



# 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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DI RIFERIMENTO PER  
L'EDUCAZIONE

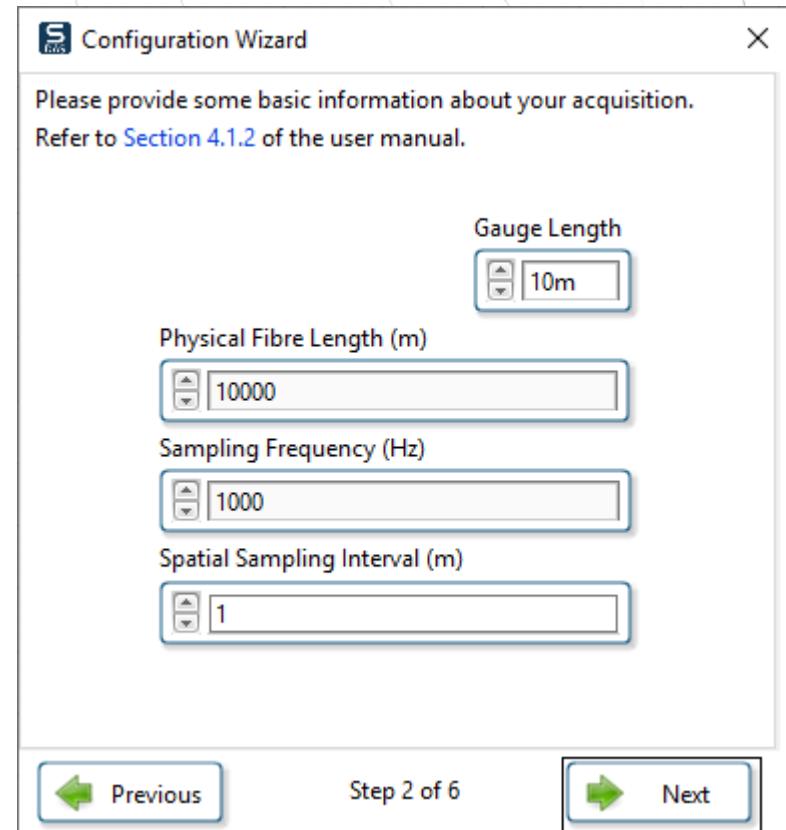


# Outline

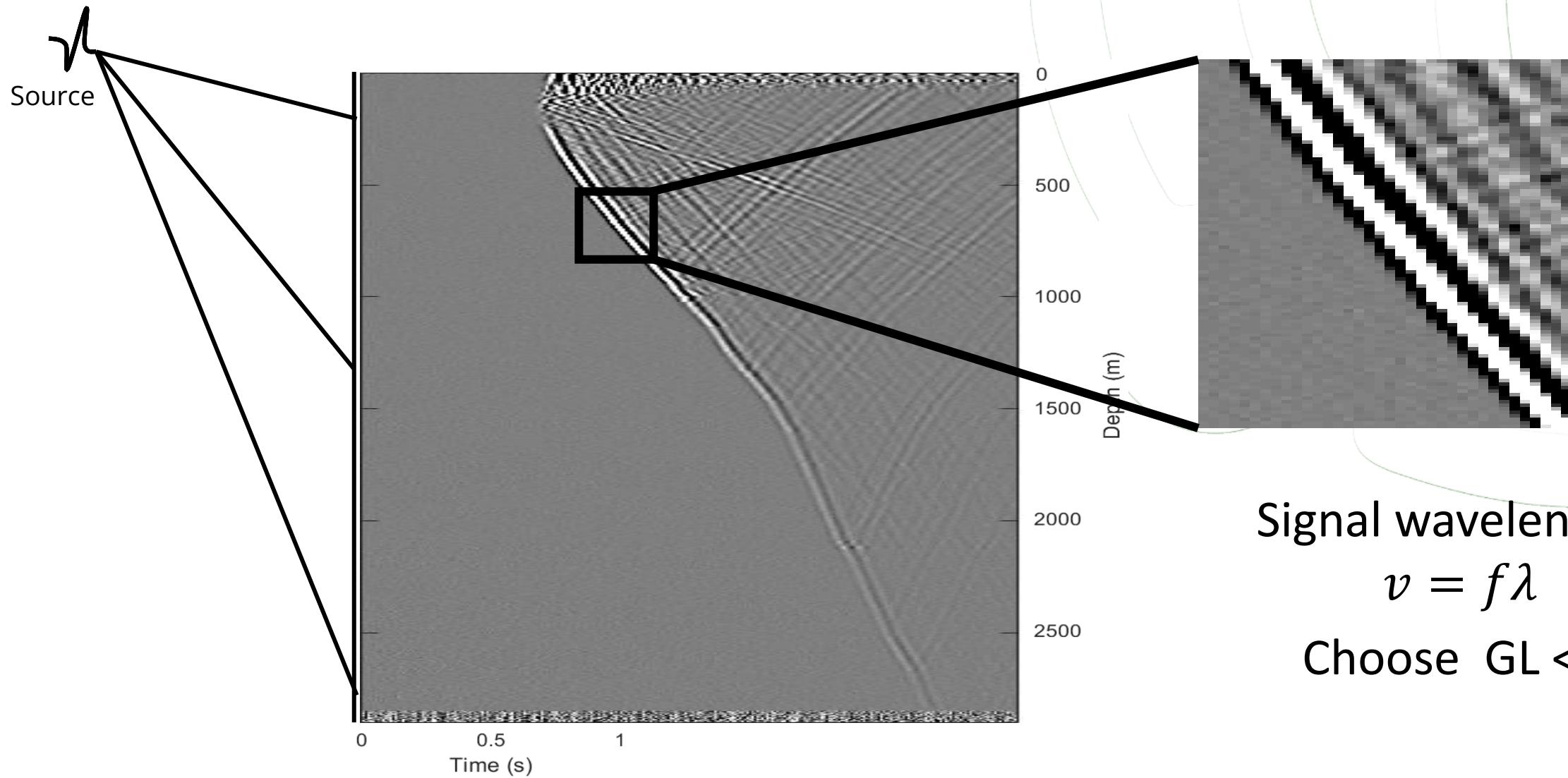
- DAS Setup wizard
- Sampling frequency
- Optical fibre losses
- Gauge length
- Dynamic range
- Comparison with Geophones

