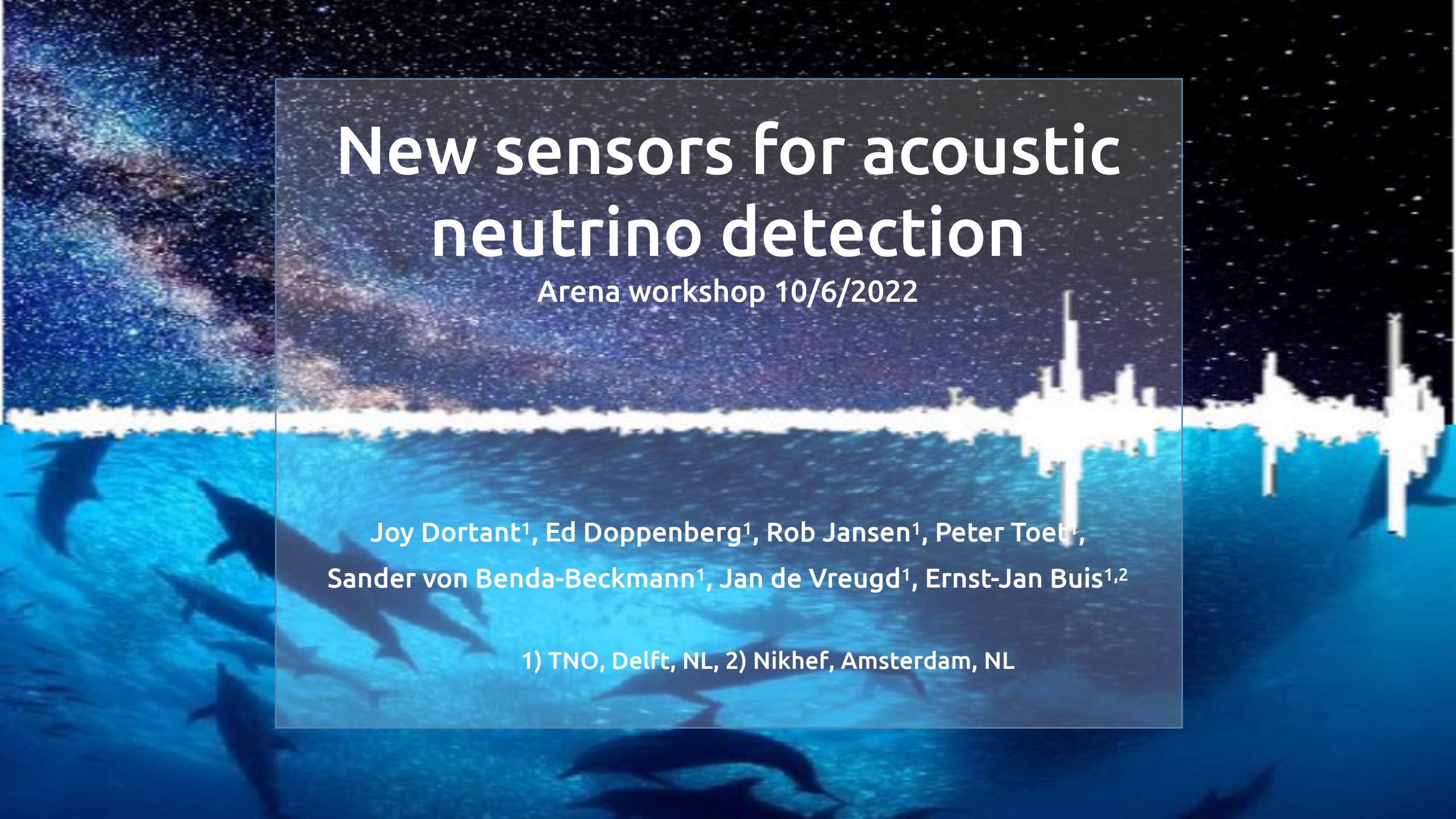


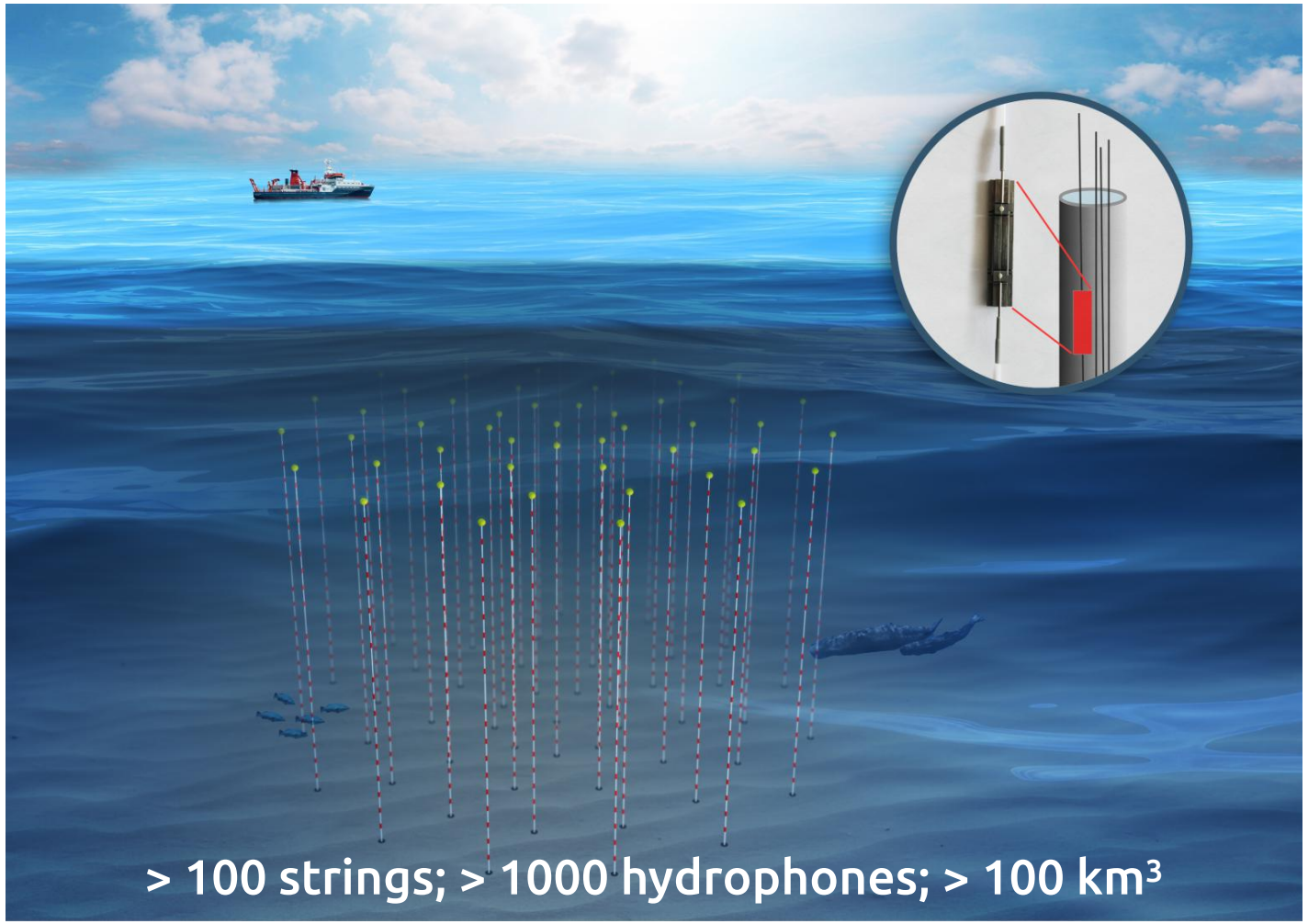
New sensors for acoustic neutrino detection

Arena workshop 10/6/2022

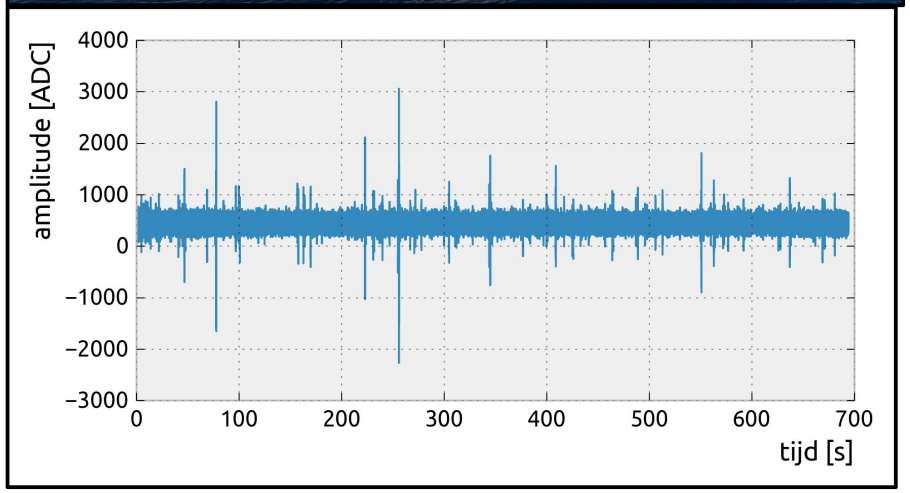
Joy Dortant[1], Ed Doppenberg[1], Rob Jansen[1], Peter Toet[1],
Sander von Benda-Beckmann[1], Jan de Vreugd[1], Ernst-Jan Buis[1,2]

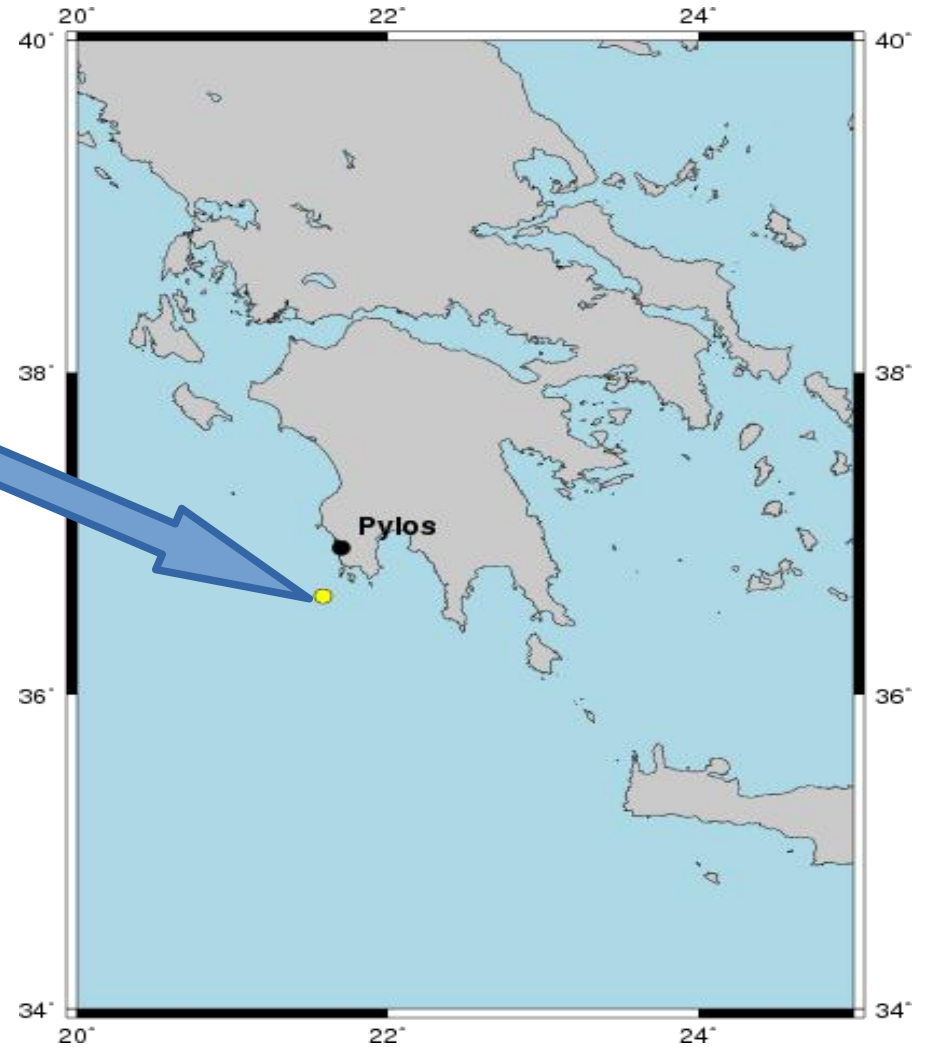
1) TNO, Delft, NL, 2) Nikhef, Amsterdam, NL

