



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

DAS configuration best practices

- Jack Maxwell

IR0000032 – ITINERIS, Italian Integrated Environmental Research Infrastructures System
(D.D. n. 130/2022 - CUP B53C22002150006) Funded by EU - Next Generation EU PNRR-
Mission 4 "Education and Research" - Component 2: "From research to business" - Investment
3.1: "Fund for the realisation of an integrated system of research and innovation infrastructures"



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Ministero
dell'Università
e della Ricerca

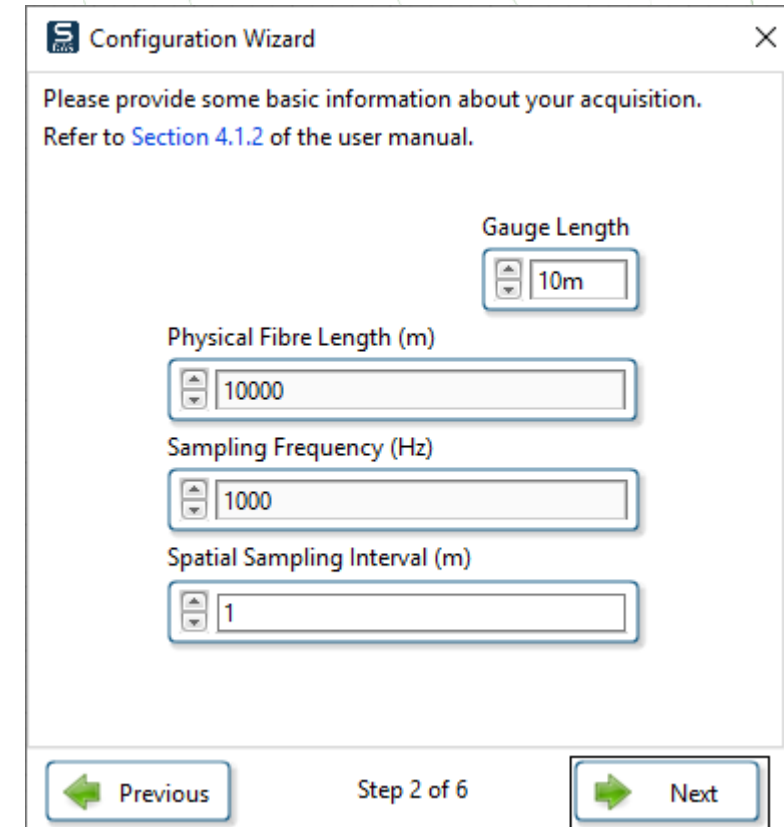


Outline

- DAS Setup wizard
- Sampling frequency
- Optical fibre losses
- Gauge length
- Dynamic range
- Comparison with Geophones

Configuration Wizard

- Gauge Length
- Physical Fibre Length
- Sampling Frequency
- Spatial Sampling Interval

A screenshot of a software configuration wizard window titled "Configuration Wizard". The window contains instructions to provide basic acquisition information and four input fields: Gauge Length (10m), Physical Fibre Length (m) (10000), Sampling Frequency (Hz) (1000), and Spatial Sampling Interval (m) (1). Navigation buttons for "Previous" and "Next" are at the bottom, along with a "Step 2 of 6" indicator.

Configuration Wizard

Please provide some basic information about your acquisition.
Refer to [Section 4.1.2](#) of the user manual.

Gauge Length
10m

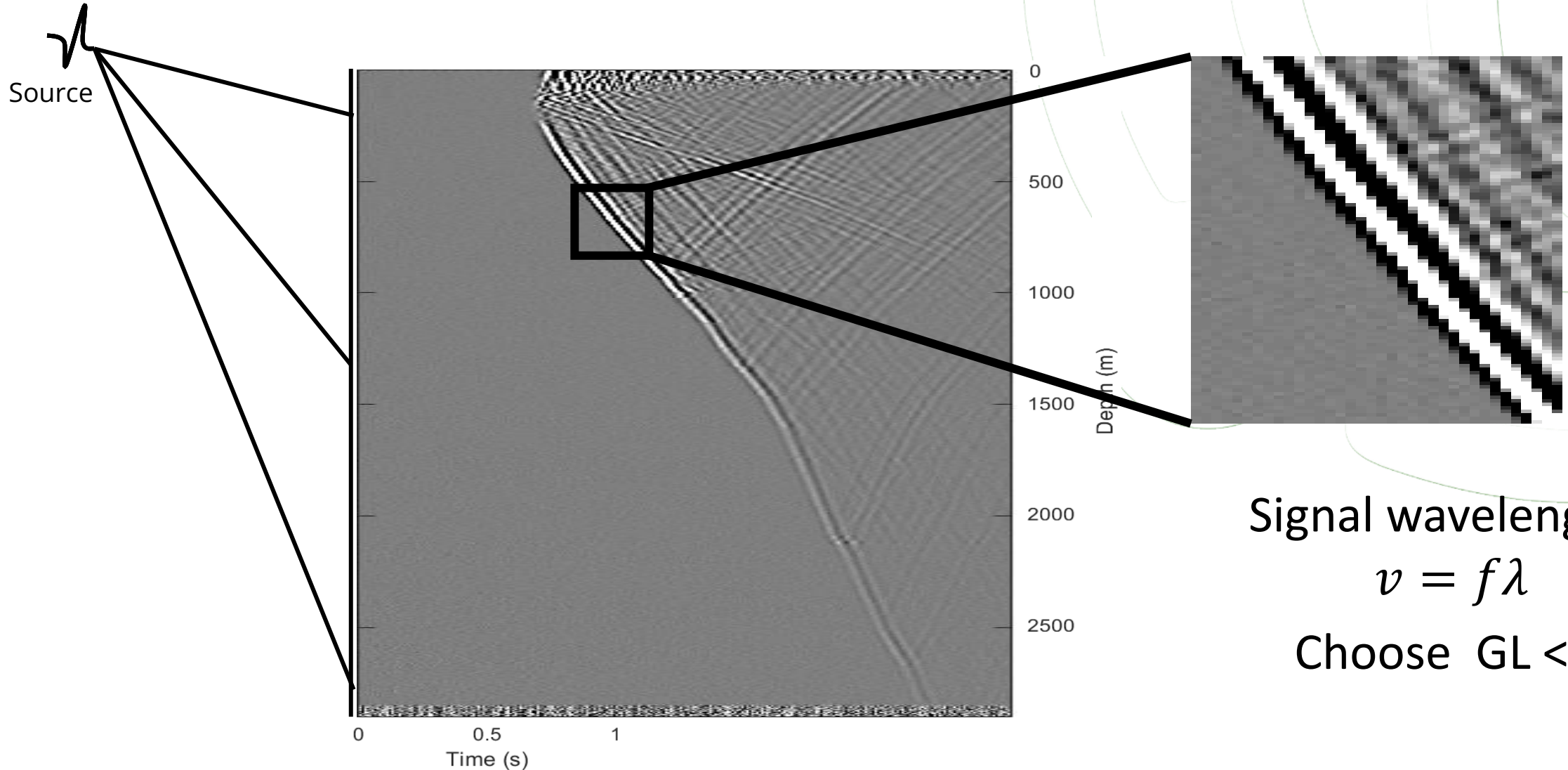
Physical Fibre Length (m)
10000

Sampling Frequency (Hz)
1000

Spatial Sampling Interval (m)
1

Previous Step 2 of 6 Next

Gauge length



Signal wavelength?