# Configuration Wizard

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



# Gauge length

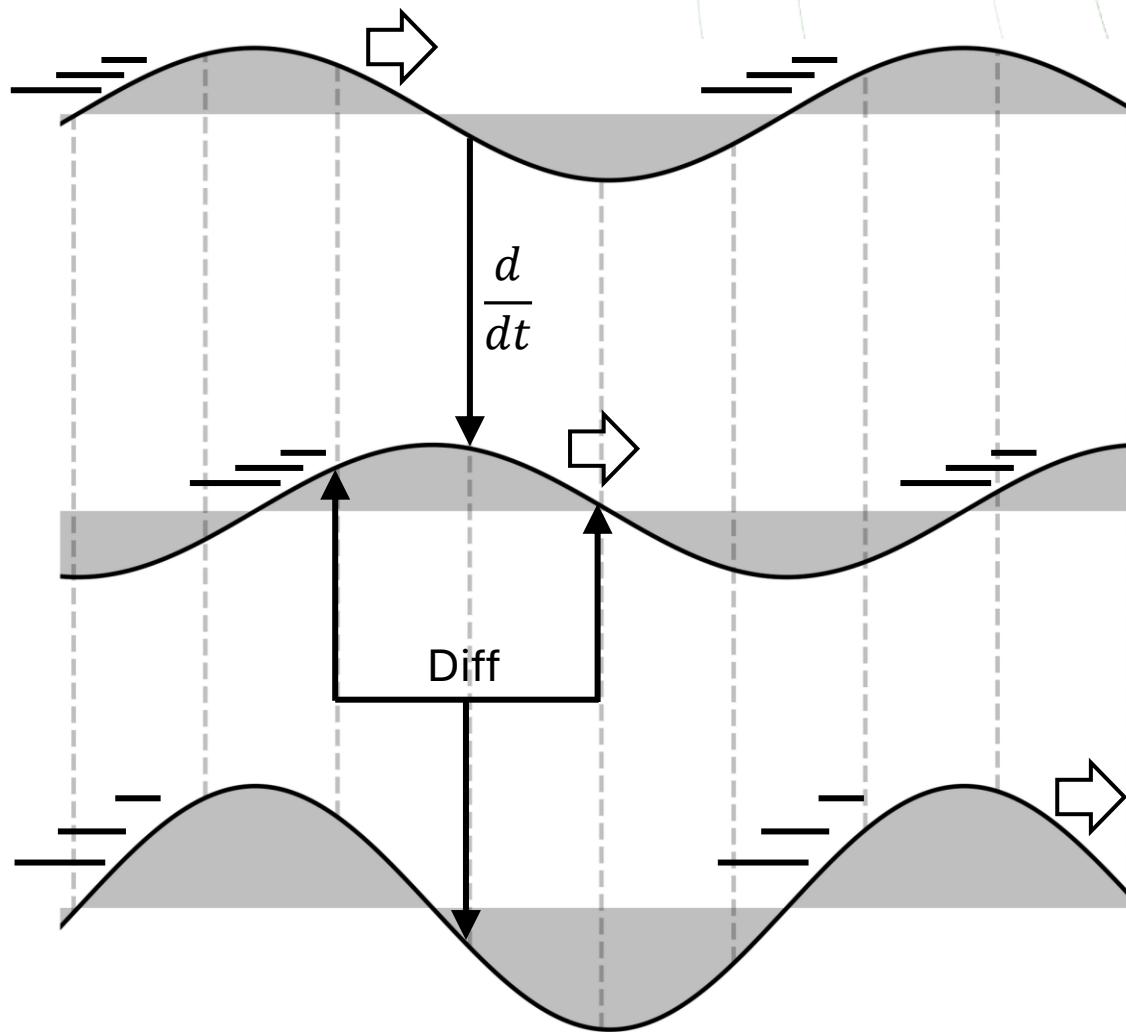


# Gauge length

Displacement  $u_x$

Velocity

DAS  
= velocity differential

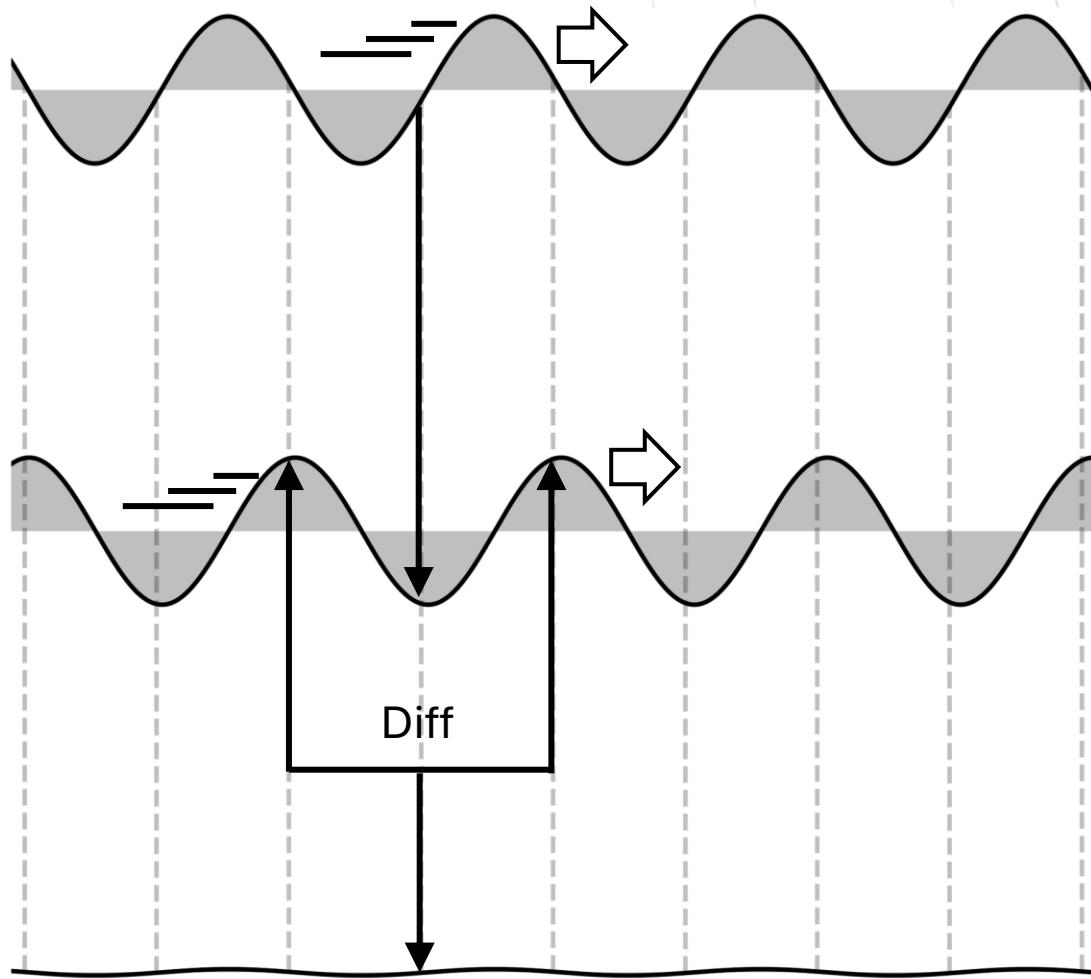


# Gauge length

Displacement  $u_x$

Velocity

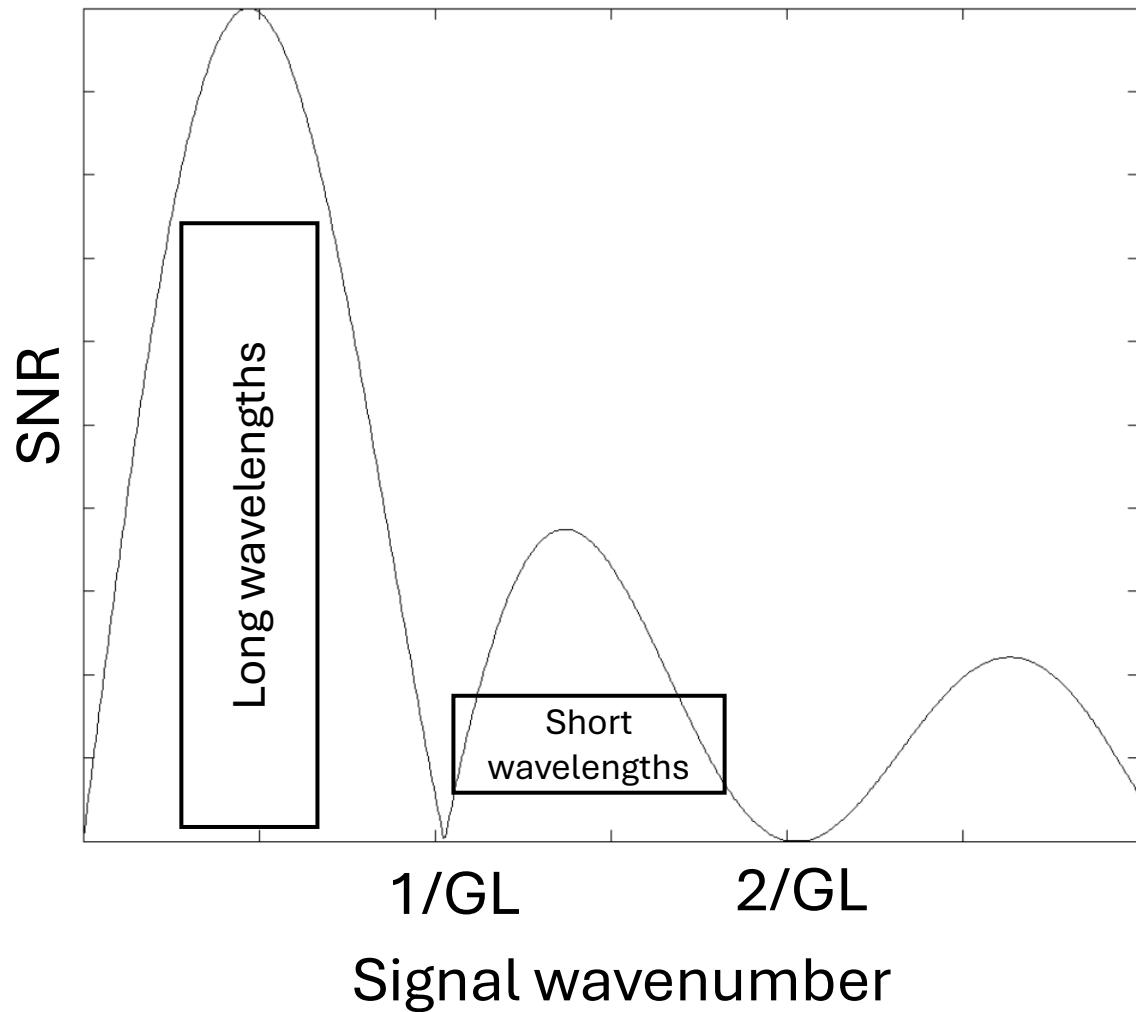
DAS  
= velocity differential



Travelling wave

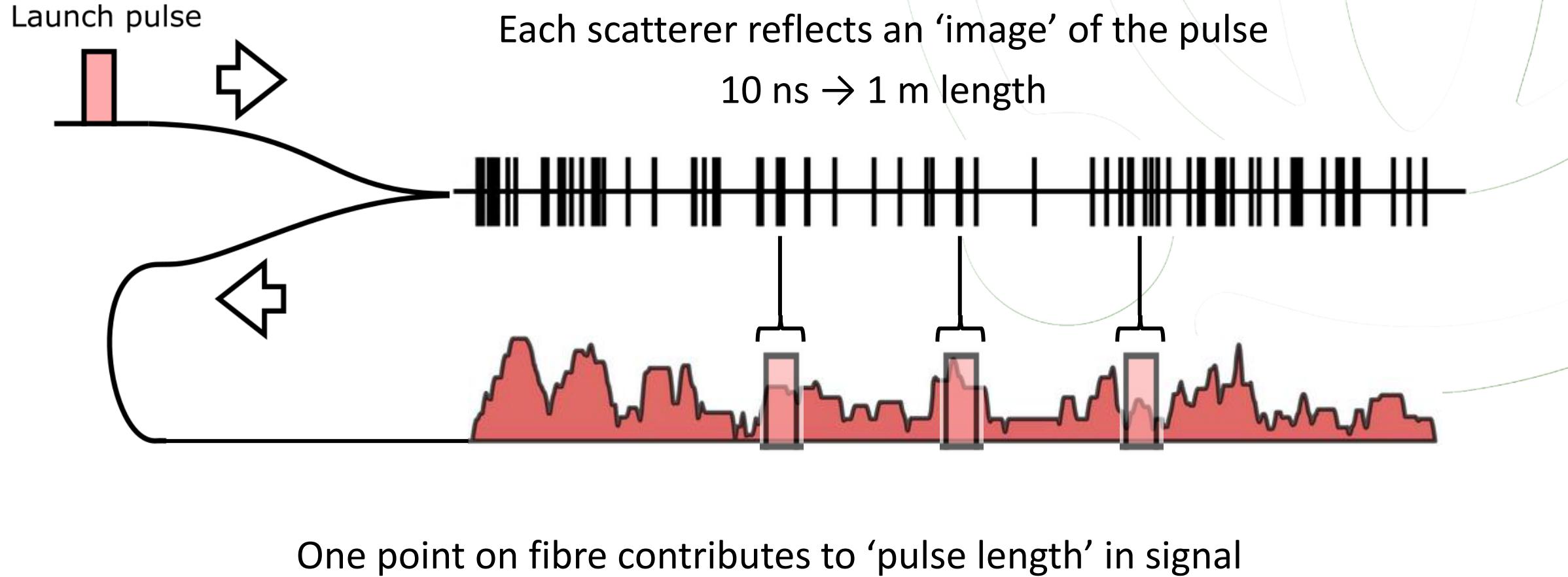
$GL \approx \lambda$   
Zero sensitivity