Acoustic neutrino telescope concept



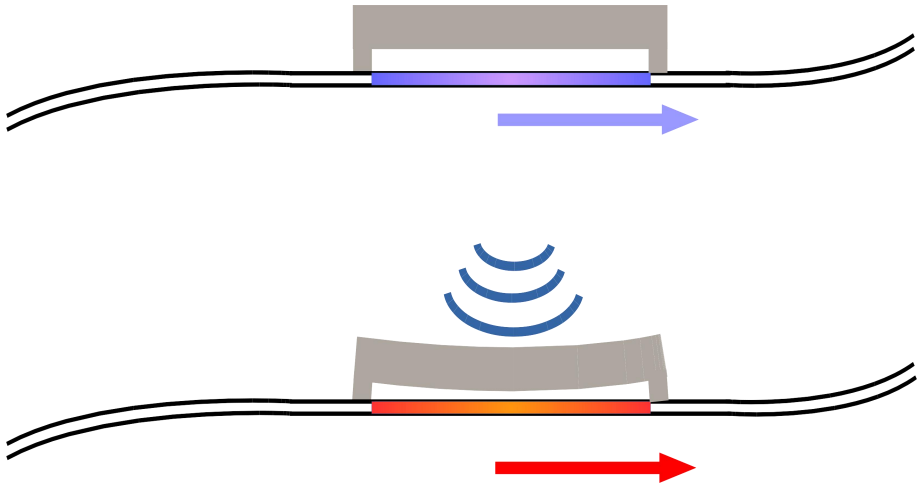
Sneak preview



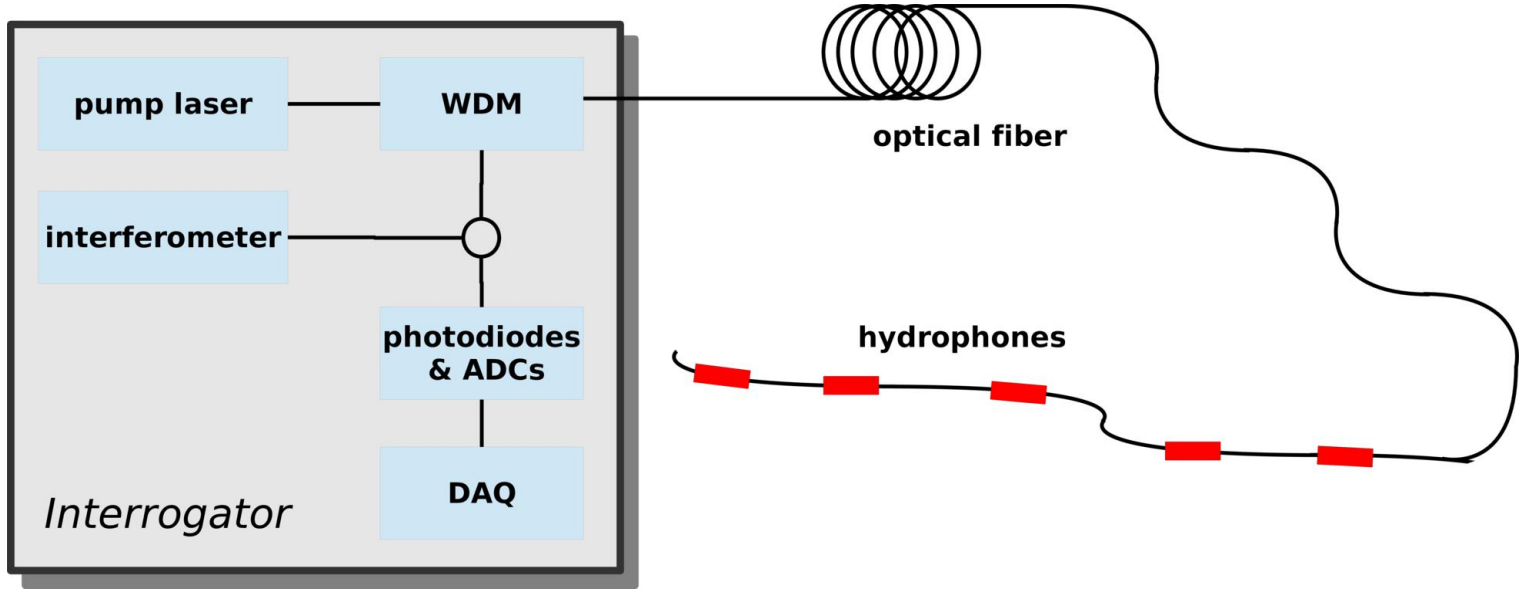


Hydrophone concept based optical fibers

Transducer convert pressure into a wavelength shift.



Hydrophone concept

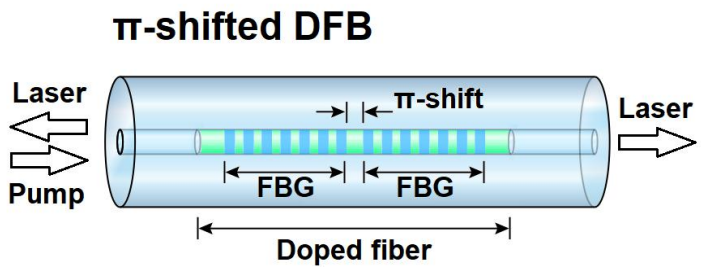


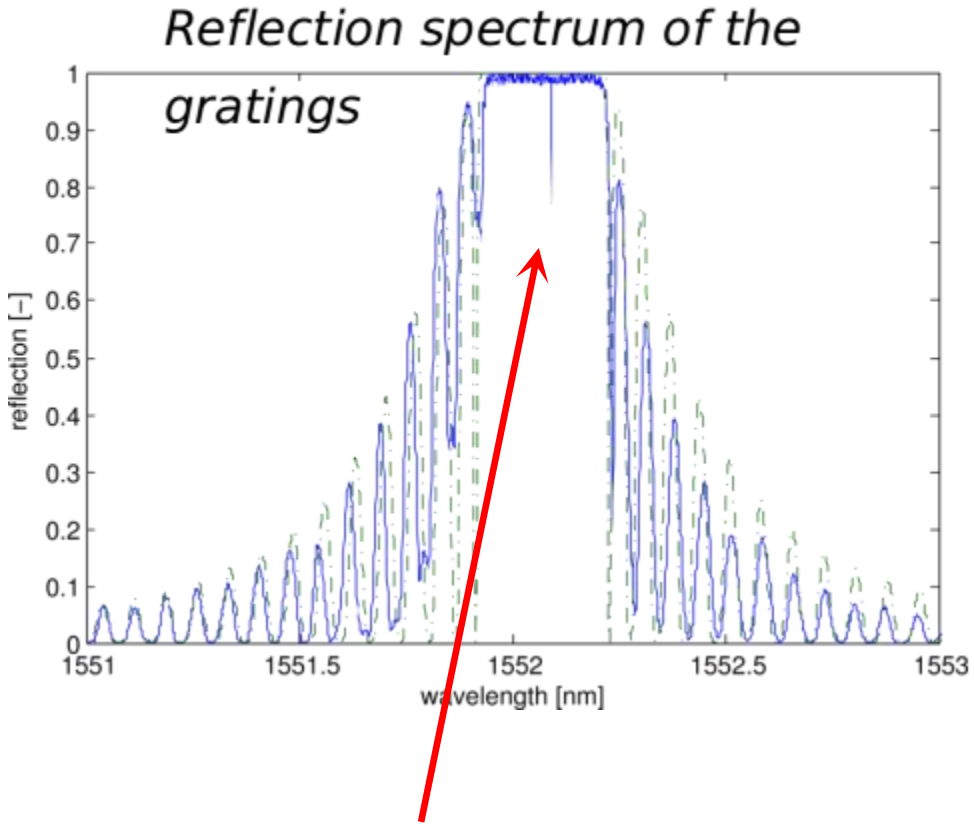
Three components

1. Transducer
2. Fiber laser
3. Interrogator

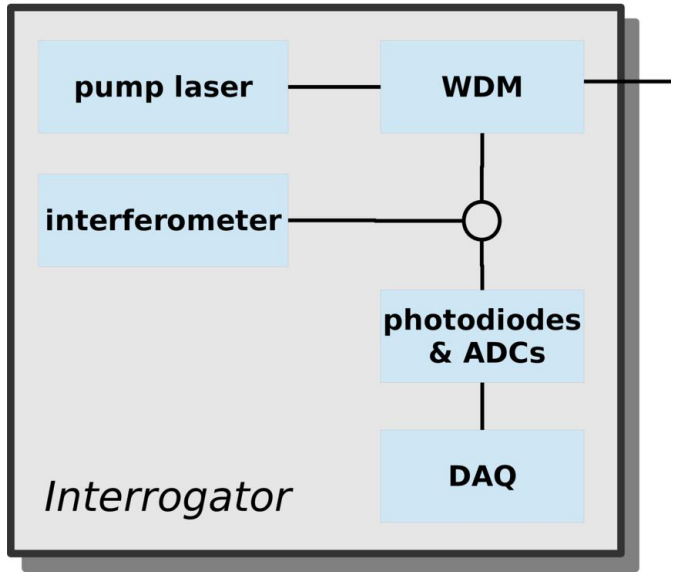
Fiber laser

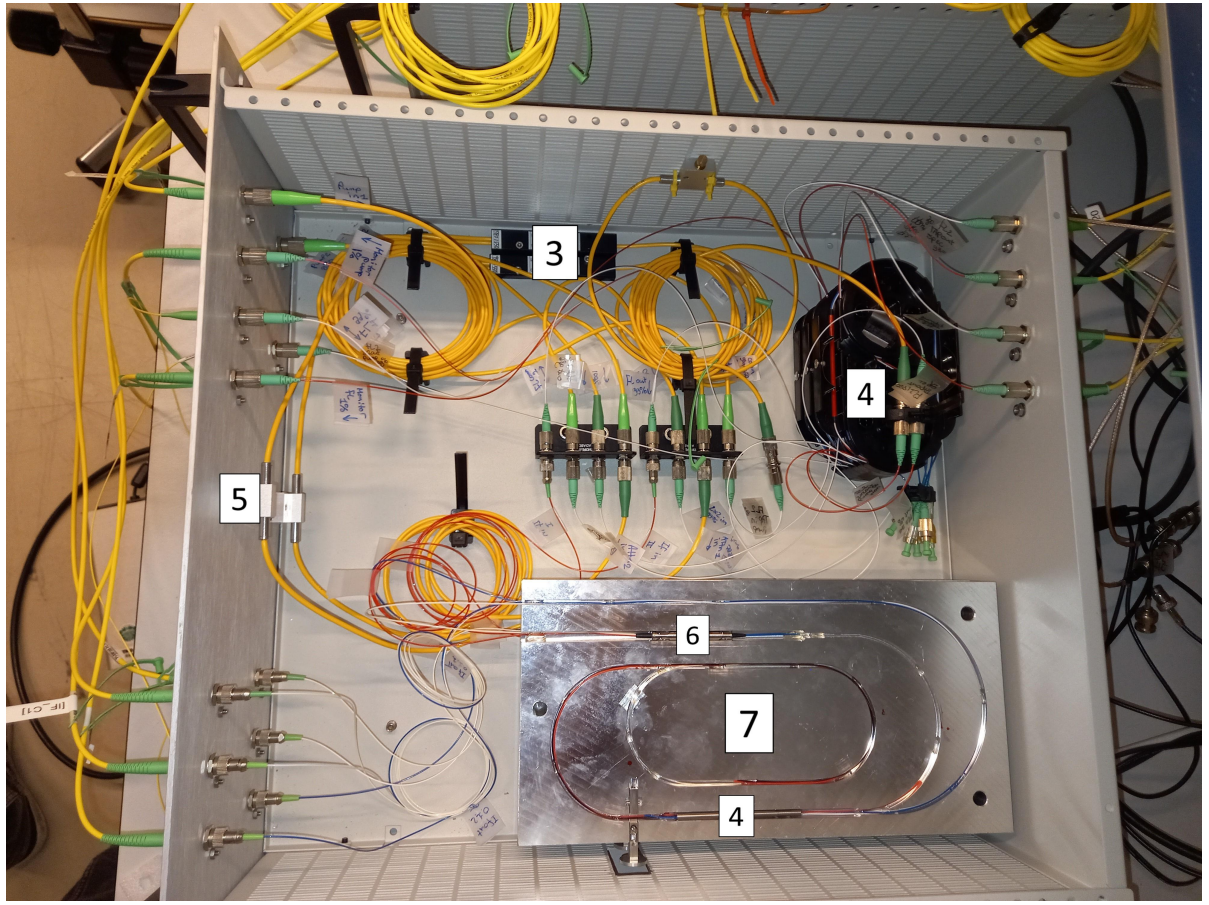
- Erbium doped fiber laser inserted in the optical fiber.
- Fiber laser is of Distributed Freedback type
- Linewidth 5 kHz



