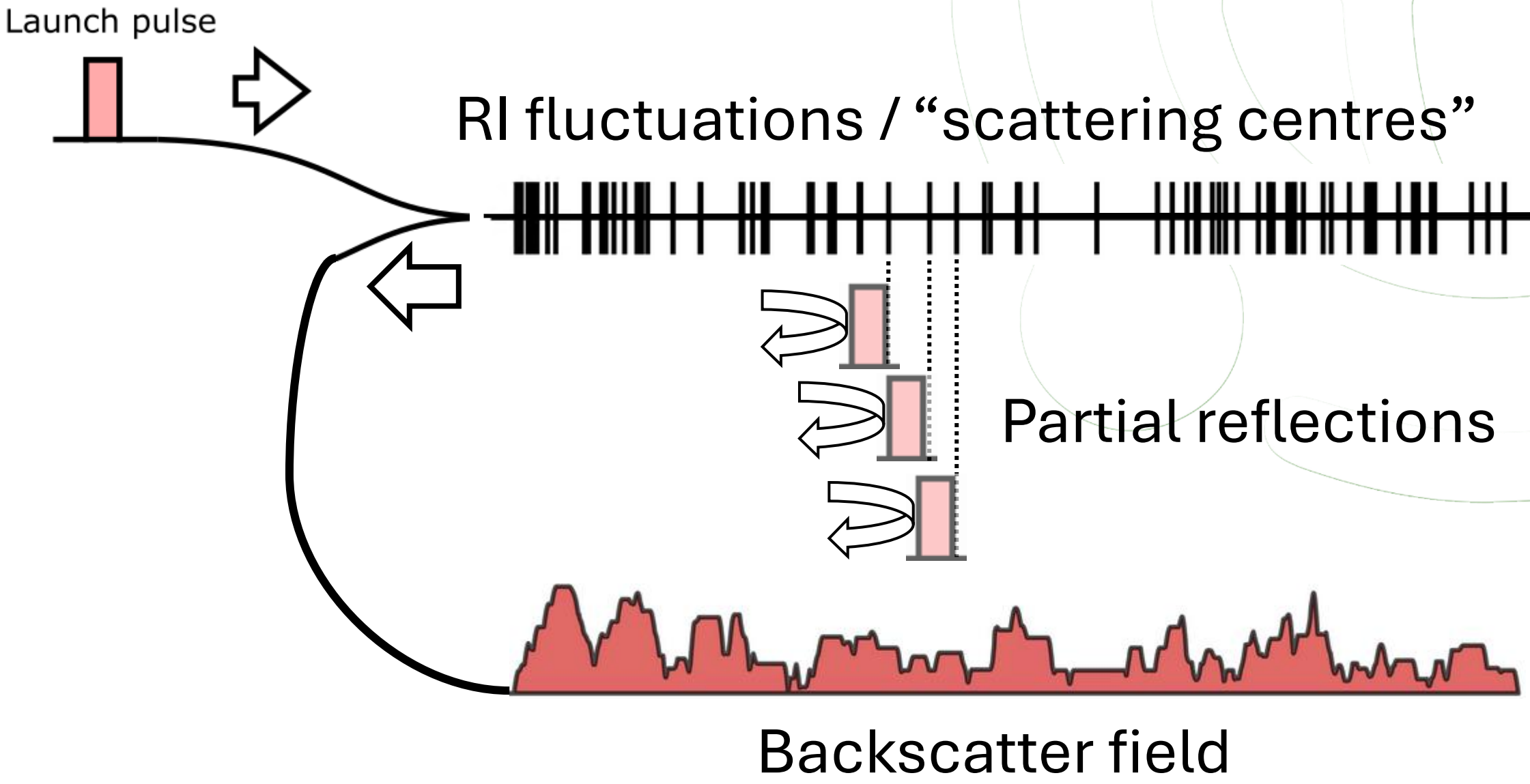
Optical pulse



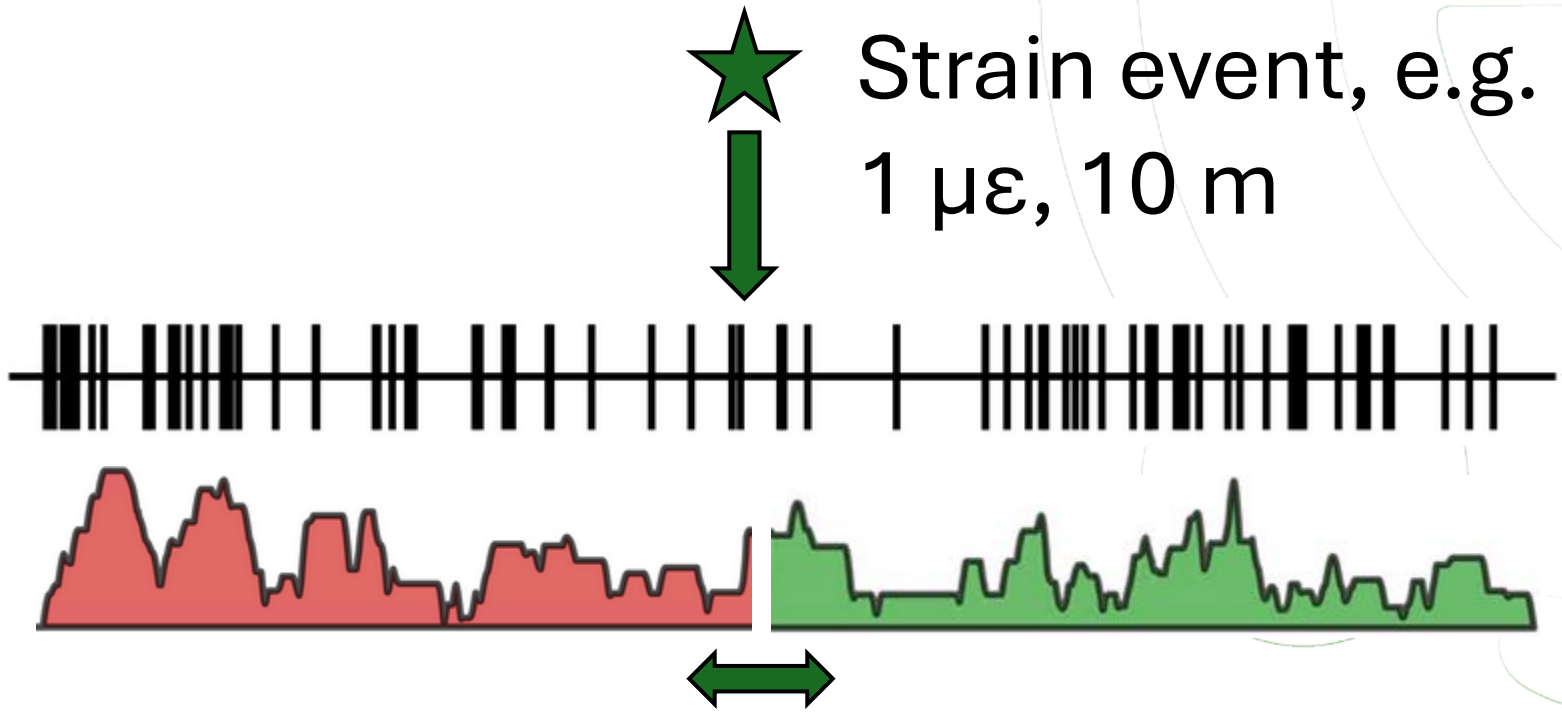
Bacskatered light



What DAS measures



