

# The development of: Fiber Optic Ultrasound Transducer (FOPUT)

## Offering new parameters in Structural Health Monitoring (SHM) applications

Rob Jansen | Enschede

# We are TNO

TNO's mission is to create impactful innovations for the sustainable wellbeing and prosperity of society.



# Locations & lab facilities

## Some lab facilities highlighted:

-  Building Innovation Lab (Delft)
-  Solar Lab (Petten & Eindhoven)
-  Castel Milieulab (Utrecht)
-  Nano Lab (Delft)
-  Accelerator Mass Spectrometer (Leiden)
-  Brightlands Materials Center



# TNO Units

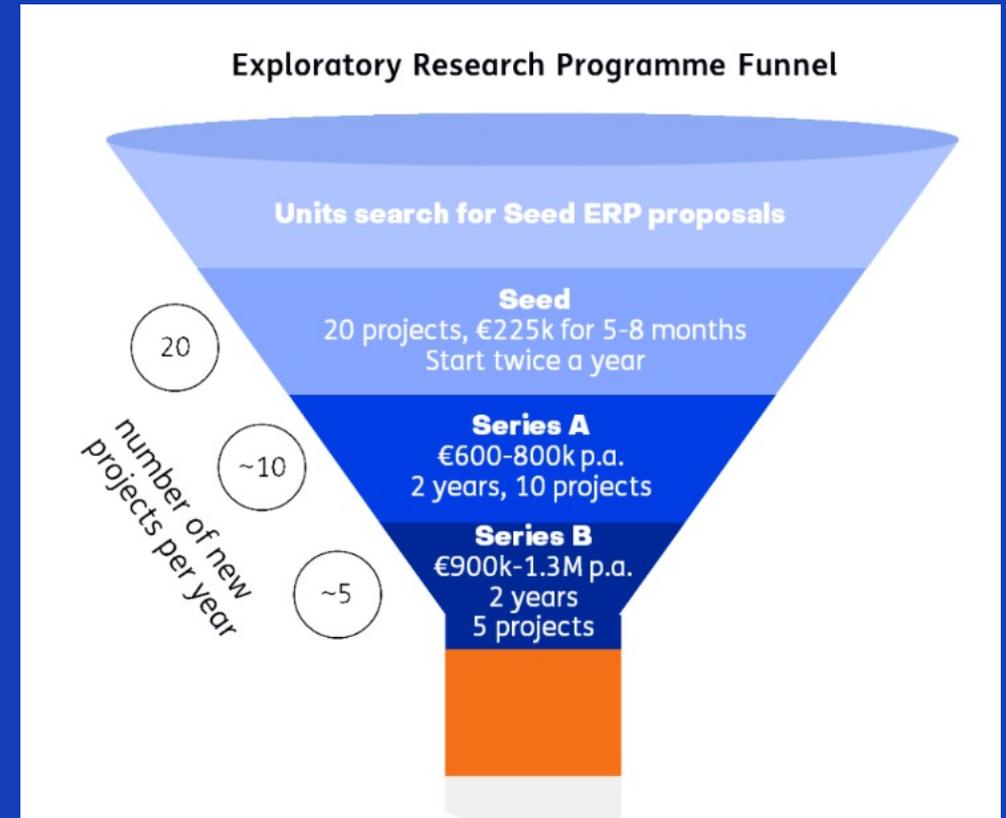


# Exploratory Research Programmes

The Exploratory Research Programmes (ERPs) at TNO focus on applied scientific research that drives economic and societal impact.

They serve as a mechanism to renew TNO's portfolio, maintain its knowledge base, and establish a unique position in the research landscape.

ERP projects aim for concrete knowledge and technology breakthroughs, bridging the gap between foundational and demand-driven research.