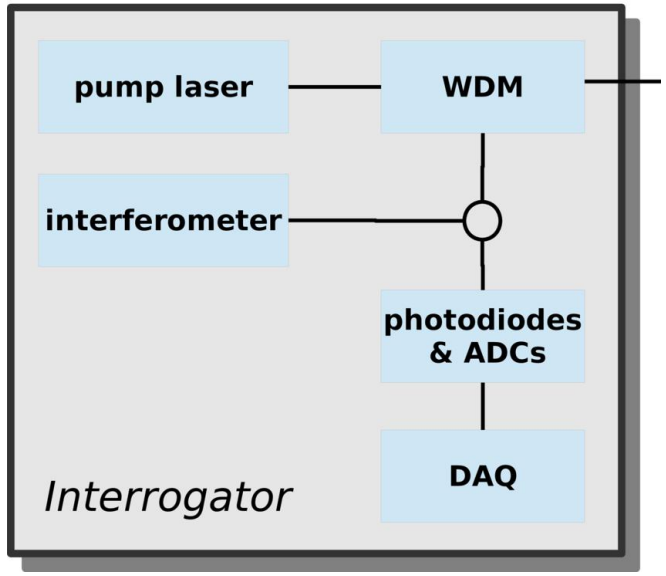


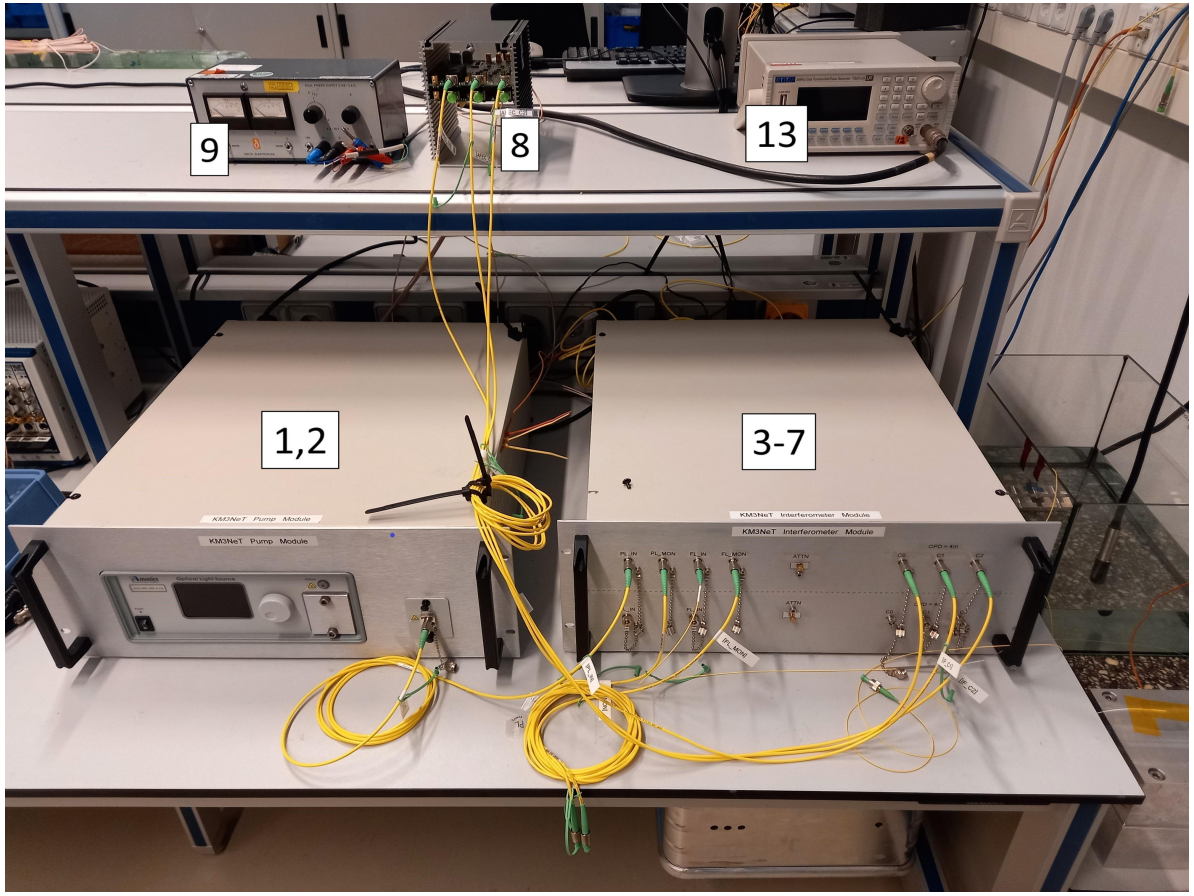
Interrogator



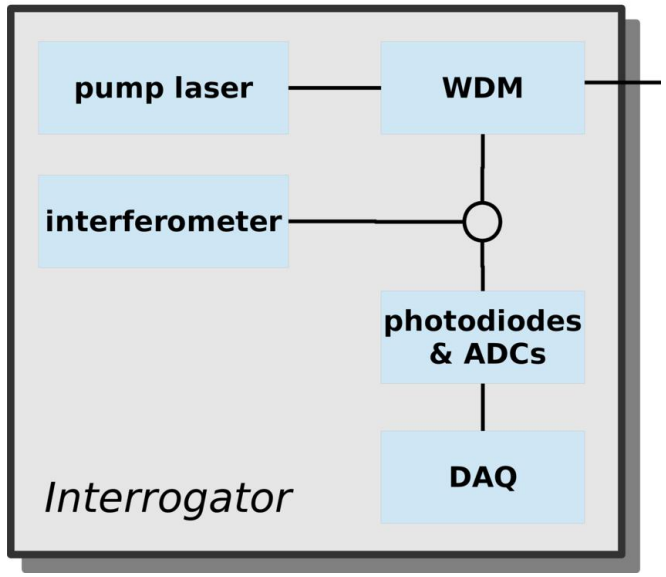


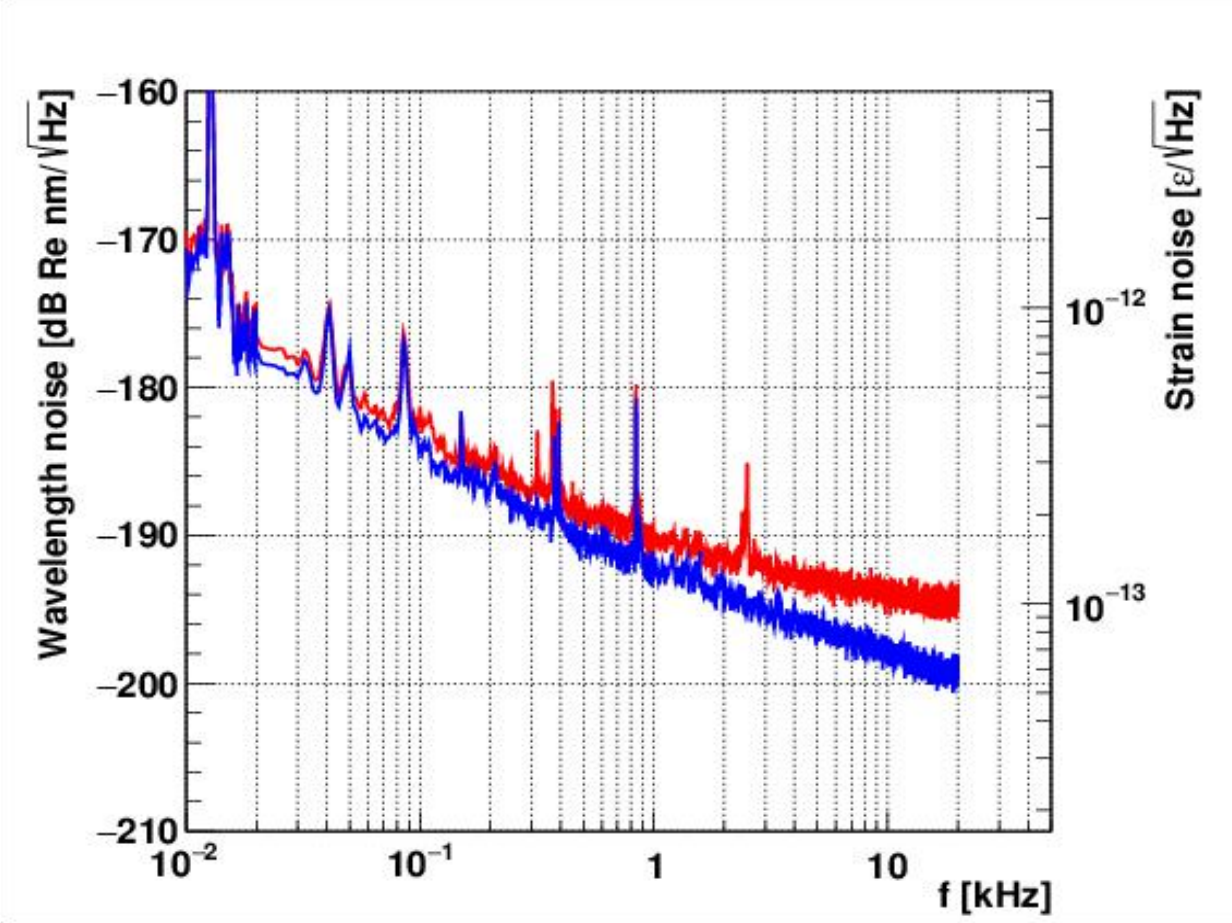
Interrogator





Interrogator





Interferometer sensitivity to 10^{-19} m/√Hz

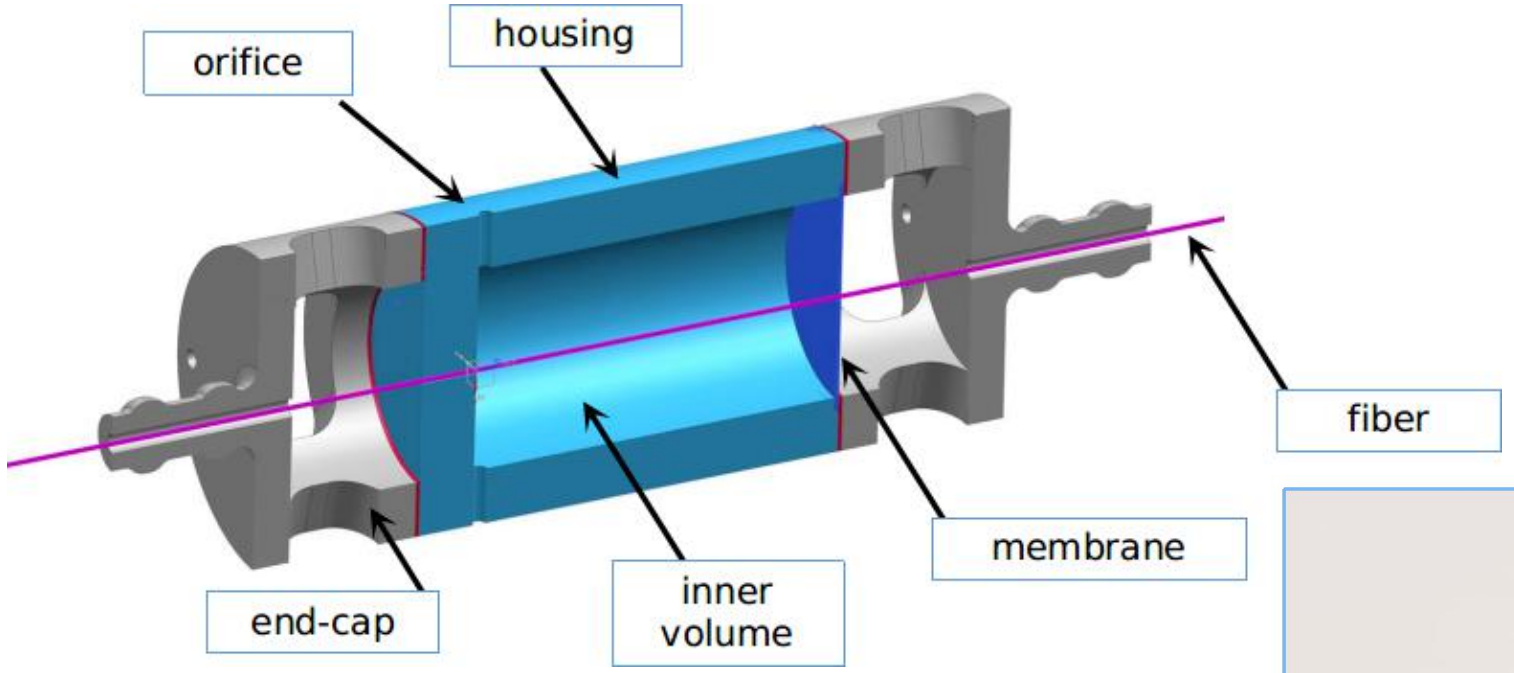
New transducer design, requirements

- Shall be operated in the deep sea:
  - Static pressure mechanism

- High sensitivity to detect neutrinos
  - Sea state 0 sensitivity

-> Detect mPa pulses in a static pressure environment of MPa.