What DAS measures

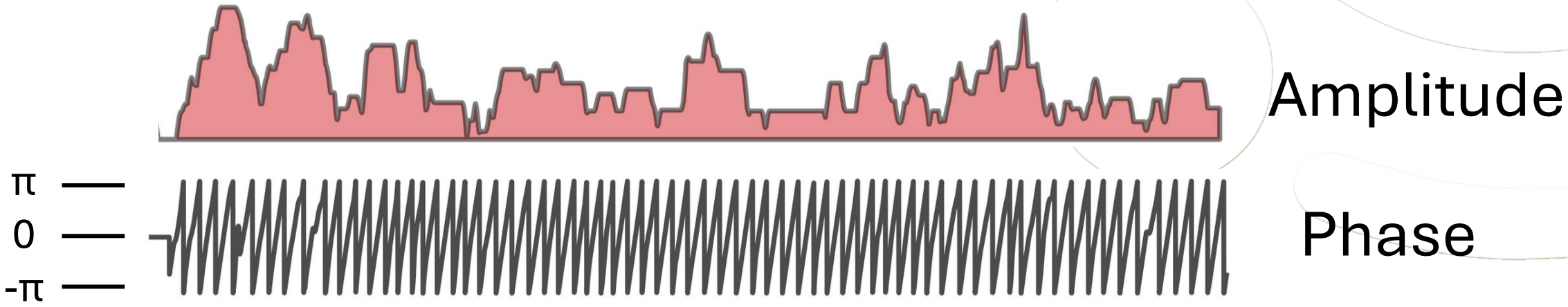


Optical path delay, e.g. ~10 μm

(Acquisition systems sample at >0.1 m spacing)