$$v = f\lambda$$

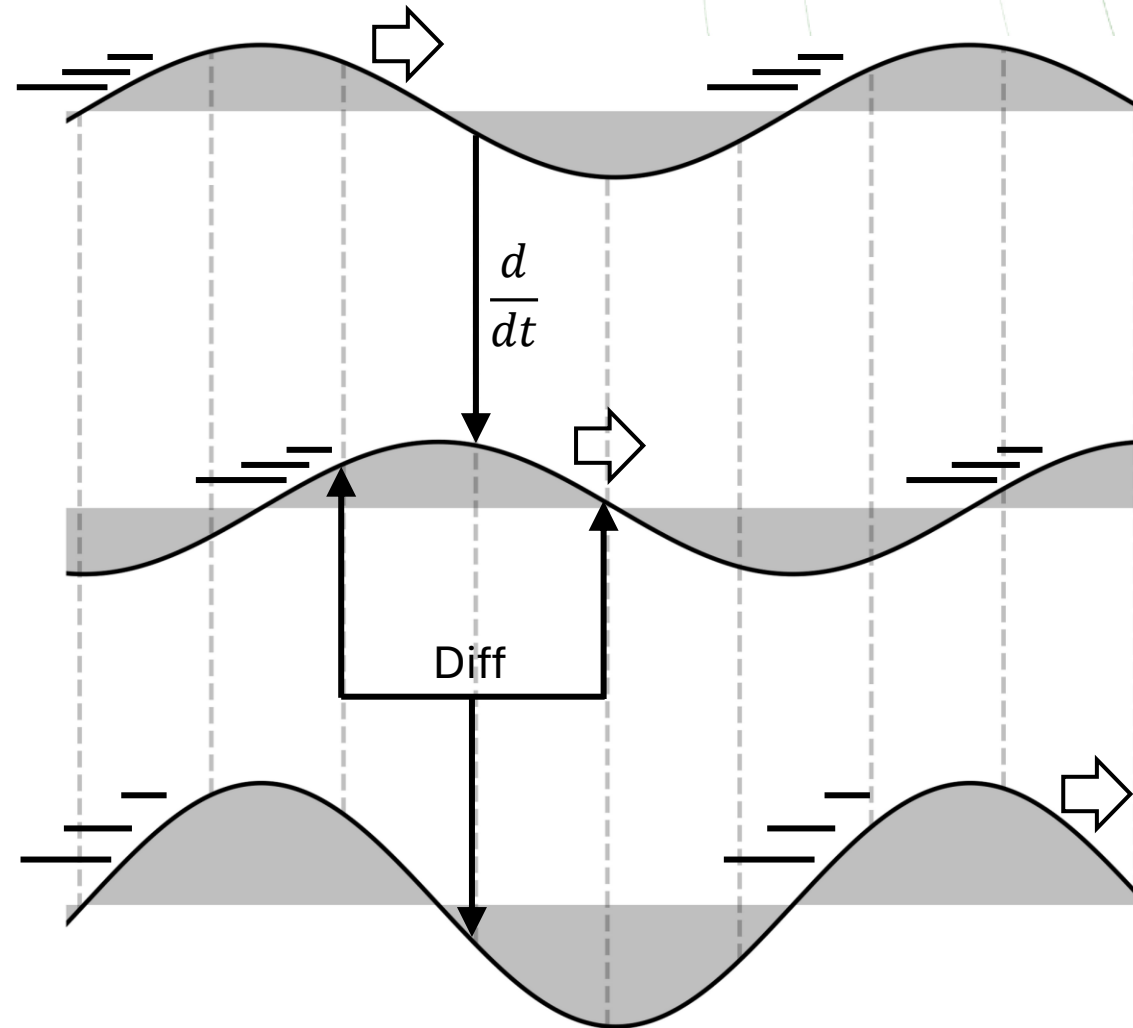
Choose $GL < \lambda$

Gauge length

Displacement u_x

Velocity

DAS
= velocity differential

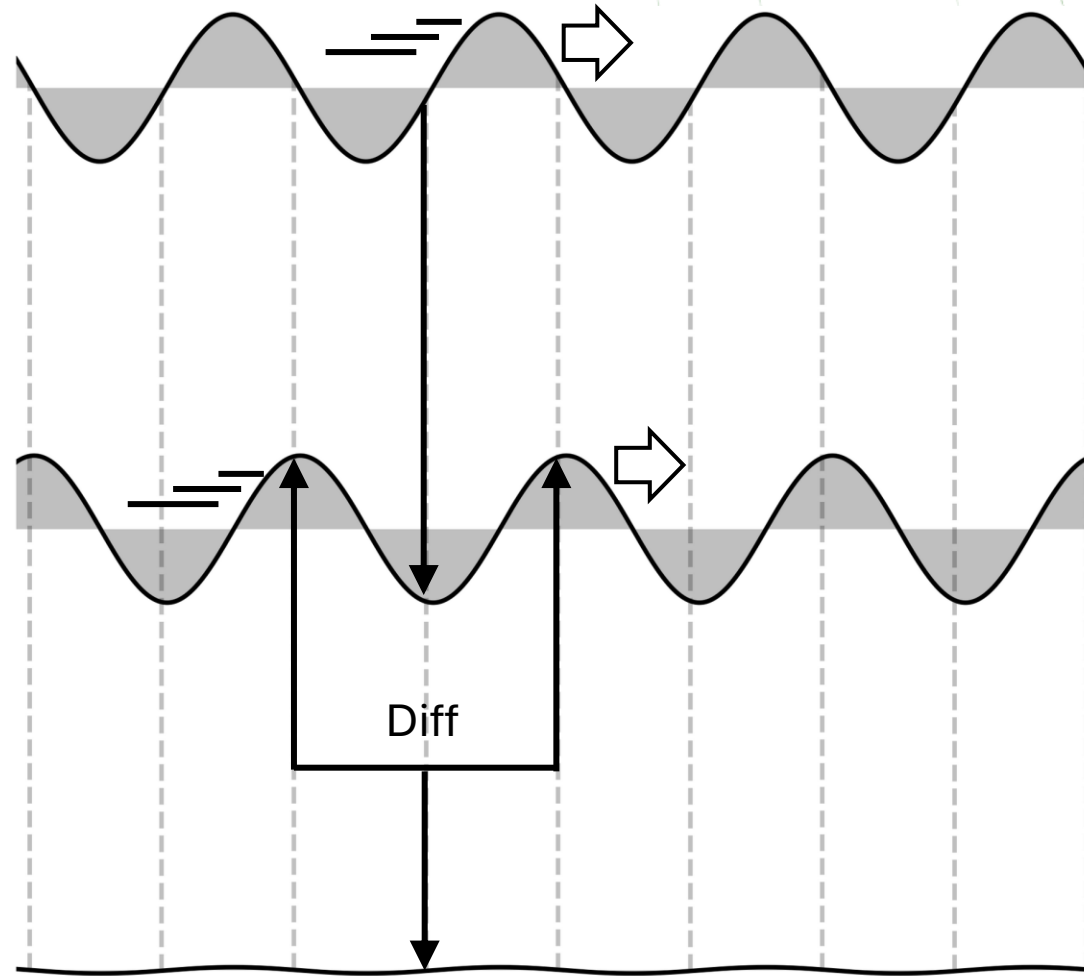


Gauge length

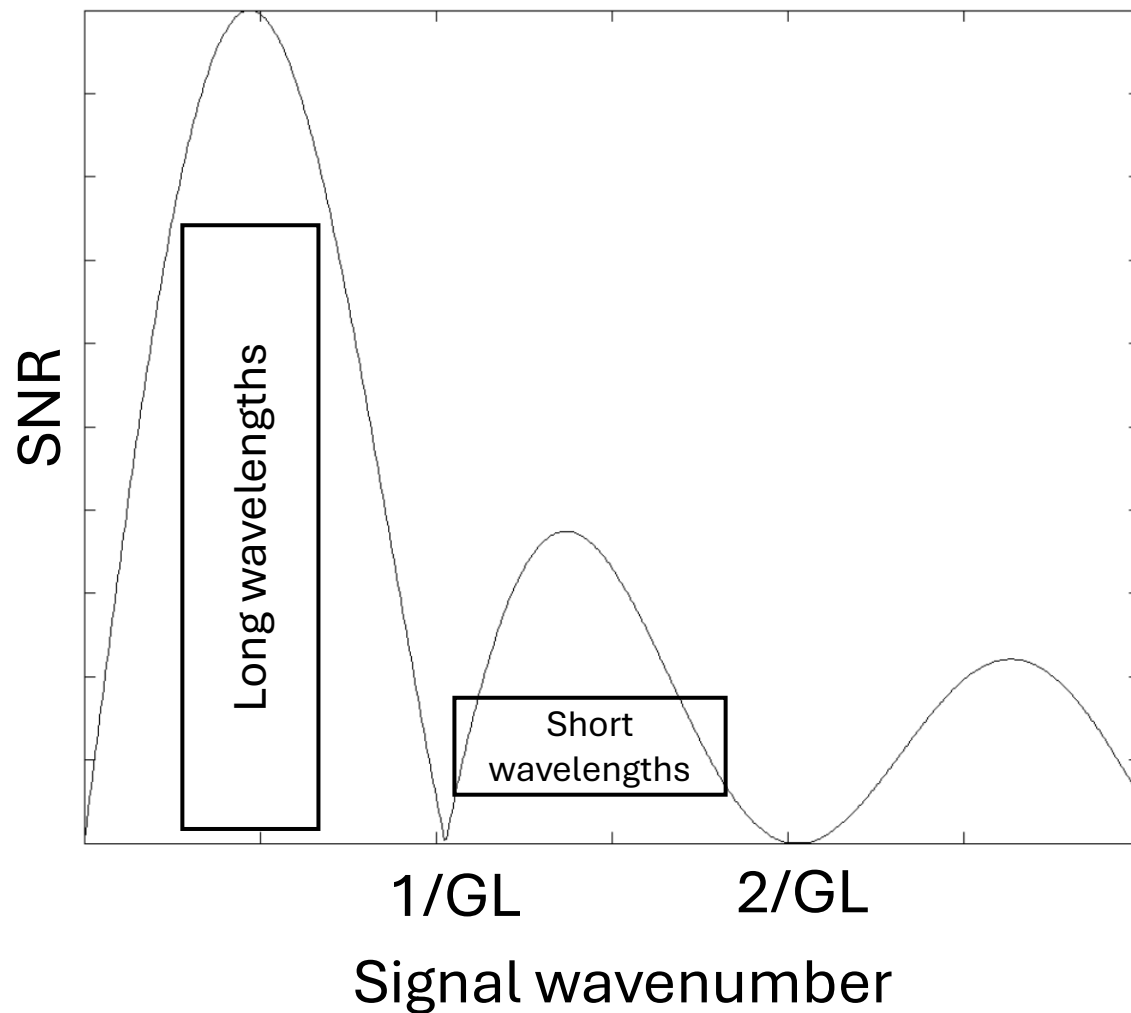
Displacement u_x

Velocity

DAS
= velocity differential

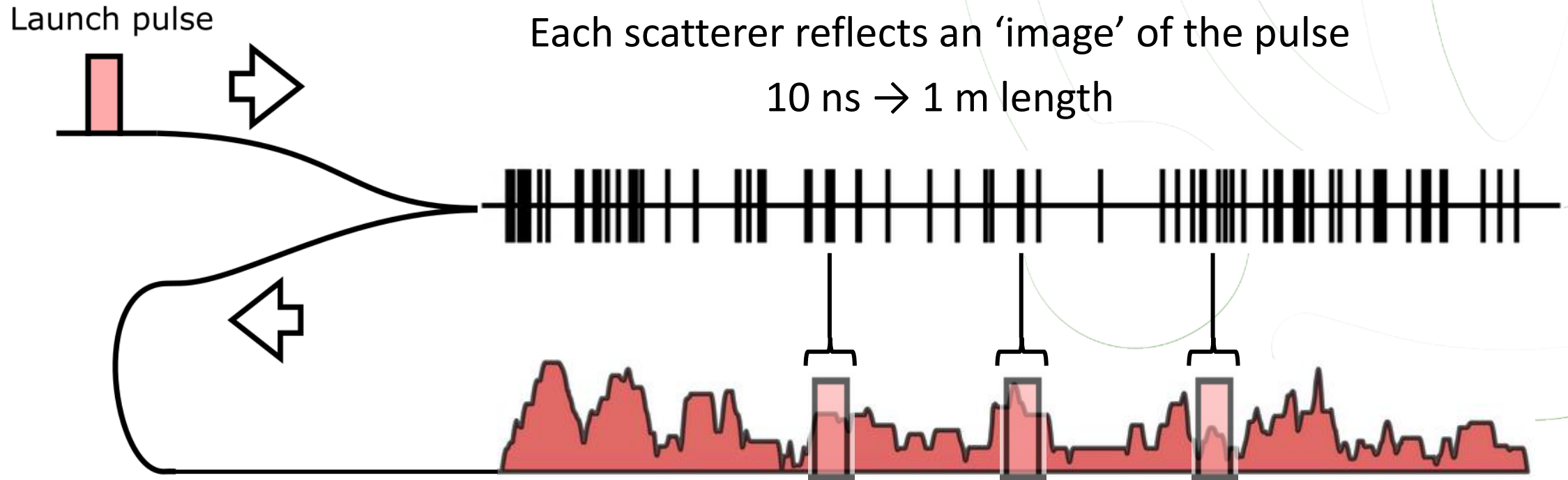


Gauge length



Signal wavenumber – as projected along the fibre

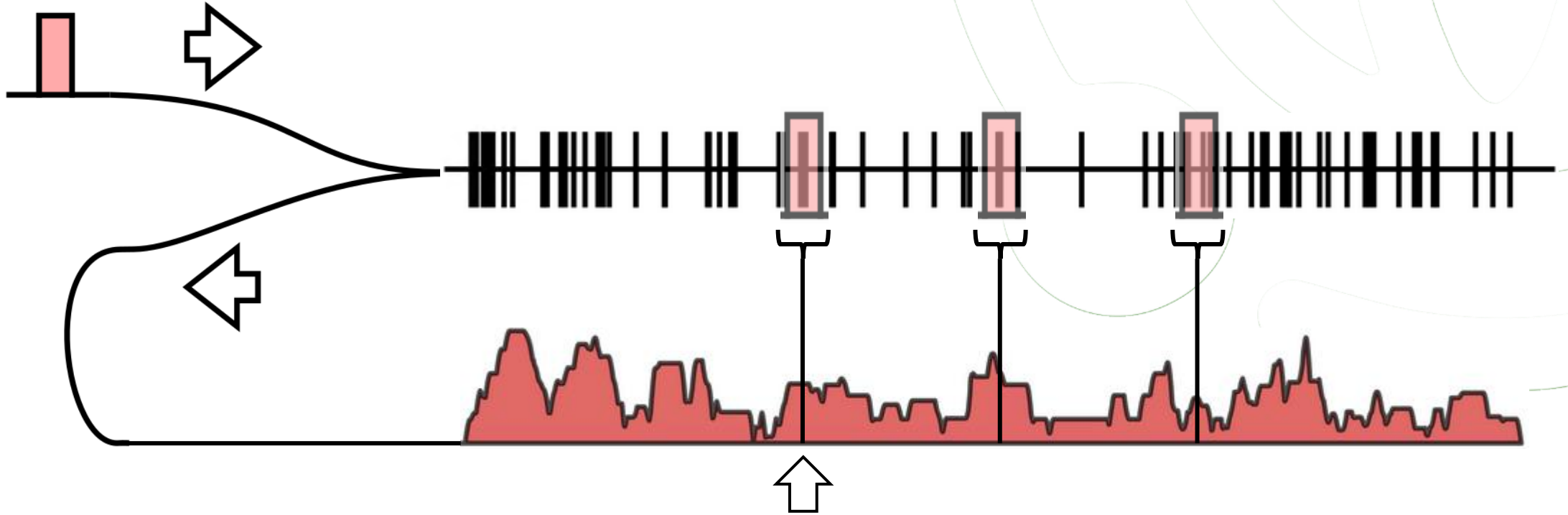
How Pulse Width relates to Gauge Length



One point on fibre contributes to 'pulse length' in signal

How Pulse Width relates to Gauge Length

Launch pulse



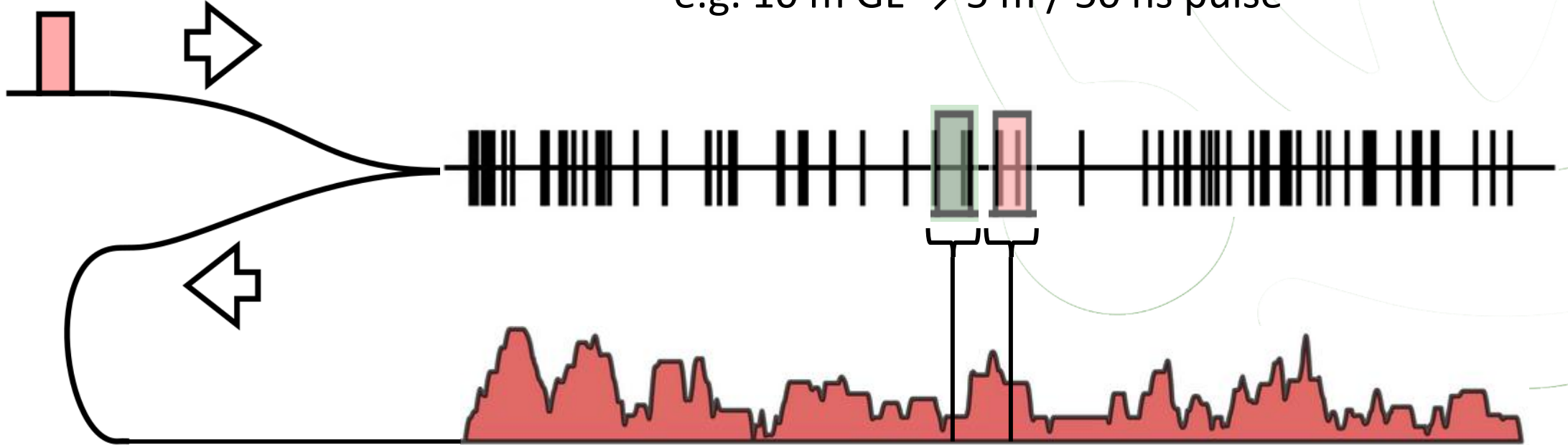
Instantaneous signal comes from 'pulse length' of fibre

How Pulse Width relates to Gauge Length

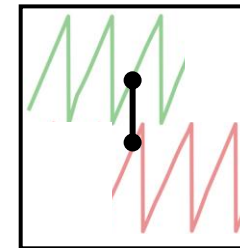
Rule: Pulse length = Gauge length \div 2

e.g. 10 m GL \rightarrow 5 m / 50 ns pulse

Launch pulse



Phase signals must come from distinct fibre segments

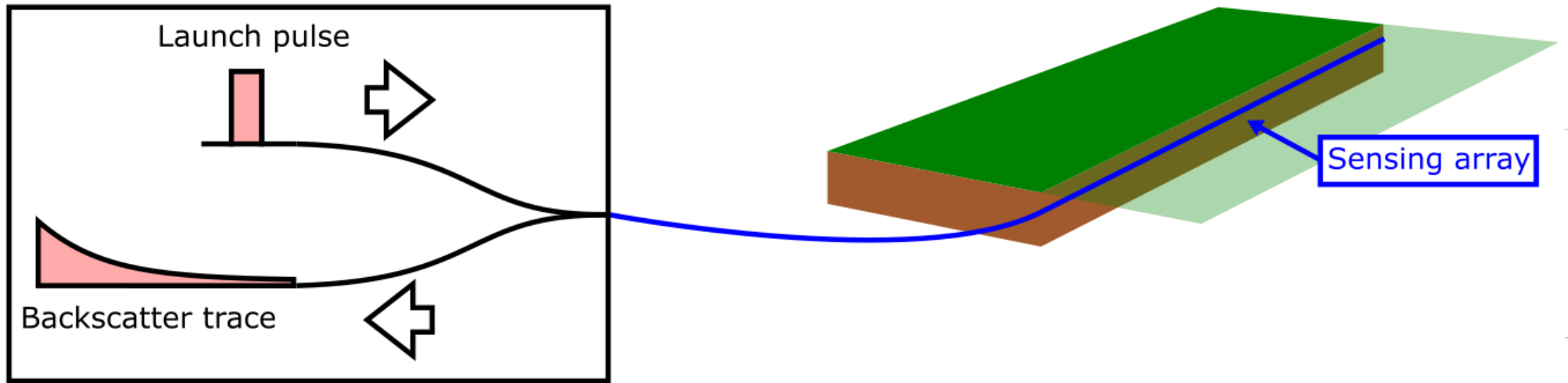


Longer pulse \rightarrow greater Intensity signal

Gauge length defines:

- Minimum clearly detectable wavelength
- Pulse width (optical SNR)