New transducer design

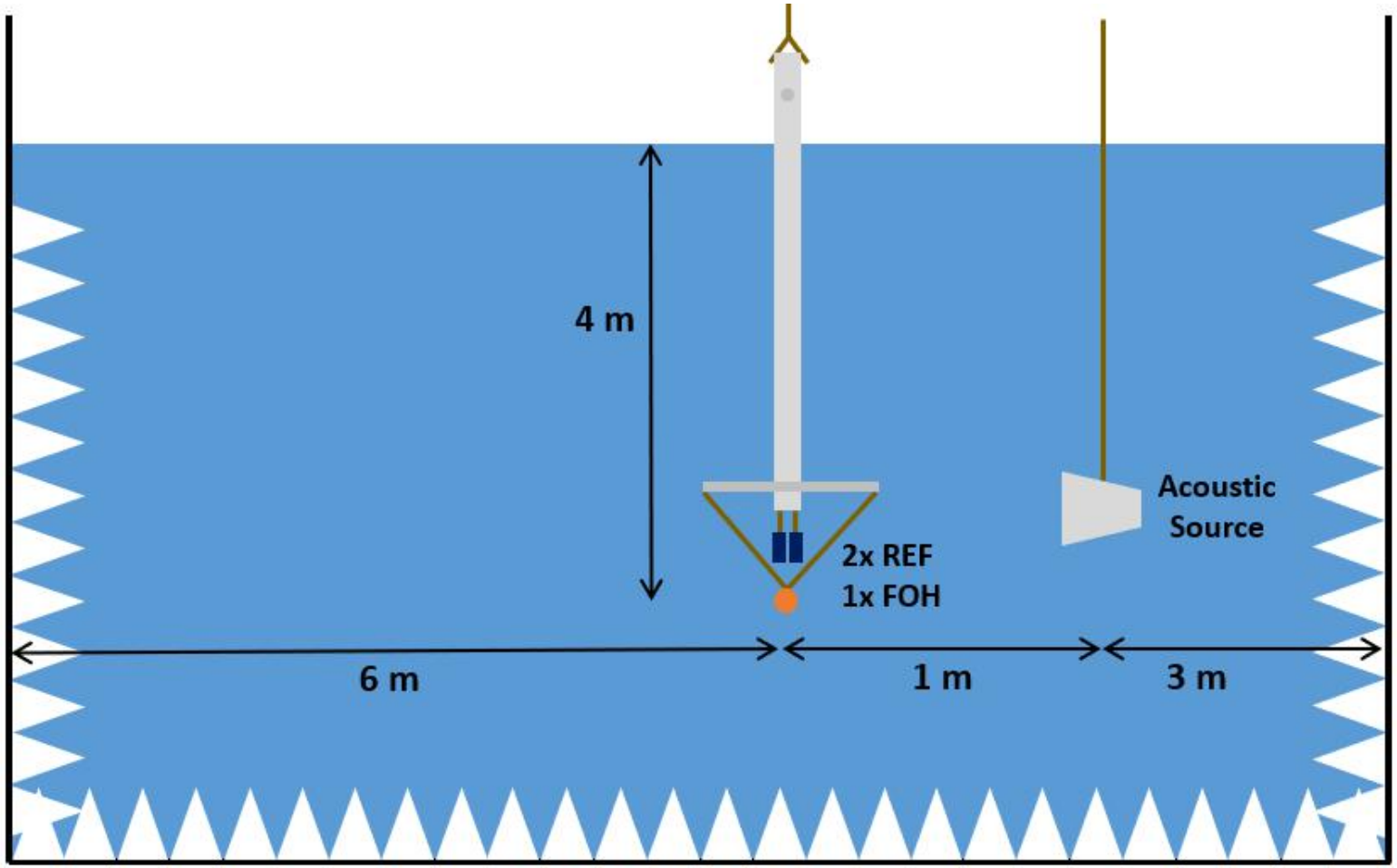


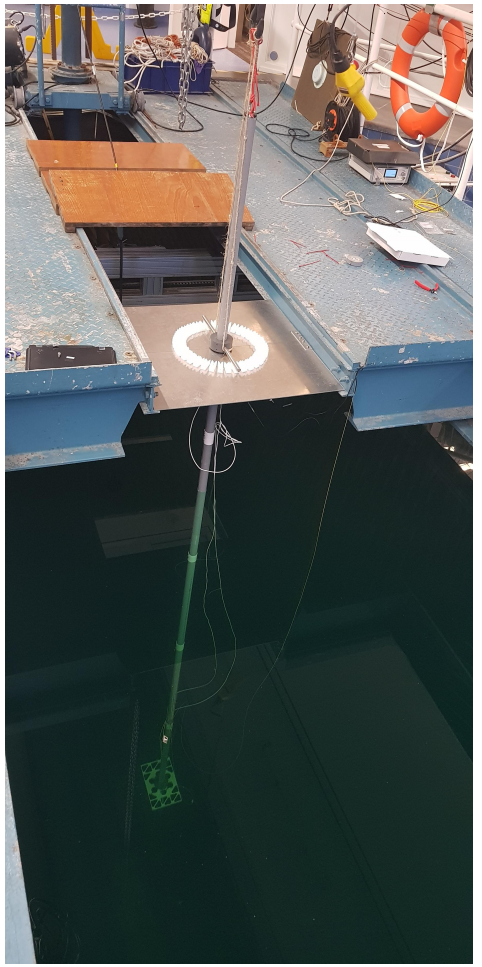
Two types:
- single membrane
- double membrane