What DAS measures

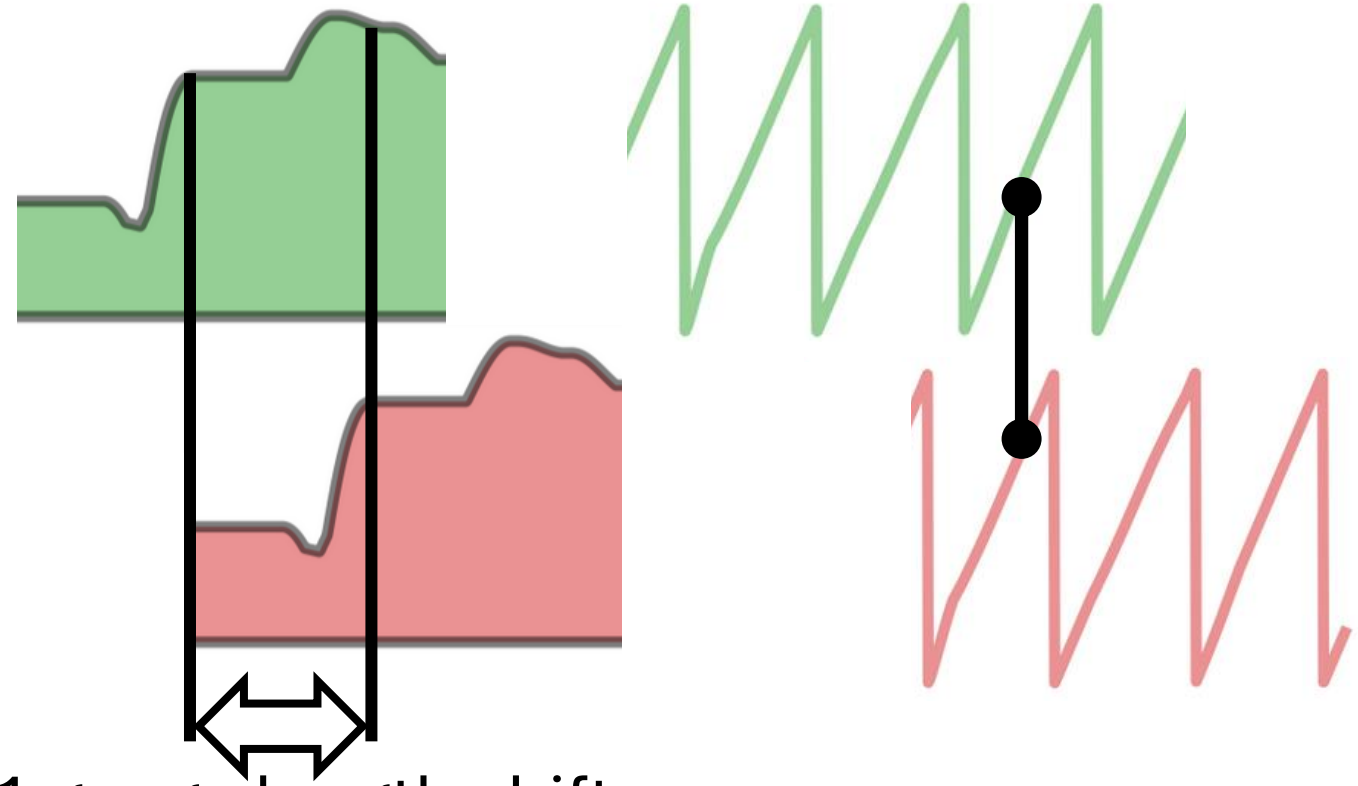
Interferometric detection



350 nm path delay → π phase change

What DAS measures

Gauge length shift and comparison



1 gauge length shift

DAS = phase difference time evolution $\delta\varphi$

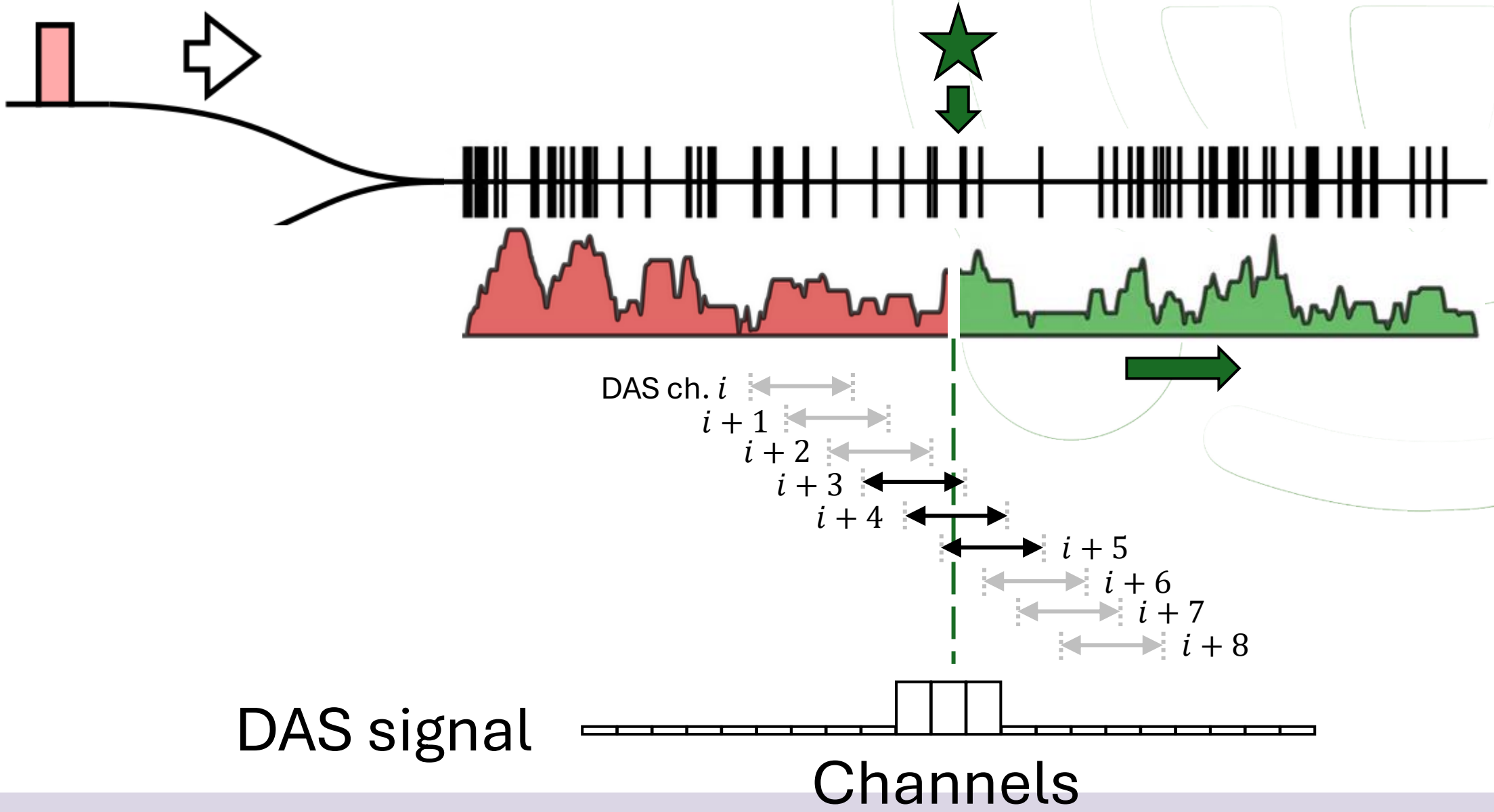
$$\dot{\varepsilon} = \frac{\alpha f_s}{L_G}\delta\varphi$$