Physical Fibre Length

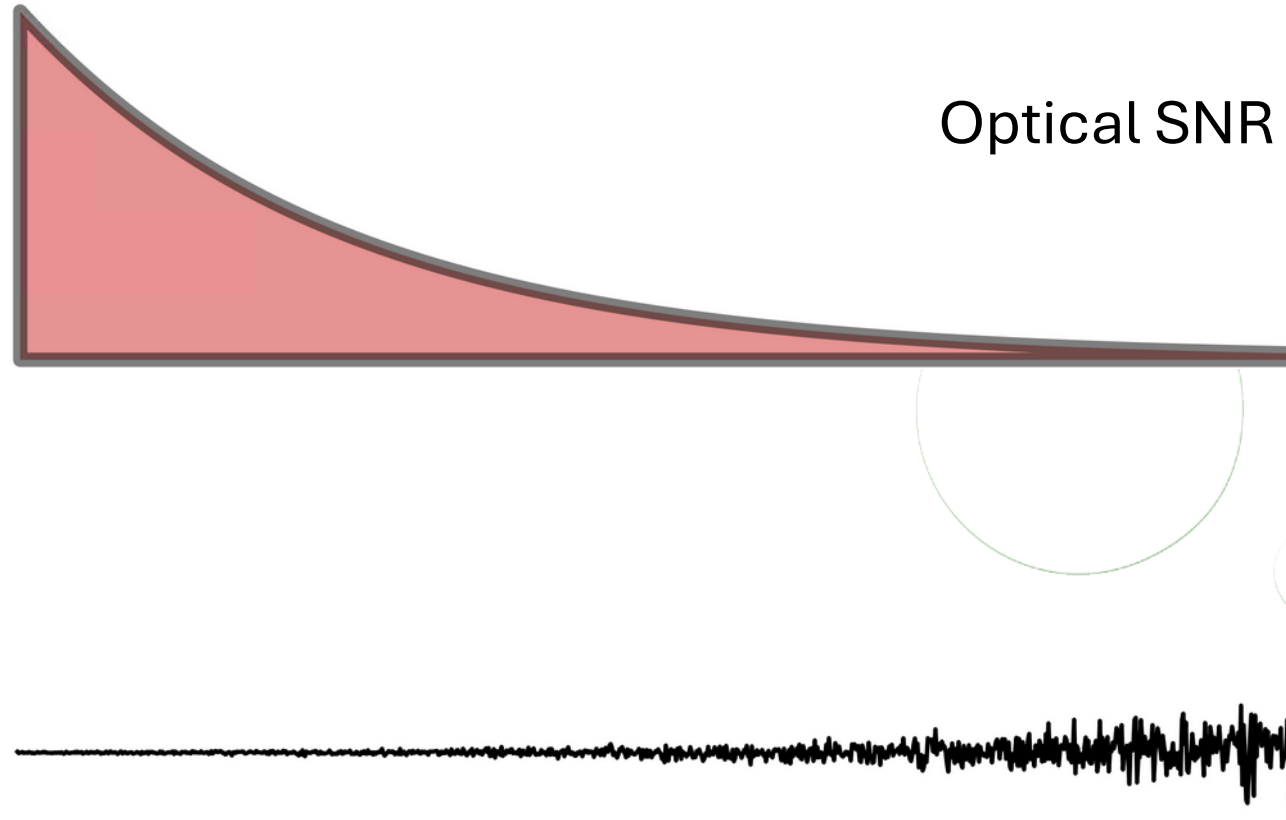


Physical Fibre Length

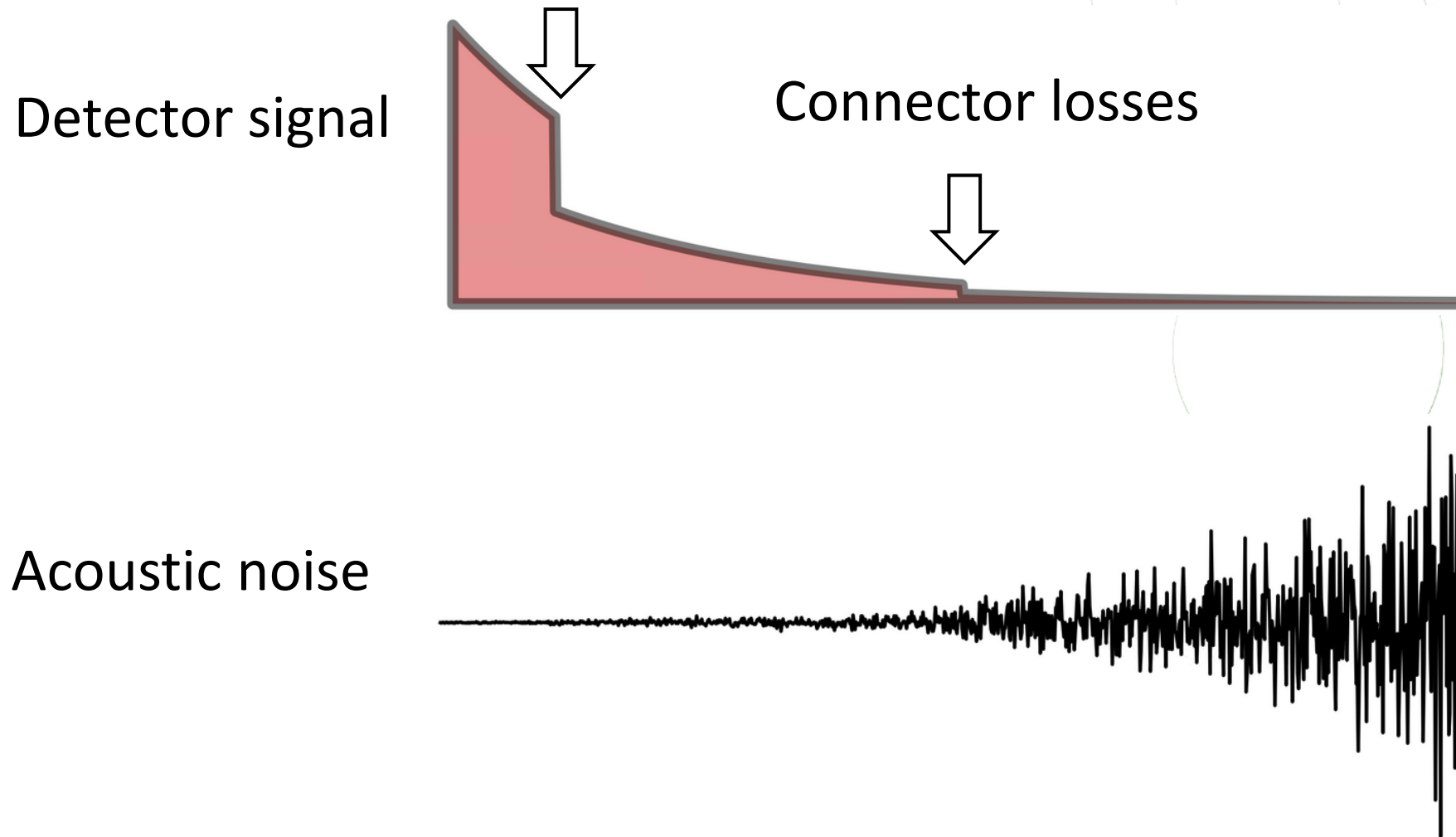
Detector signal

Optical SNR \rightarrow acoustic SNR

Acoustic noise



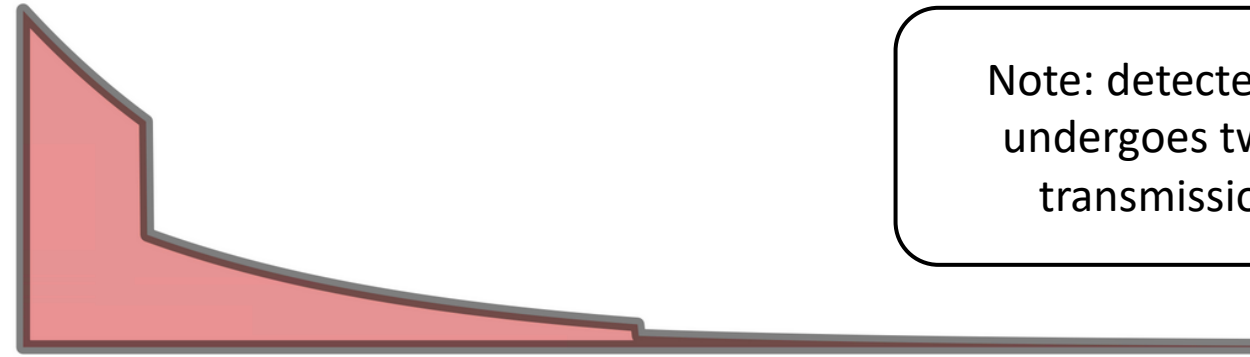
Physical Fibre Length



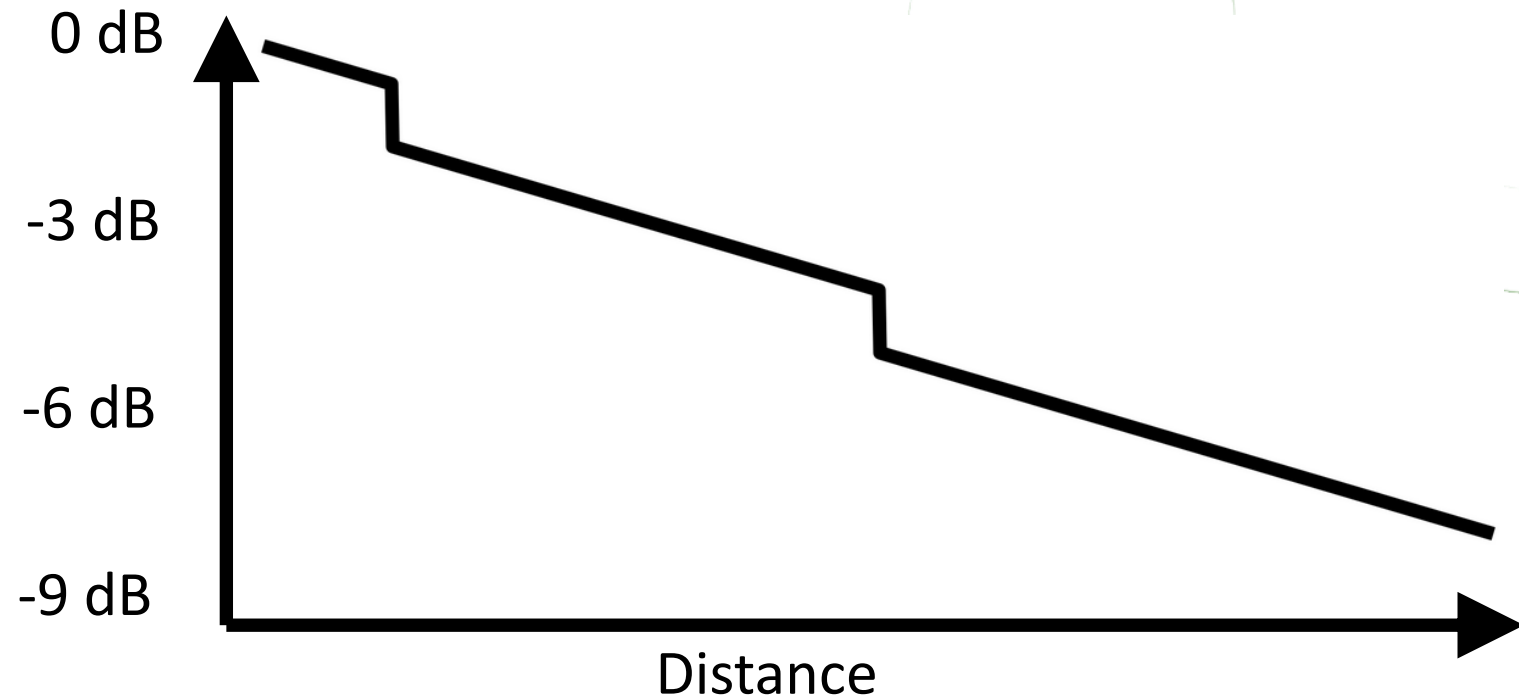
Physical Fibre Length

One-way transmission T_1

Note: detected signal
undergoes two-way
transmission T^2



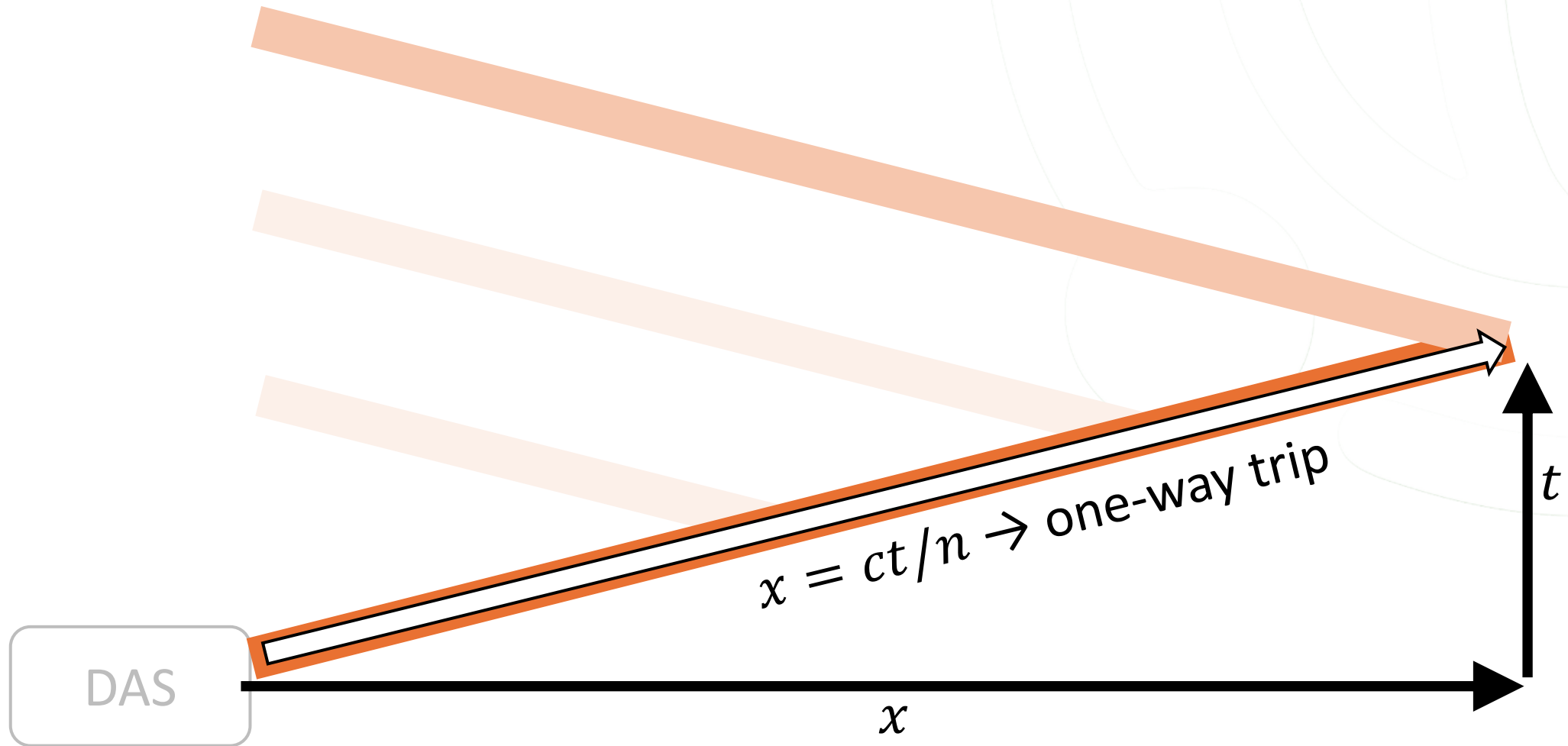
$$\text{OTDR} = 10 \log_{10} T_1$$



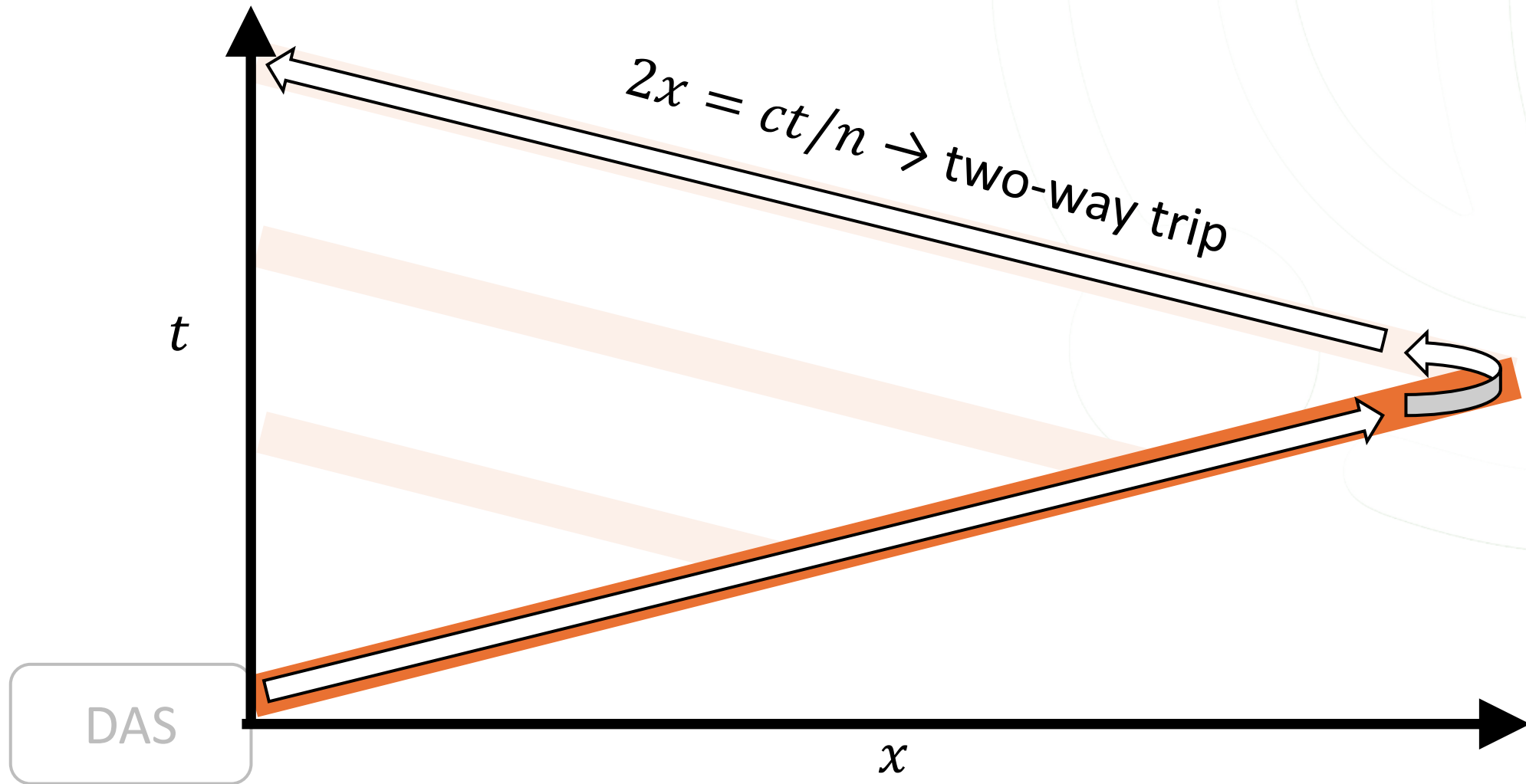
Physical Fibre Length



Physical Fibre Length



Physical Fibre Length



Physical Fibre Length

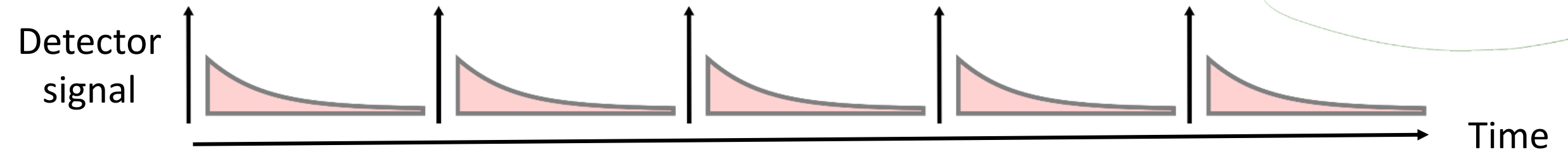
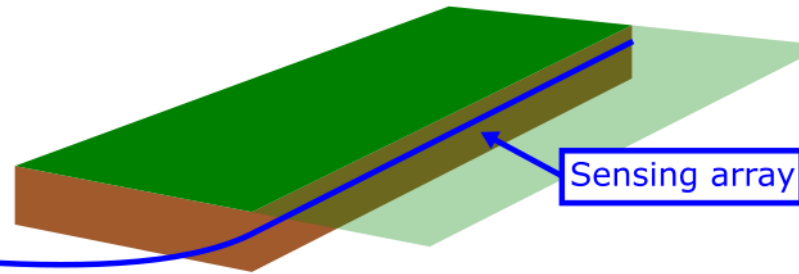
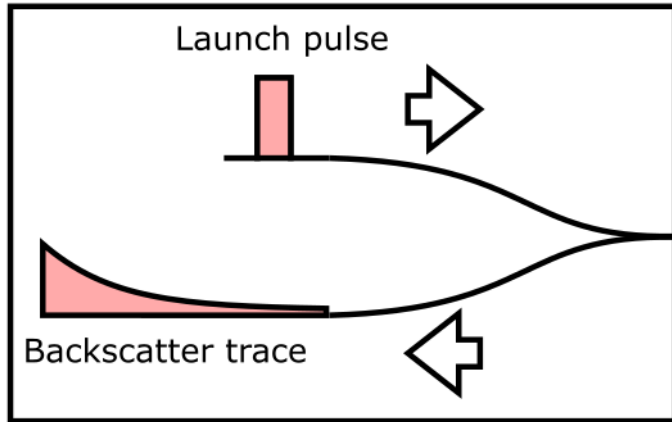
Maximum Laser Pulse Frequency:

$$f_{MAX} \approx \frac{10^8 \text{ m/s}}{L} = \frac{100 \text{ kHz}}{L [\text{km}]}$$

- 10 km fibre: $f_{MAX} \approx 10 \text{ kHz}$
- 30 km fibre: $f_{MAX} \approx 3.3 \text{ kHz}$

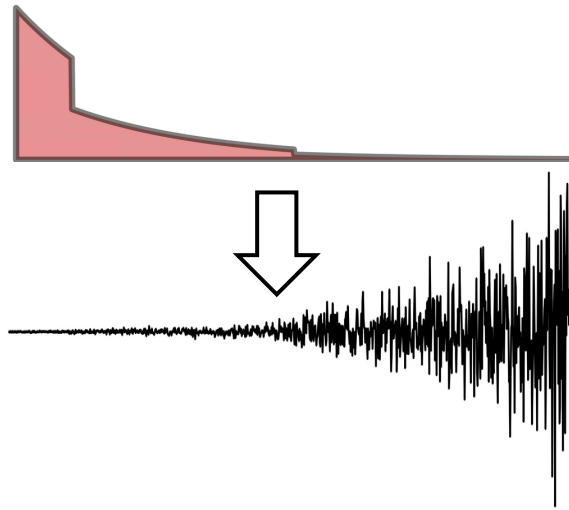
Rule of thumb:
10 km at 10 kHz

Physical Fibre Length

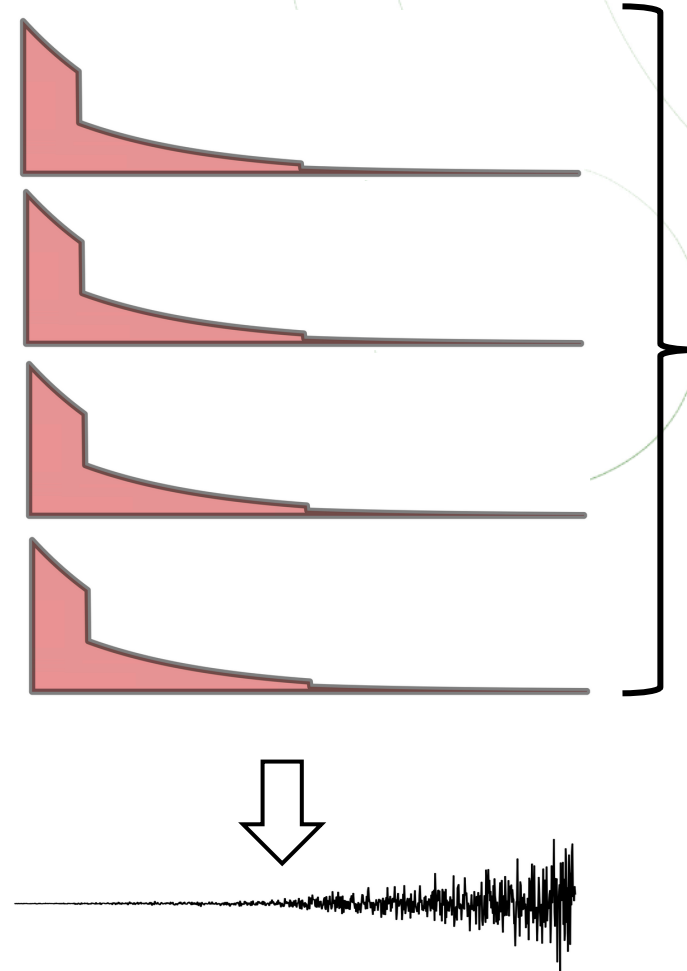


Physical Fibre Length

Can you average traces over time?