Orifice: 300 micron EDM drilling
Membrane: laser welding

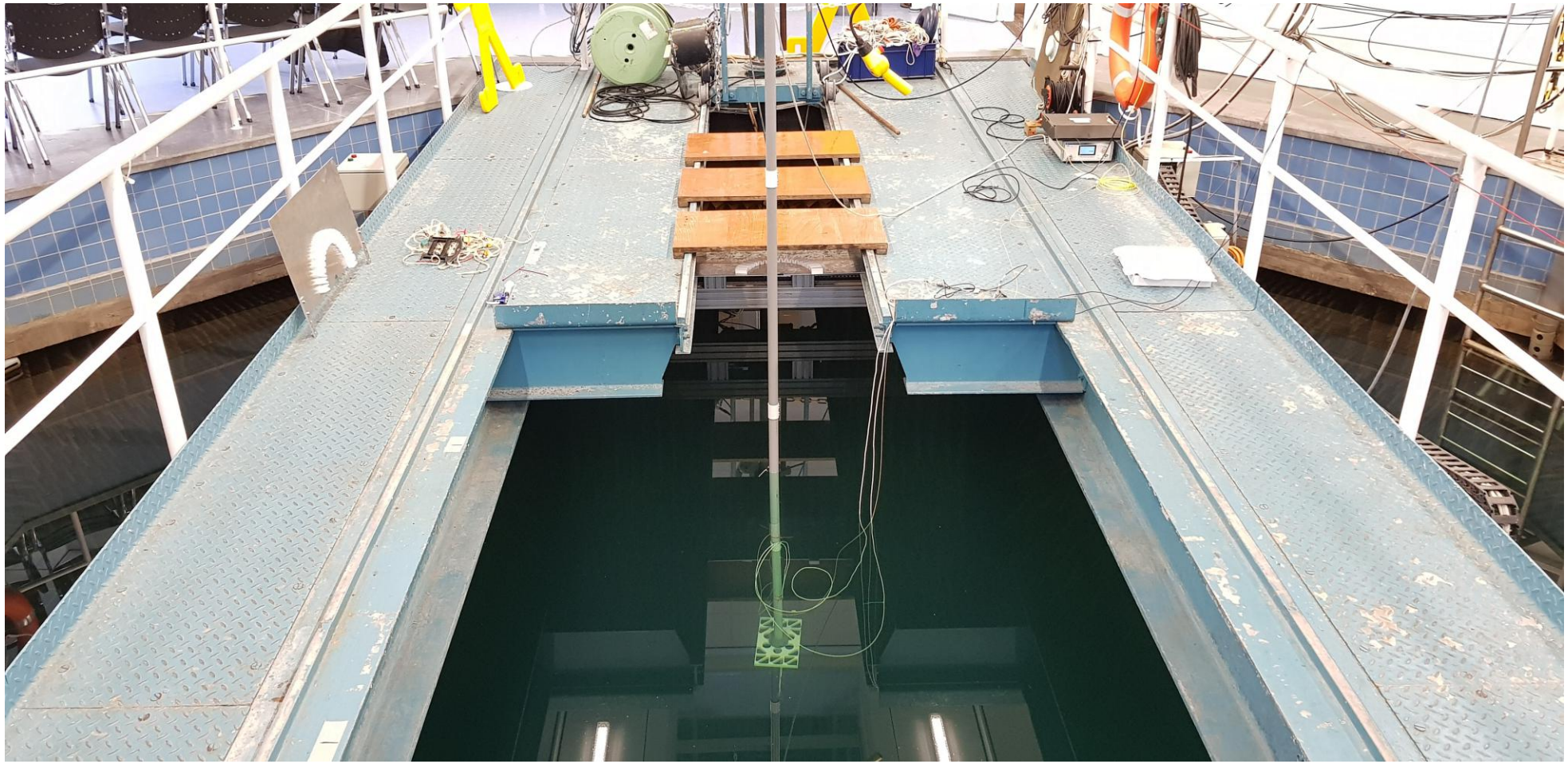
Experimental setup in an anechoic basin

Experimental setup in an anechoic basin

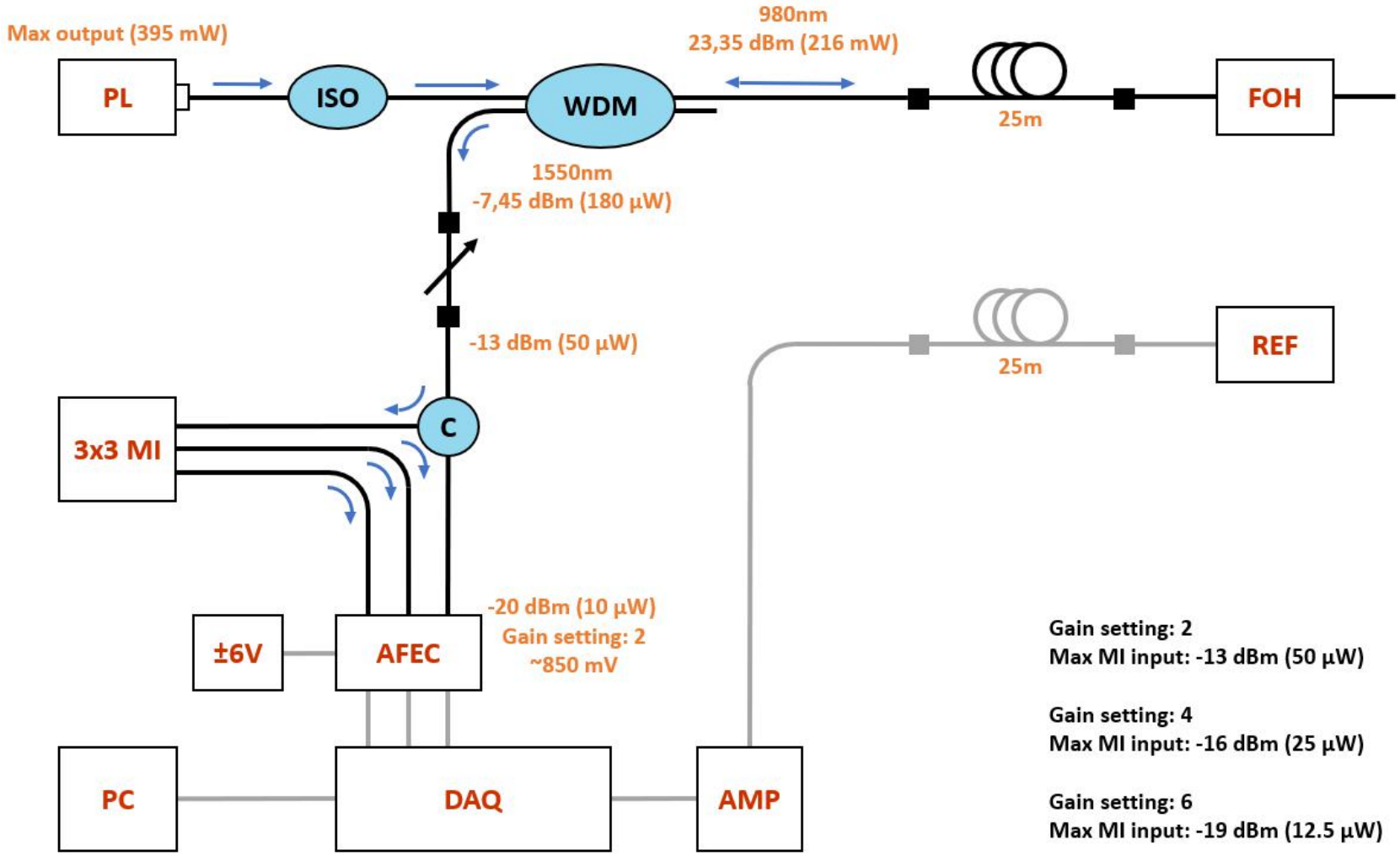




Experimental setup in an anechoic basin



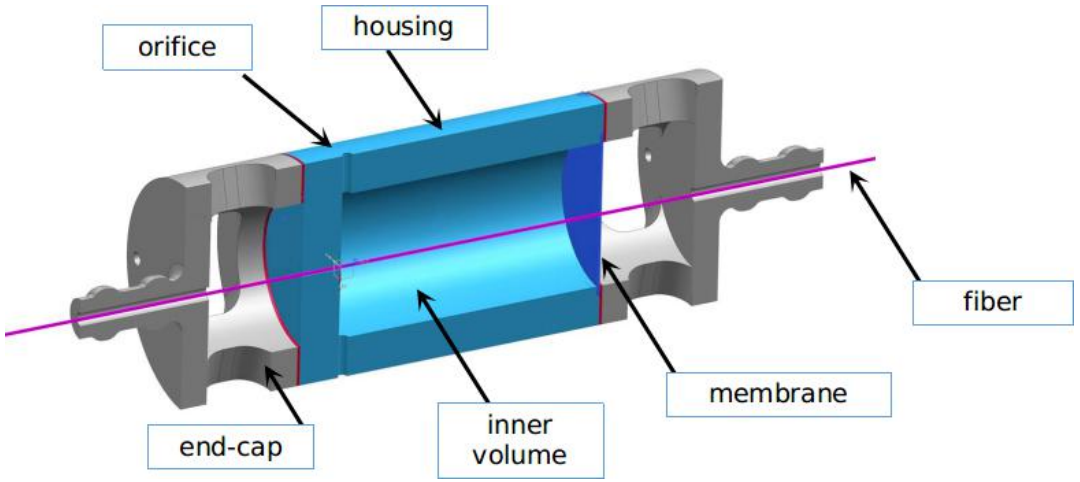
Data acquisition

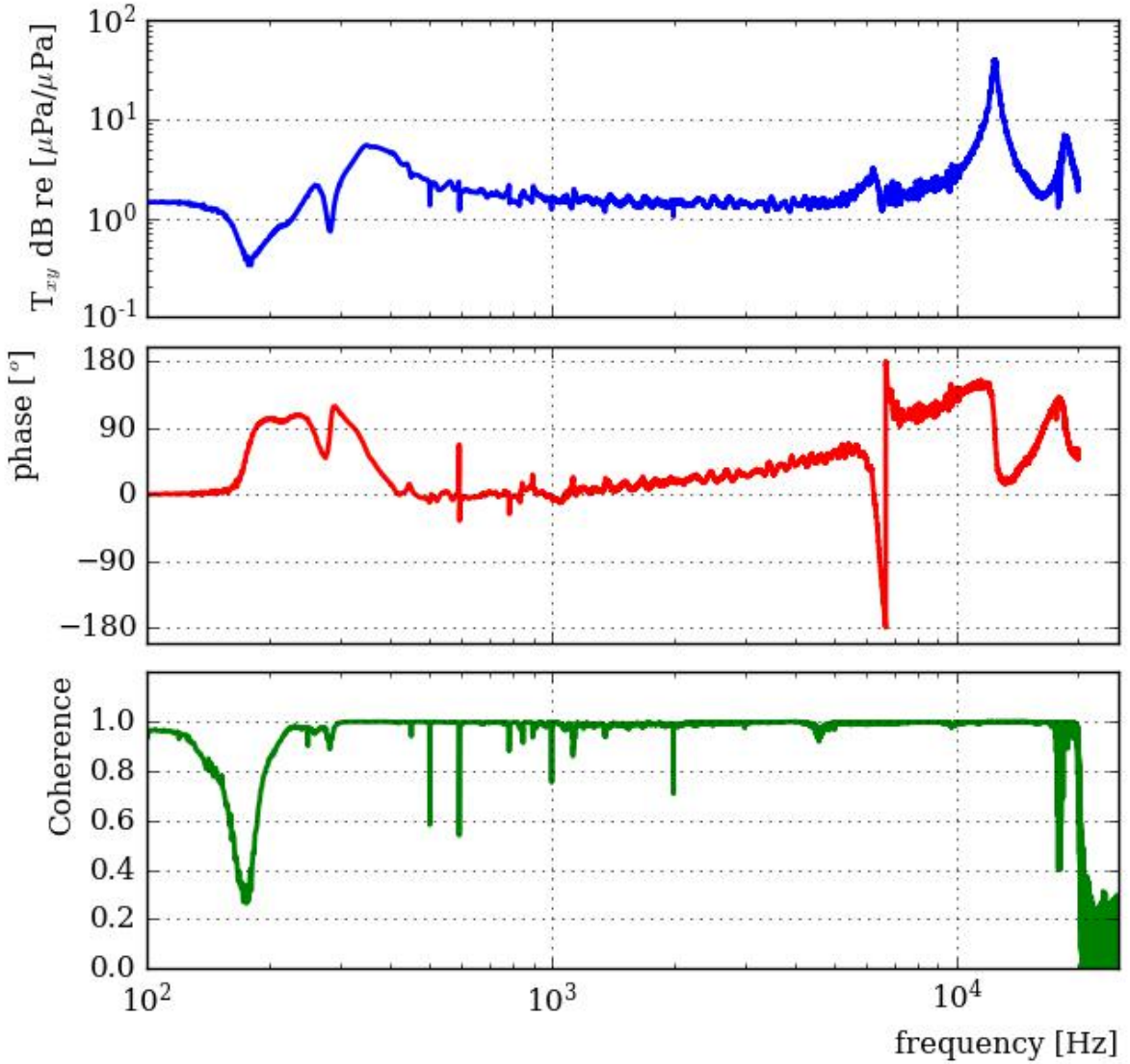


Bode plot

- Mechanical resonance peak ~15 kHz
- Helmholtz resonance peak at 600 Hz

- Two types:
  - single membrane
  - double membrane

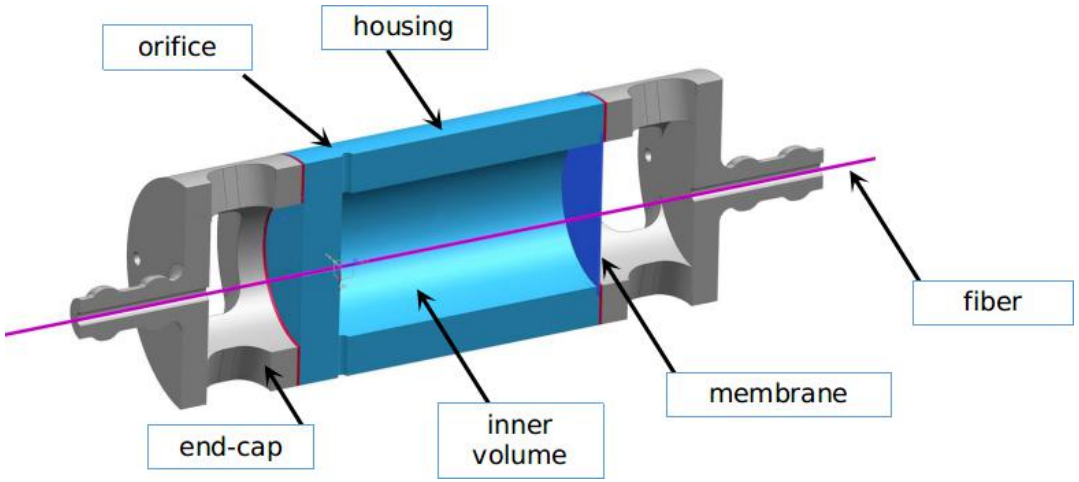


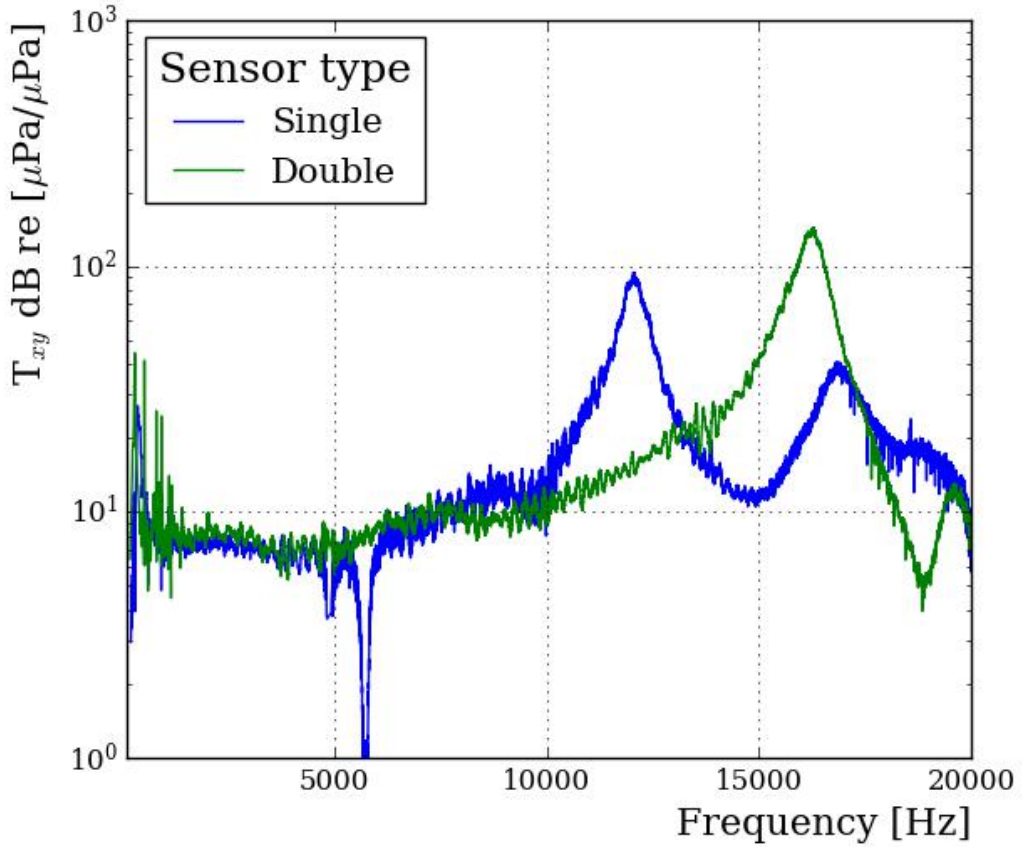


Transfer function

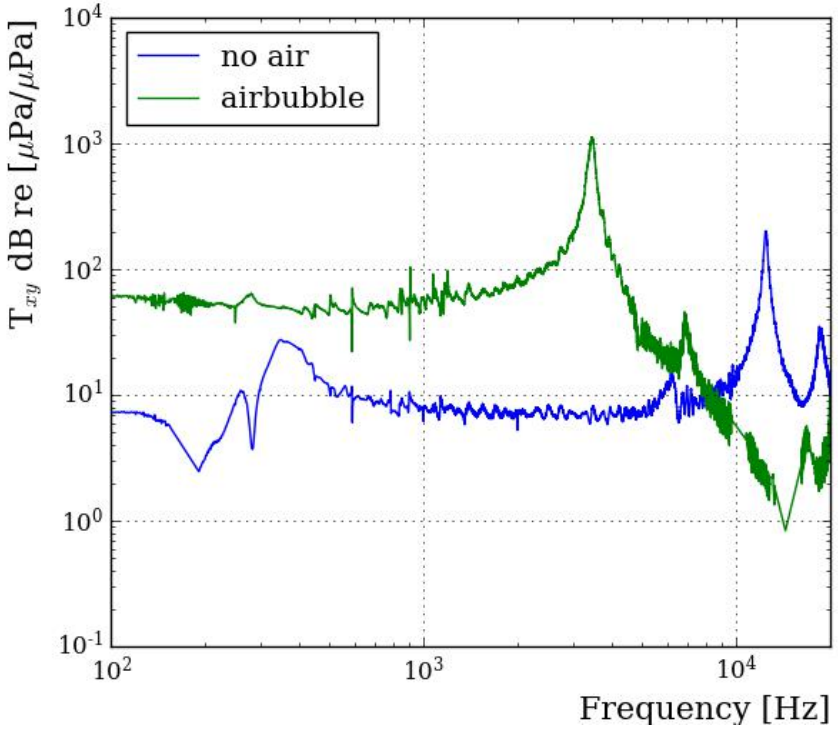
- Mechanical resonance peak ~15 kHz
- Helmholtz resonance peak at 600 Hz

