ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

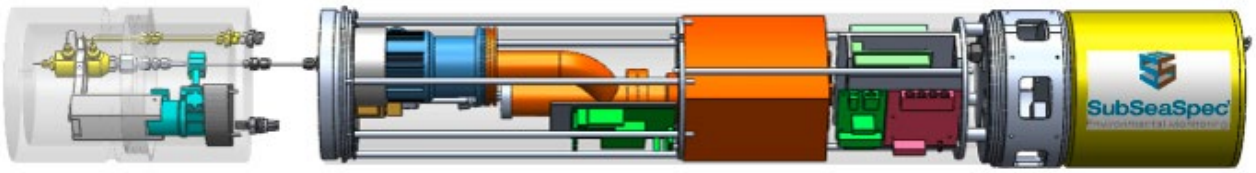
An optimized membrane inlet system (MIS) for underwater sensors

-

From idea to product

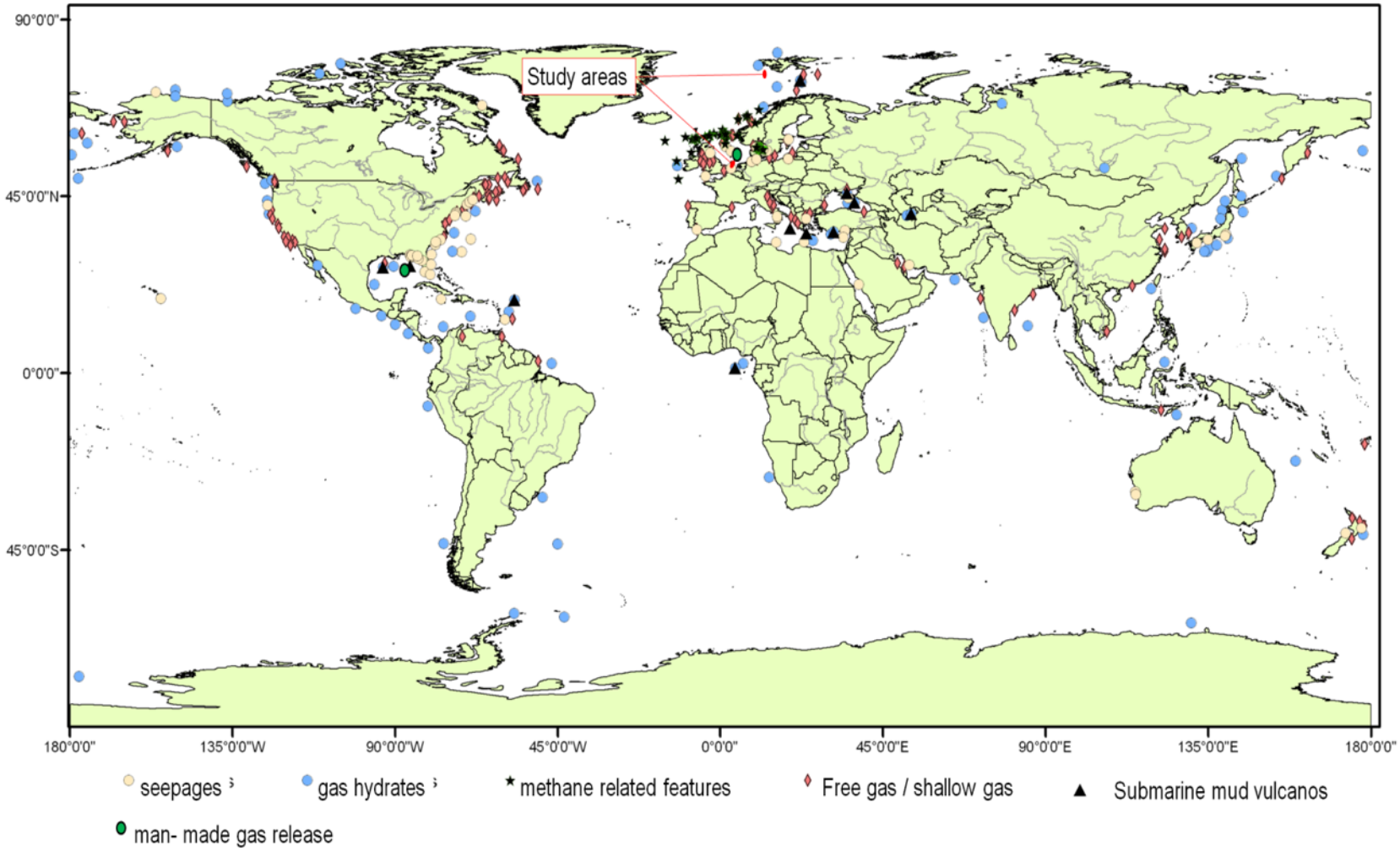
Torben Gentz, Malte Hoehn

Alfred-Wegener-Institute for Polar and Marine Research, Bremerhaven, Germany



SubSeaSpec®
Environmental Monitoring

GLOBAL RELEVANCE OF METHANE IN AQUATIC SYSTEMS



Worldwide distribution of submarine mud volcanos (Milkov 2000), gas hydrates (Kvenvolden et al. 2001), free gas occurrence (Fleischer et al. 2001), and pockmarks (Hovland et al. 2002).