- Reduced acoustic bandwidth
- Lower data rate
- Optical SNR resilience

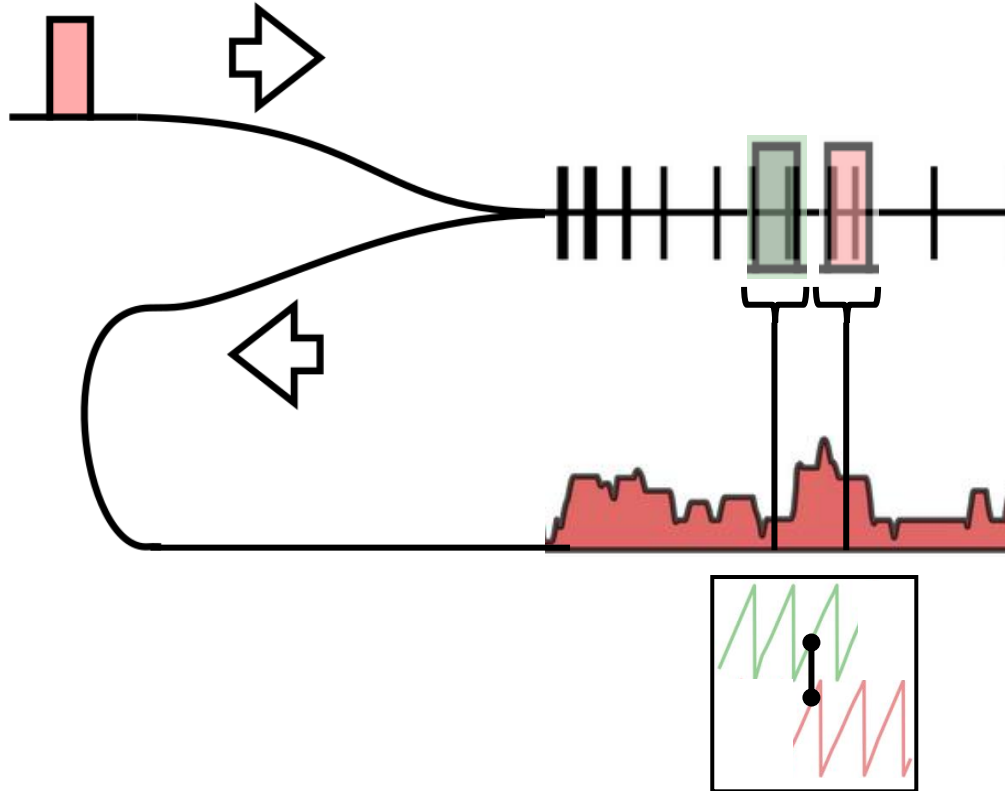


Average before
processing

“Time
decimation”

Dynamic range

Launch pulse

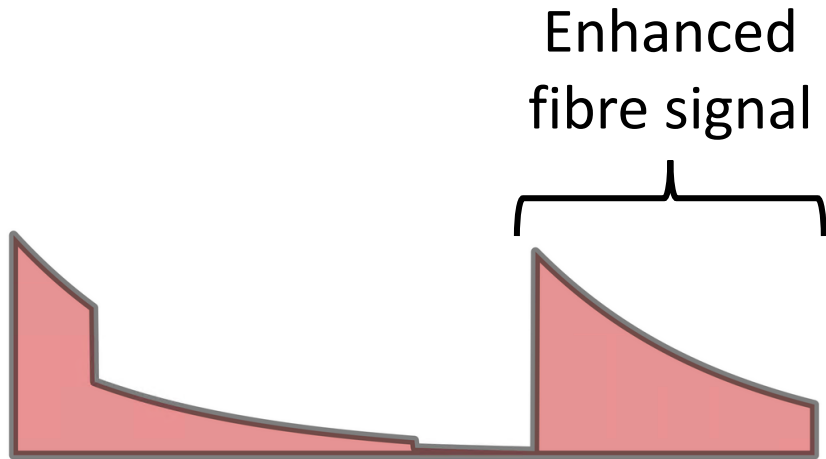


- Raw DAS data = phase change across:
 - 1 gauge length
 - 1 time sample
- Signal \propto GL
- Signal $\propto 1/F_s$
- Maximum signal = π

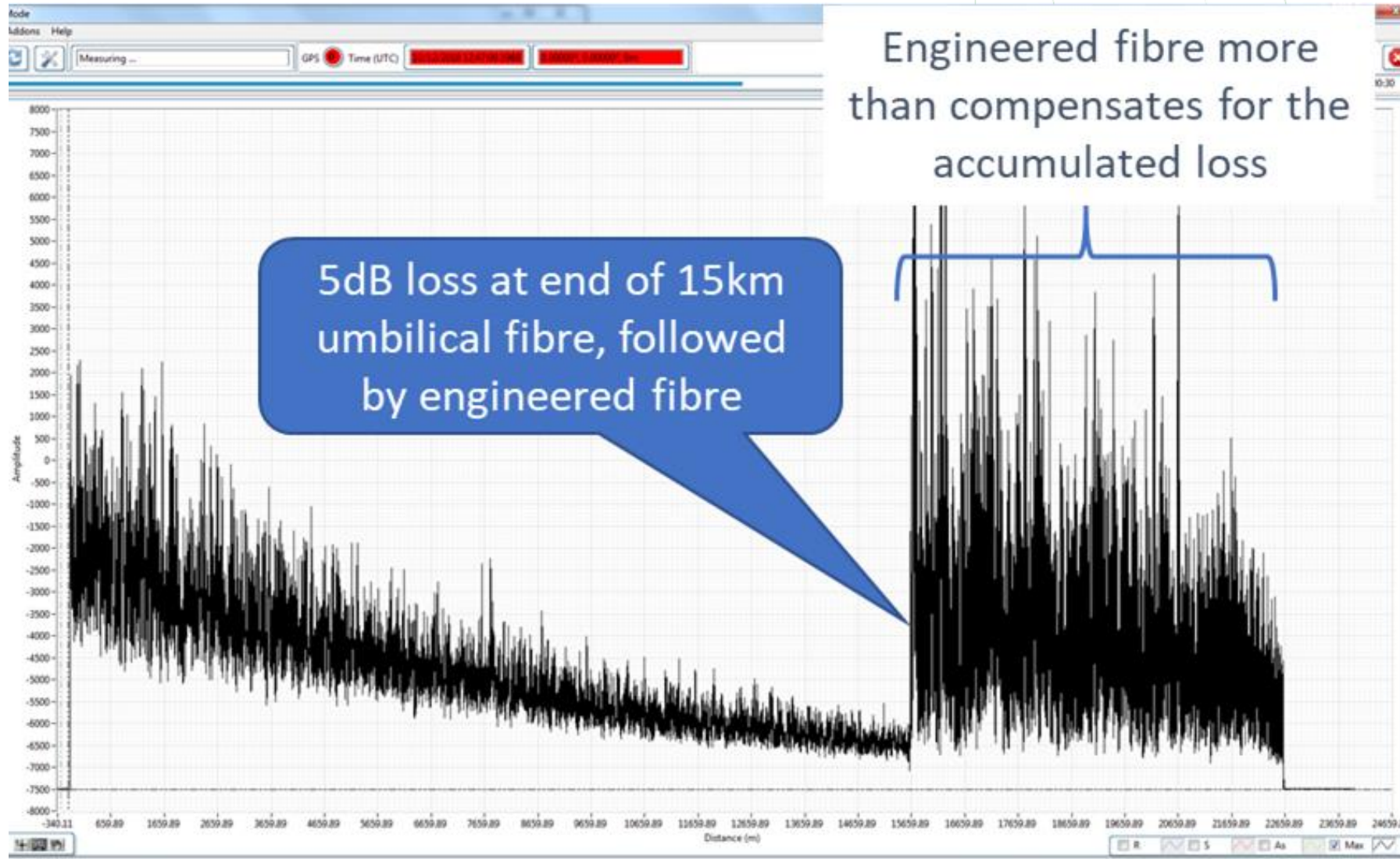
Maximum dynamic range when:

- Shorter fibre
- Highest sampling frequency
- Shortest gauge length

Can you use enhanced backscatter fibre?



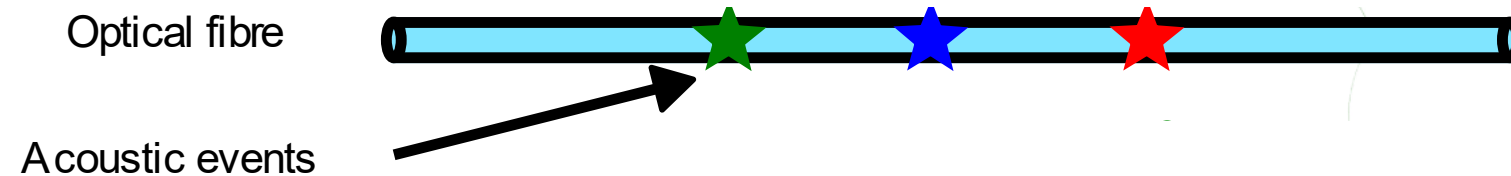
Physical Fibre Length



Physical fibre length affects:

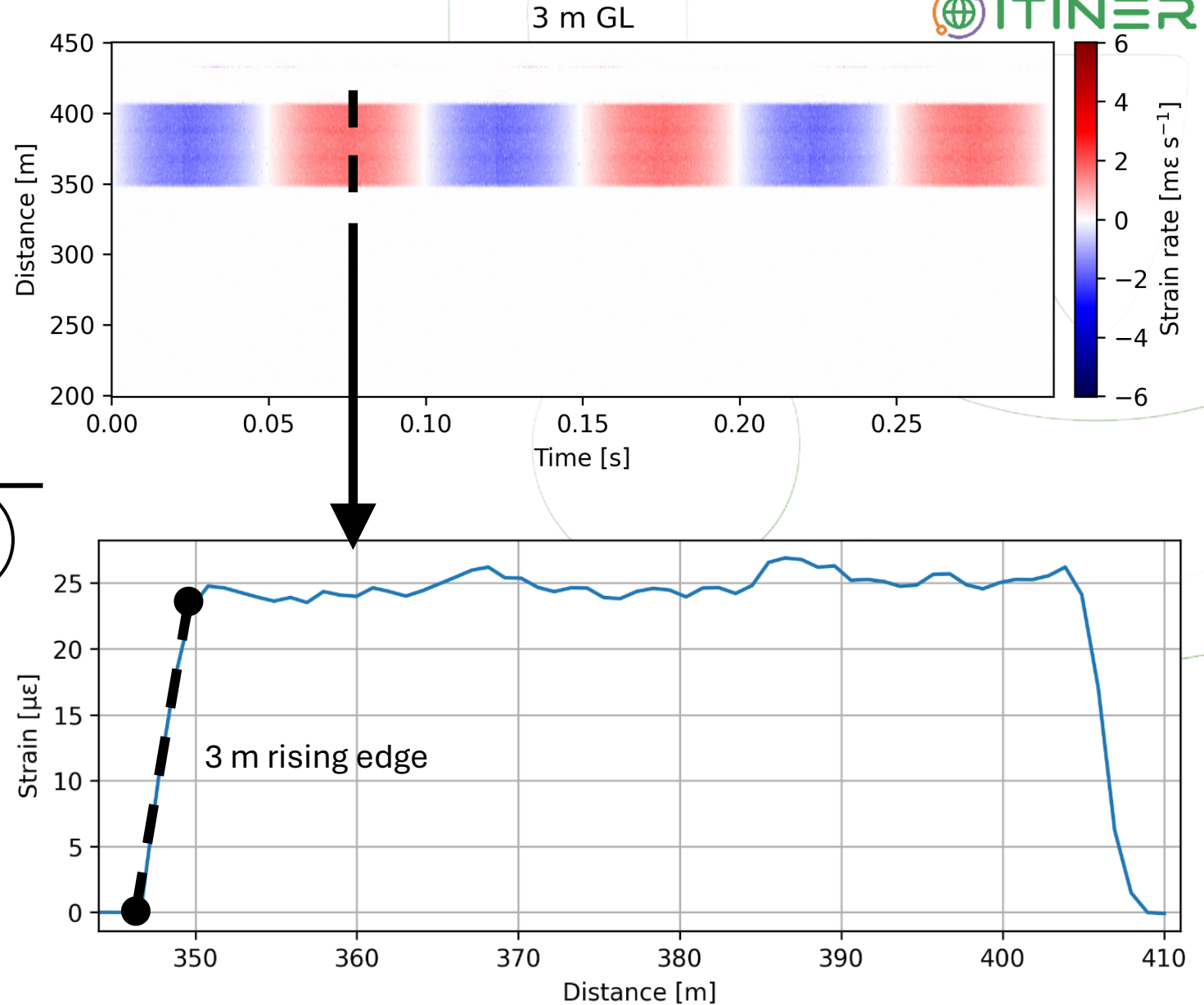
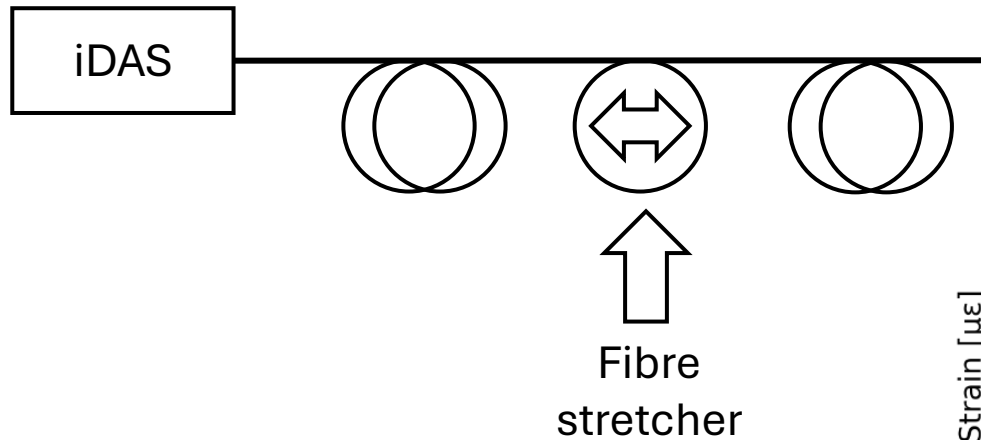
- Maximum sampling frequency
- Dynamic range limit
- Optical signal profile and SNR