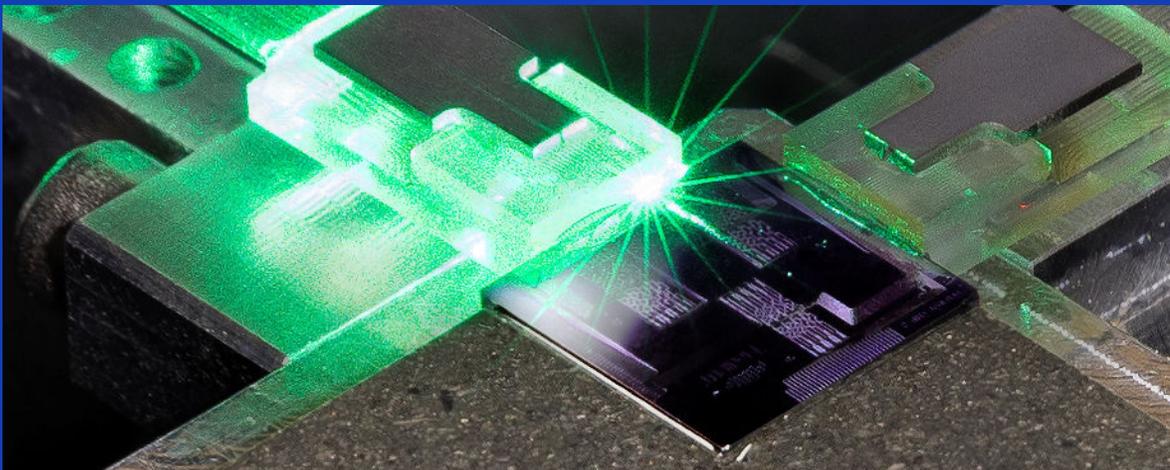
# ERP OptoAcoustics

The ERP OptoAcoustics creates a next generation acoustic platform, using optical means only, to generate and receive acoustic waves. Such a system will radically outperform existing (often piezo based) acoustic systems.

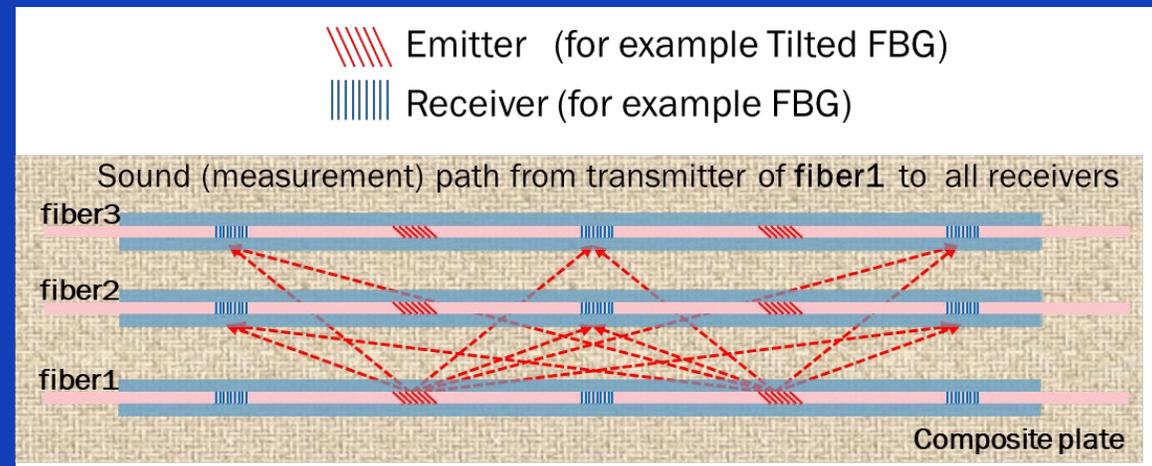
## Societal challenges:

- **Medical:** High quality images will result in earlier, better and specific diagnoses and therefore to increased patient health, well-being and lower health-care costs.
- **Clean energy transition:** Reduction of costs per unit energy is required to speed-up the clean energy revolution. Opto-Acoustic monitoring contributes in extending the lifetime of light-weight composite structure and will accelerate composite material developments in re-use or recycling.