# Gauge length

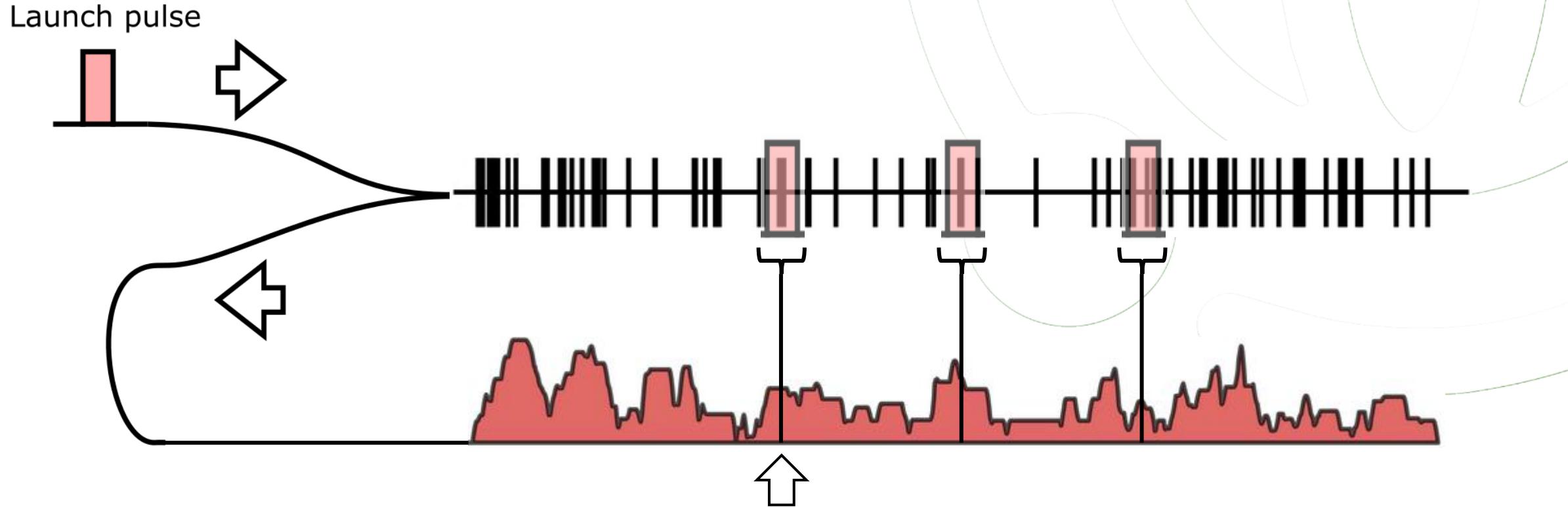


Signal wavenumber – as projected along the fibre

# How Pulse Width relates to Gauge Length

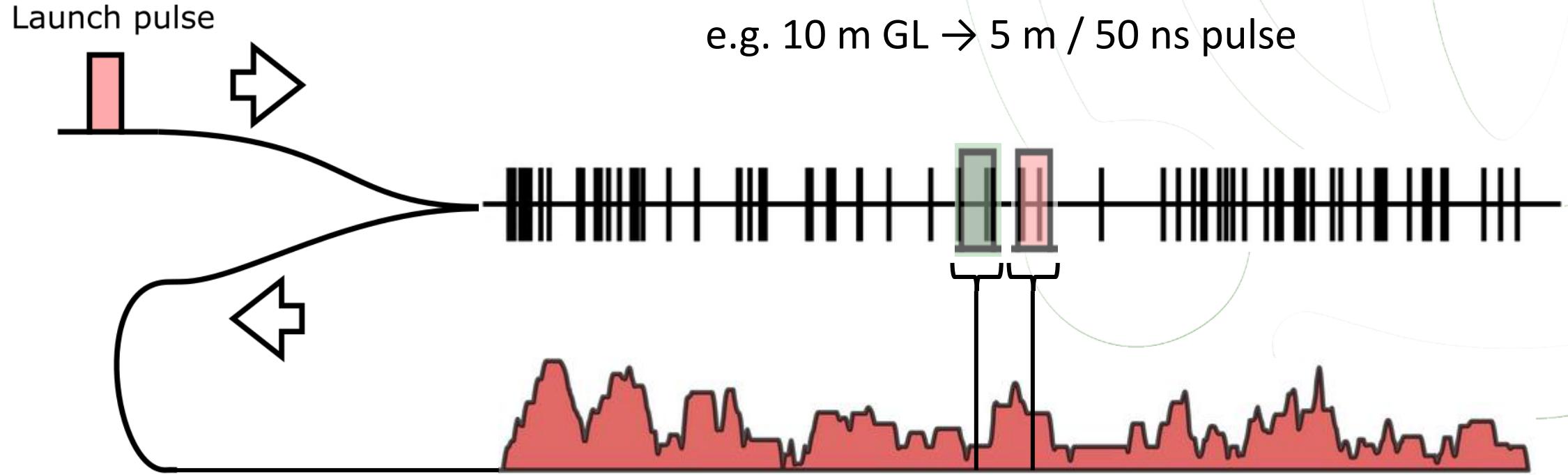


# How Pulse Width relates to Gauge Length

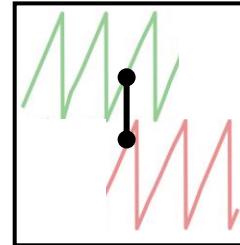


Instantaneous signal comes from 'pulse length' of fibre

# How Pulse Width relates to Gauge Length



Phase signals must come from distinct fibre segments

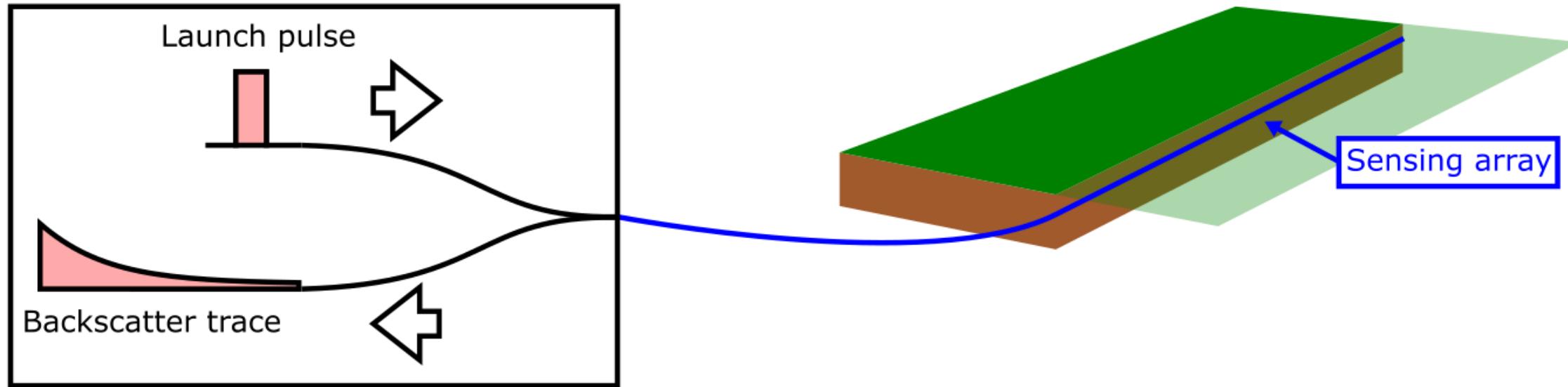


Longer pulse → greater Intensity signal

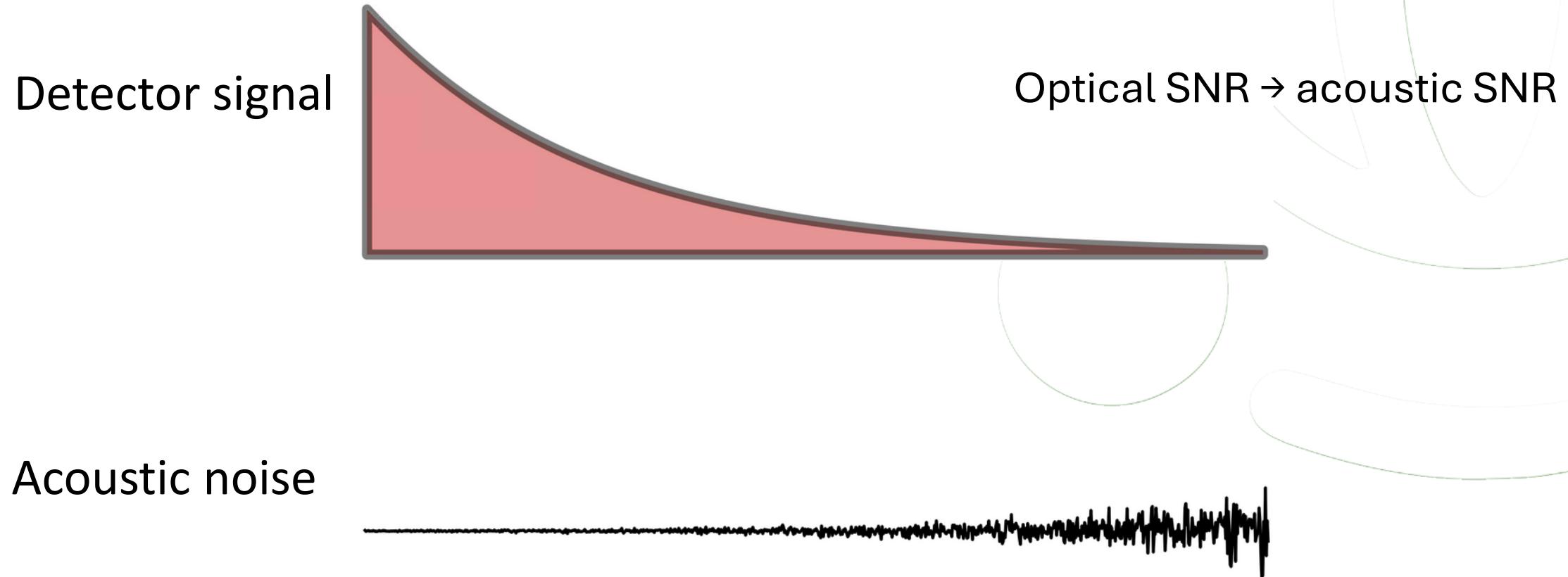
**Gauge length defines:**

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

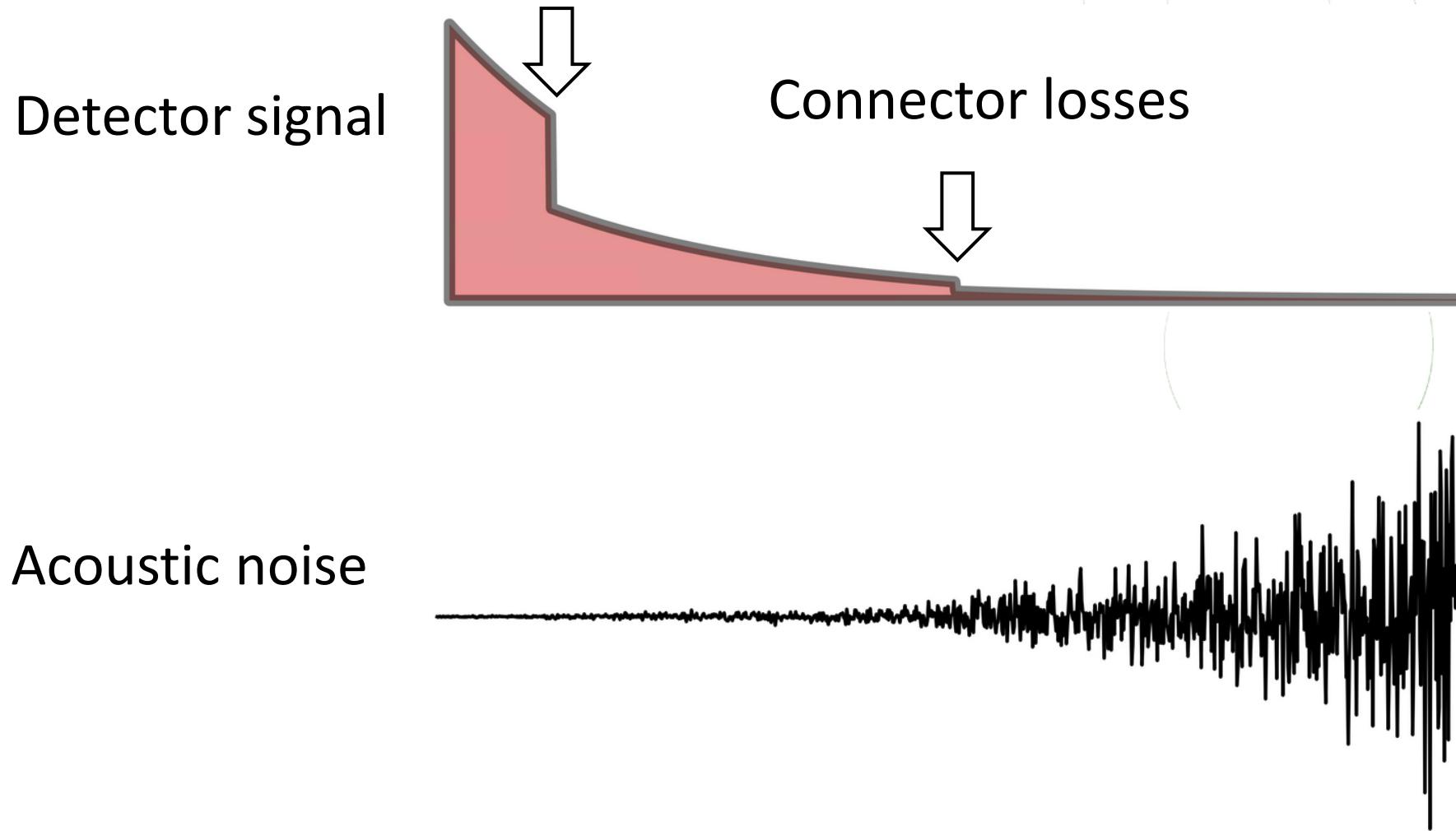
# Physical Fibre Length



# Physical Fibre Length



# Physical Fibre Length

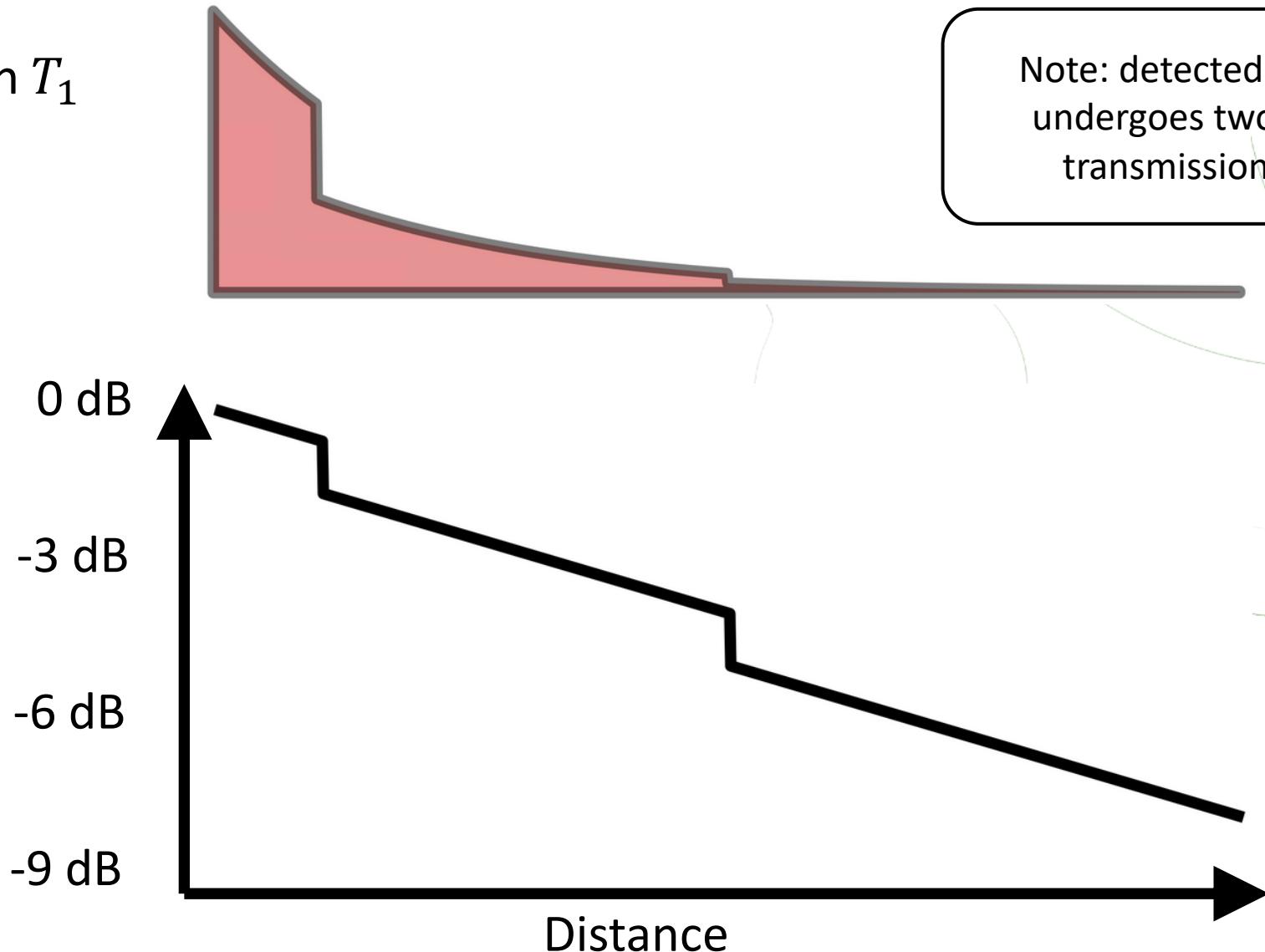


# Physical Fibre Length

One-way transmission  $T_1$

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

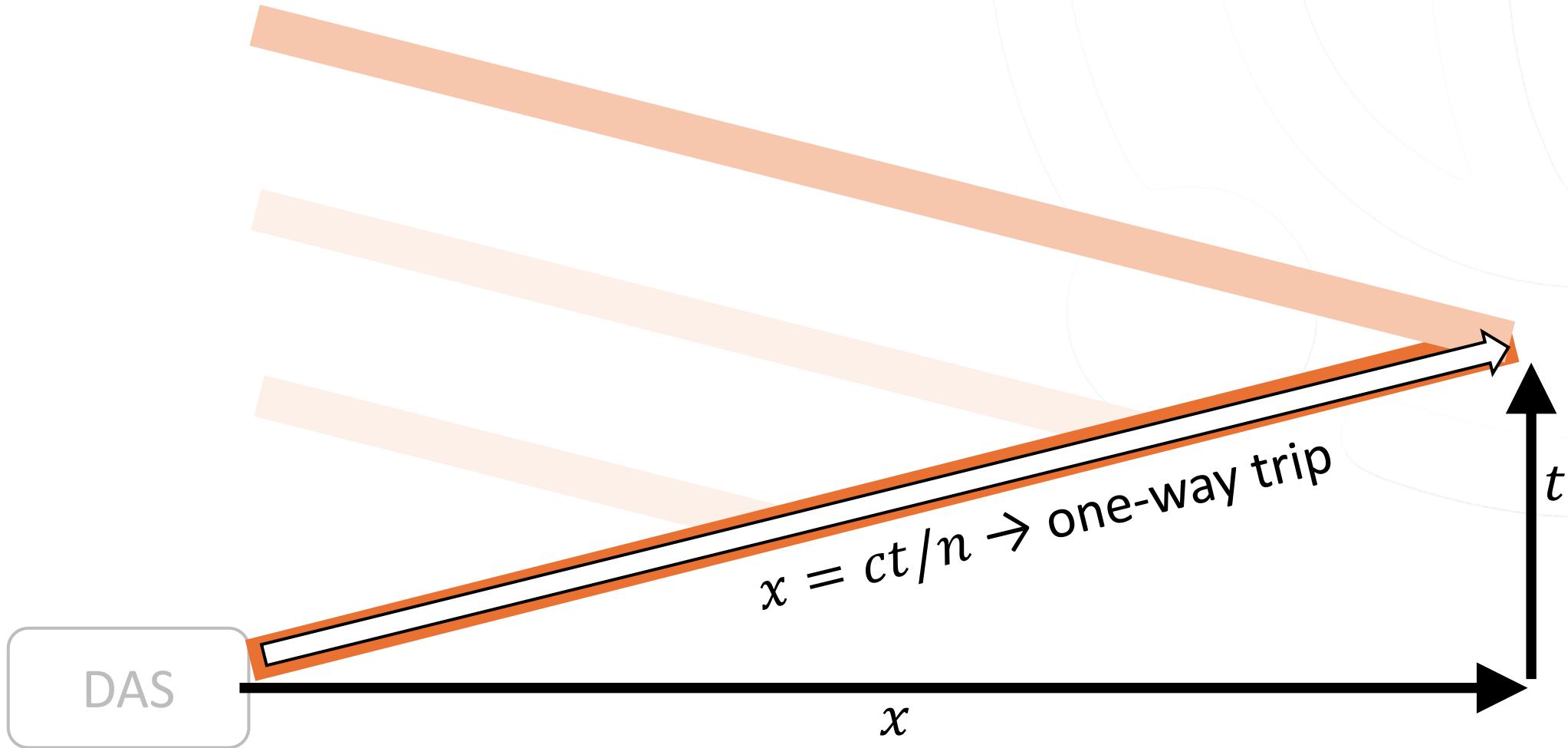
Note: detected signal undergoes two-way transmission  $T^2$



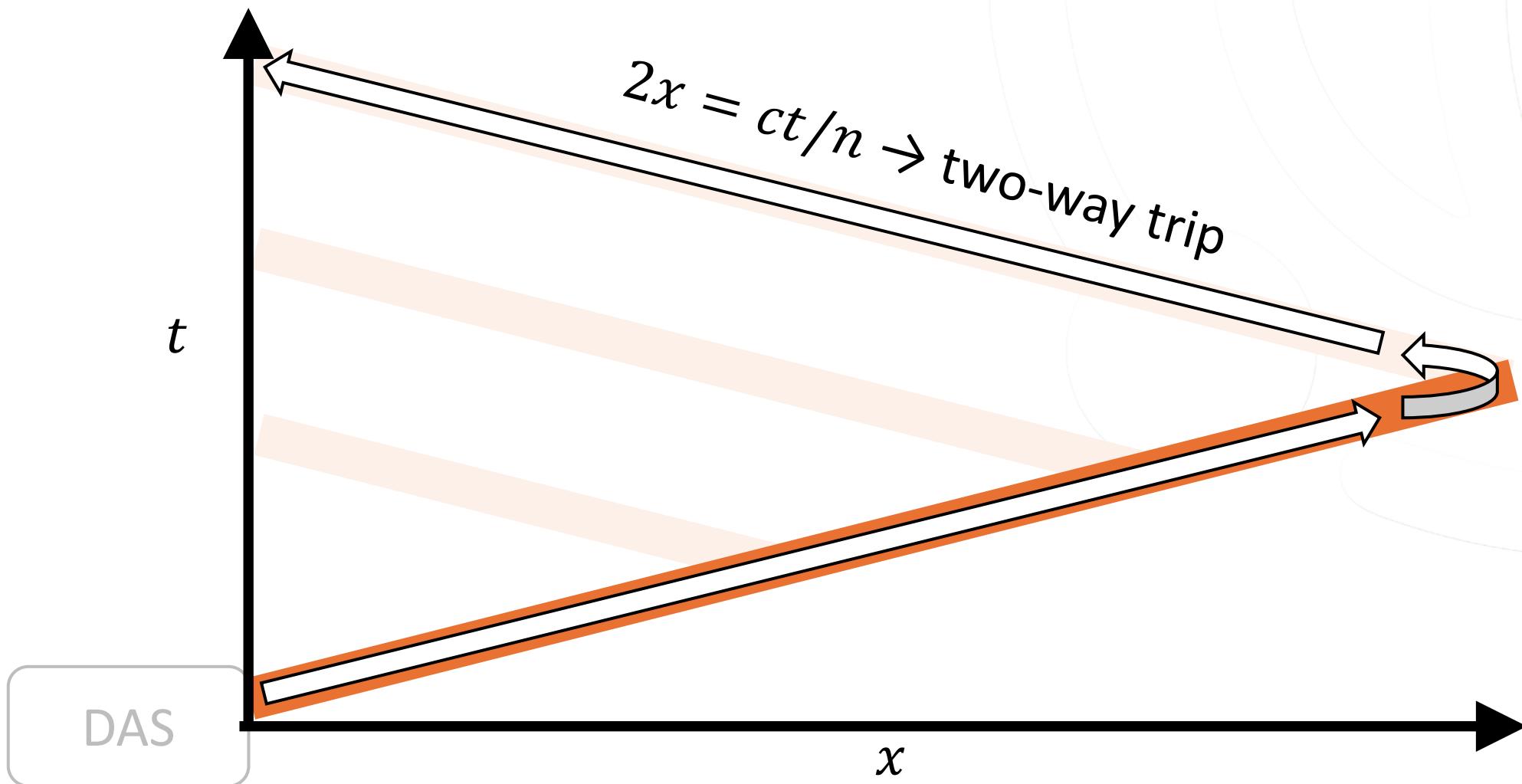
# Physical Fibre Length



# Physical Fibre Length



# Physical Fibre Length



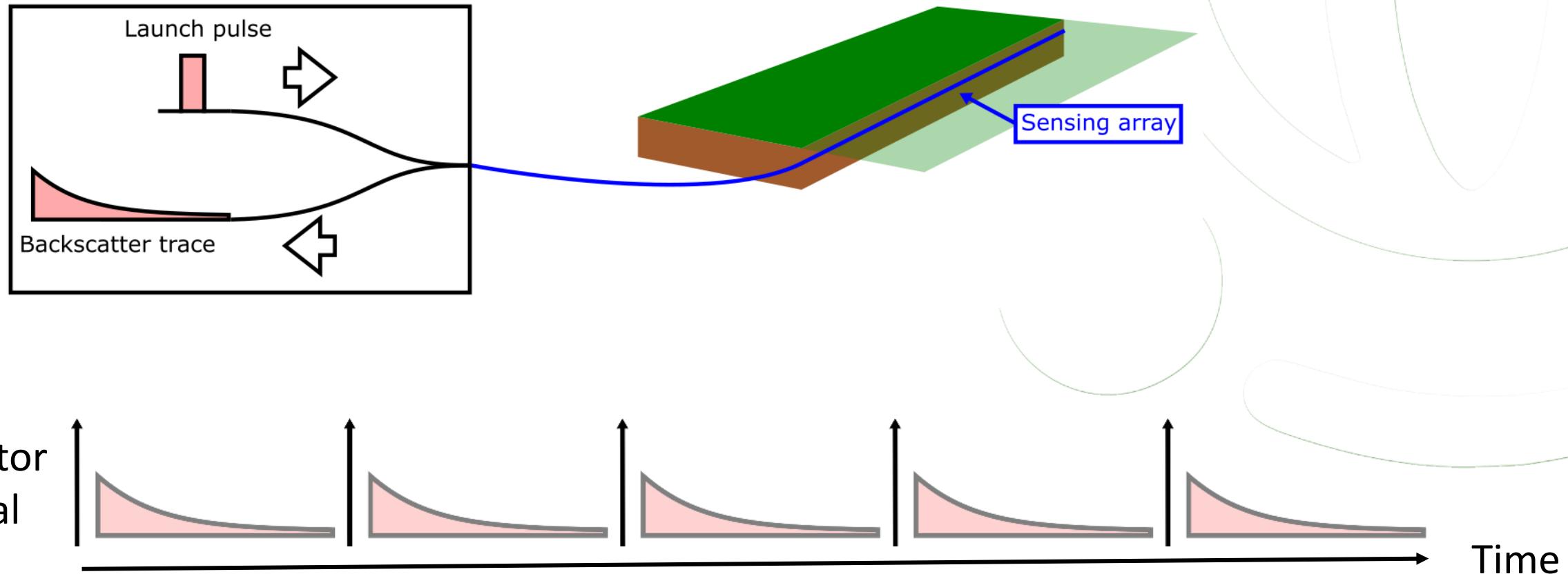
Maximum Laser Pulse Frequency:

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

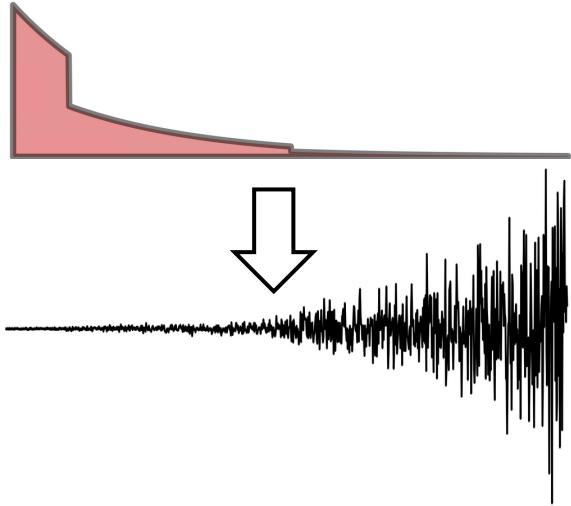
- 10 km fibre:  $f_{MAX} \approx 10 \text{ kHz}$
- 30 km fibre:  $f_{MAX} \approx 3.3 \text{ kHz}$

Rule of thumb:  
10 km at 10 kHz

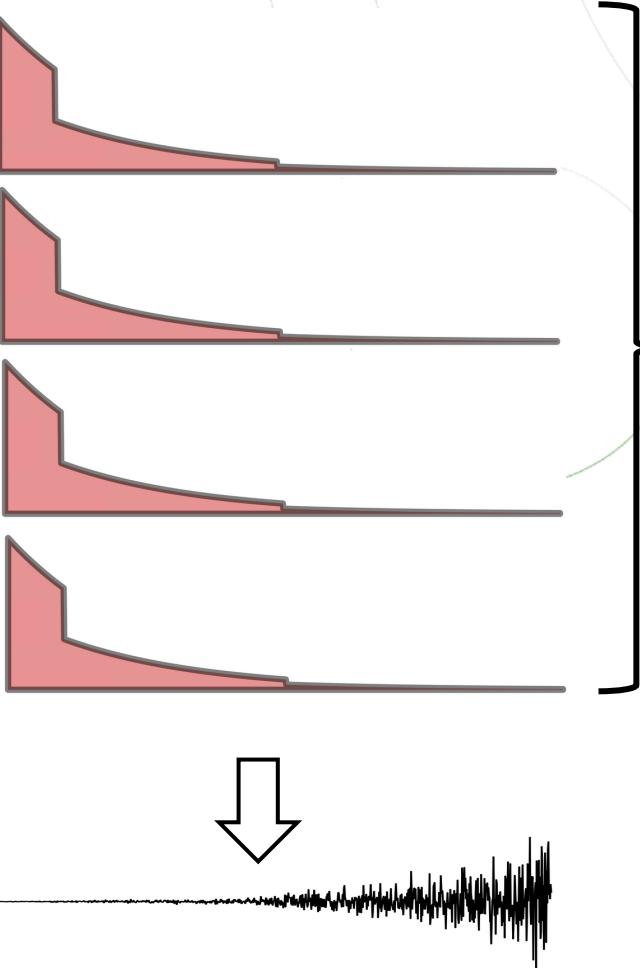
# Physical Fibre Length



Can you average traces over time?