$\alpha = 116\text{nm/rad}$

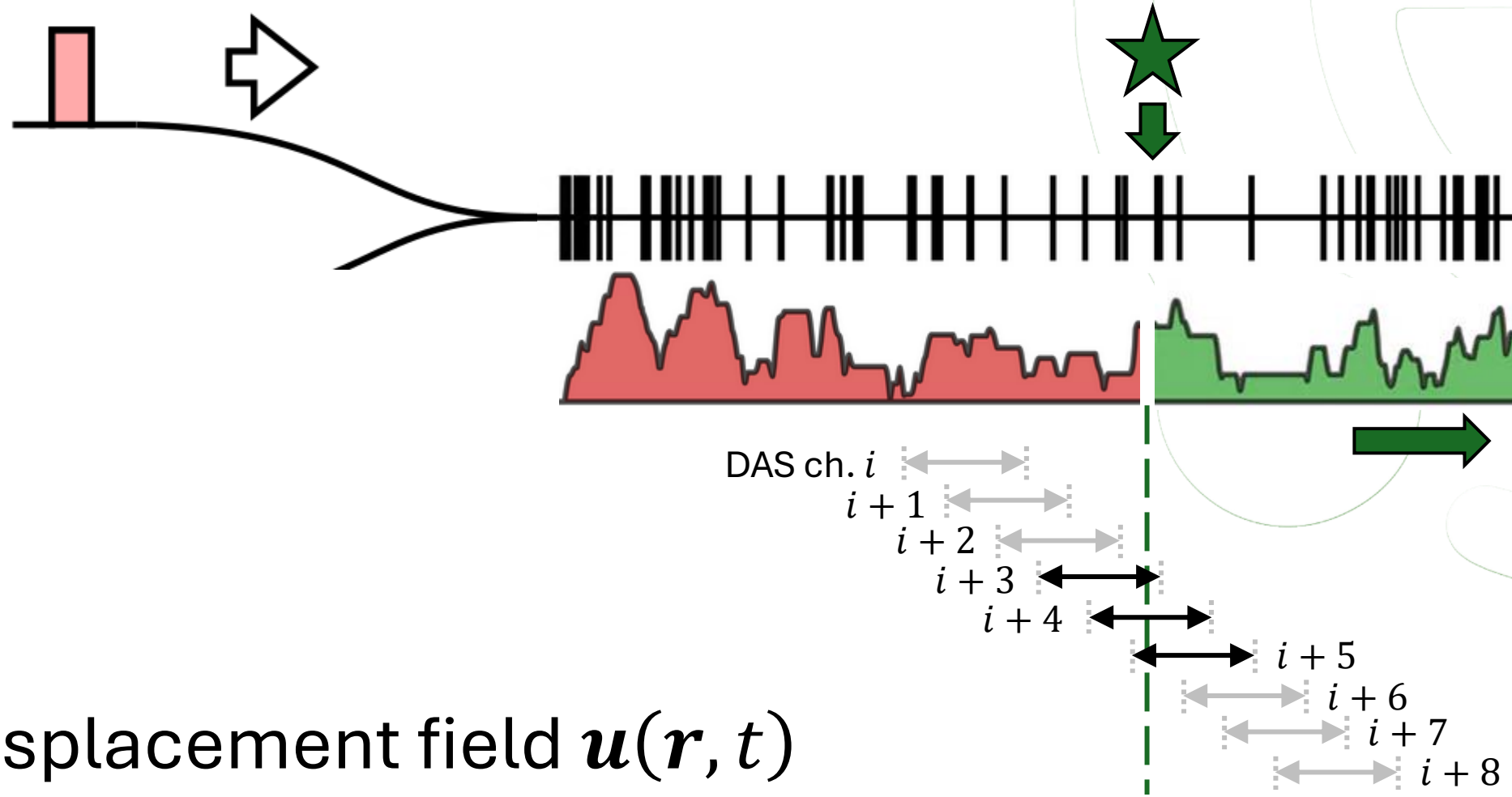
f_s = Sampling frequency

L_G = Gauge length

What DAS measures



What DAS measures

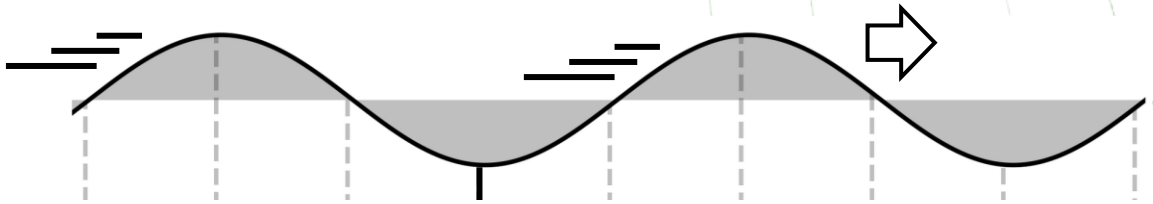