## IPUT™ (Integrated Photonic Ultrasound Transducer)



## FOPUT (Fiber Optic Ultrasound Transducer)



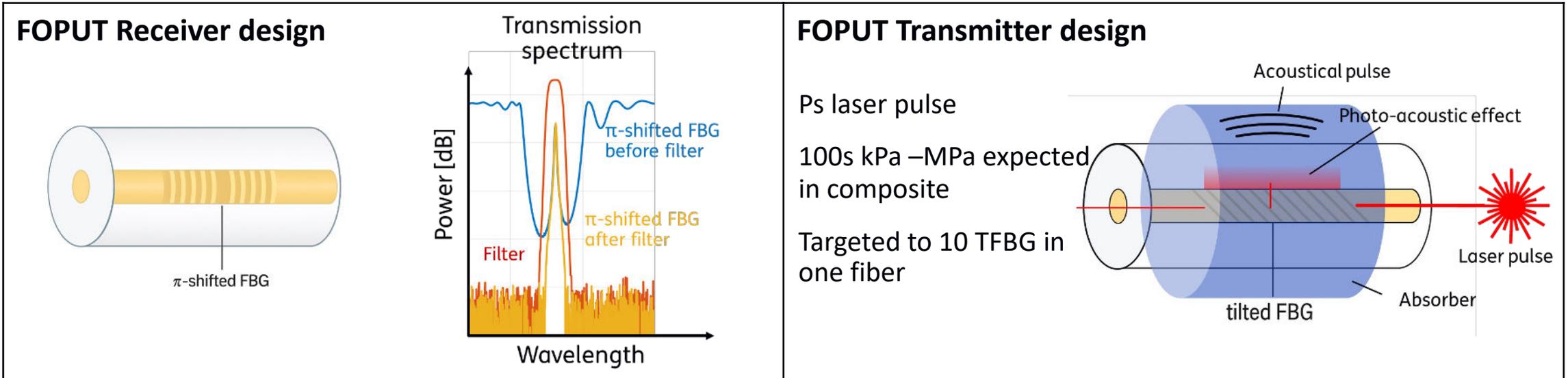
# Introduction – problem statement

- Wind farms placed in remote locations (e.g. at sea)
- Standard piezo-electric monitoring and inspection suffer from a few drawbacks:
  - Requires long cables to cover large structure sizes
    - ➔ Needs signal pre-amplification (higher costs)
  - Many cables (typically one cable per transducer)
    - ➔ Higher costs (installation, readout)
  - Sensitive to lightning
    - ➔ Chance that the system is damaged



# What if we could make an **all-optical** system?

Fiber **O**ptic **P**hotonic **U**ltrasound **T**ransducer (FOPUT)



Main advantages:

- Minimal optical losses in optical fibers:
  - Multiple FOPUTs can be put in series on a single fiber (in transmission or reception)
- Can be permanently surface mounted or embedded during structure production
- Insensitive to lightning (EM shock)