- Two types:
  - single membrane
  - double membrane

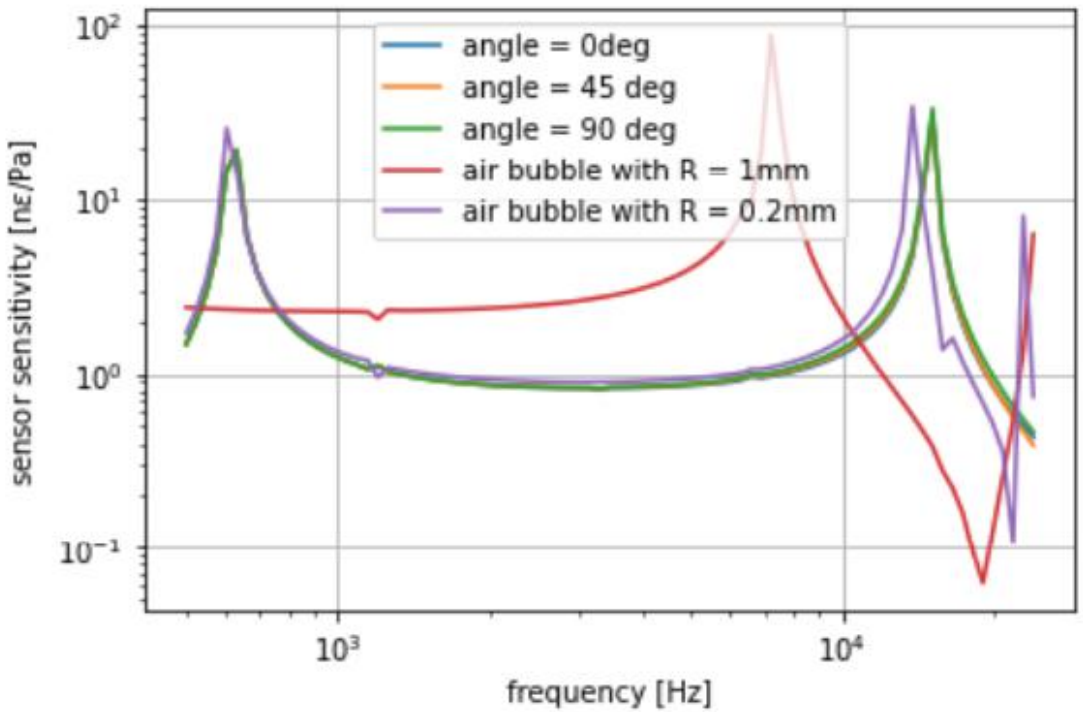




Transfer function: residual air



Comsol simulations

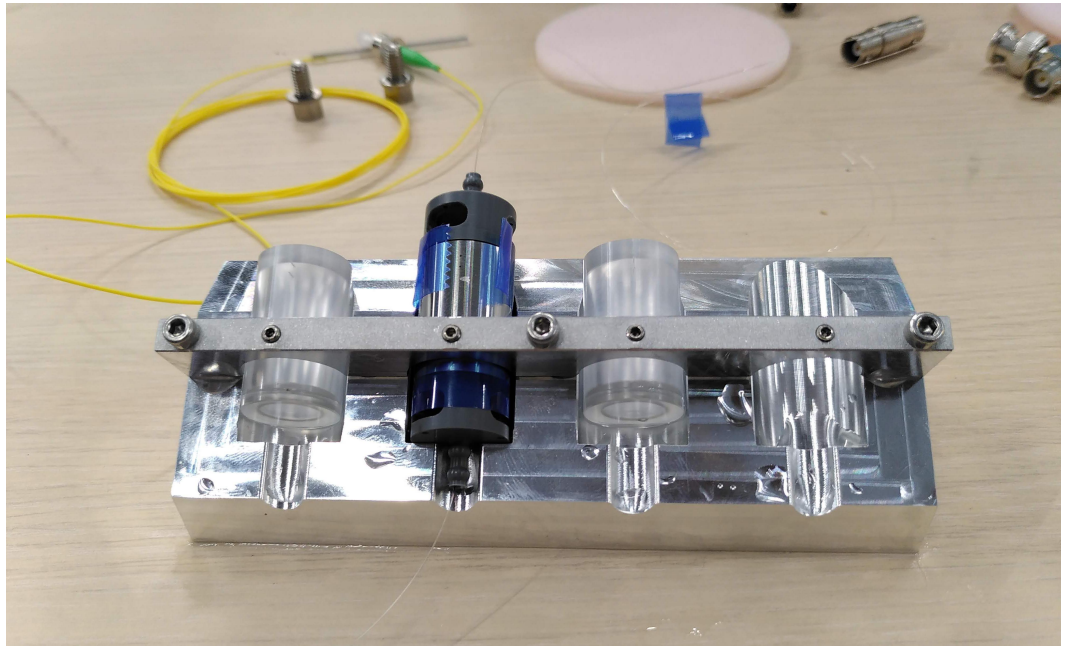


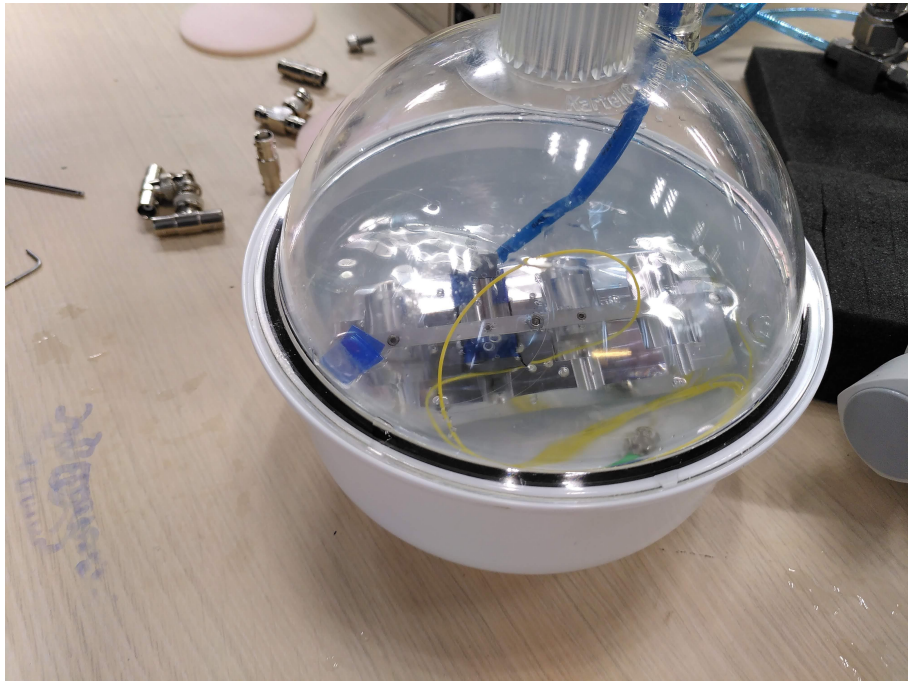
- Residual air in the transducer has a large impact on the transfer function!
  (an air bubble of 1mm diameter has only 0.5% volume percentage)

- Established a procedure to fill the sensor

Transfer function: residual air

Include dummy sensors in the process

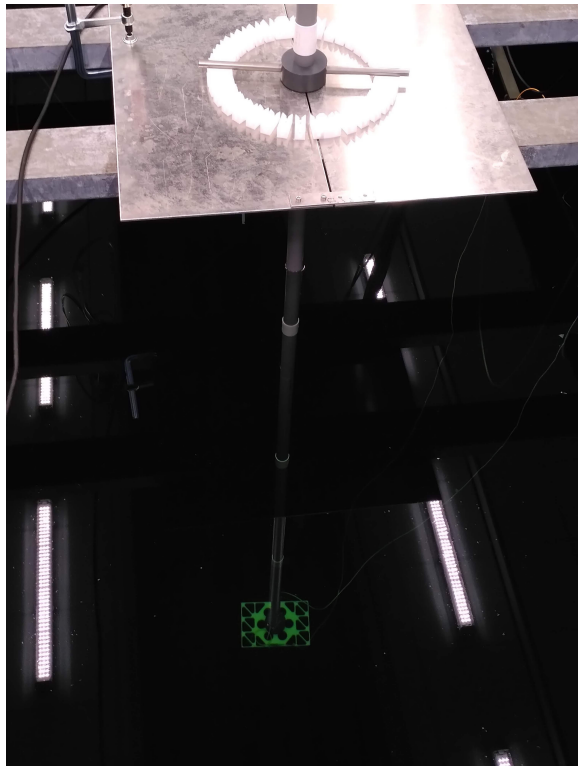


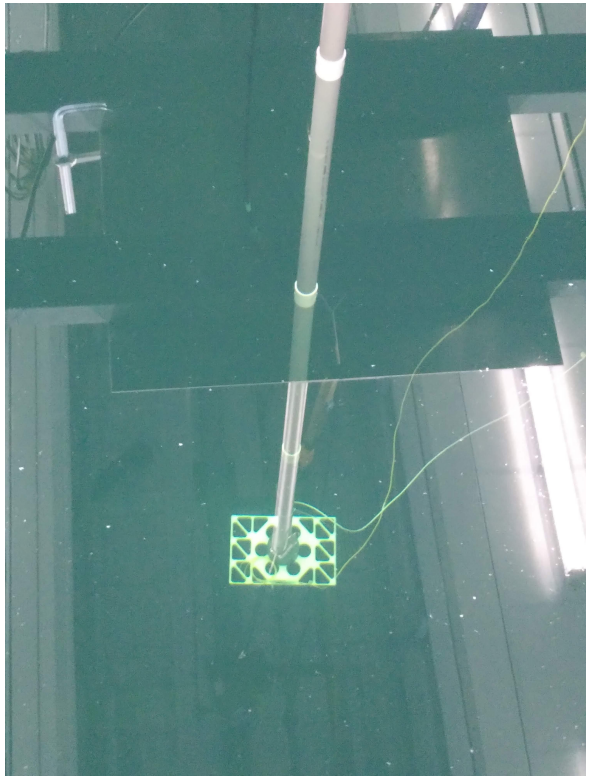


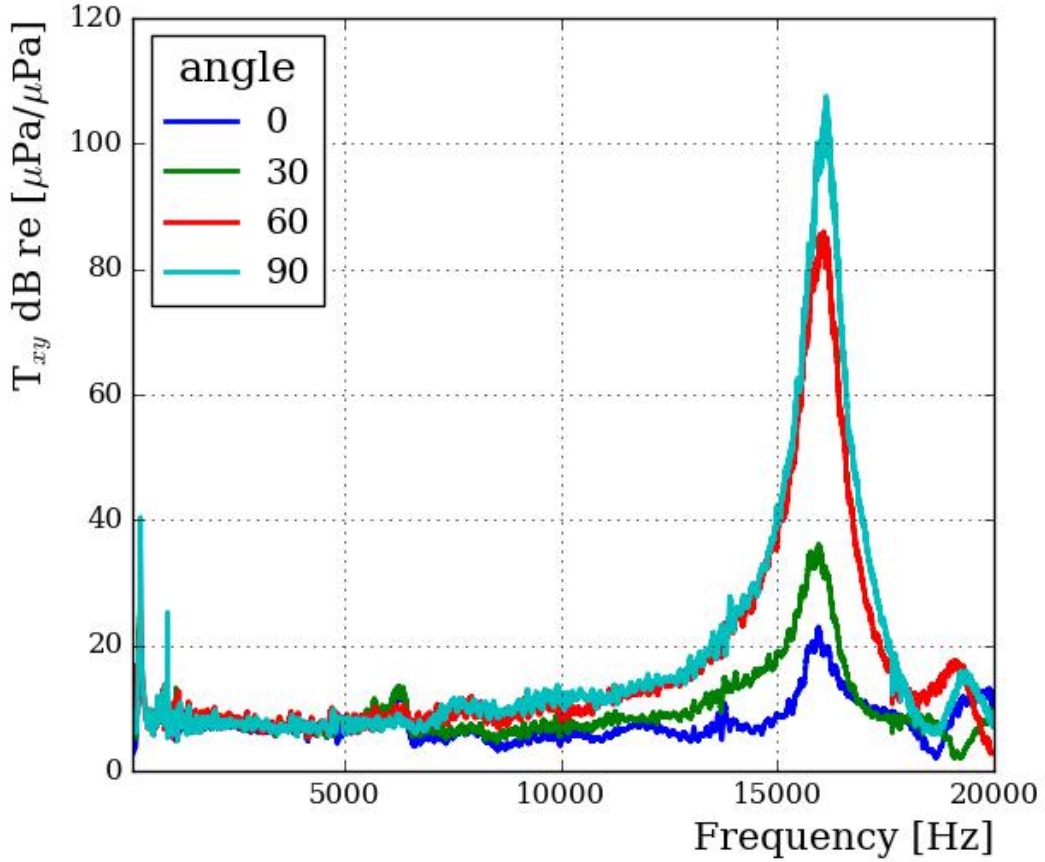
- Residual air in the transducer has a large impact on the transfer function!
  (an air bubble of 1mm diameter has only 0.5% volume percentage)