HELMHOLTZ

METHAN SEEPS

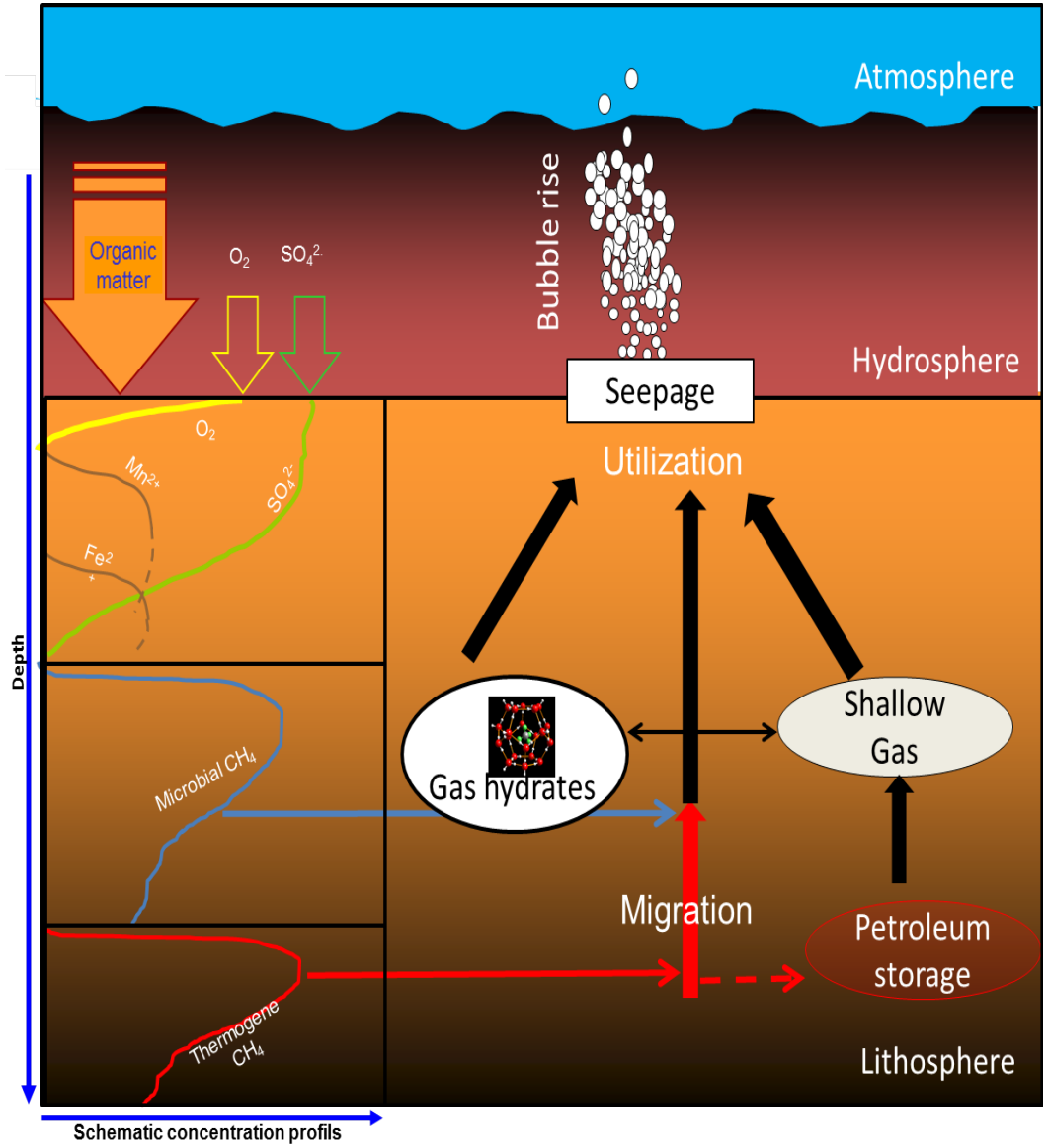
Baltic Sea, leak in pipeline, Sep 2022

https://www.tagesanzeiger.ch/

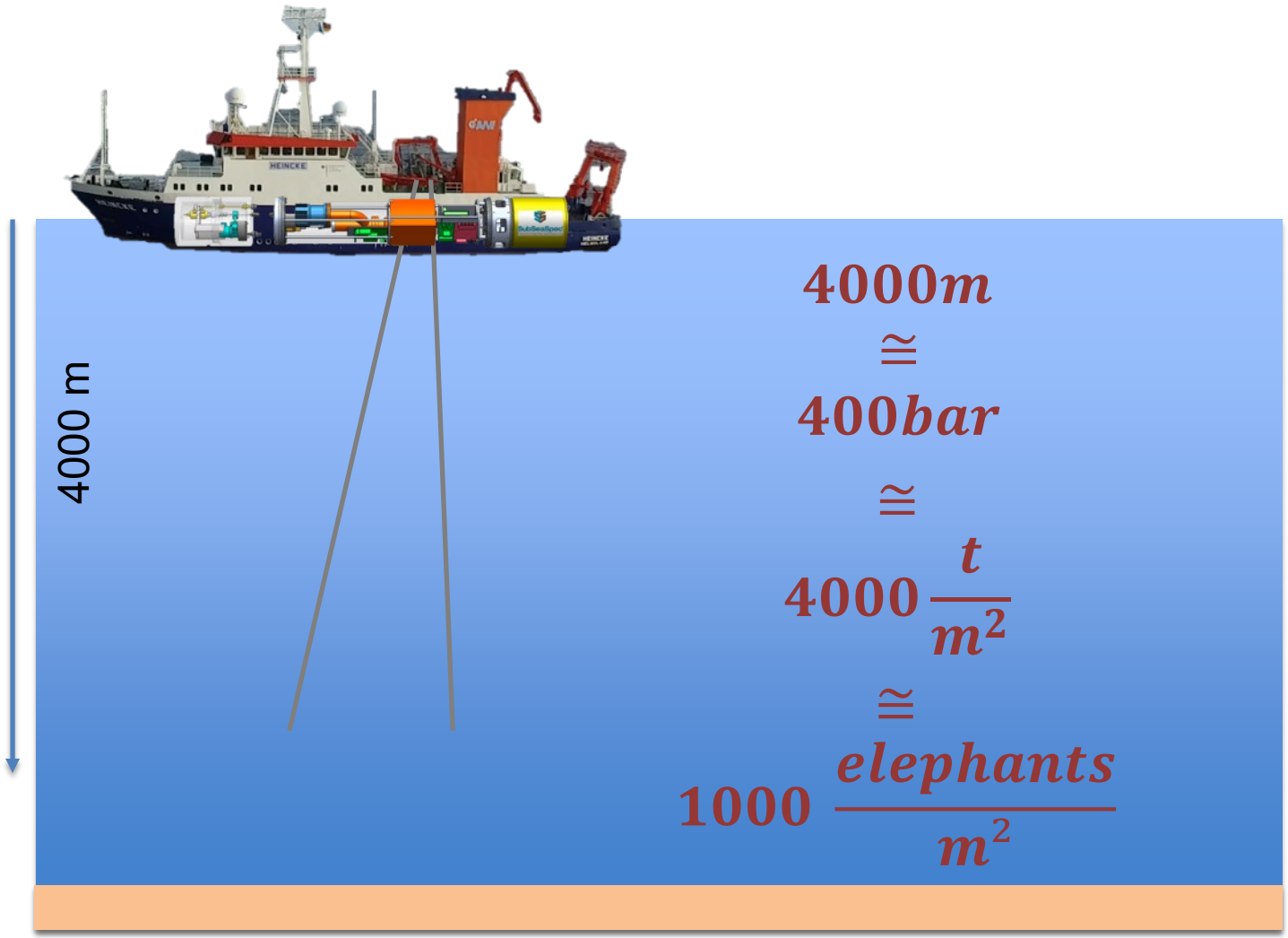
METHAN SEEPS

Picture by Torben Gentz