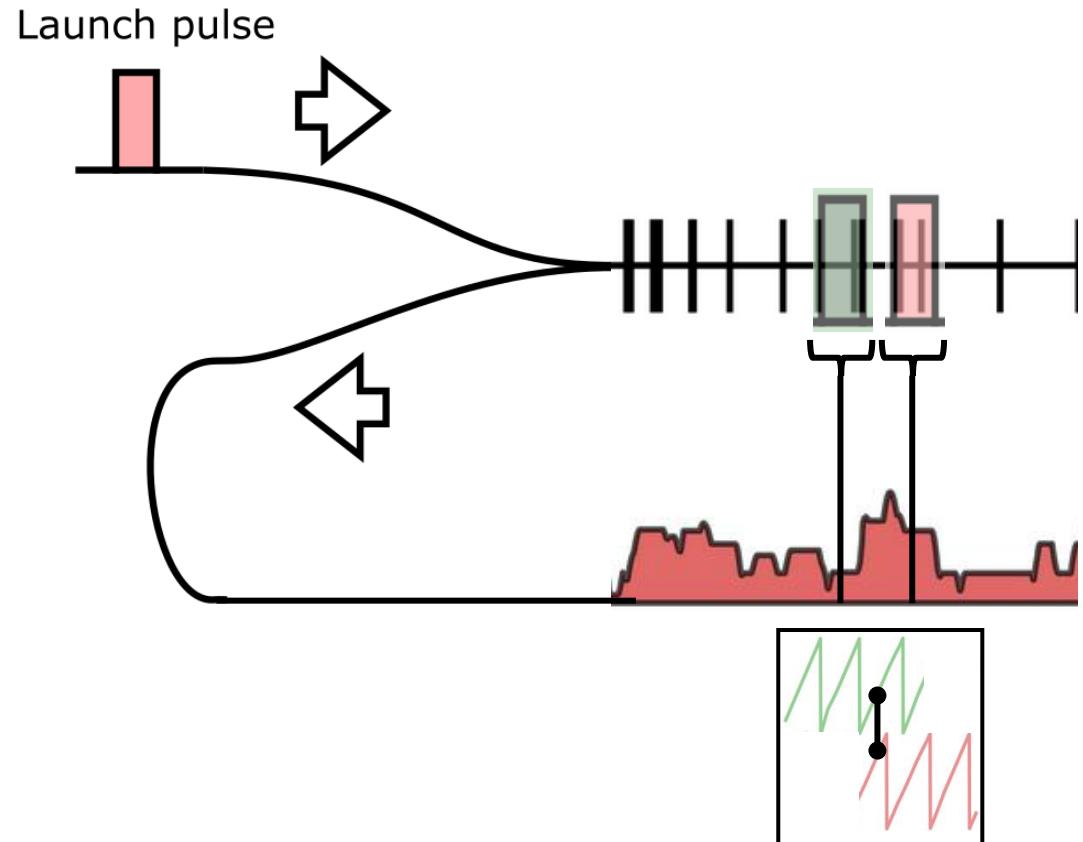
- Reduced acoustic bandwidth
- Lower data rate
- Optical SNR resilience



Average before  
processing

“Time  
decimation”

# Dynamic range

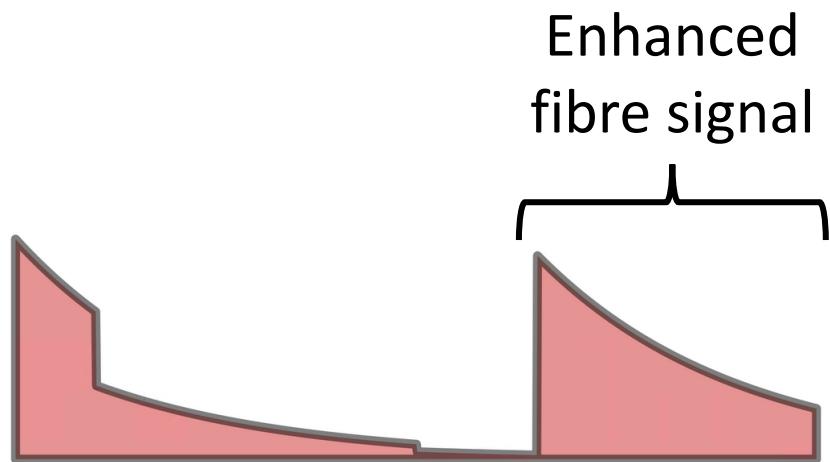


- Raw DAS data = phase change across:
  - 1 gauge length
  - 1 time sample
- Signal  $\propto$  GL
- Signal  $\propto 1/F_S$
- Maximum signal =  $\pi$

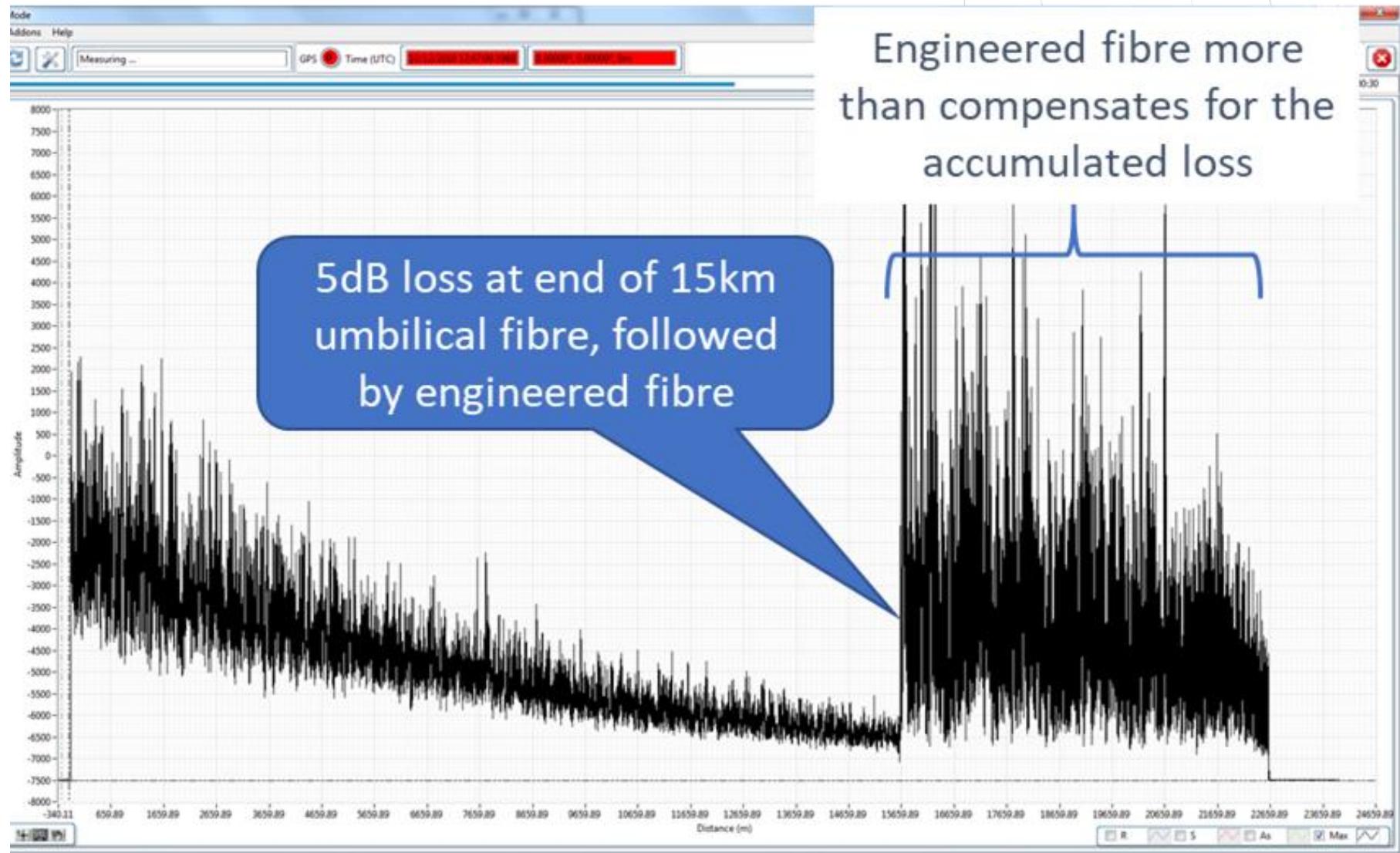
Maximum dynamic range when:

- Shorter fibre
- Highest sampling frequency
- Shortest gauge length

## Can you use enhanced backscatter fibre?



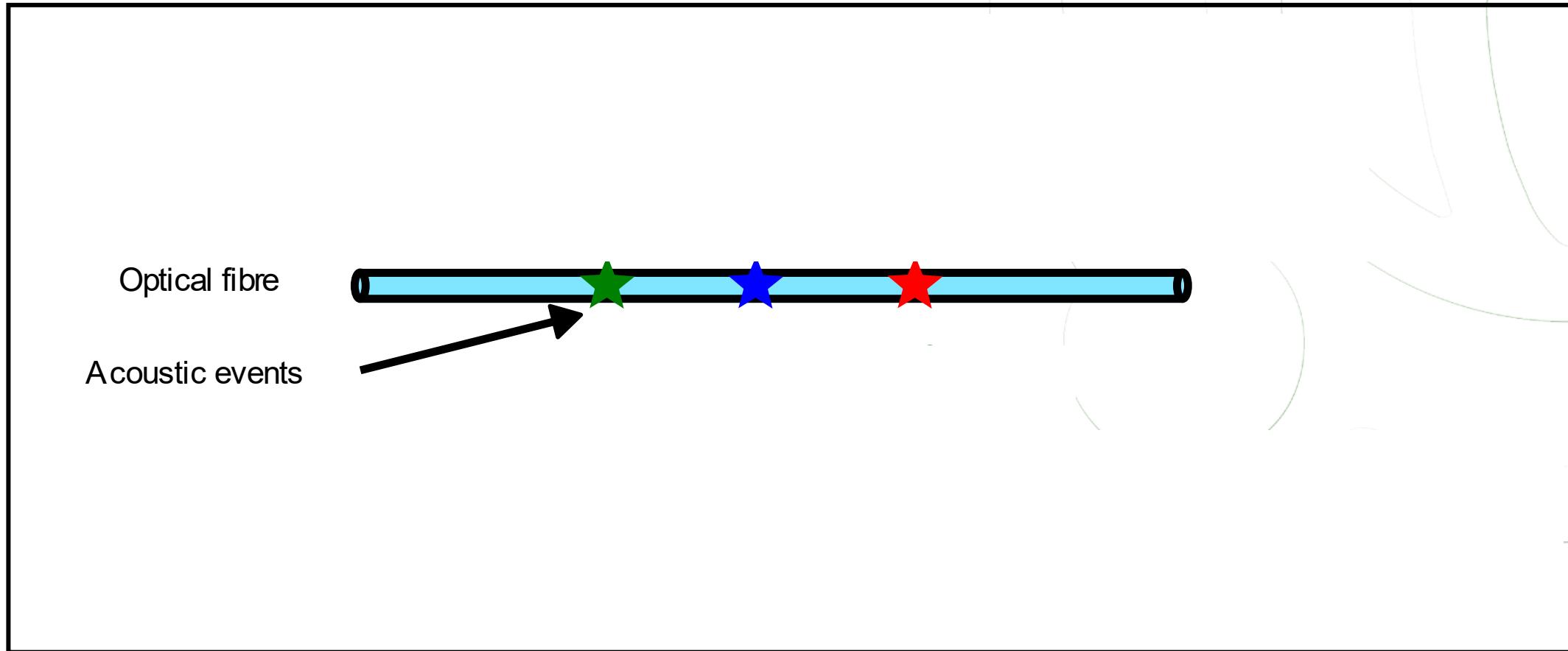
# Physical Fibre Length



**Physical fibre length affects:**

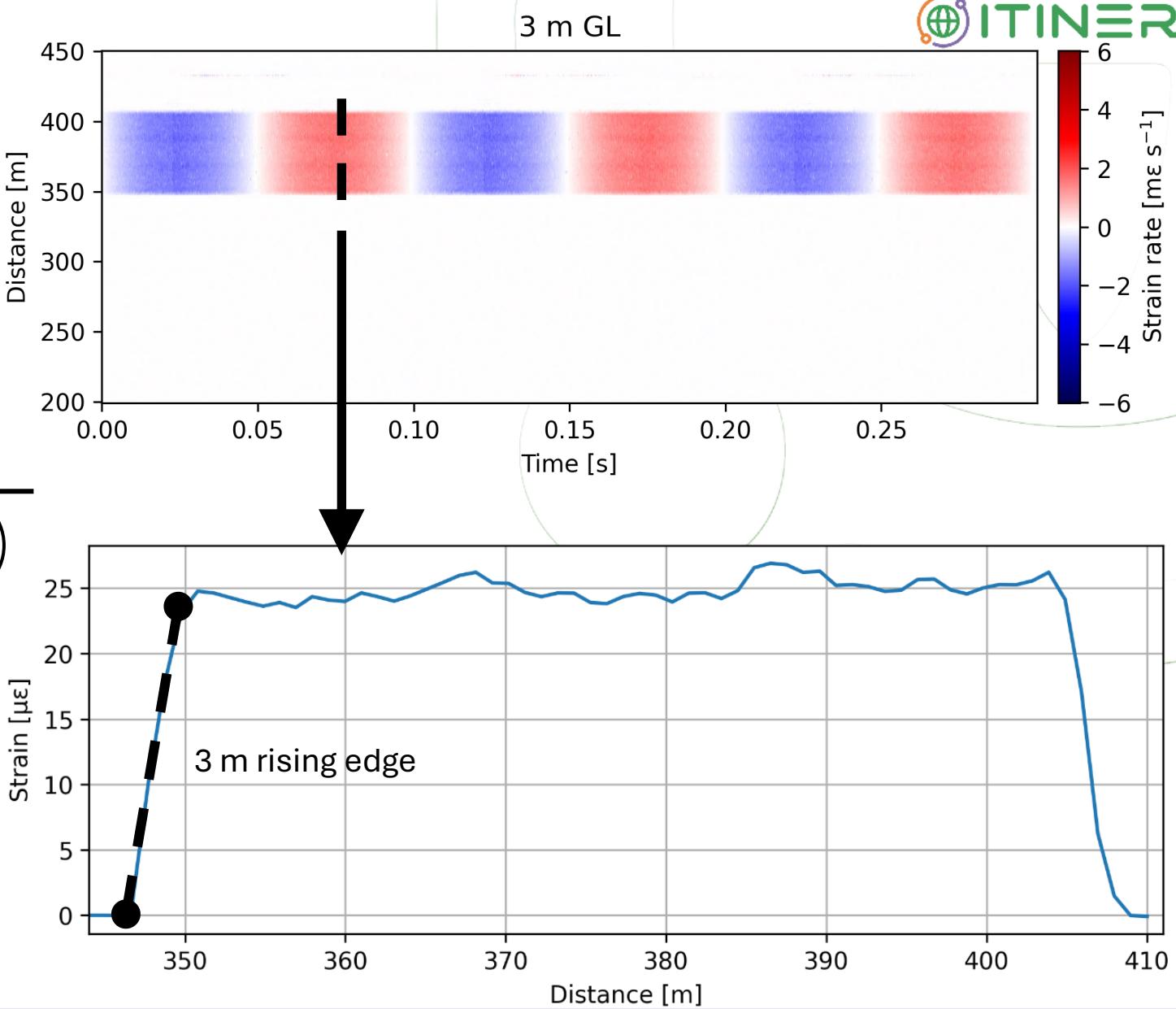
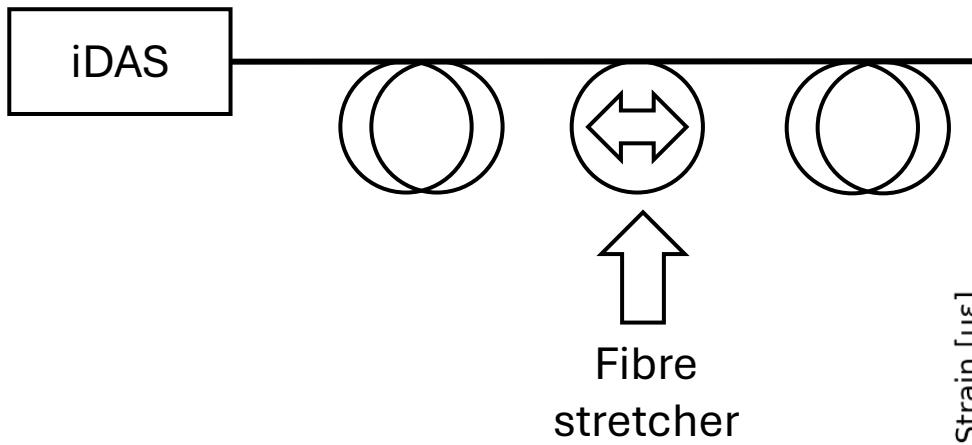
- Maximum sampling frequency
- Dynamic range limit
- Optical signal profile and SNR

# Spatial Sampling Interval

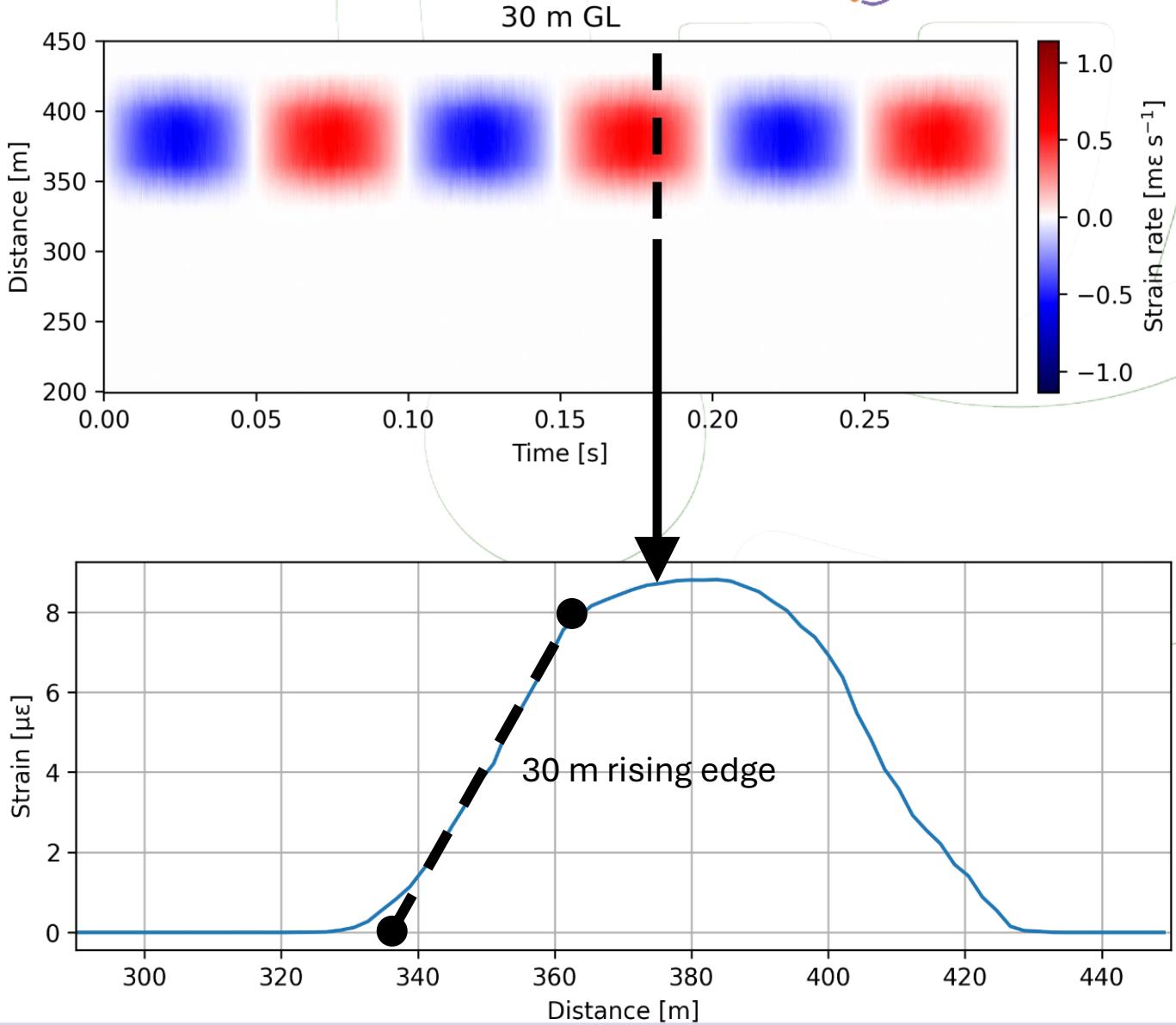
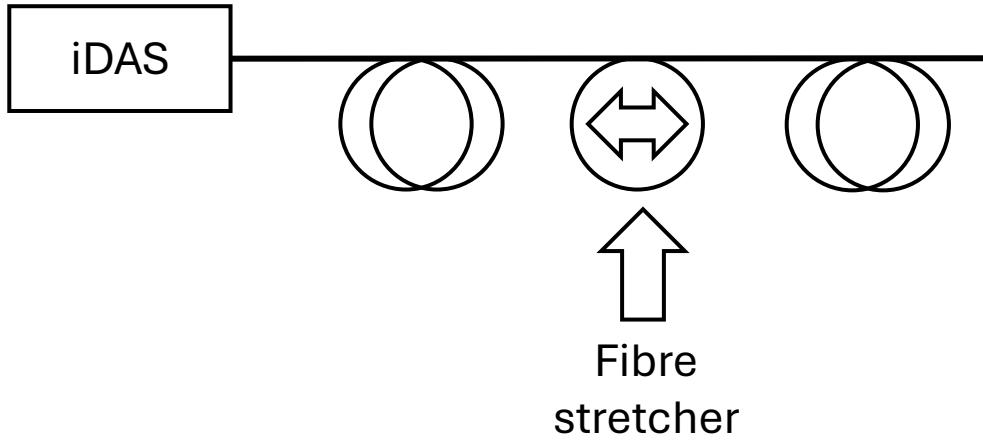


Rule of thumb: Gauge length  $\div 10$

# Spatial Sampling Interval



# Spatial Sampling Interval



**Spatial Sampling Interval affects:**

- Maximum spatial resolution
- Data rate

# Configuration Wizard

**S<sub>DAS</sub>** Configuration Wizard X

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

Gauge Length

Physical Fibre Length (m)

Sampling Frequency (Hz)

Spatial Sampling Interval (m)

[Previous](#) Step 2 of 6 [Next](#)



User parameters

**S<sub>DAS</sub>** Configuration Wizard X

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)

Output Decimation (Input Resolution)

Measure Length (m)

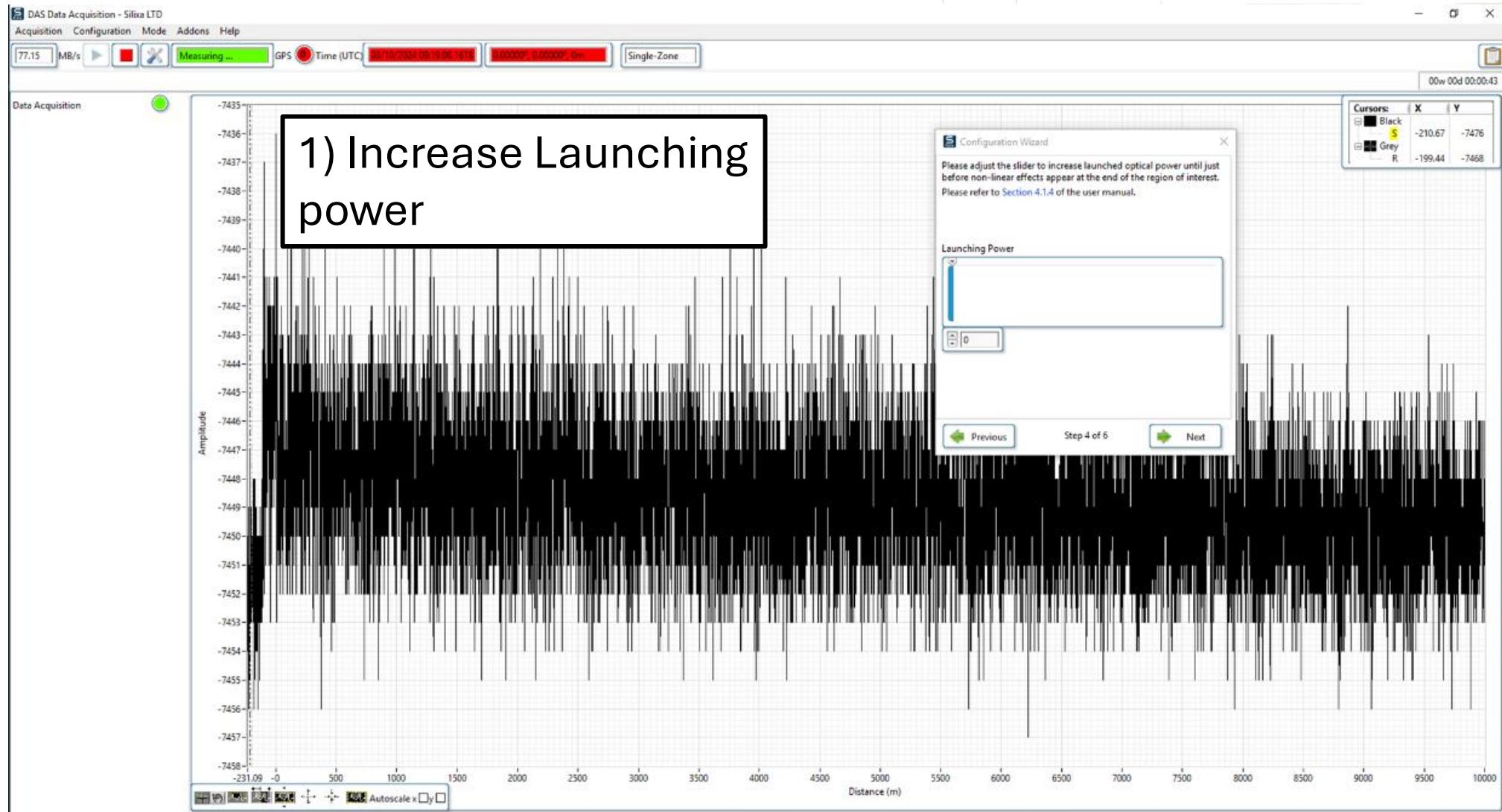
Pulse Width (ns)  P Average Samples

[Previous](#) Step 3 of 6 [Next](#)