Spatial Sampling Interval

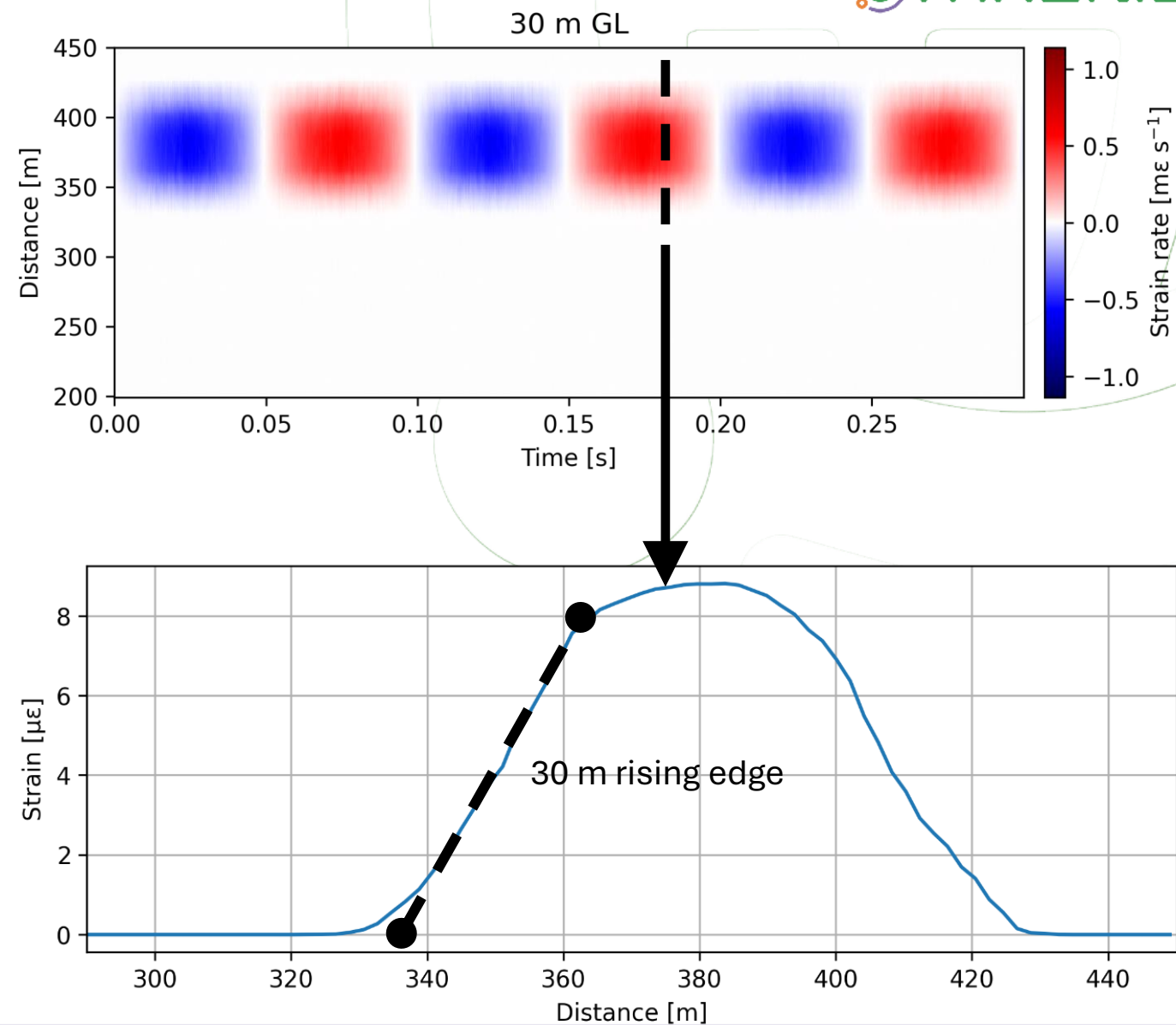
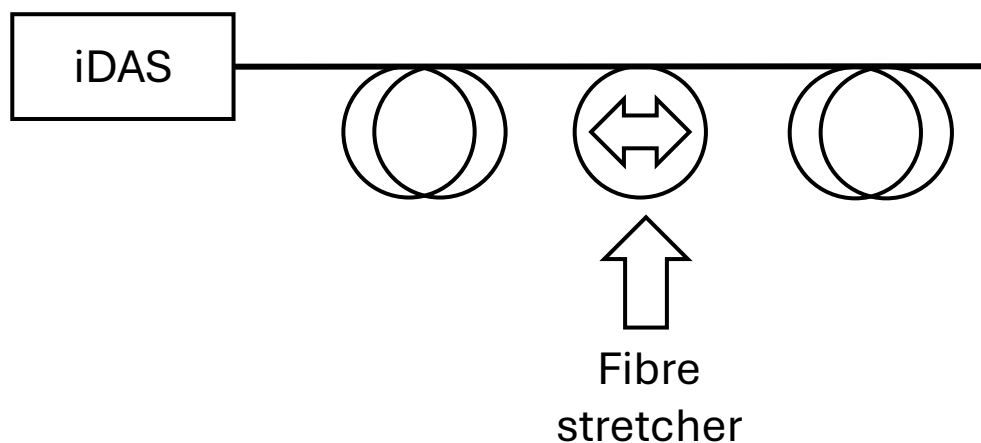


Rule of thumb: Gauge length $\div 10$

Spatial Sampling Interval



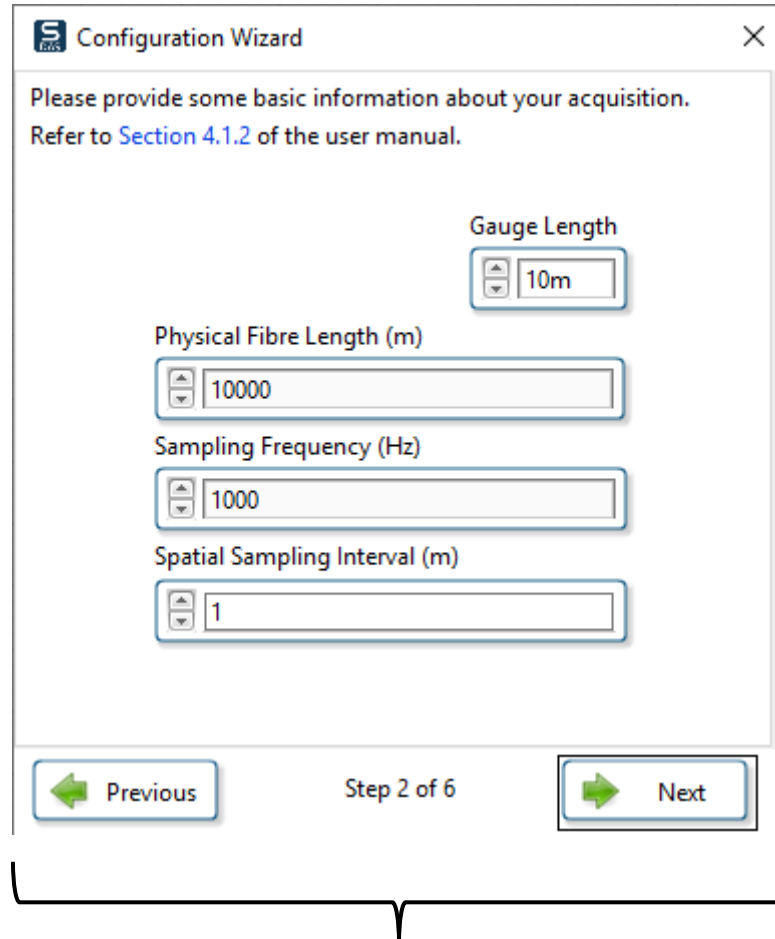
Spatial Sampling Interval



Spatial Sampling Interval affects:

- Maximum spatial resolution
- Data rate

Configuration Wizard



Configuration Wizard

Please provide some basic information about your acquisition.
Refer to [Section 4.1.2](#) of the user manual.

Gauge Length
10m

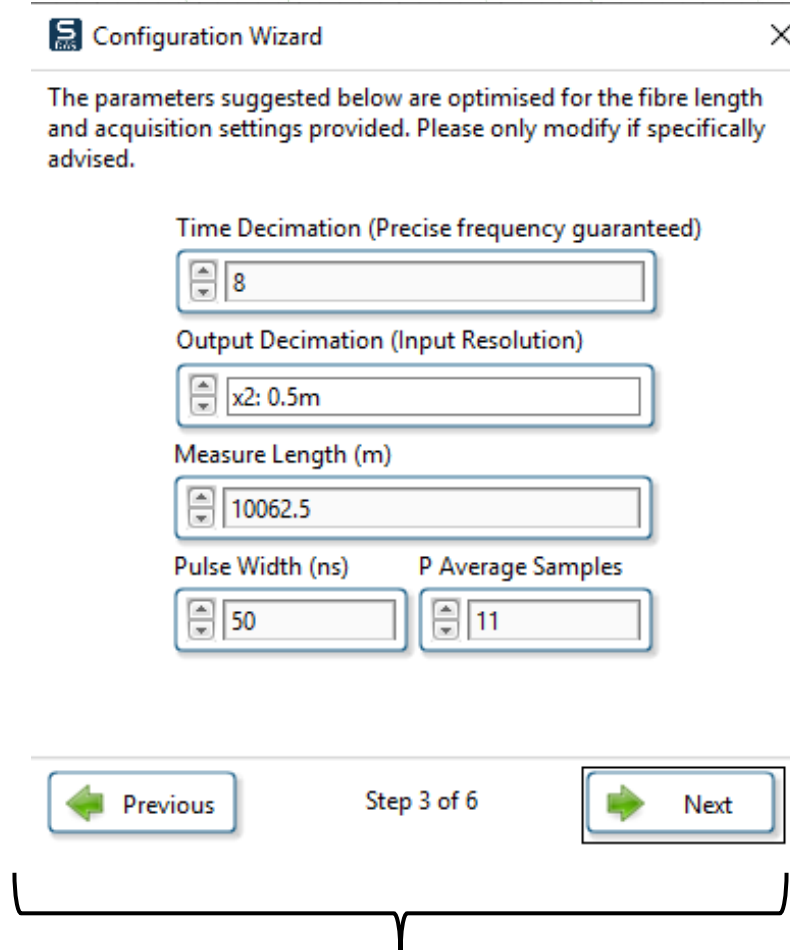
Physical Fibre Length (m)
10000

Sampling Frequency (Hz)
1000

Spatial Sampling Interval (m)
1

Previous Step 2 of 6 Next

User parameters



Configuration Wizard

The parameters suggested below are optimised for the fibre length and acquisition settings provided. Please only modify if specifically advised.