# What if we could make an all-optical **scalable** system?

Fiber **O**ptic **P**hotonic **U**ltrasound **T**ransducer (FOPUT) based design

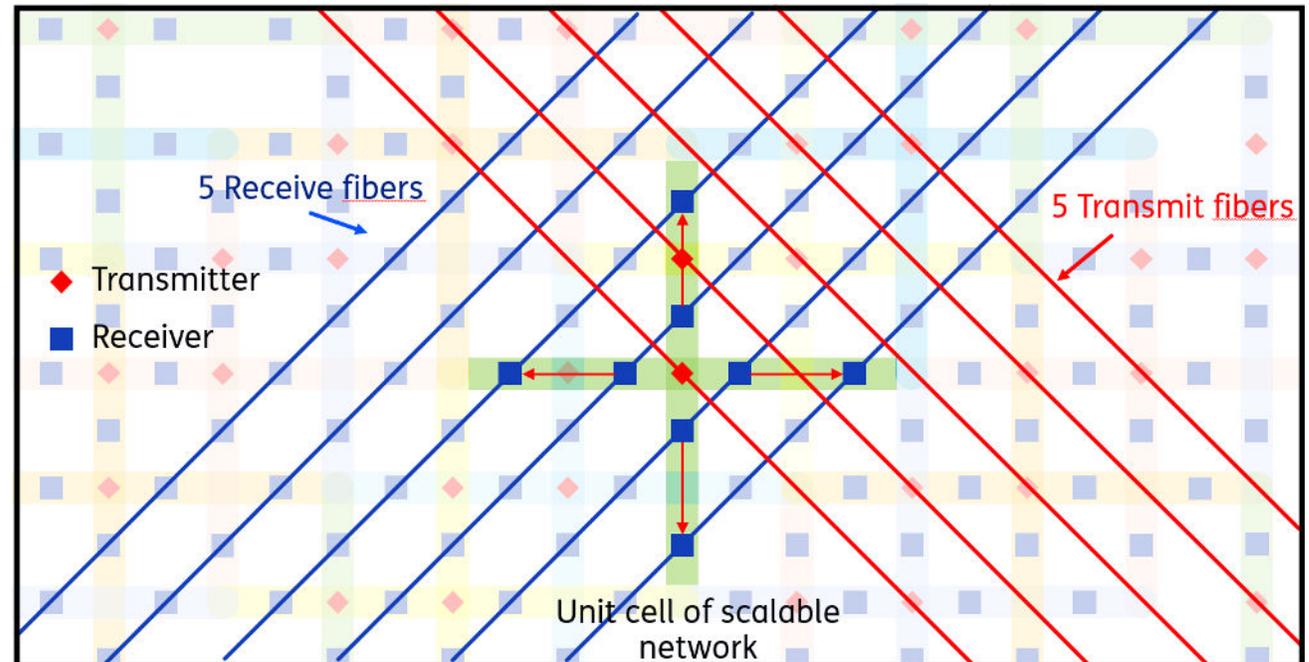
Separate transmit and receive fibers

Unit cell can be scaled to cover smaller

or larger areas:

- Hot spot monitoring
- Full blade or structure

FOPUTs spacing scalable



# Active and passive monitoring

## Active monitoring of defects such as:

- Delamination
- Stiffness variations
- Defects

Monitoring principle using

→ Guided wave generation (e.g.  $S_0$ )

→ Cross-correlation between receivers

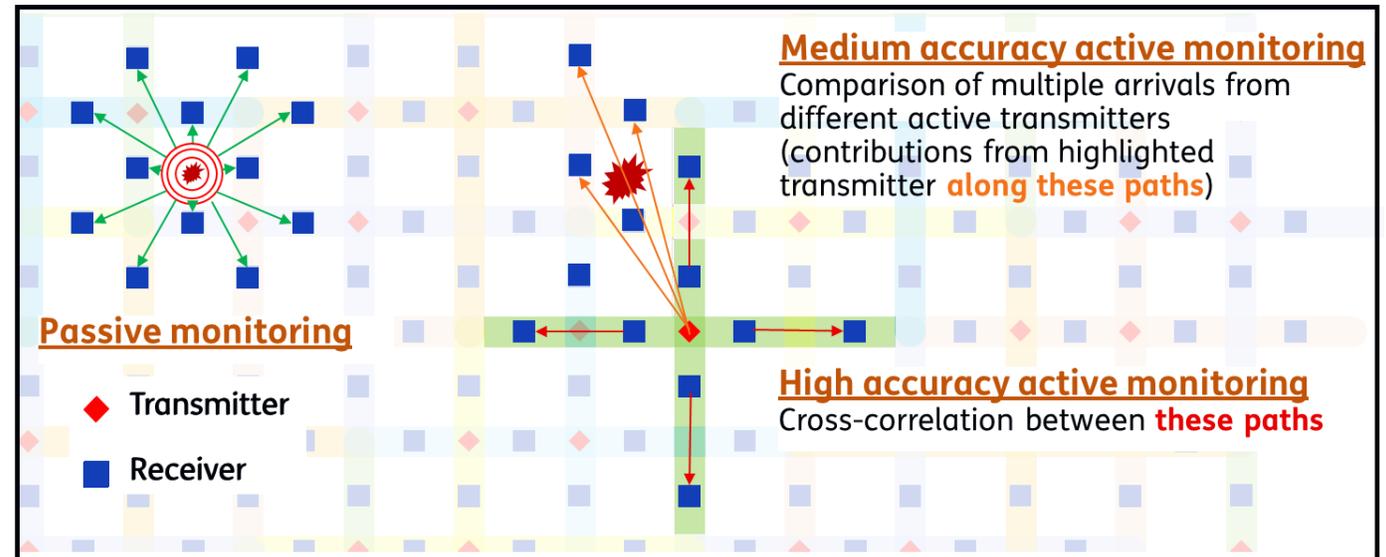
(velocity variation monitoring for instance)

## High and medium accuracy

- High: Use of direct receivers in cross around transmitter
- Medium: Use of additional receivers

## Passive monitoring (Acoustic Emission)

- Acoustic emission (characterization and localization)