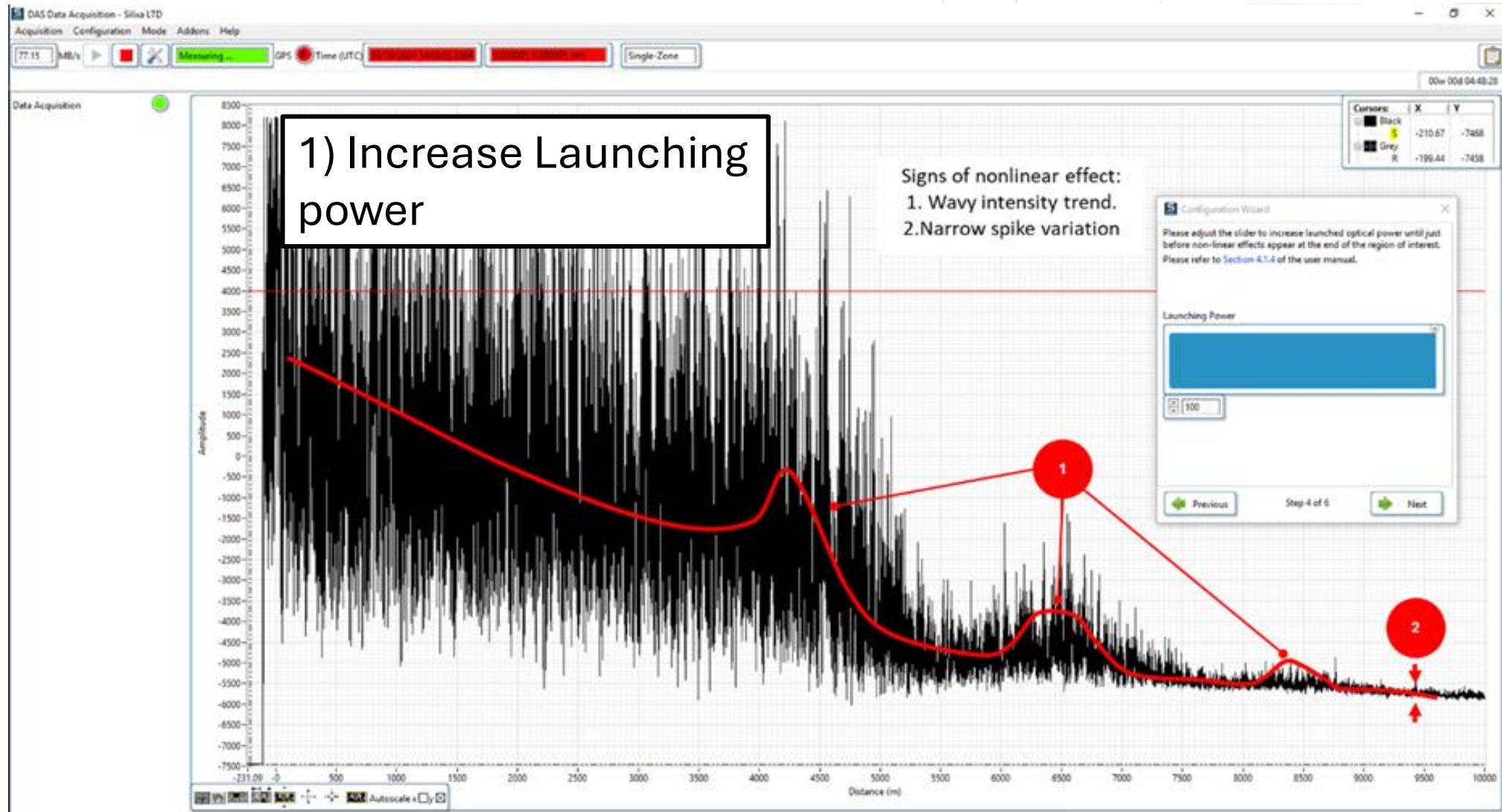


Internal parameters – do not change

# Configuration Wizard

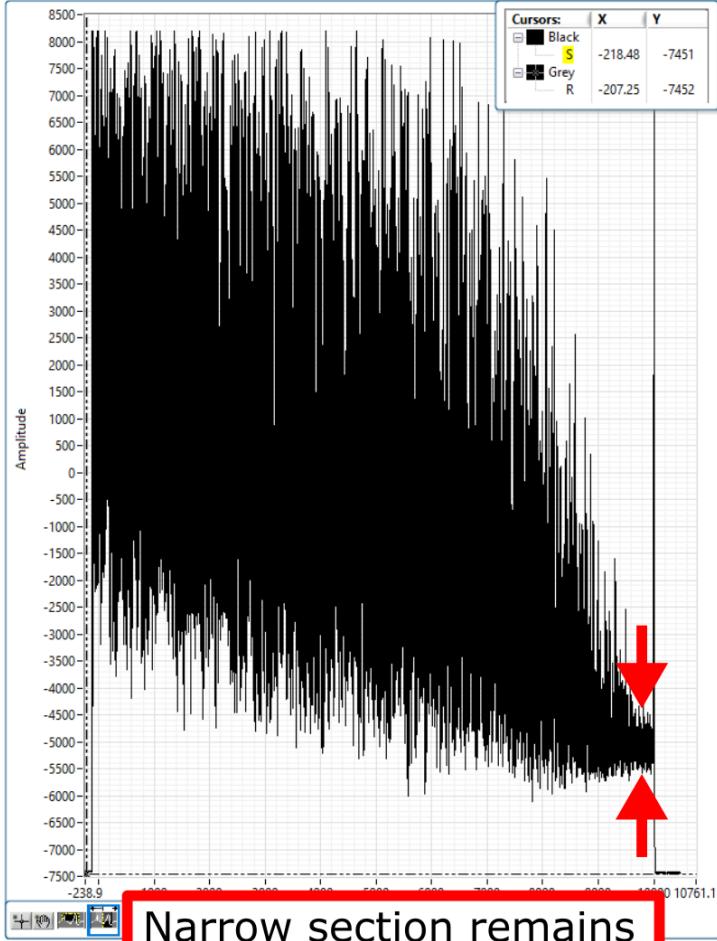


# Configuration Wizard

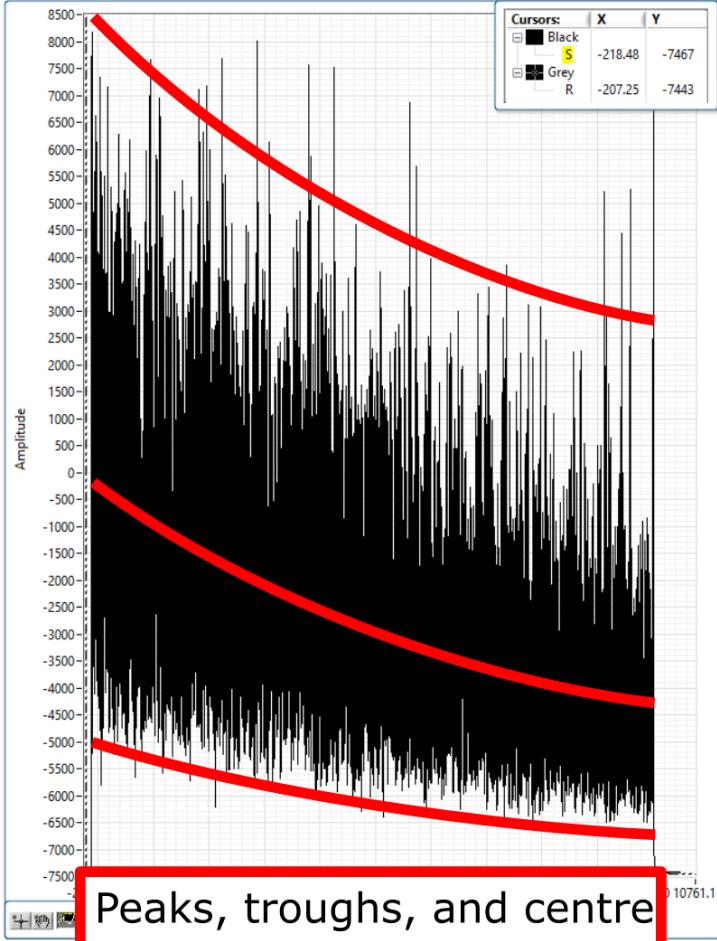


# Configuration Wizard

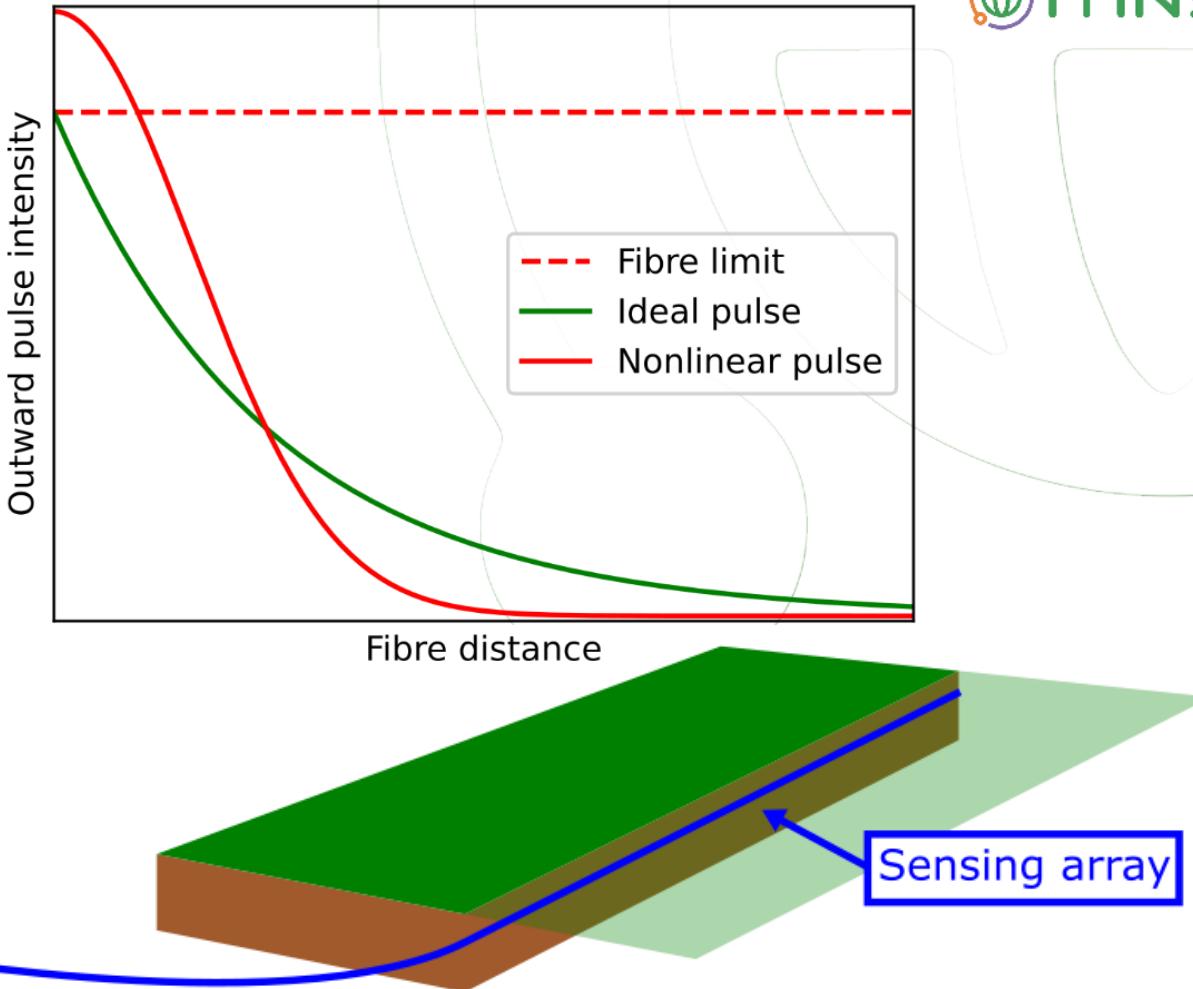
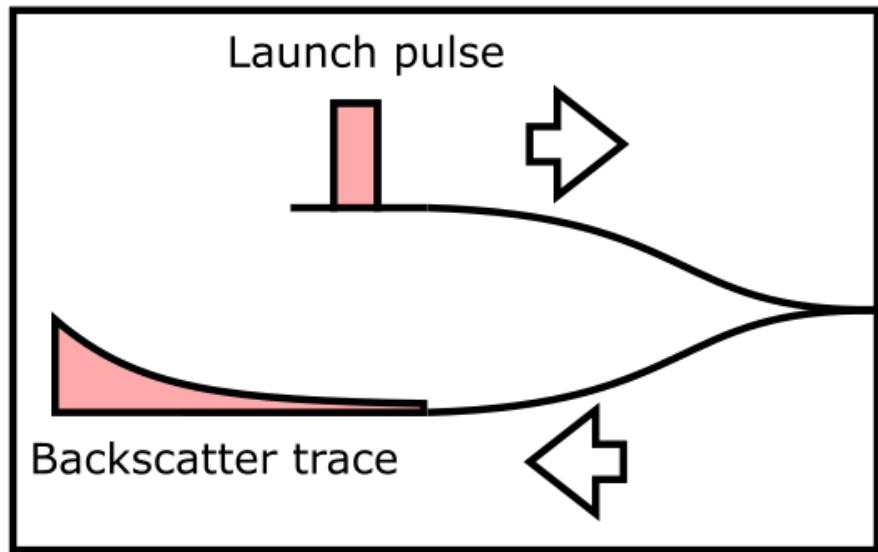
Optical power still too high