Time Decimation (Precise frequency guaranteed)
8

Output Decimation (Input Resolution)
x2: 0.5m

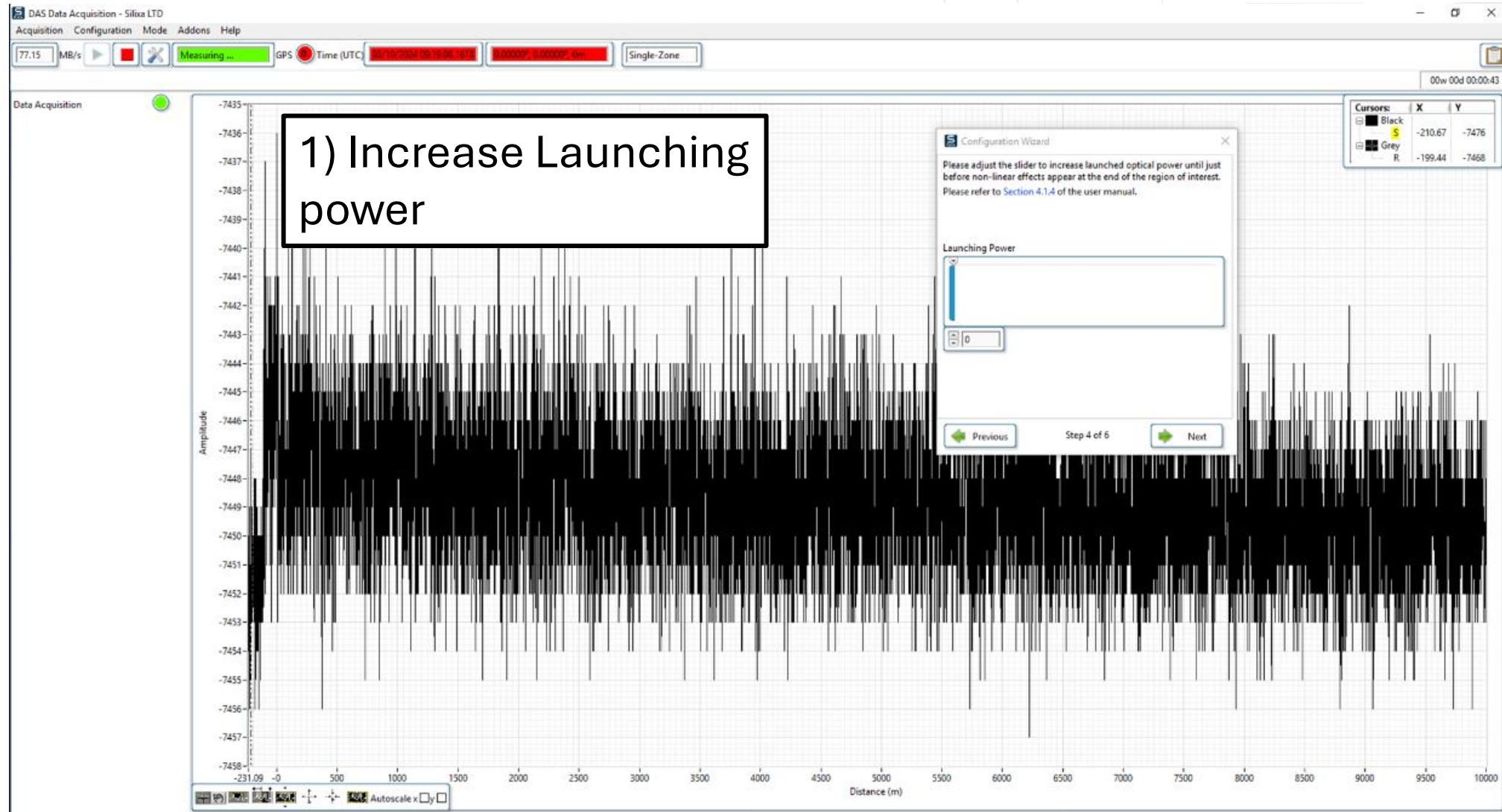
Measure Length (m)
10062.5

Pulse Width (ns) P Average Samples
50 11

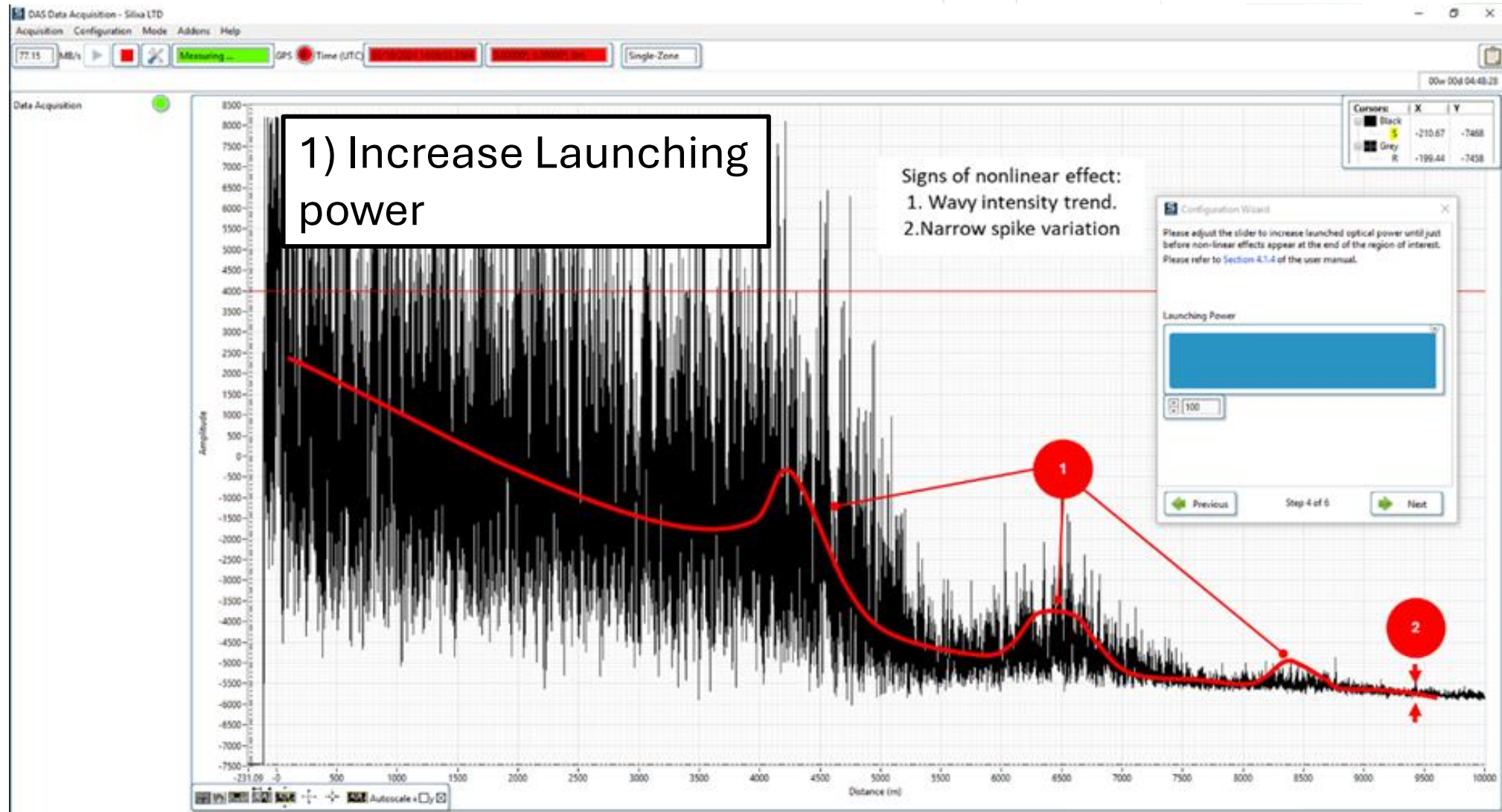
Previous Step 3 of 6 Next

Internal parameters – do not change

Configuration Wizard

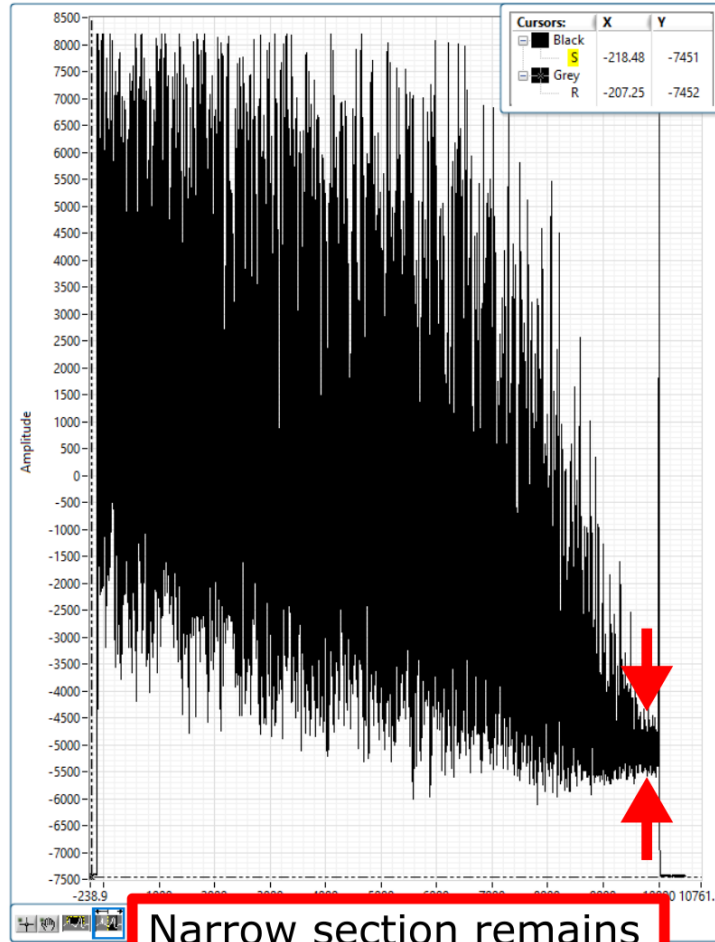


Configuration Wizard

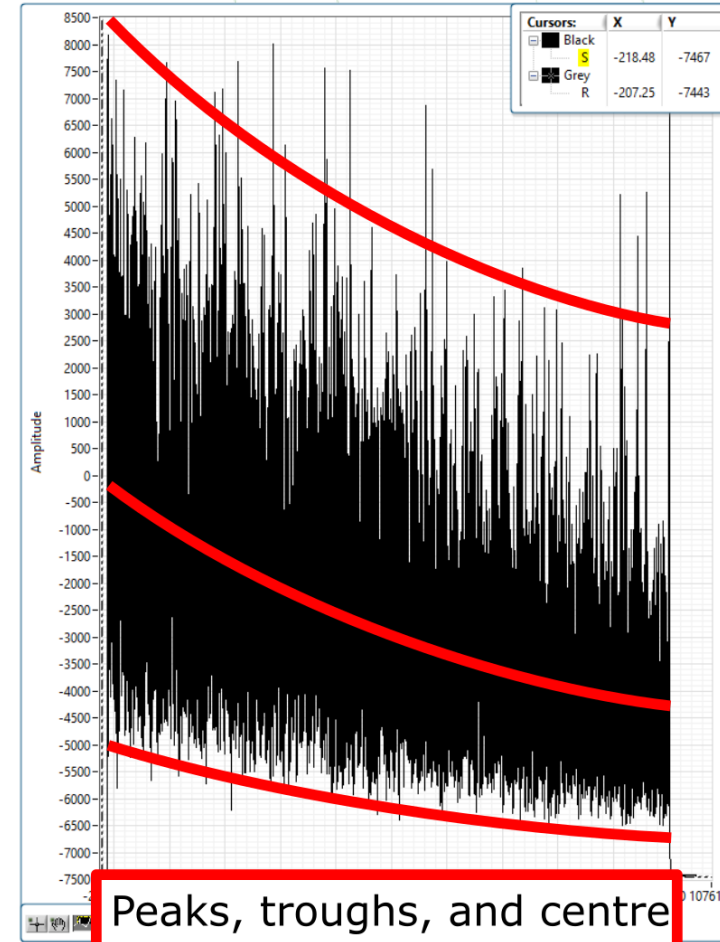


Configuration Wizard

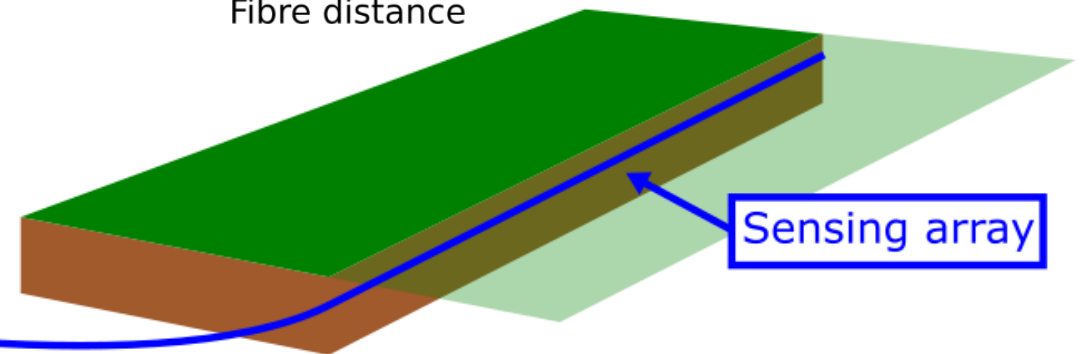
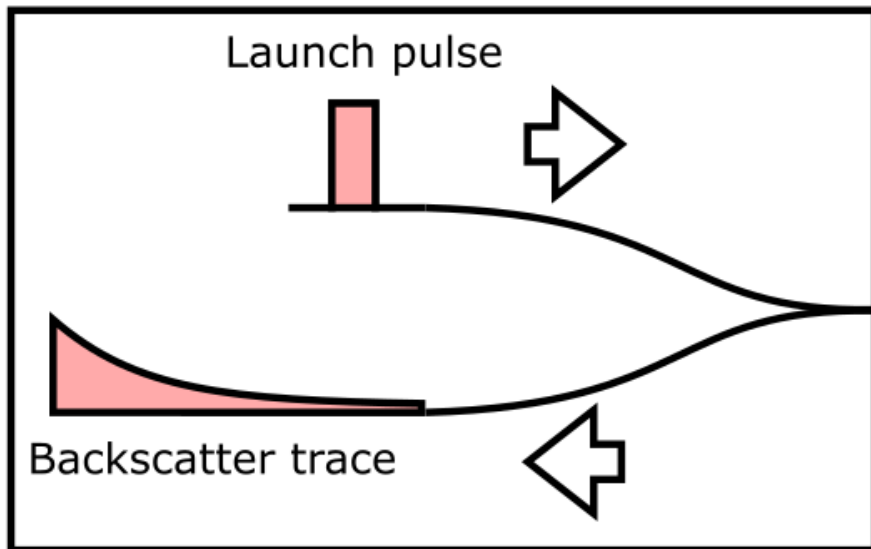
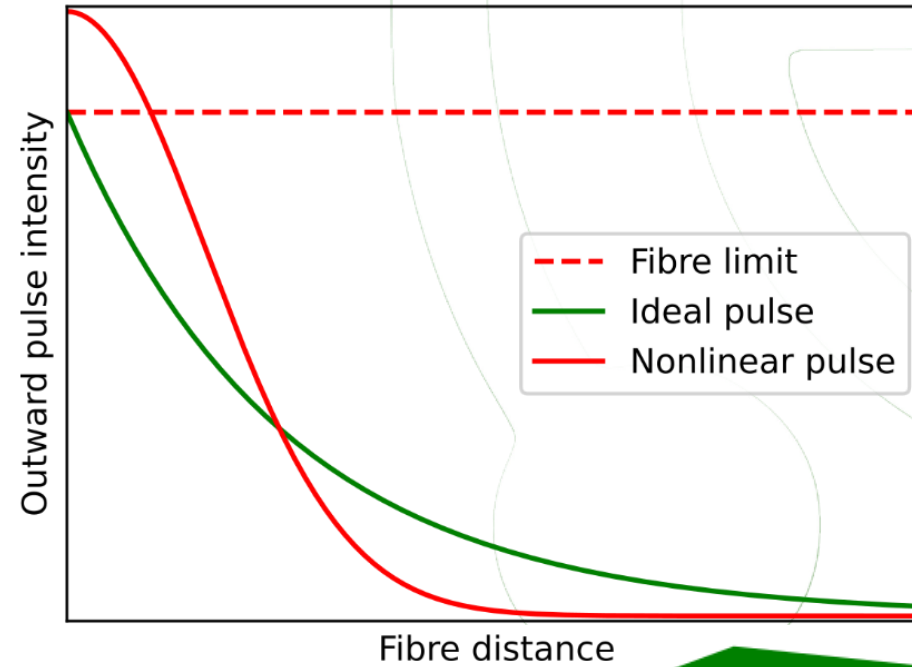
Optical power still too high