Displacement field $\boldsymbol{u}(\boldsymbol{r}, t)$

DAS signal $\propto \frac{d^2 u_x}{dxdt}$

DAS as particle velocity, spatial derivative

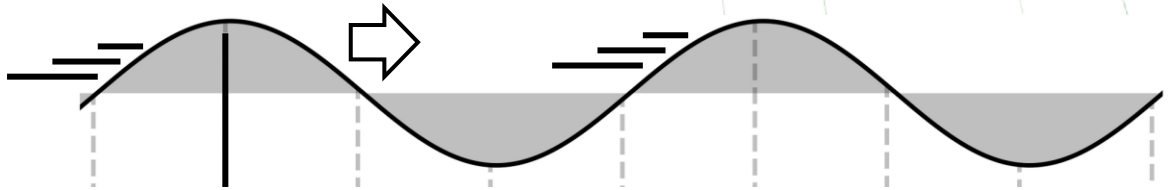
Displacement u_x



Travelling wave

DAS as strain-rate, window-averaged

Displacement u_x



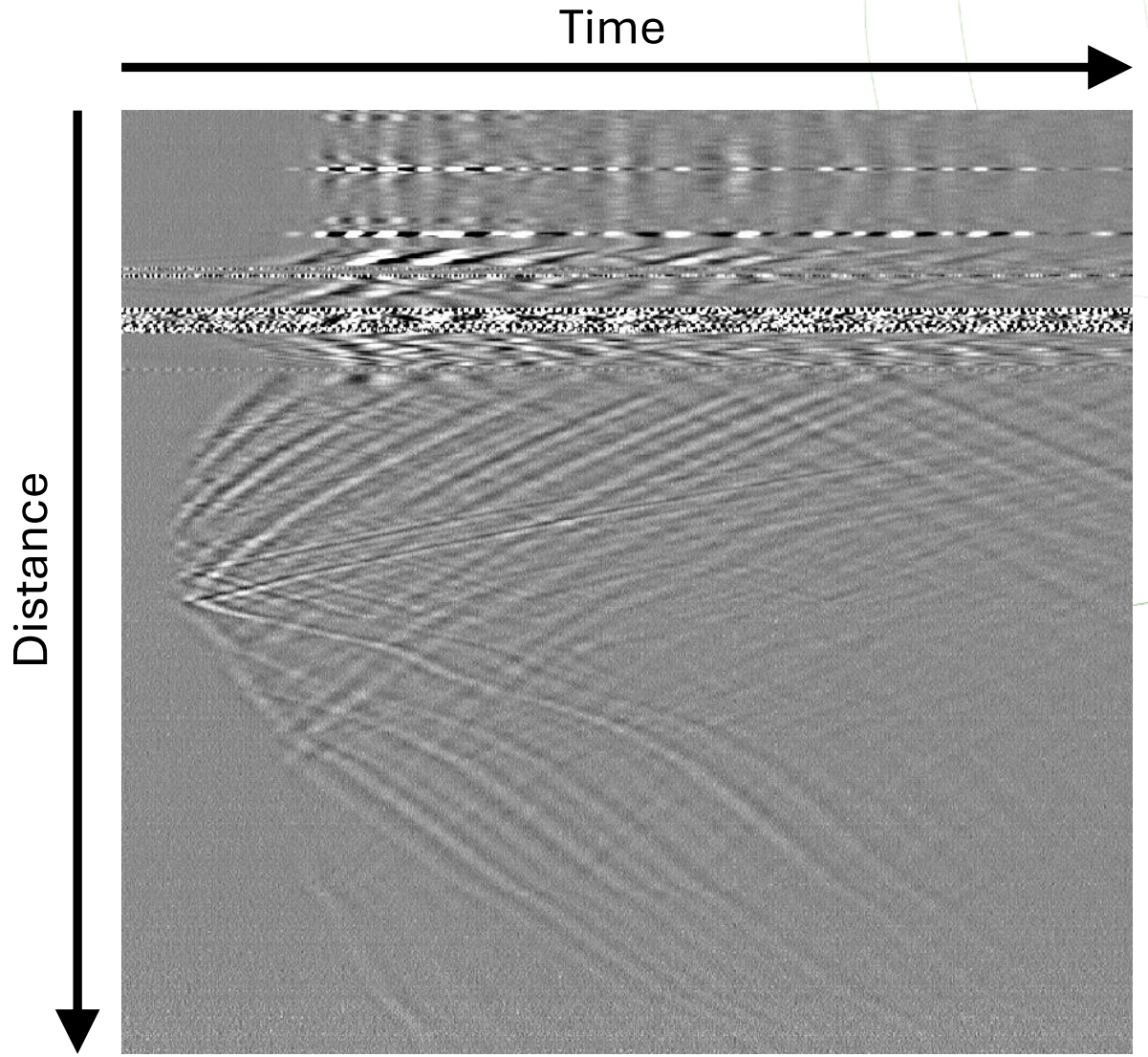
Travelling wave

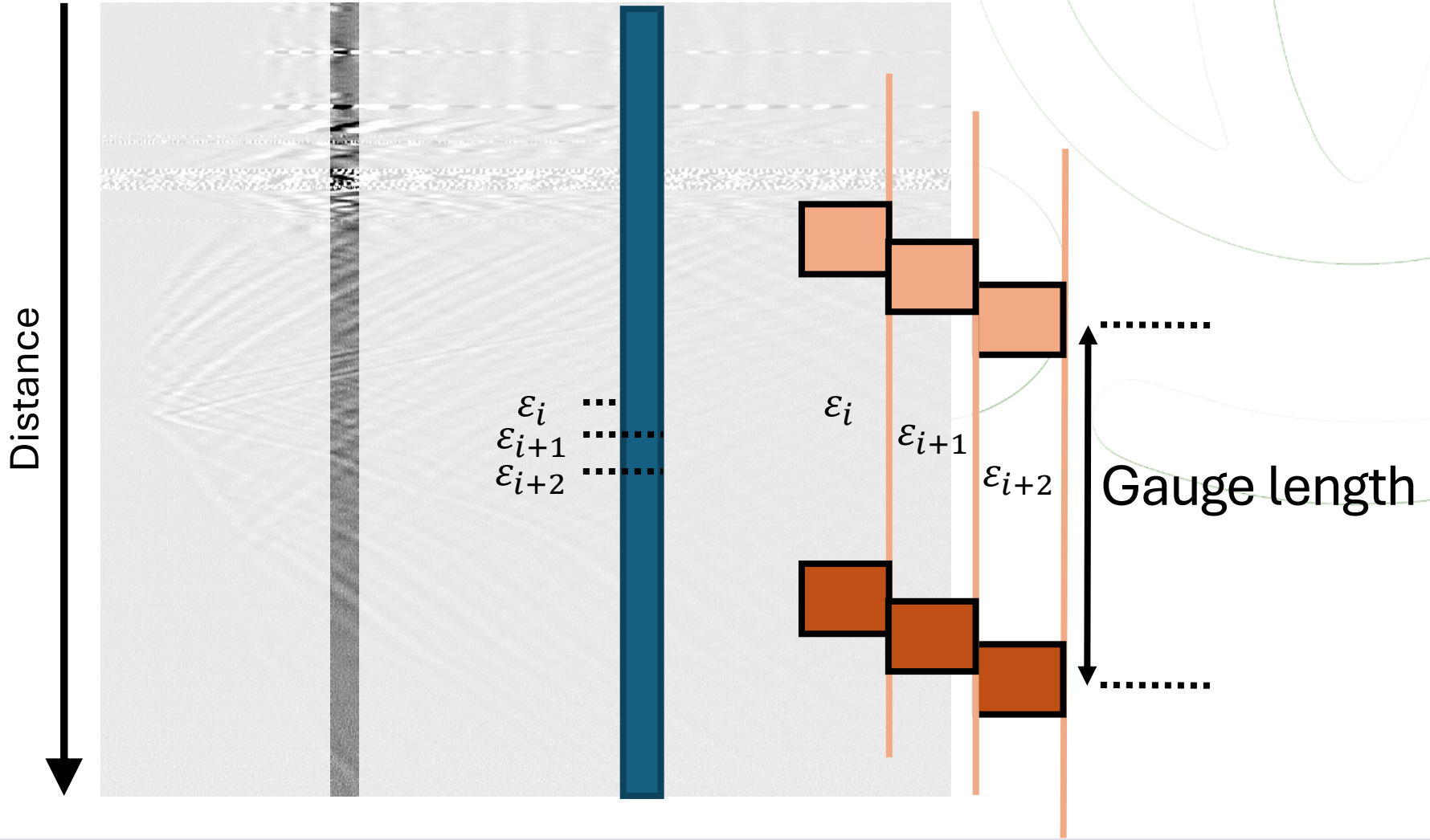
Strain-rate $\dot{\varepsilon}_x = \frac{d^2 u_x}{dxdt}$