Optical power ideal

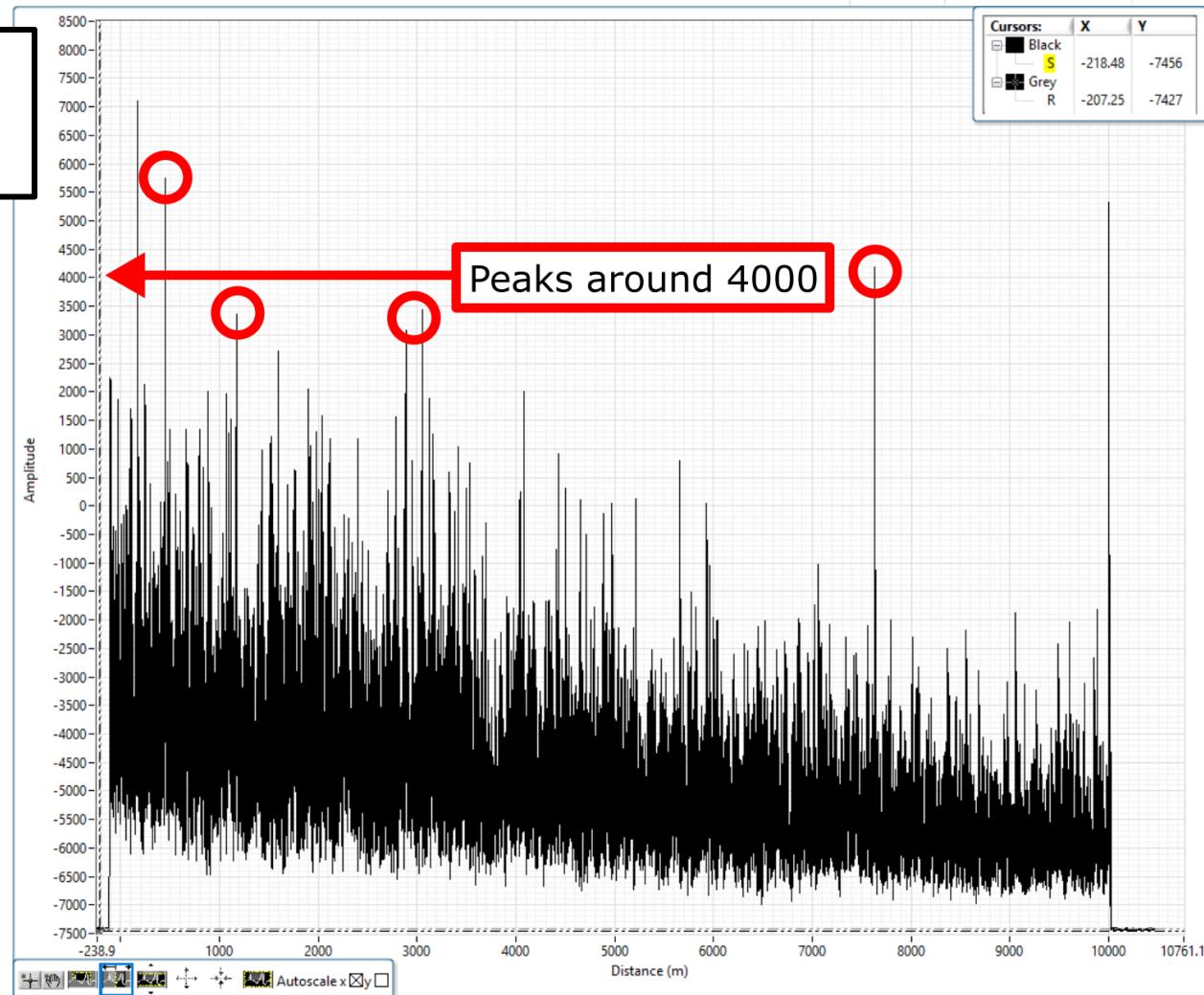


# Configuration Wizard

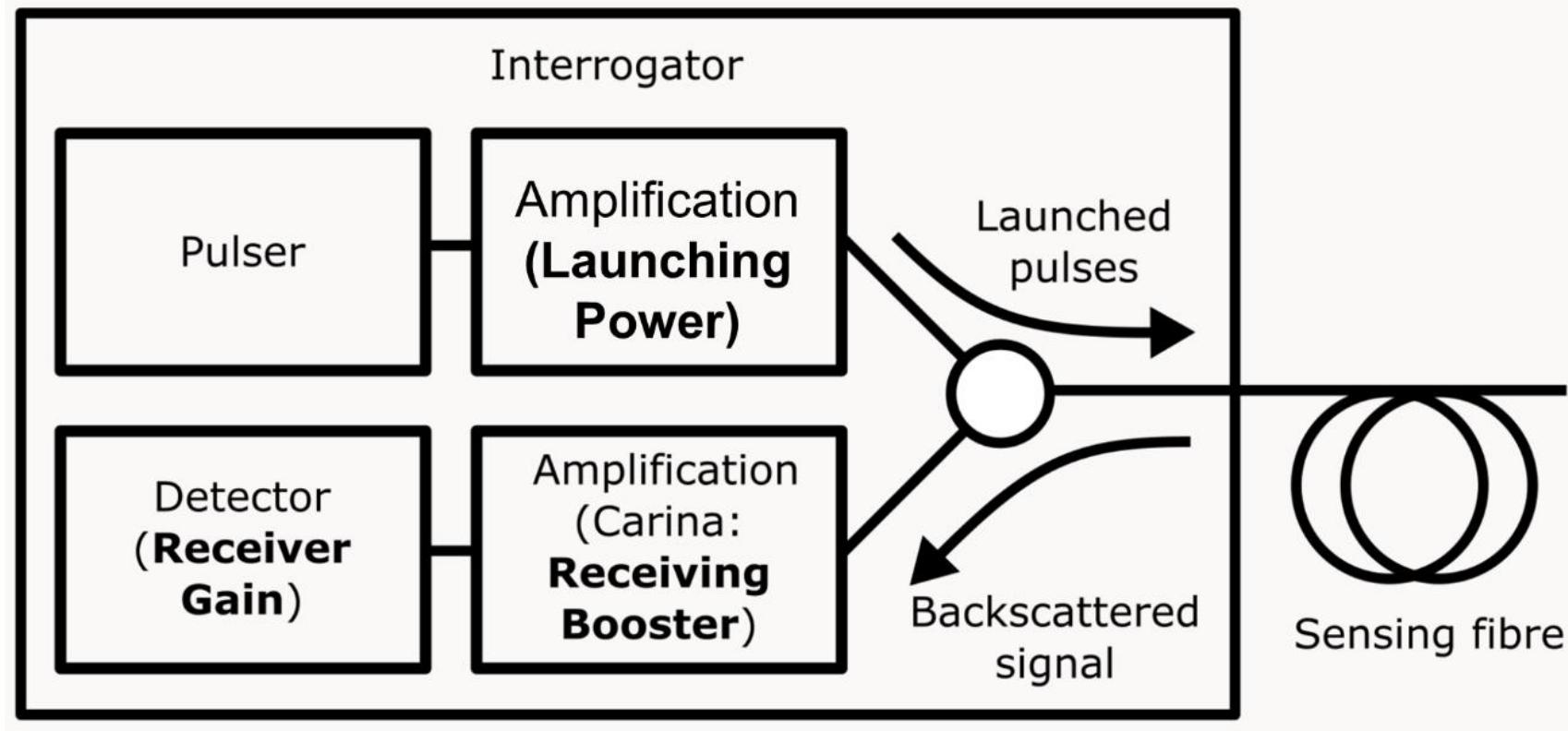


# Configuration Wizard

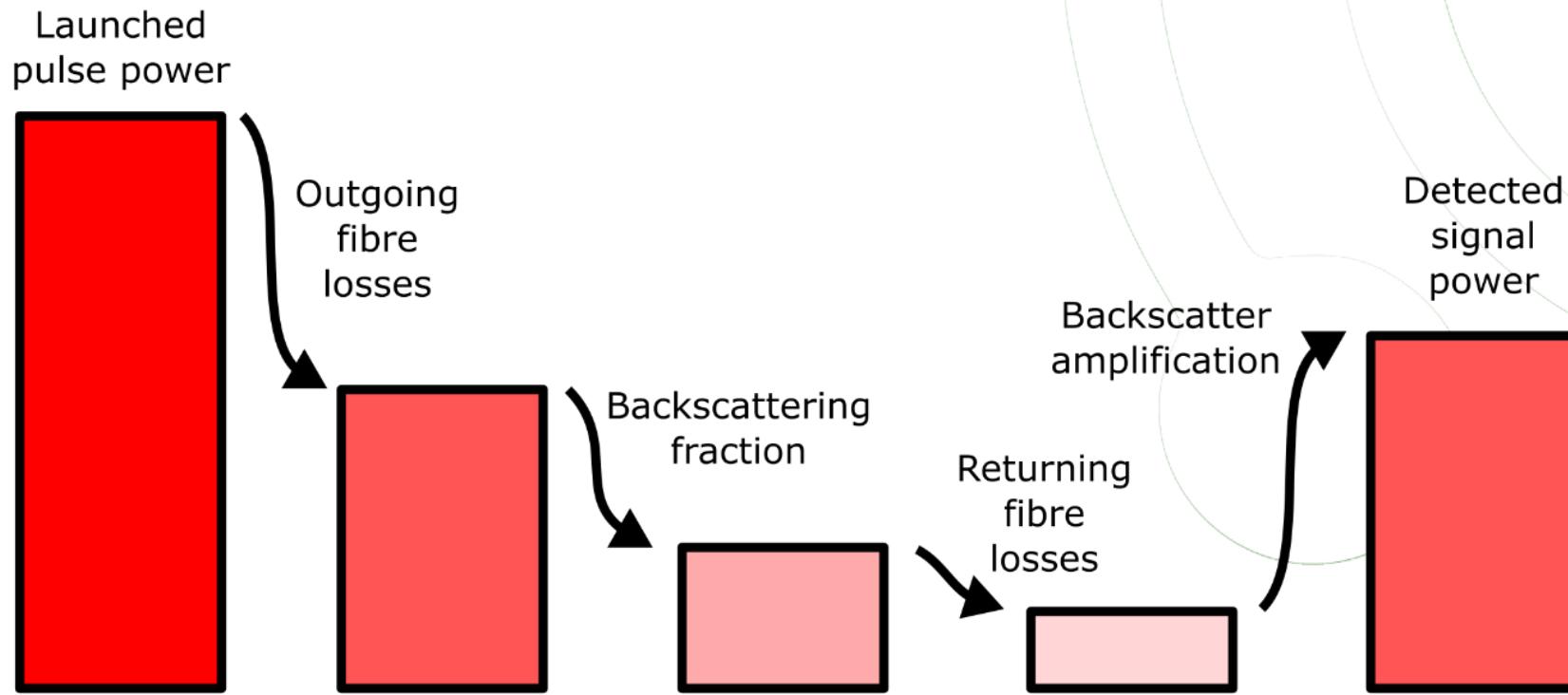
## 2) Increase Receiver amplifier power



# Configuration Wizard

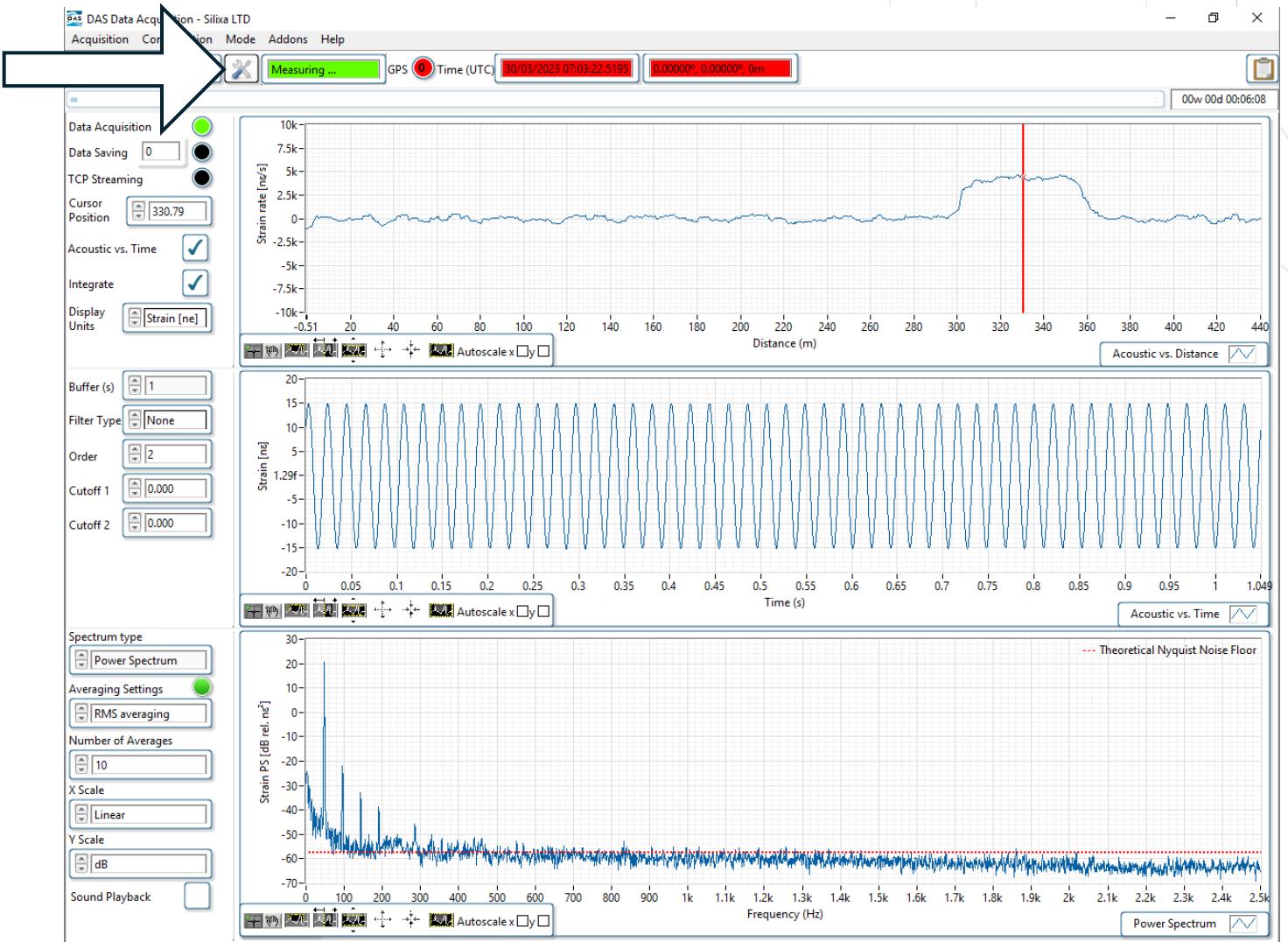


# Configuration Wizard

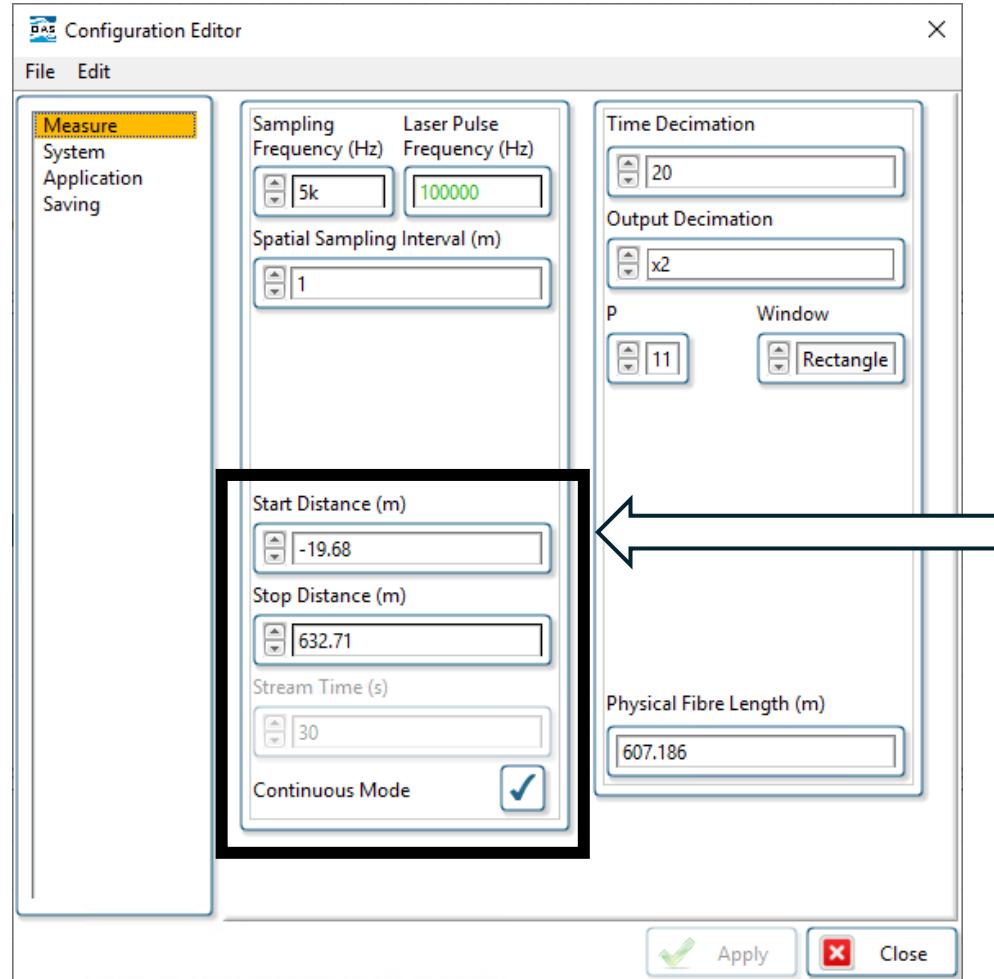


# Configuration

Remaining settings to adjust



# Configuration Editor



- Only change these
- Change other settings via wizard

# Configuration Editor

## Saving settings

Enable Data Saving	<input type="checkbox"/>	Data Saving File	<input type="button" value="ProdML 2.1"/>
FFID in filename	<input type="checkbox"/>	Current FFID	<input type="button" value="21"/>
Saving Folder			
File Name Prefix		Timestamp	
<input type="text" value="data"/>		<input type="button" value="UTC"/>	
File Size Limit (s) (0: unlimited)		<input type="button" value="30"/>	
Saving Buffering			
<input checked="" type="checkbox"/>			
Delete oldest files			
<input type="checkbox"/>			
Disk space remaining (time)		<input type="text" value="00d08:44:49"/>	
File Header Comments			
<input type="text"/>			

# Settings trade-offs

## Dynamic range:

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

Data volume

Sampling frequency



Dynamic range

Dynamic range  
Spatial resolution

Gauge Length

Acoustic SNR

Spatial resolution

Spatial Sampling Interval

Data volume

## Minimum data rate:

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

## Finer spatial resolution

- Shorter Gauge Length
- Shorter Spatial Sampling Interval

## Maximum acoustic SNR

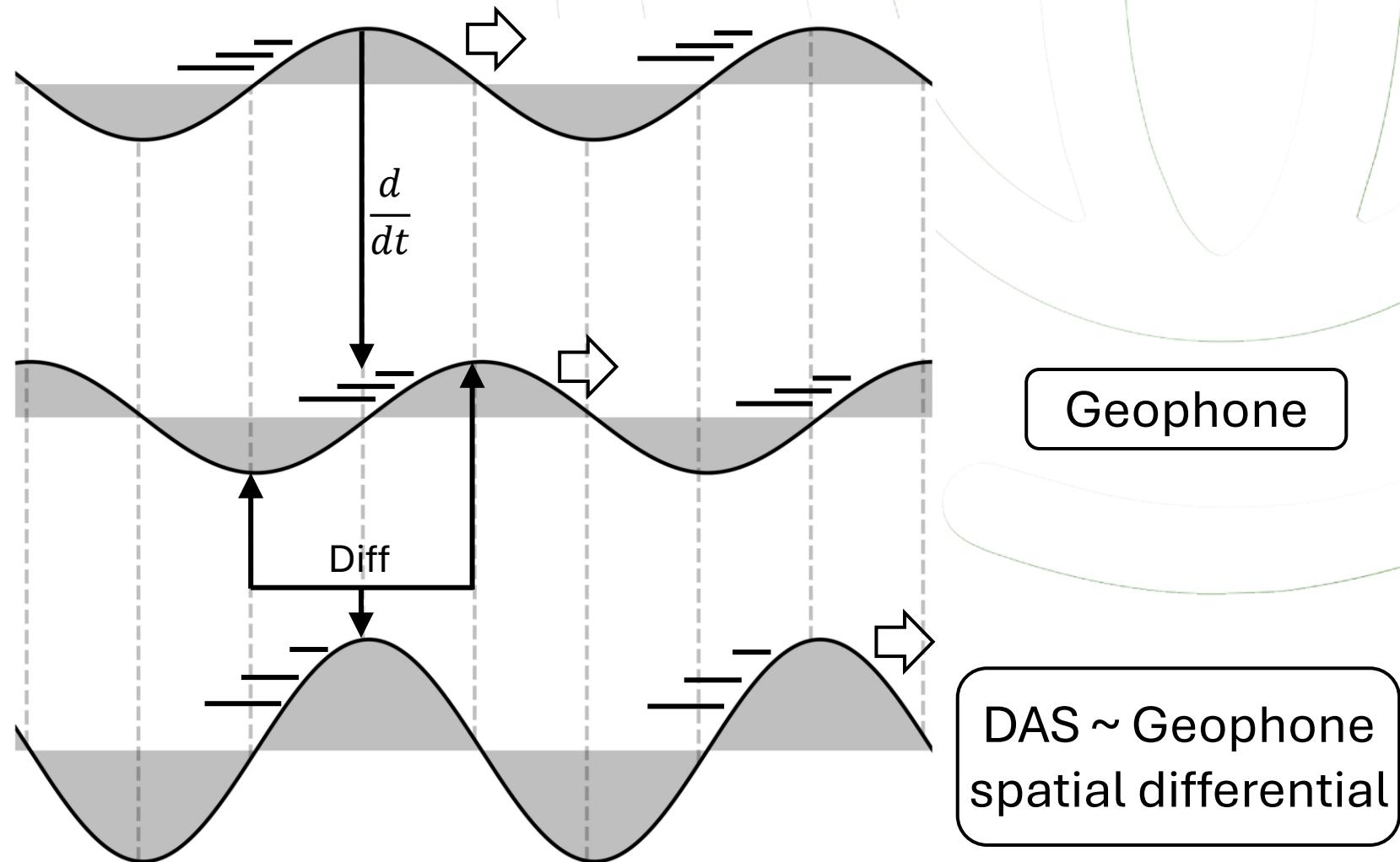
- Longer Gauge Length
- Minimum fibre losses
- Enhanced fibre (Constellation)
- Optimal Laser Pulse Frequency