Optical power ideal

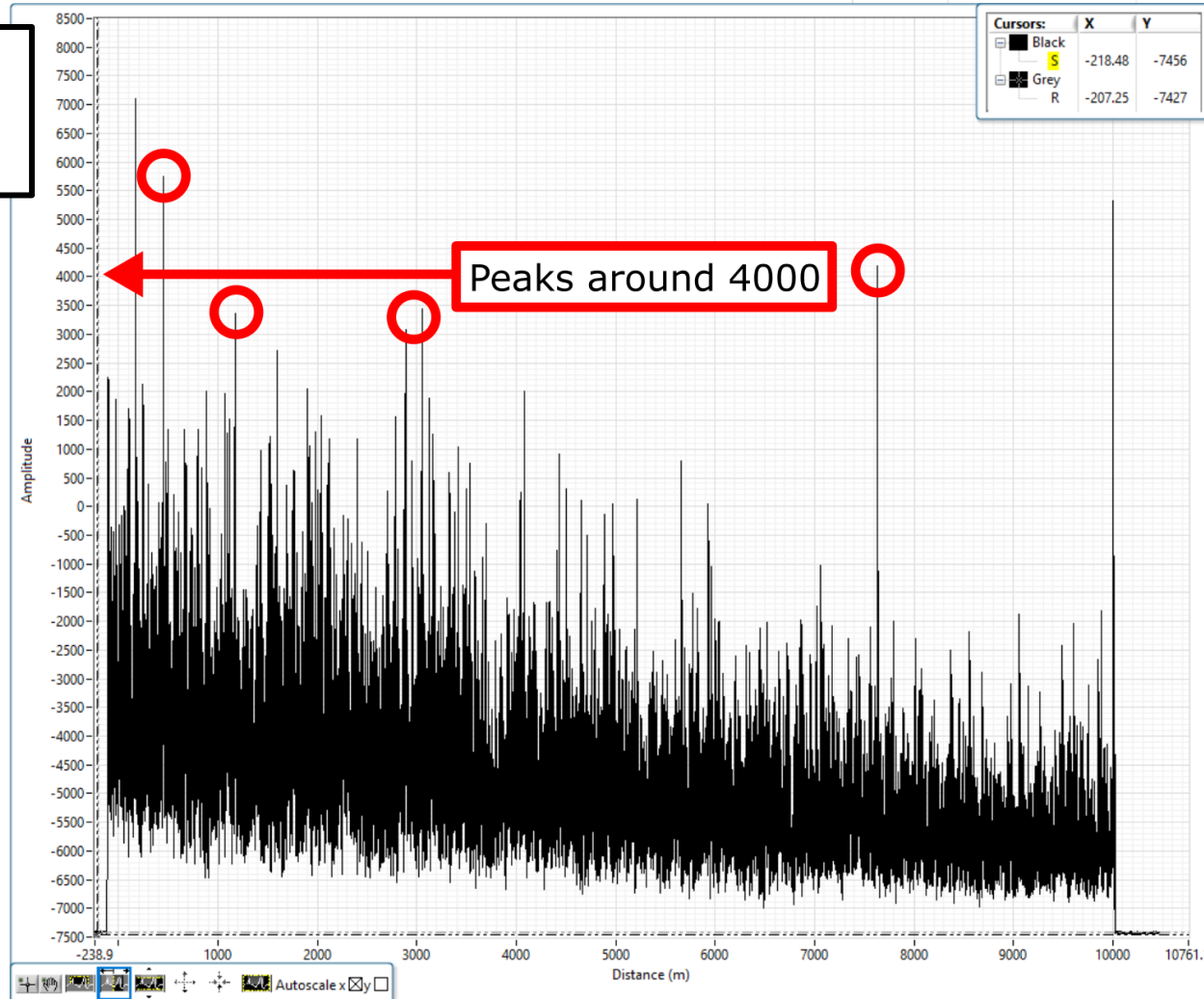


Configuration Wizard

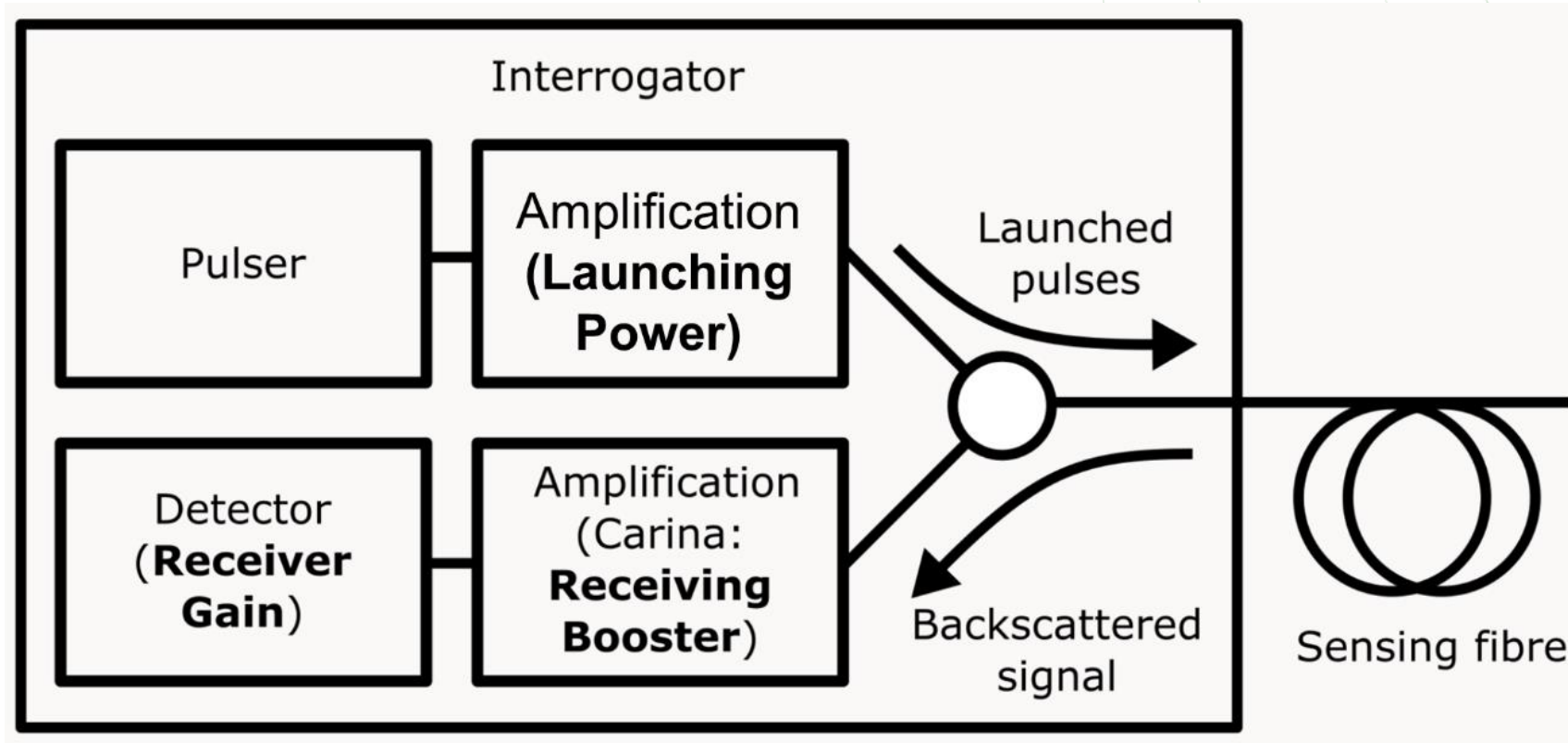


Configuration Wizard

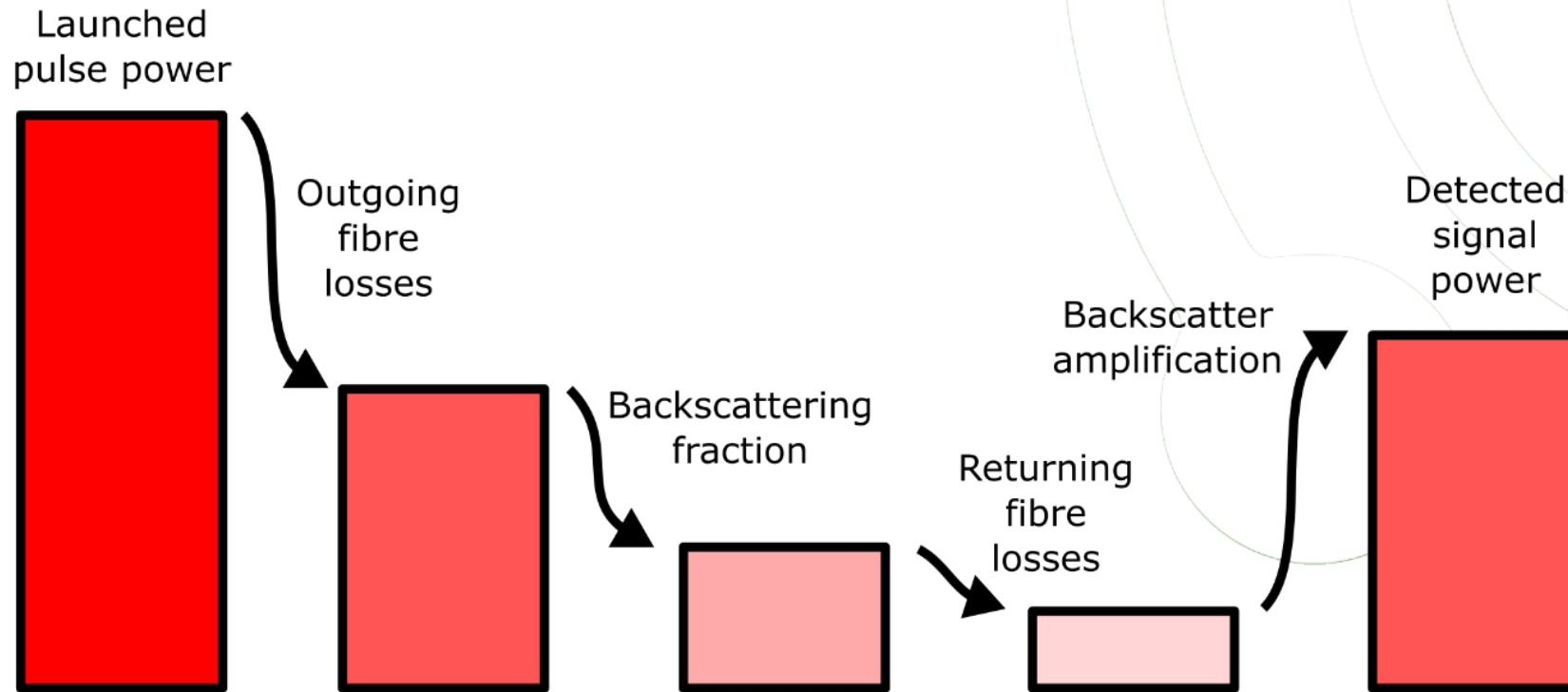
2) Increase Receiver amplifier power



Configuration Wizard

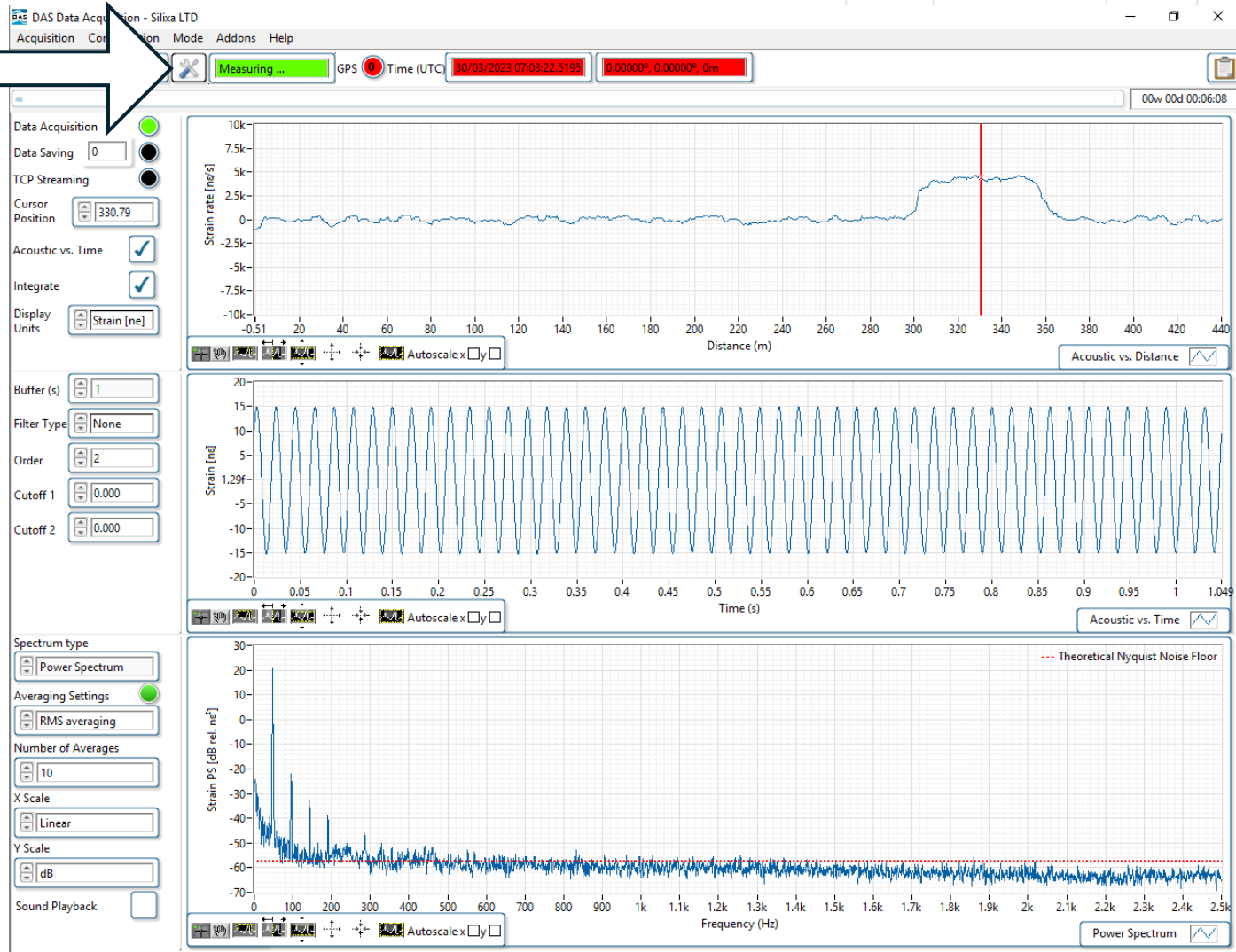


Configuration Wizard

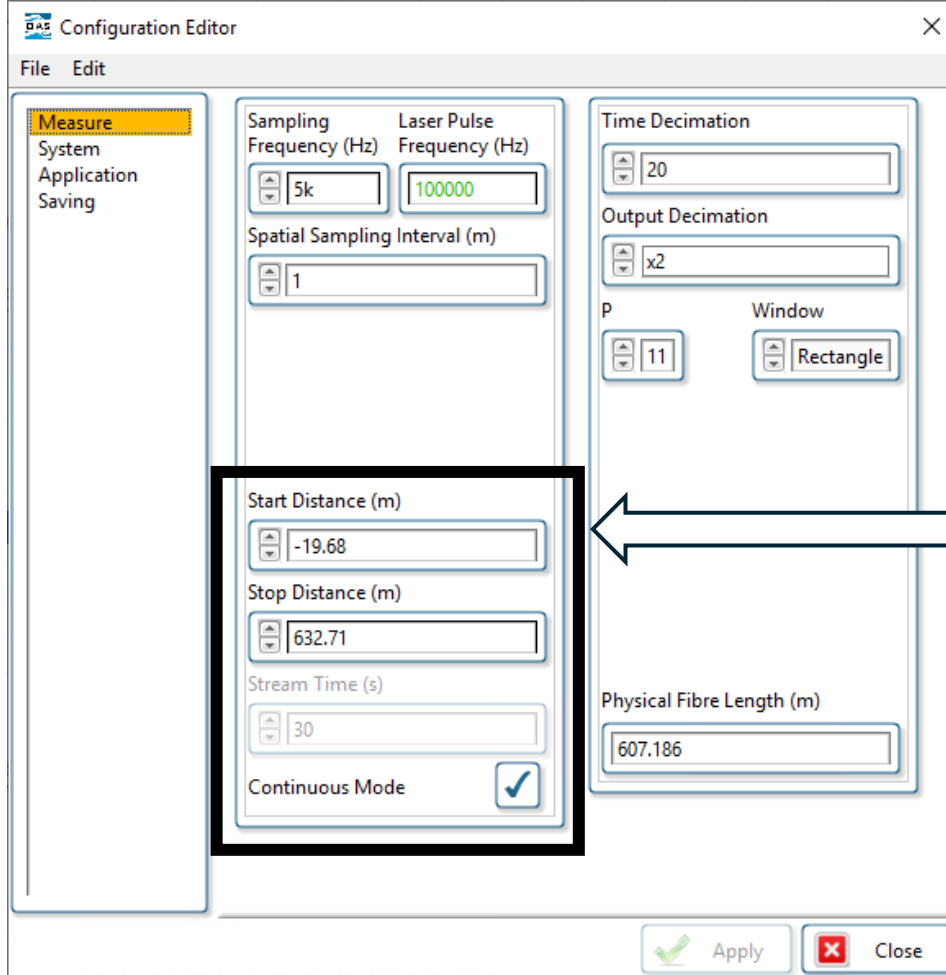


Configuration

Remaining
settings to adjust



Configuration Editor




- Only change these
- Change other settings via wizard

Configuration Editor

Saving settings

Enable Data Saving ☐ Data Saving File

FFID in filename ☐ Current FFID

Saving Folder
 

File Name Prefix Timestamp

File Size Limit (s) (0: unlimited)

Saving Buffering ☒

Delete oldest files ☐

Disk space remaining (time)

File Header Comments

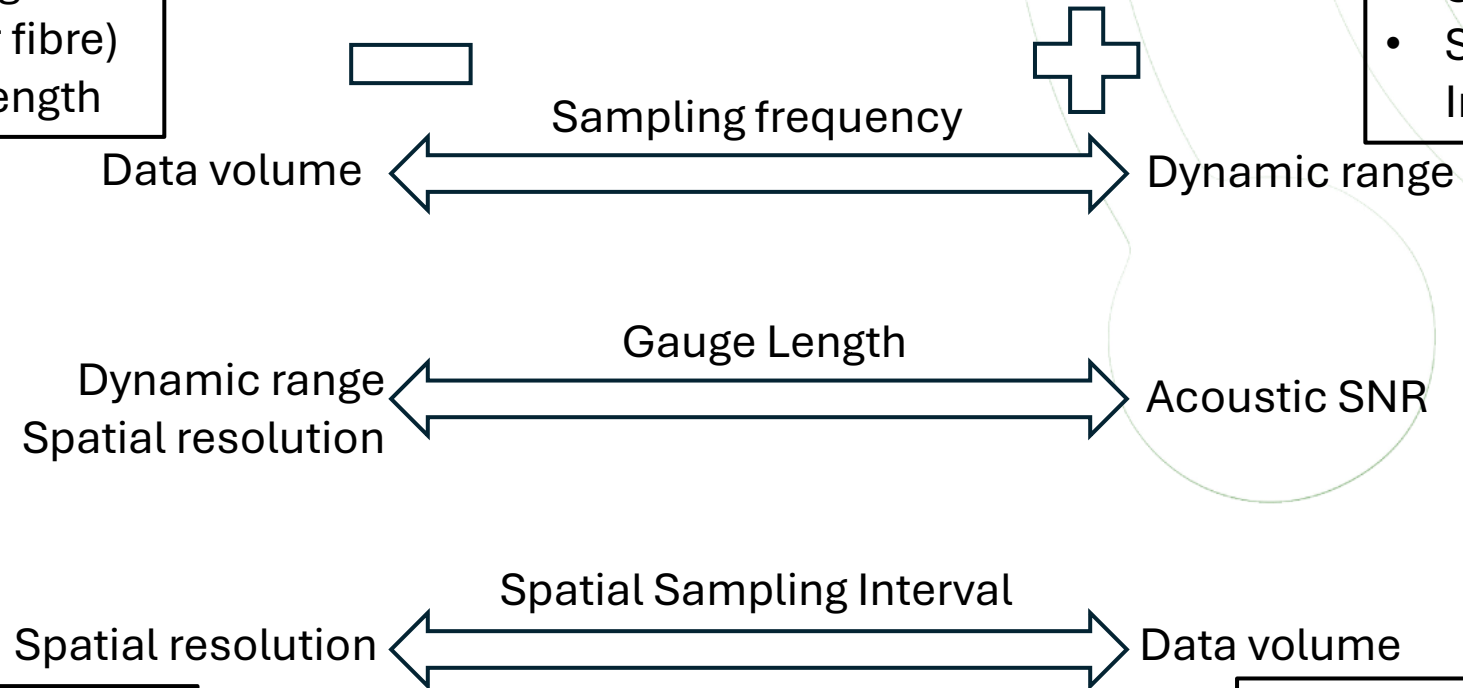
Settings trade-offs

Dynamic range:

- Maximum Sampling Frequency (shorter fibre)
- Minimum Gauge Length

Finer spatial resolution

- Shorter Gauge Length
- Shorter Spatial Sampling Interval



Minimum data rate:

- Lower Sampling Frequency
- Coarser Spatial Sampling Interval
- Shorter saving fibre range

Maximum acoustic SNR

- Longer Gauge Length
- Minimum fibre losses
- Enhanced fibre (Constellation)
- Optimal Laser Pulse Frequency