# FOPUT - modelling

FEM model of panel with optical fiber

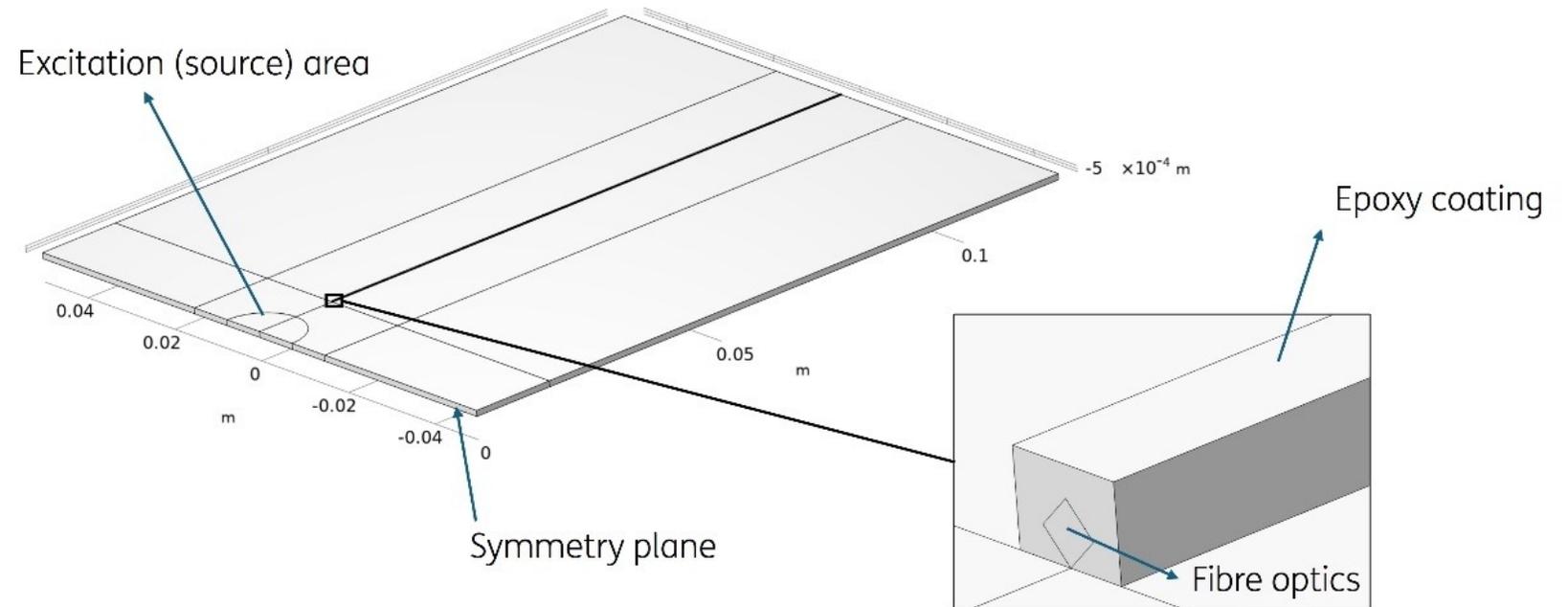
Results:

0 deg

- S0 → 4546 m/s
- A0 → 1589 m/s

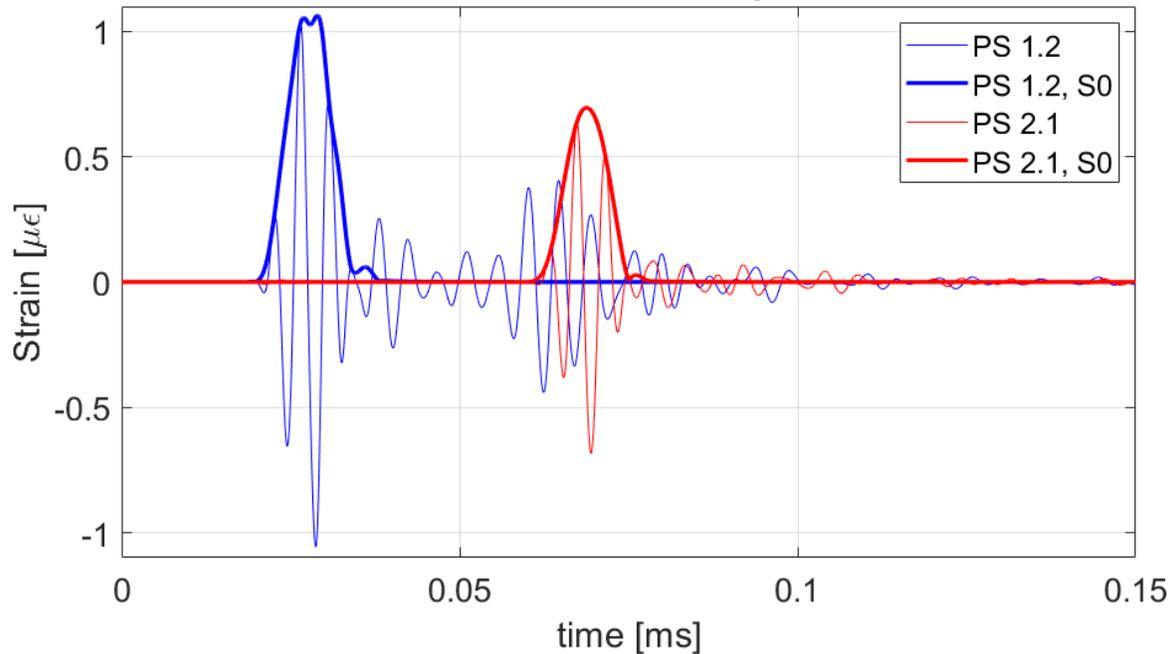
90 deg

- S0 → 2551 m/s
- A0 → 1334 m/s

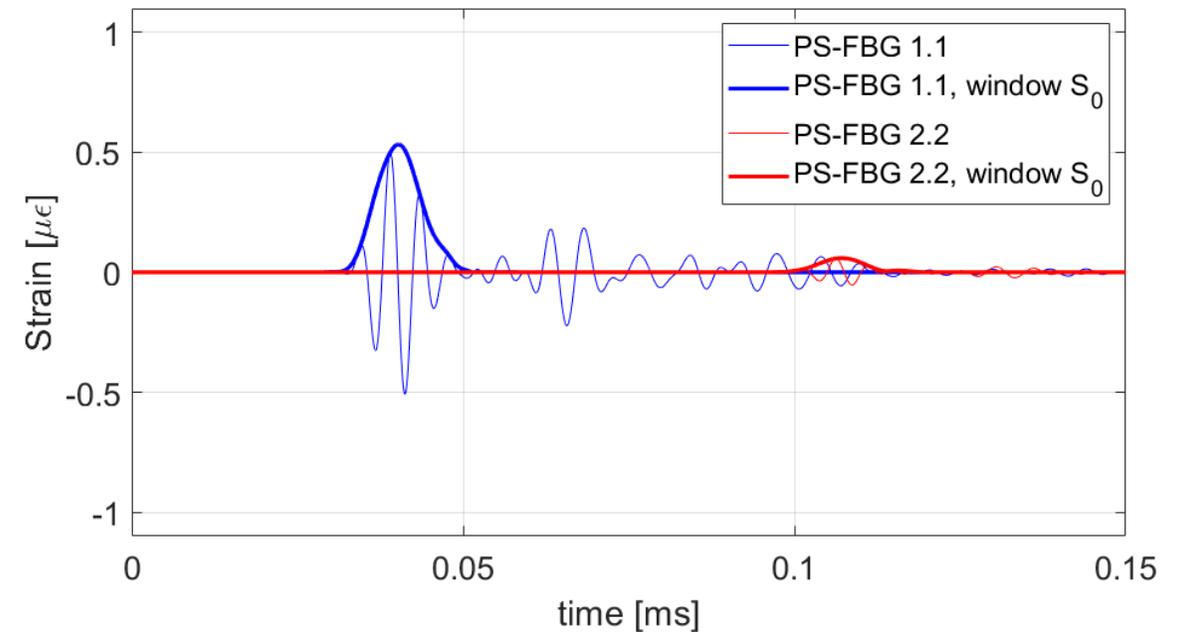


# FOPUT – measurement results

$S_0$  on PS 1.2 and PS 2.1: est. speed = 4902 m/s



$S_0$  on PS 1.1 and PS 2.2: est. speed = 2972 m/s

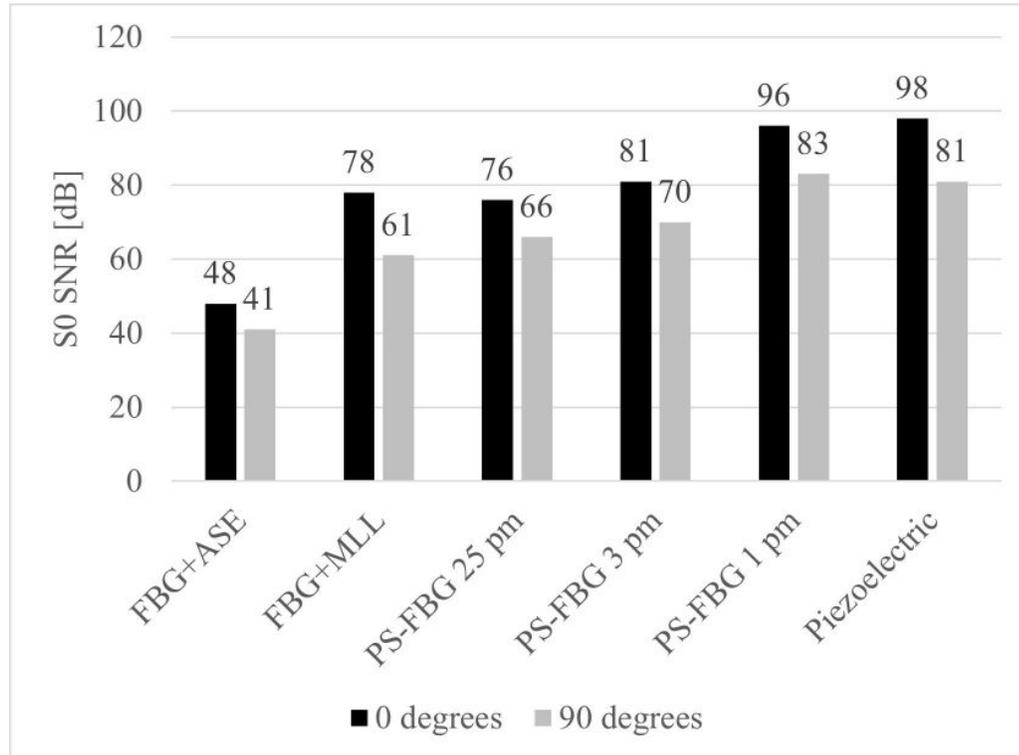


$\pi$ -shifted FBG along (left) and across (right) composite fiber glass

$S_0$  guided mode identification and windowing,

Group velocity estimated from cross correlation between windowed traces on  $\pi$ -shifted FBGs

# FOPUT versus Piezoelectric



**Conclusion:** the sensitivity of a 1 pm PS-FBG+MLL+3x3 MZI system is comparable with COTS piezoelectric transducers. This opens the possibility of using the fully optical FOPUT concept integrated in a SHM system for an efficient area coverage.

**Sensitivity investigation of new fiber optic read-out system for guided waves based on Pi Shifted Fiber Bragg Gratings and Mode Locked Lasers**

A. Gonzalez Jimenez<sup>1</sup>, B.A.J. Quesson<sup>1</sup>, L. Scherino<sup>2</sup>, M.A. Zandi<sup>2</sup>, D. Piras<sup>3</sup>, W. de Jong<sup>2</sup>, L.K. Cheng<sup>2</sup>, T.H. Jansen<sup>2</sup>, P.L.M.J. van Neer<sup>1</sup>

<sup>1</sup>Acoustic sensors and sonar systems department, TNO, The Netherlands; <sup>2</sup>Optics department, TNO, The Netherlands; <sup>3</sup>Acoustic Signatures and Noise Control, TNO, The Netherlands

# Summary and Conclusions

## Summary

- Full optical scalable system for monitoring and inspection of large structure presented
- Preliminary measurements results on a composite panel presented in reception on a cut-down unit cell:
  - Piezoelectric transducer as transmitter and 2 arrays of 2x 25pm  $\pi$ -shifted FBGs
  - Good agreement between measured and modelled group velocities for  $S_0$  (for mechanical properties assumed from literature)
  - Active monitoring of defects such as: Delamination, stiffness variations & defects

## Conclusion and way ahead

Preliminary results in reception promising for the further development of an all optical scalable FOPUT architecture: good agreement with modelling, readout and interrogation of multiple arrays,

( $\pi$ -shifted FBG sensitivity on par with piezo transducer\*)

Work on optical transmitter in progress



**Thank you for  
your attention**

 TNO Stieltjesweg 1 Delft

 [Rob.Jansen@tno.nl](mailto:Rob.Jansen@tno.nl)

 06-22544344