- Established a procedure to fill the sensor

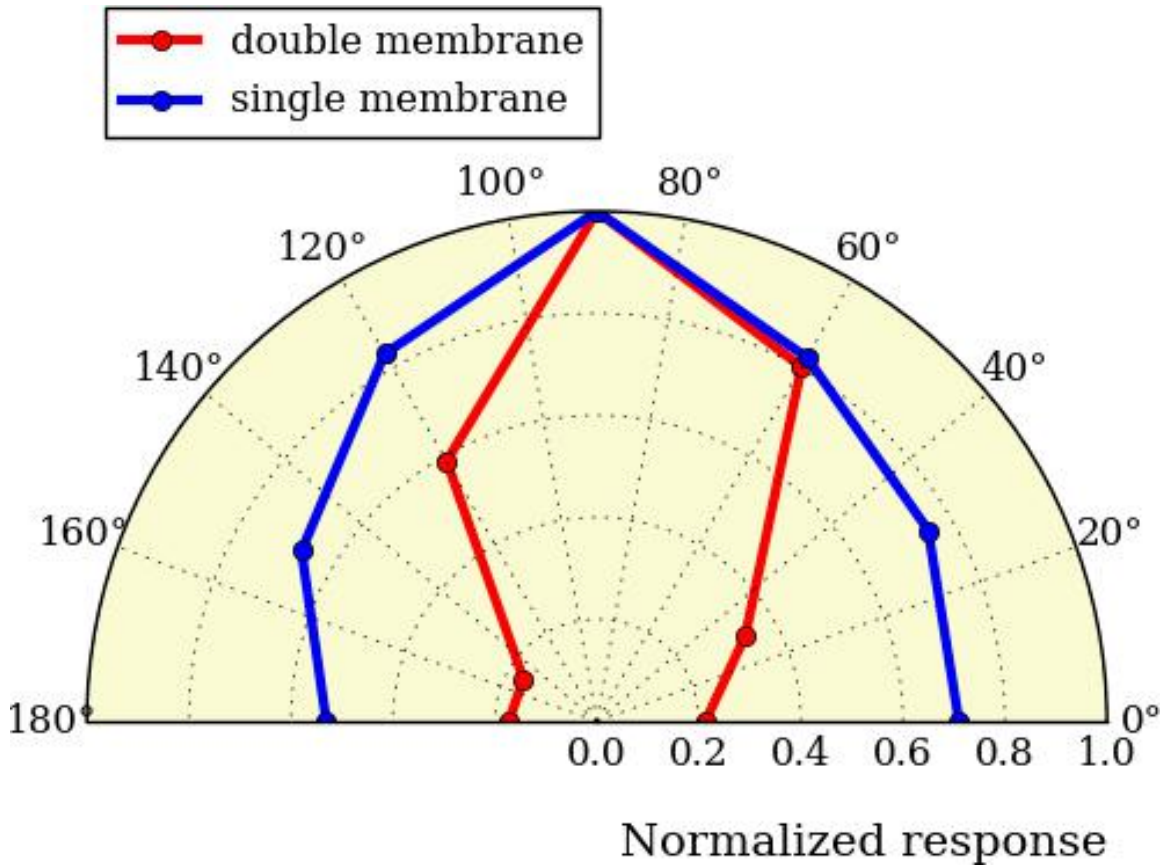
Directionality

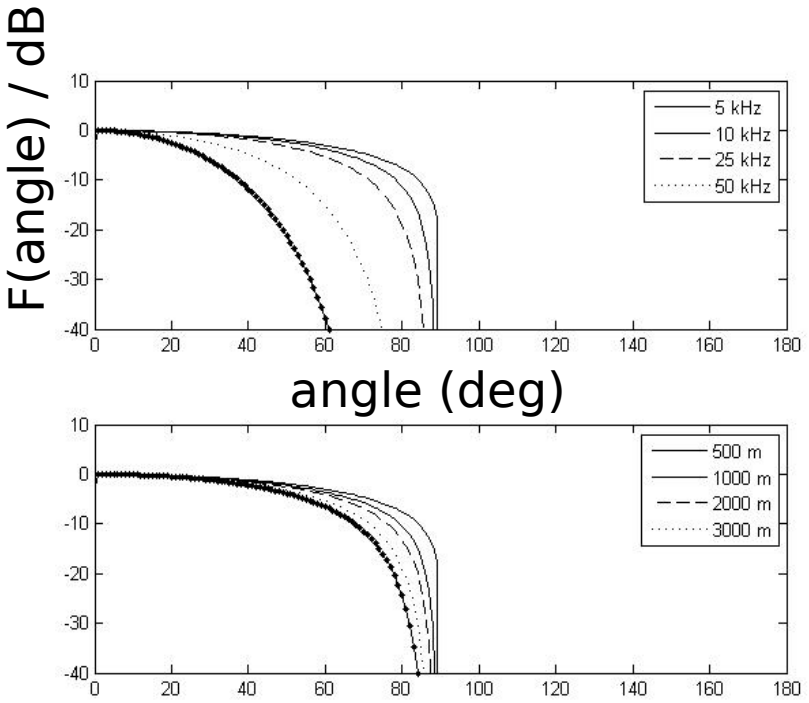






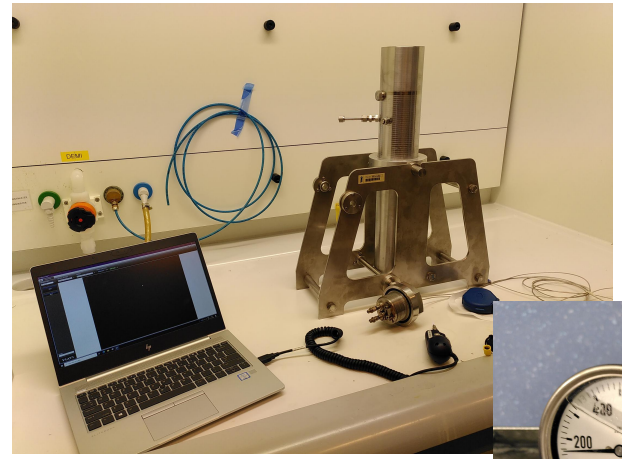
Directionality

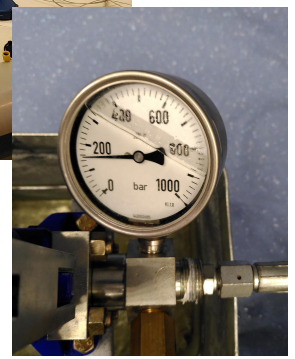




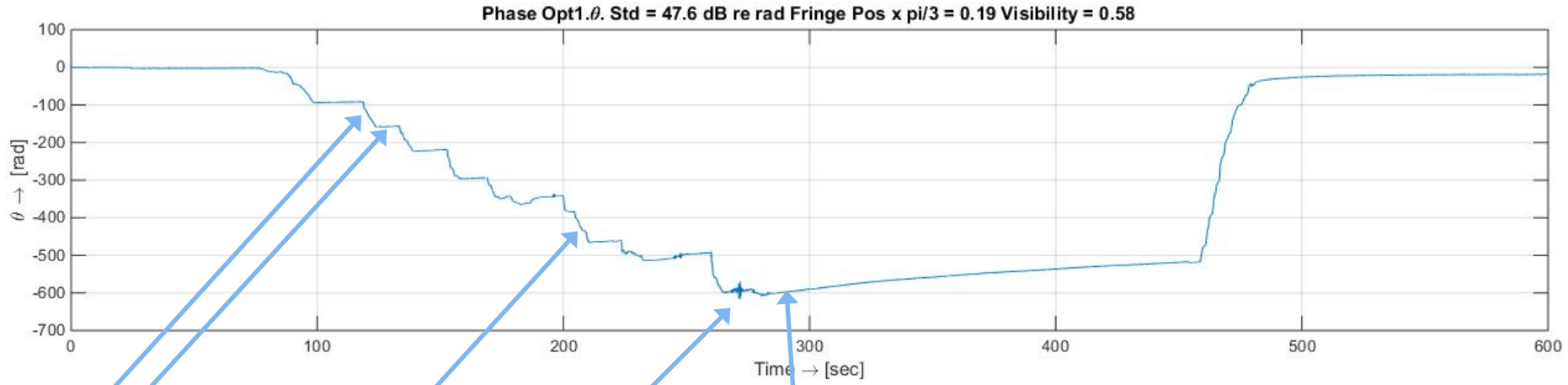
Theoretical deep-sea
vertical angle distribution