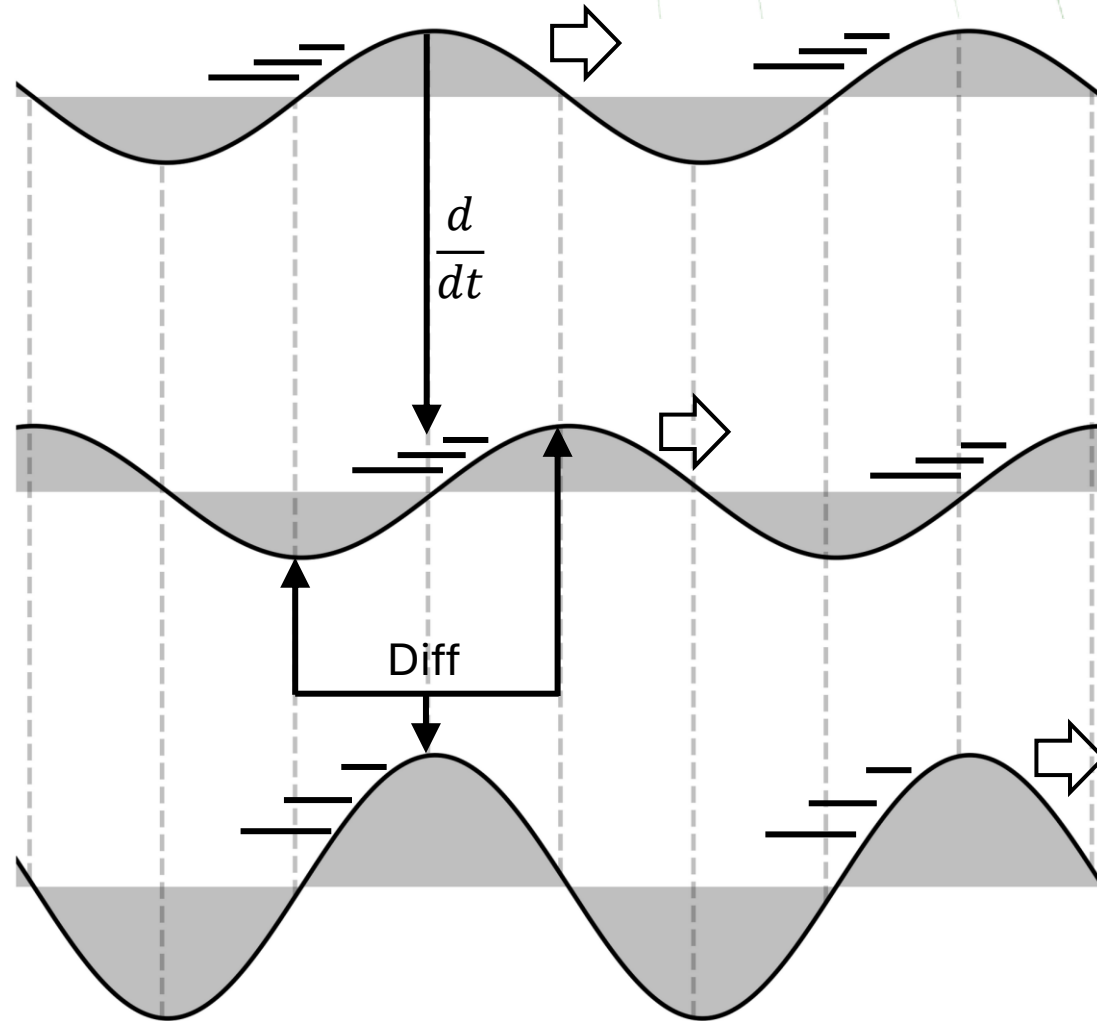
Comparison with Geophones

Displacement u_x

$$\text{Velocity } \dot{u}_x = \frac{du_x}{dt}$$

DAS

$$\dot{u}_x(x) - \dot{u}_x(x - L_G)$$



Geophone

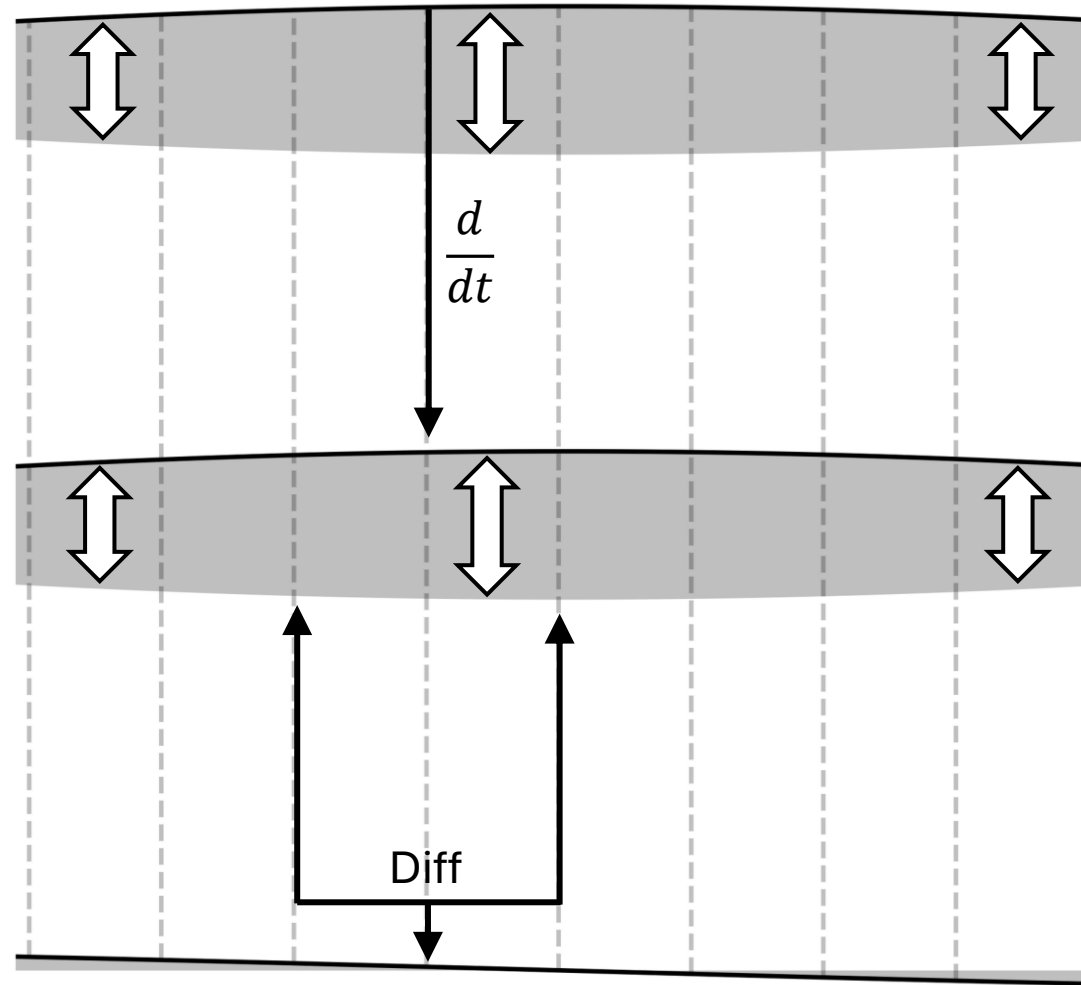
DAS ~ Geophone
spatial differential

Comparison with Geophones

Displacement u_x

Velocity $\dot{u}_x = \frac{du_x}{dt}$

DAS
 $\dot{u}_x(x) - \dot{u}_x(x - L_G)$

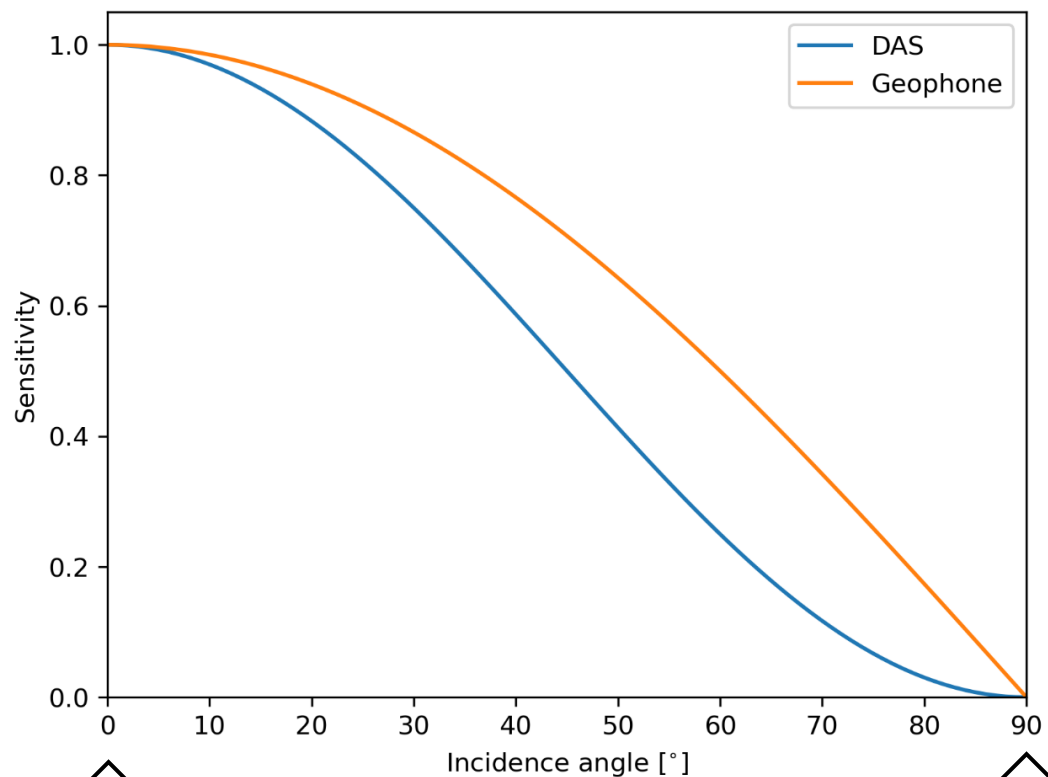


Geophone

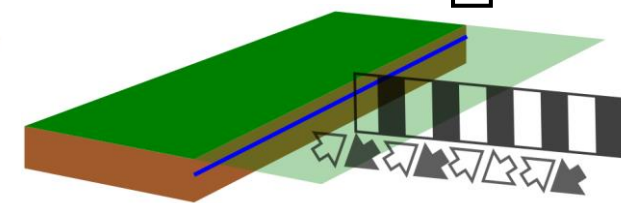
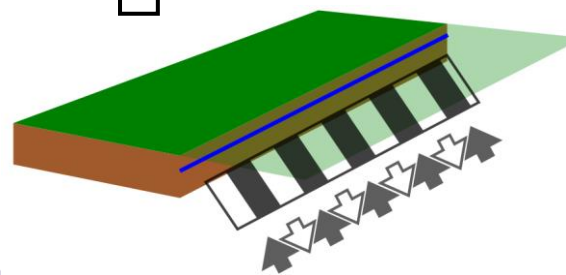
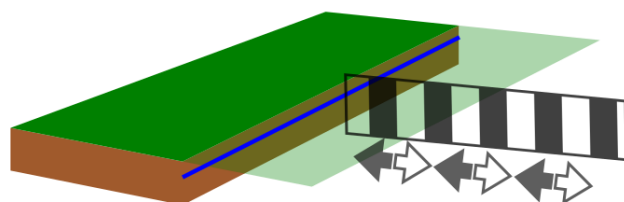
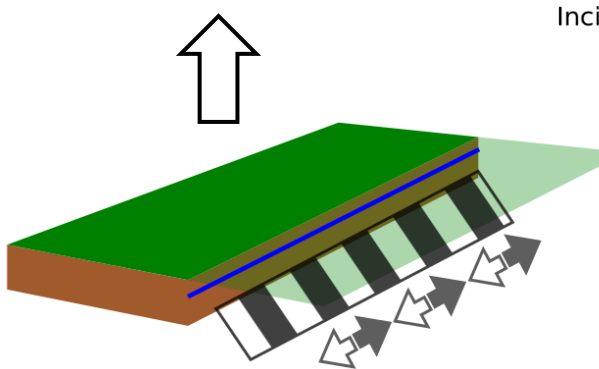
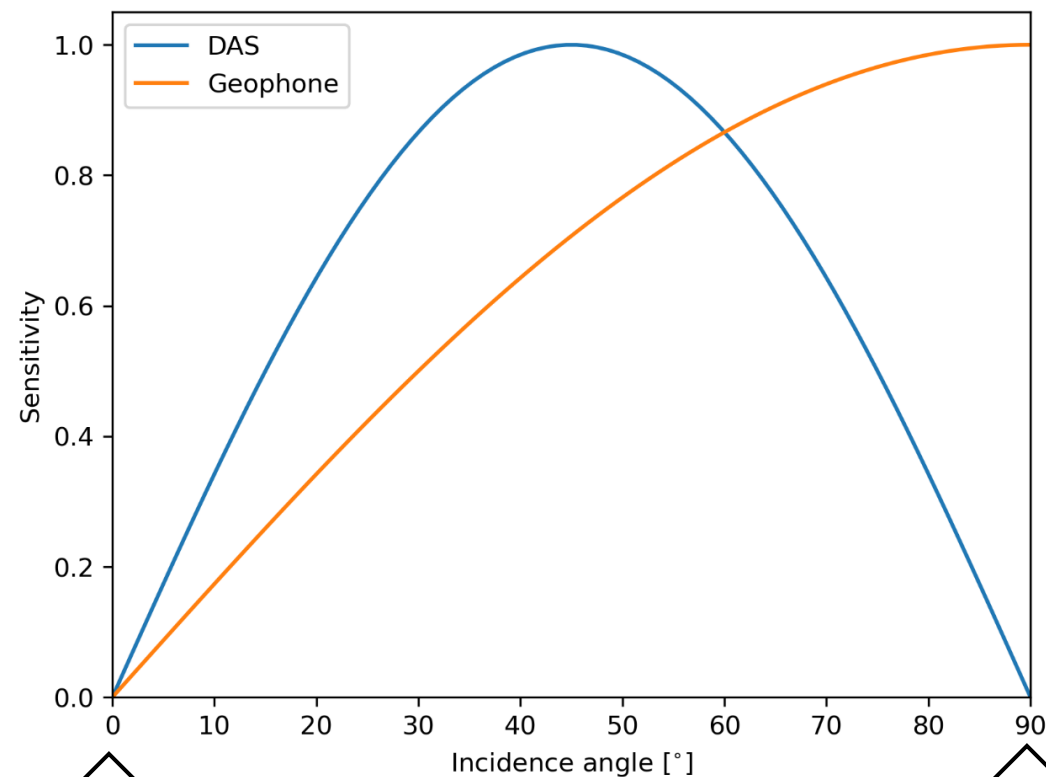
Uniform velocity
→ low DAS
sensitivity

Comparison with Geophones

P-waves



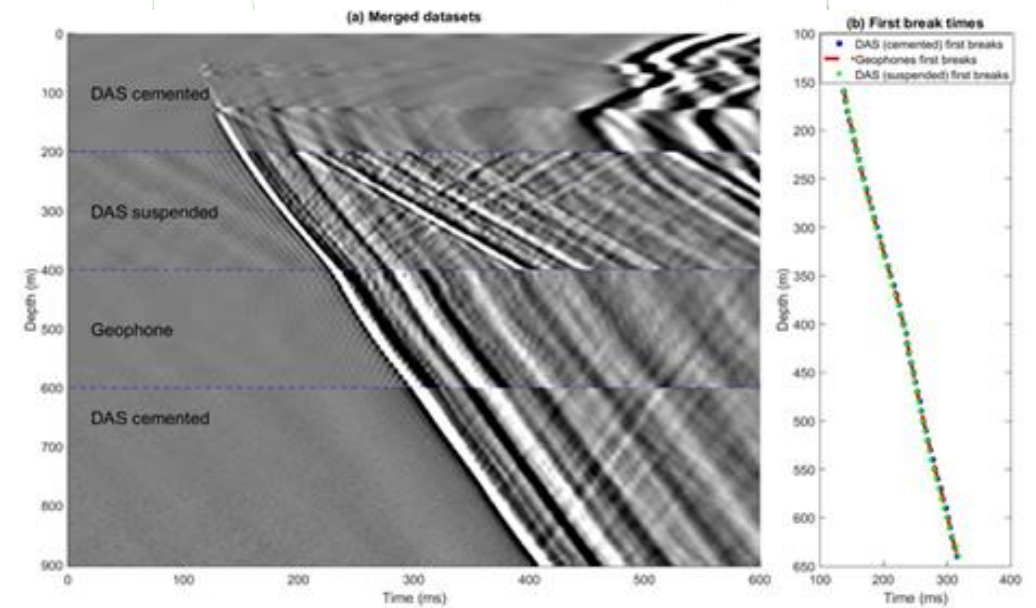
S-waves



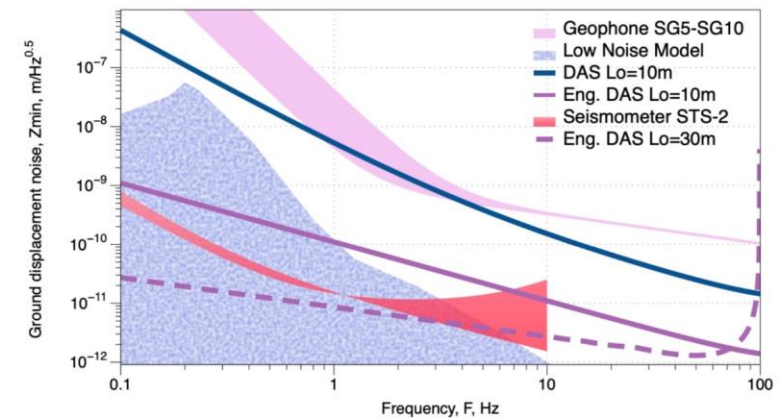
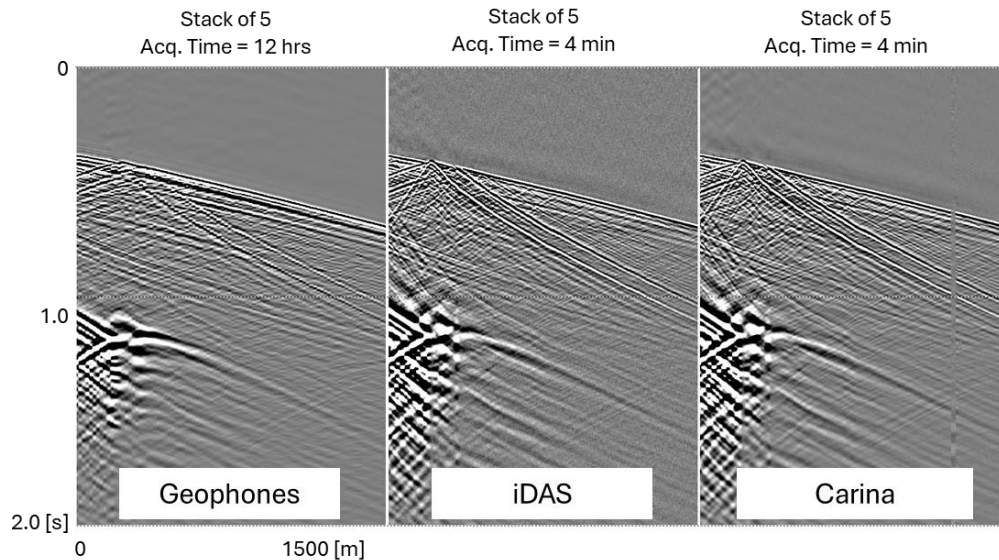
Comparison with Geophones

	iDAS	Geophone
Spatial sampling	From 0.25 m	Typically tens of m
Installation type	Flexible	Wireline logging
VSP	Record the entire wellbore with one shot	Several string positions required to cover wellbore
Response Bandwidth	0.001Hz to 50kHz	0.05Hz to few kHz
4D VSP	Repeatability @ low cost	More complex acquisition at higher cost
Data format	Standard seismic formats	Standard seismic formats
Data viewer	Real time data visualisation	Real time data visualisation

Courtesy of Curtin University



Correa, J., et al., 2017. DAS Versus Geophones: a Quantitative Comparison of a VSP Survey at a Dedicated Field Laboratory. In Fourth EAGE Borehole Geophysics Workshop.





THANKS!

IR0000032 – ITINERIS, Italian Integrated Environmental Research Infrastructures System
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INIZIATIVA DI POLITICA PUBBLICA