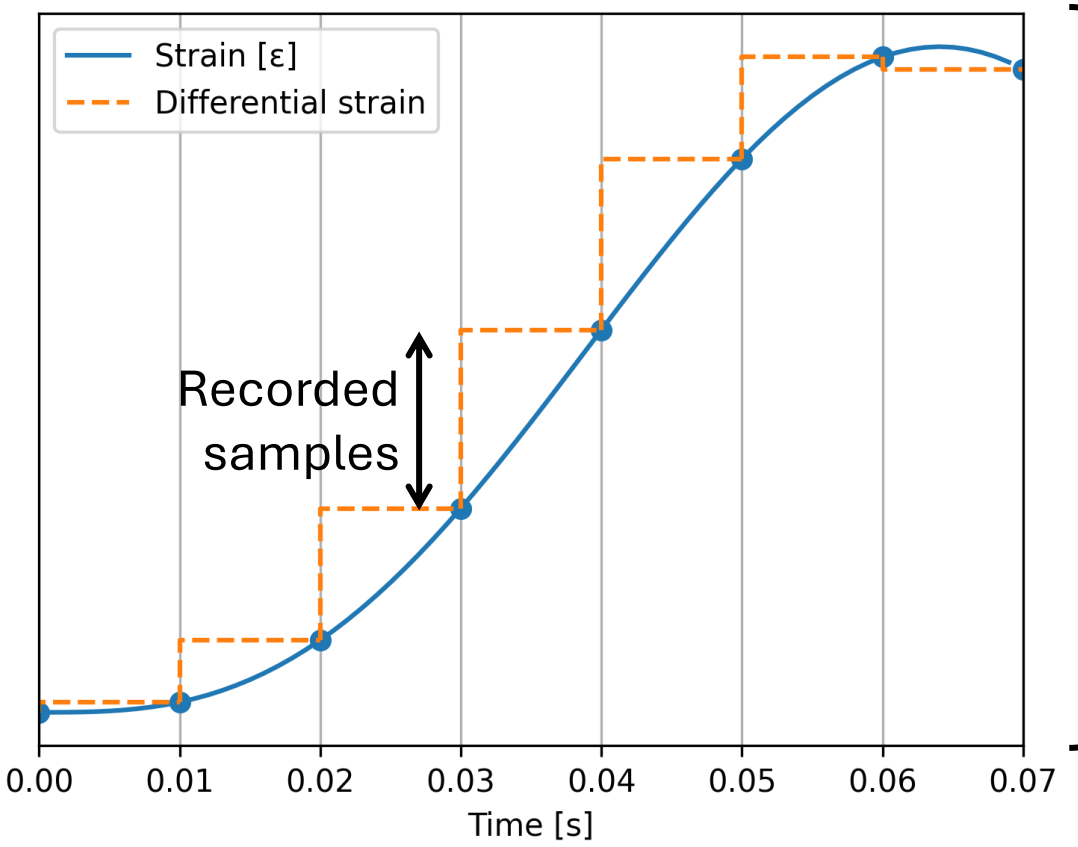
DAS

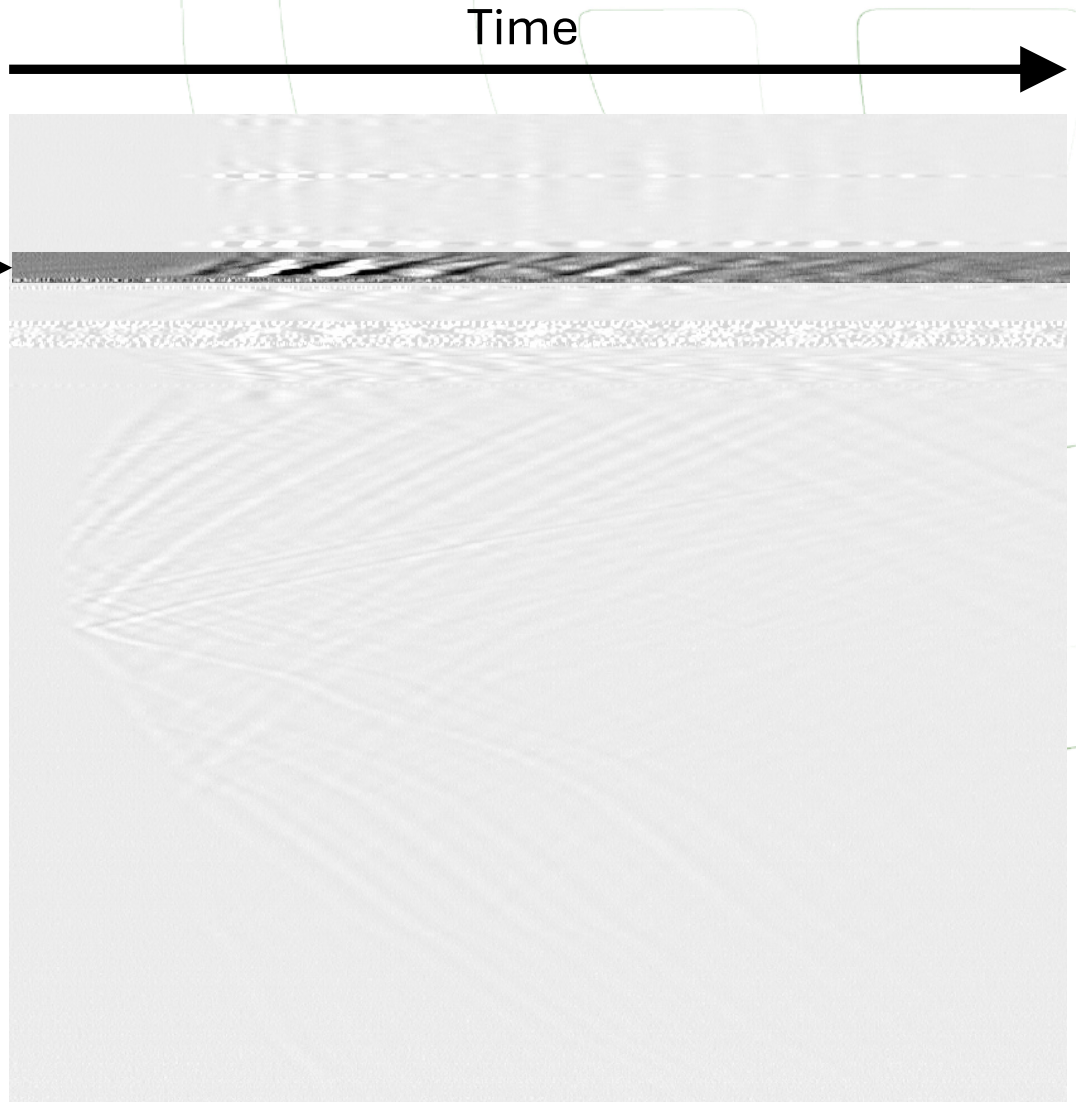
$\dot{\varepsilon}_x * \Pi(x/L_G)$

Output

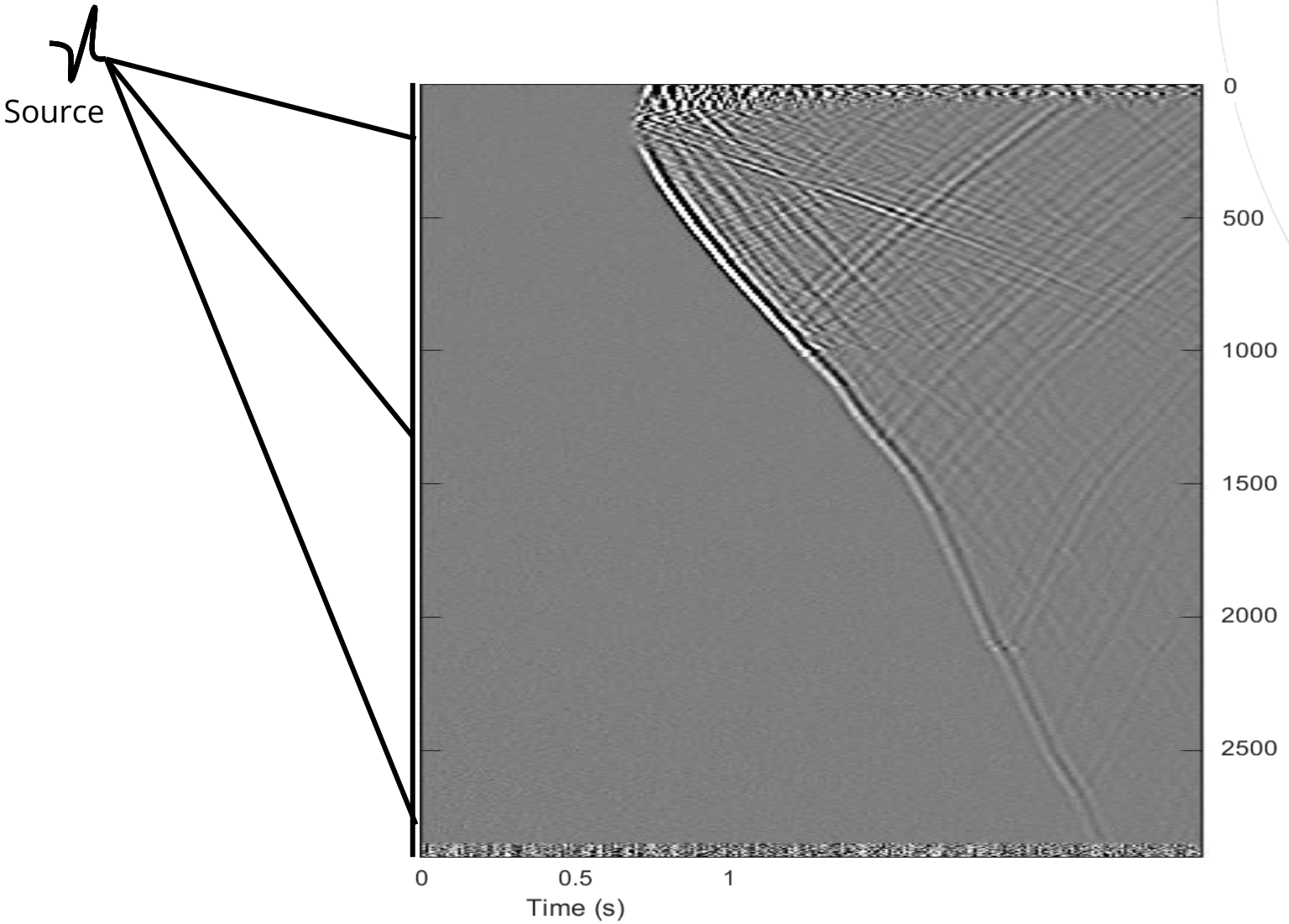



Distance
ε_i
ε_{i+1}
ε_{i+2}
ε_i
ε_{i+1}
ε_{i+2}
Gauge length


Strain [ε]
Differential strain
Recorded samples
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
Time [s]


Time

Active seismic



iDAS MG example

- Optimised for **high sensitivity, high dynamic range** acoustic detection
- Designed for **standard fibre**
- Single optical channel
- < 1 mHz – 50 kHz detection bandwidth
- Single-gauge model:
  - 10 m GL
  - 45 km range
- Multi-gauge (MG) model:
  - 3, 5, 10, 30 m GL
  - 30 - 50 km ranges respectively

Carina Example

- Optimised for **ultra-high sensitivity, high dynamic range** acoustic detection
- Designed for **Constellation fibre**, situated near or far from the interrogator
- Provides greater sensitivity on standard fibre than iDAS, at greater range.
- Single optical channel
- < 1 mHz – 50 kHz detection bandwidth
- Four gauge lengths as standard:
  - 25 cm (15 km)
  - 2 m (30 km)
  - 10 m (50 km)
  - 30 m (60 km)

THANKS!

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