Pressure qualification





Apply pressure in steps of about 20 bars



U96

Bottlenose dolphin

Beluga

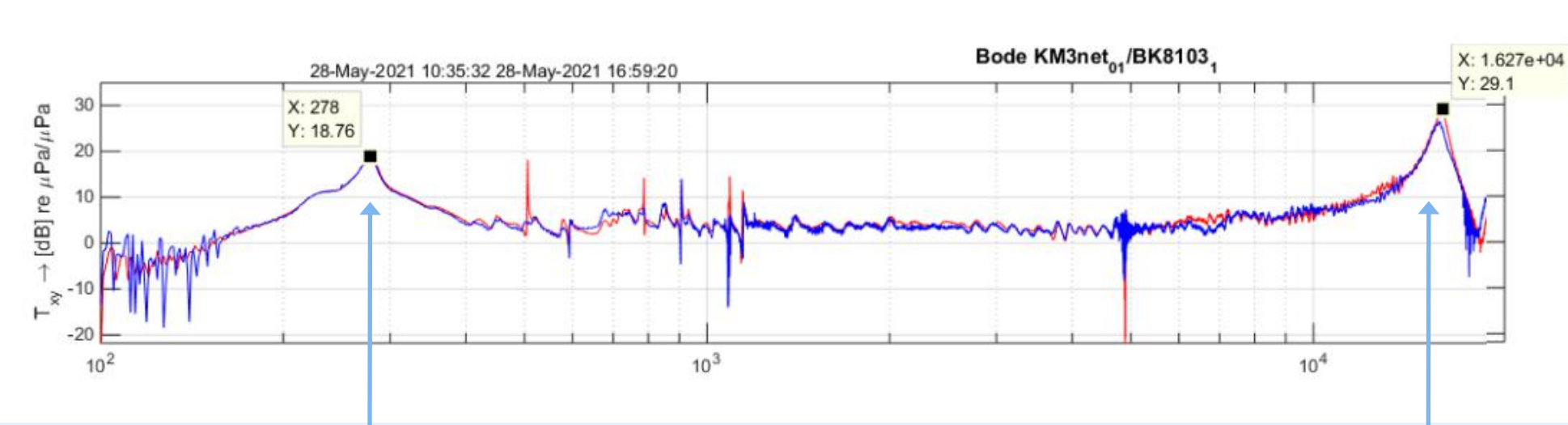
Sperm whale

1.6 km

Pressure qualification

Transfer function

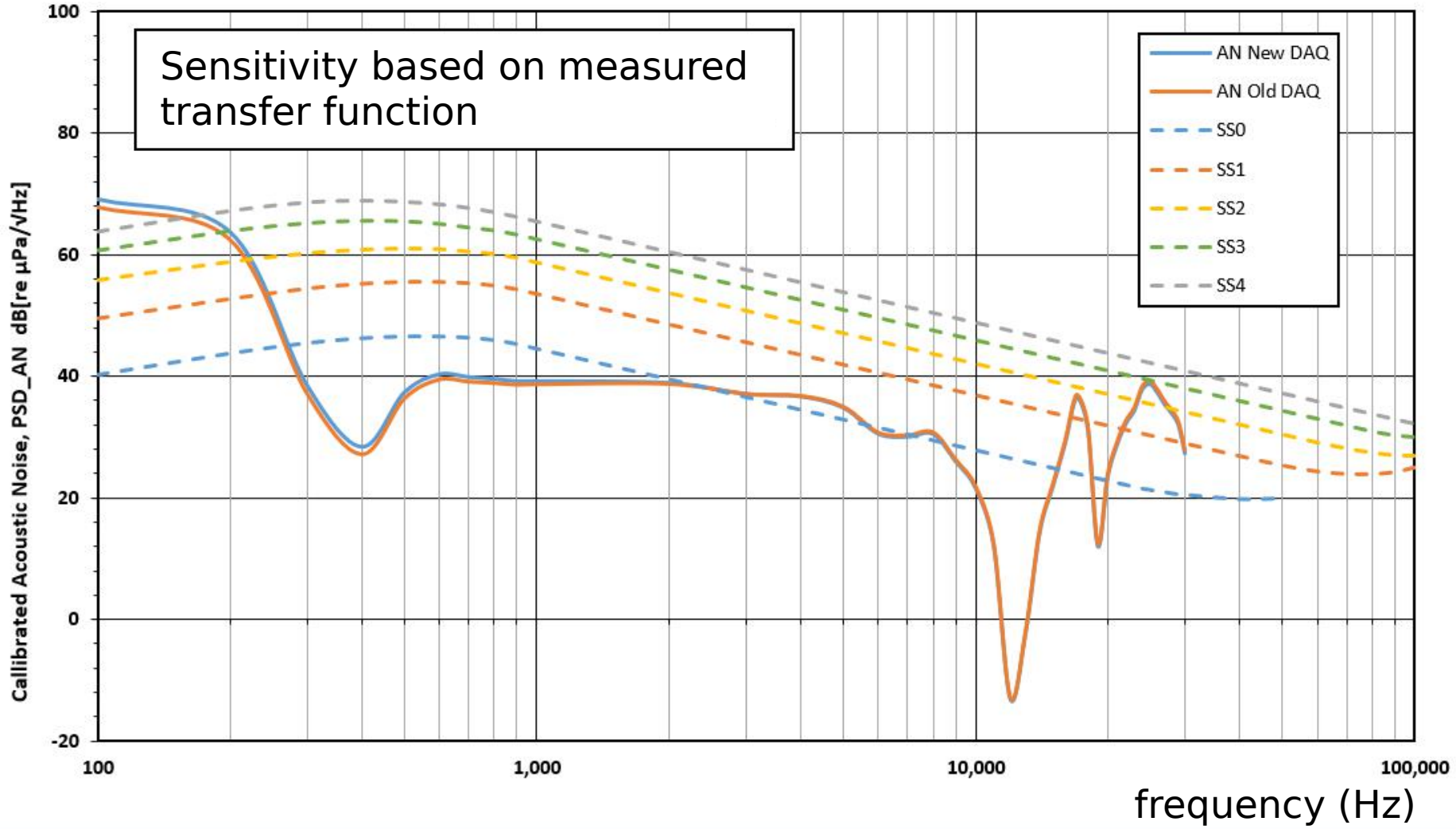
Red/blue: before and after applying 160 bar pressure



Helmholtz resonance

Mechanical eigenfrequency

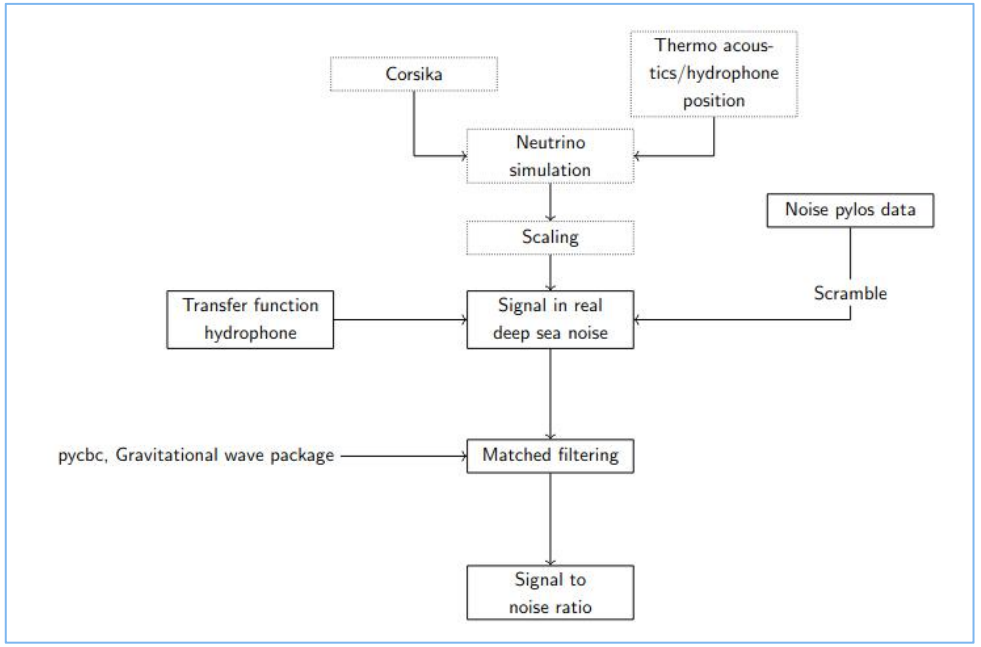
Hydrophone sensitivity

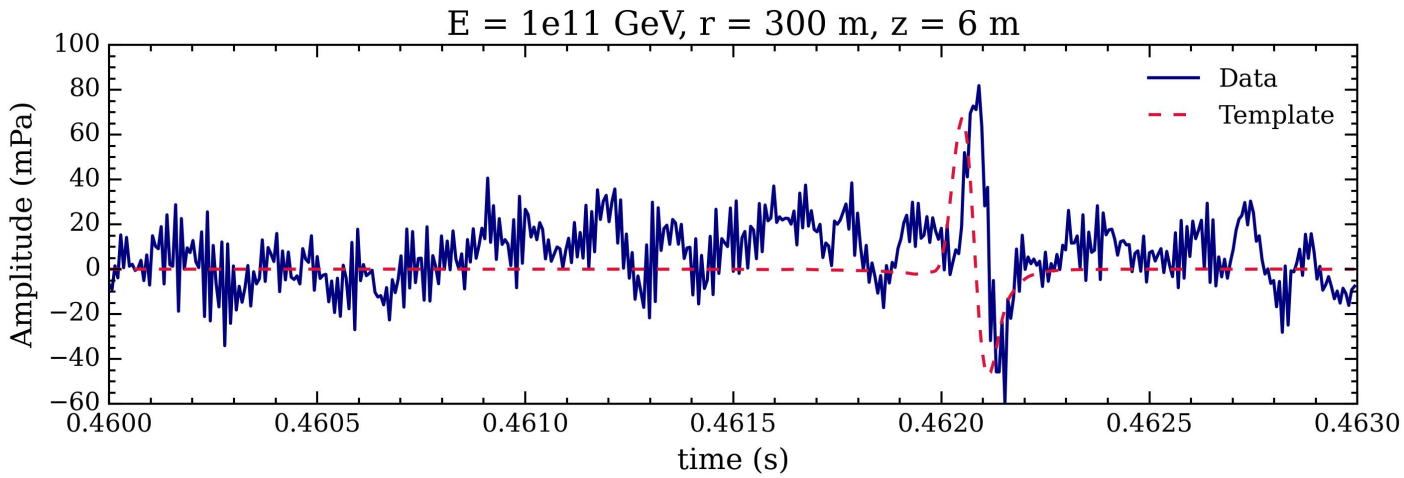


Simulation updates

work in progress by
Cecile van der Stappen

- Simulations of signals in a realistic noise environment and mixed with dolphin clicks (Greek data) shall determine the sensitivity to transients.
- Based on simulations by Clara Gatius (next talk).





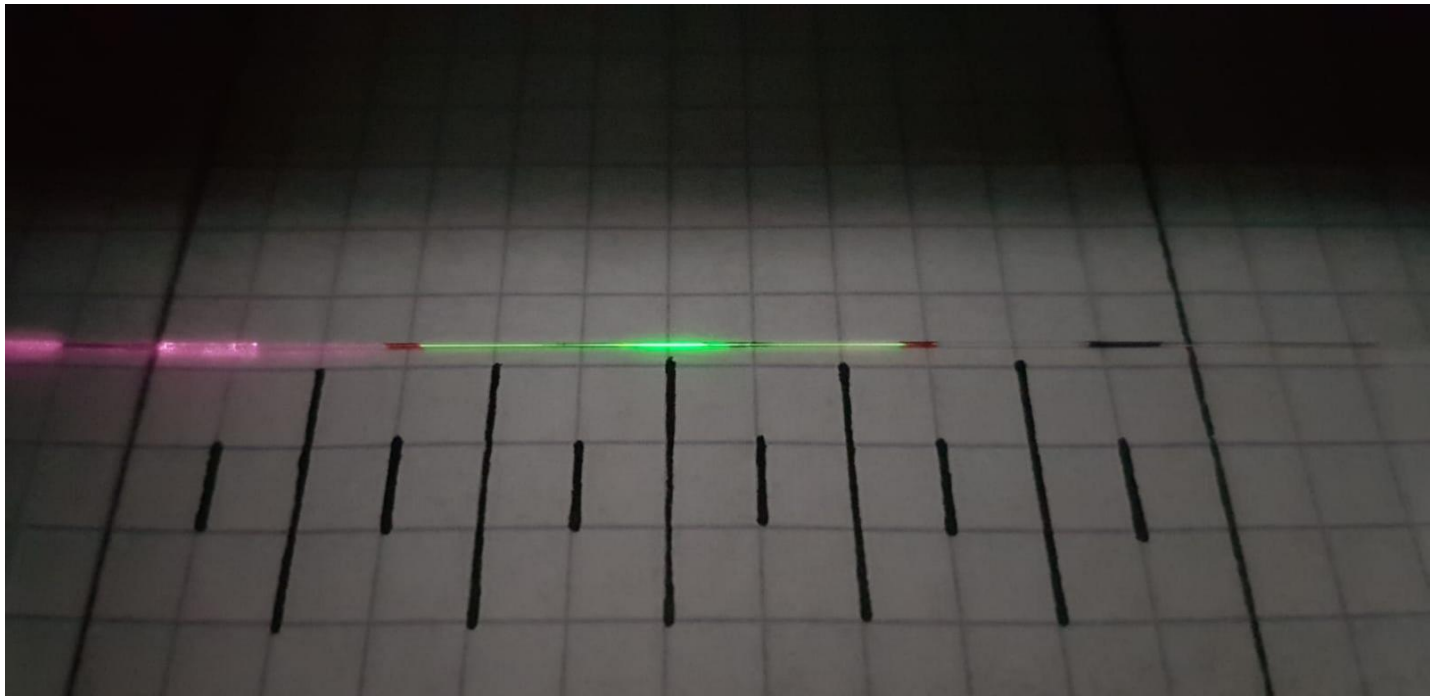
Conclusions

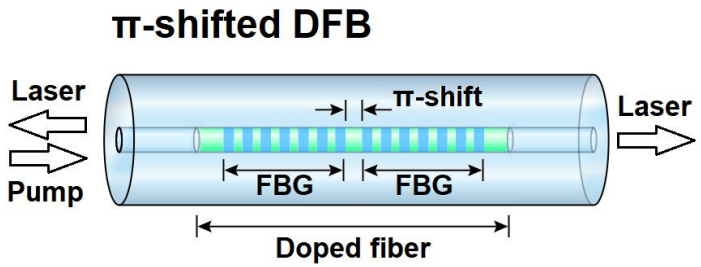
- Sensor has been design and extensively tested.
  - (All effects that impact on) transfer functions are understood
- Survives the challenging environment of the deep sea
  - Ways to further improve sensitivity has been identified
- Simulation framework has been set up to properly determine the sensitivity to transients.
  - Include cross correlation from many hydrophones
  - Directionality of sea state noise
- Ready to build a first prototype string for deployment.

Fiber laser updates: small laser cavities

- Transducer converts pressure in to strain in the optical fiber
- Short fiber laser increases sensitivity:
  - Fiber laser length improved from 30 mm -> 22mm -> 14 mm

iXblue





Fiber laser updates: Stress tests

work done by Thijs van Eeden

- Degradation qualification measurements
- Monitor fiber laser output with 500 mW pump laser power.
- No degradation after 2500 hours and 20 times required pump power.