# Comparison with Geophones

Displacement  $u_x$

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

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

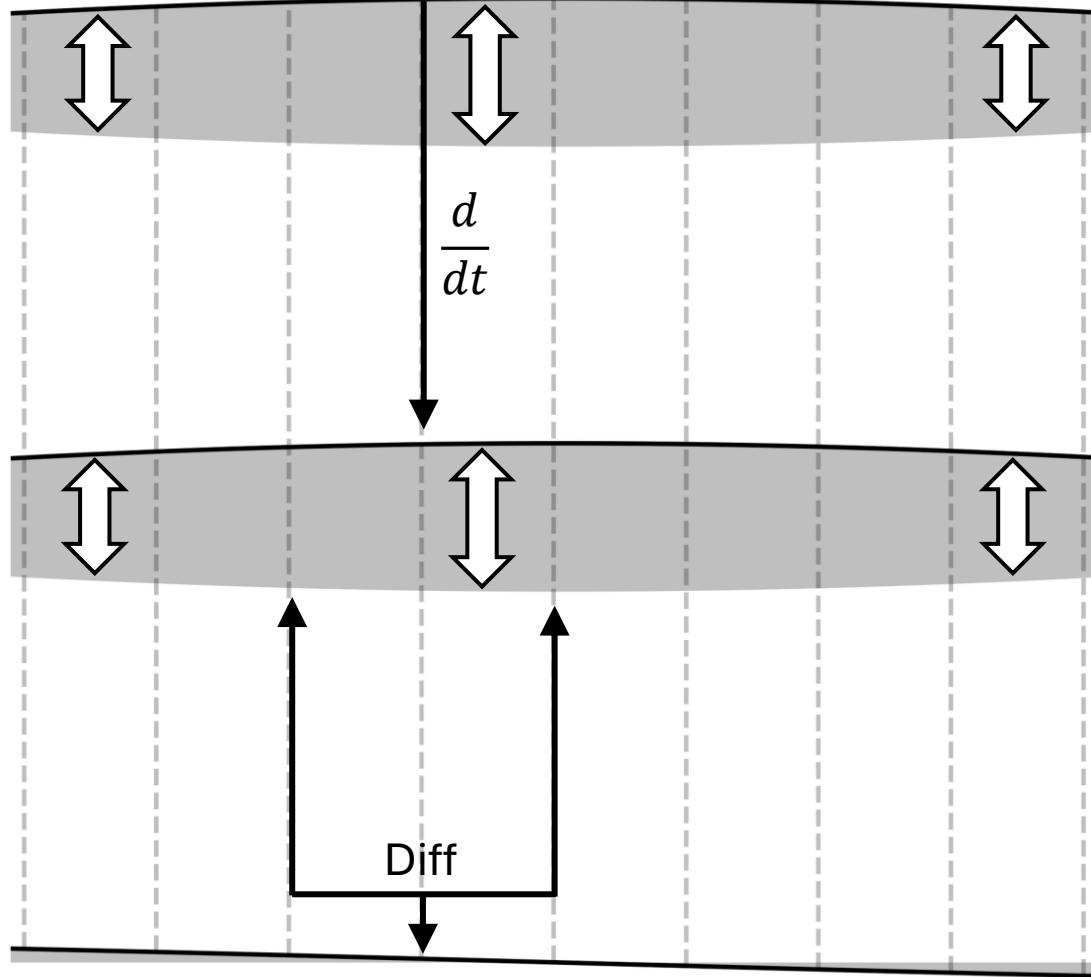


# Comparison with Geophones

Displacement  $u_x$

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

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

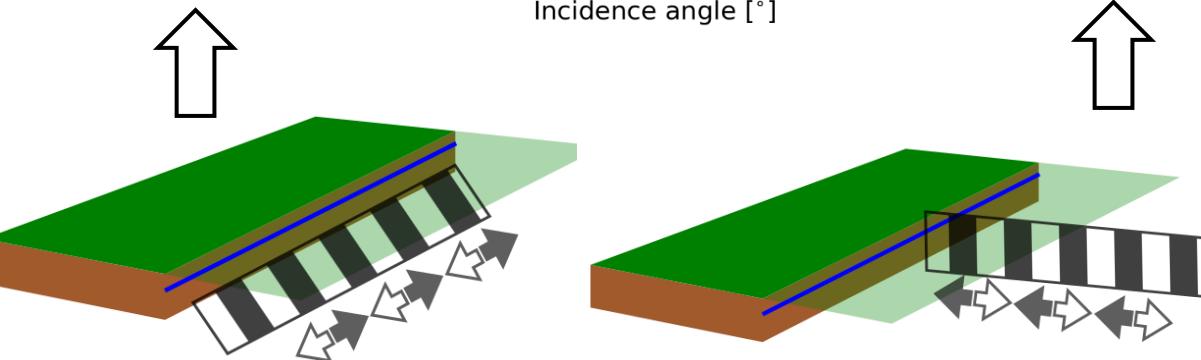
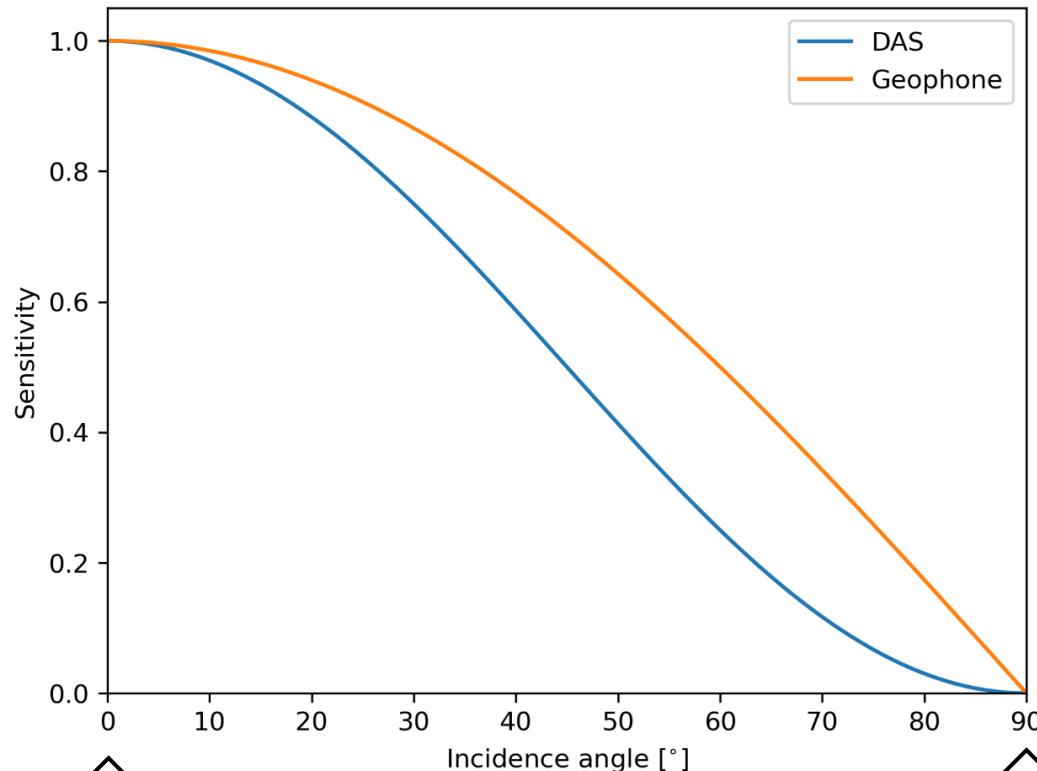


Geophone

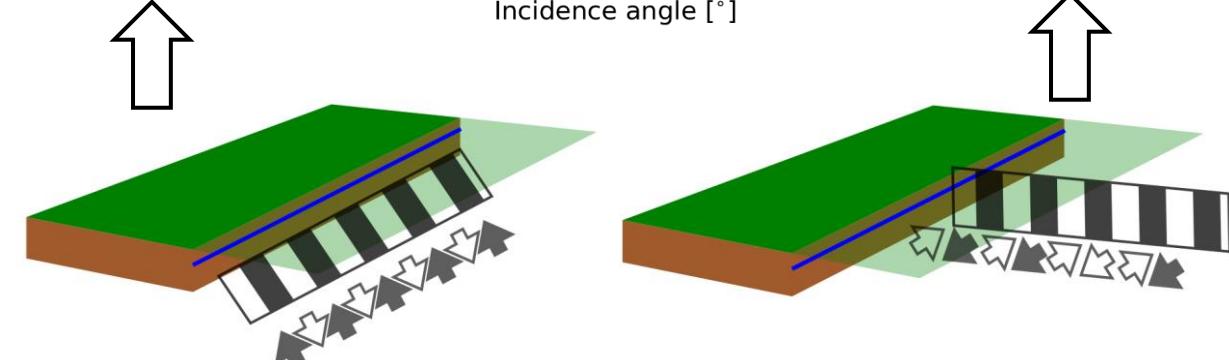
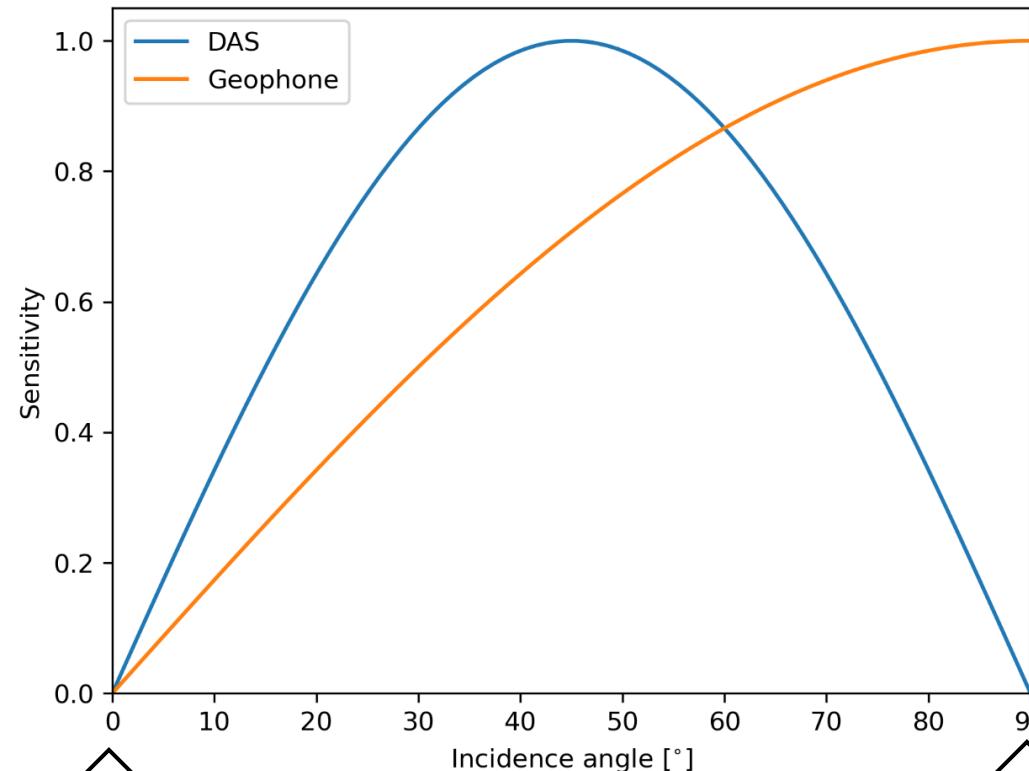
Uniform velocity  
→ low DAS  
sensitivity

# Comparison with Geophones

P-waves



S-waves



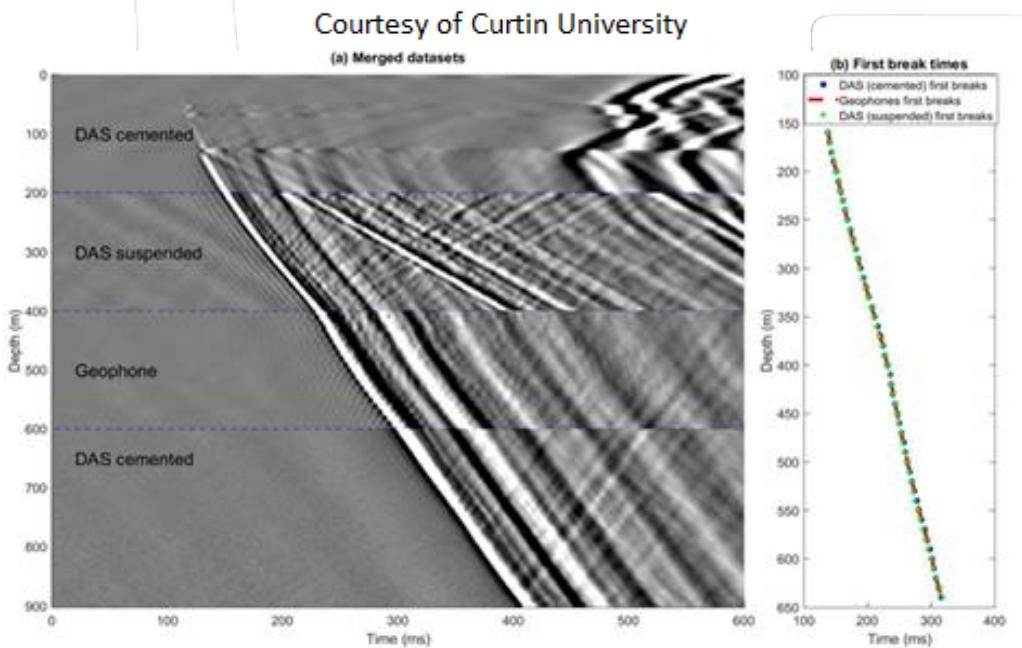
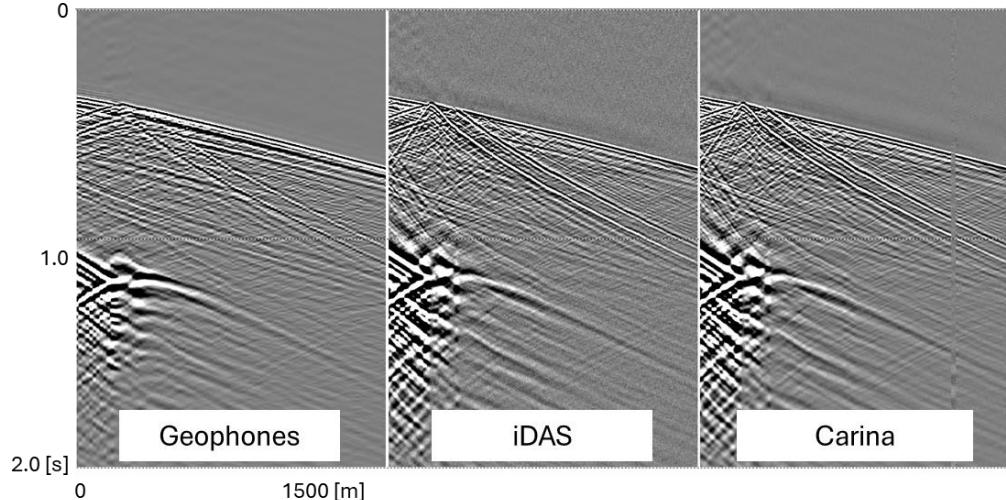
# Comparison with Geophones

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

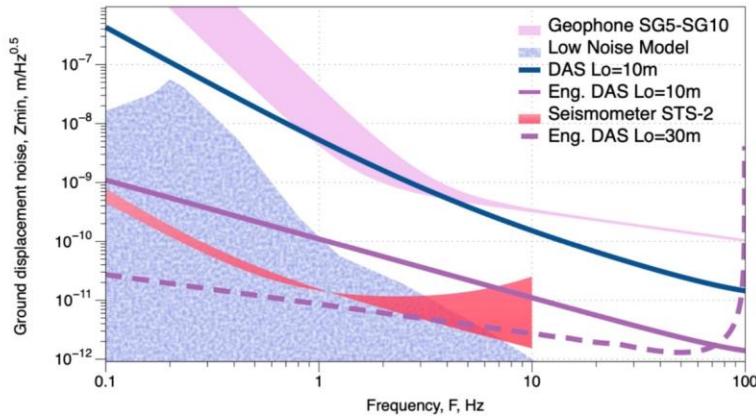
Stack of 5  
Acq. Time = 12 hrs

Stack of 5  
Acq. Time = 4 min

Stack of 5  
Acq. Time = 4 min



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!

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