FORMATION OF METHANE



INSITU SENSORS

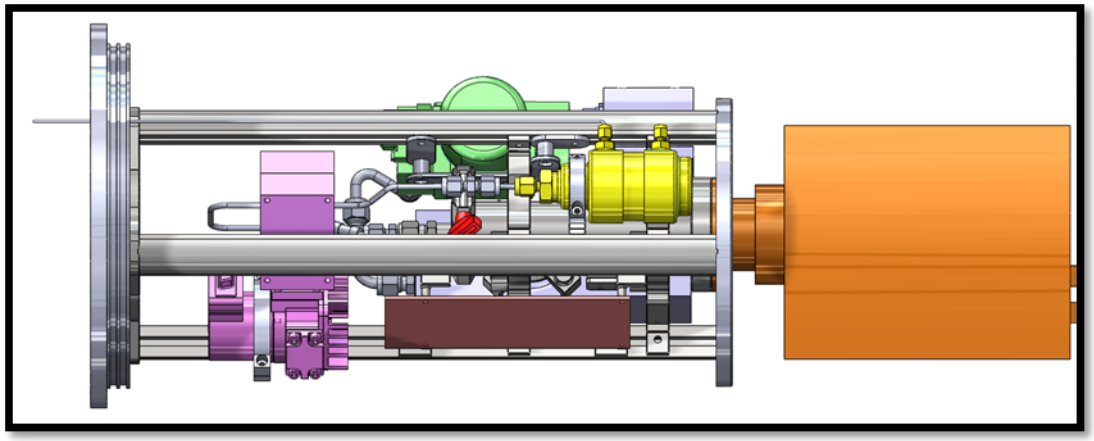


INSITU SENSORS

Franatech:
METS Methane
Sensor

Los Gatos Research:
Ultraportable Greenhouse Gas
Analyzer

-4H- JENA engineering
GmbH: CONTROS
HydroC CH_4

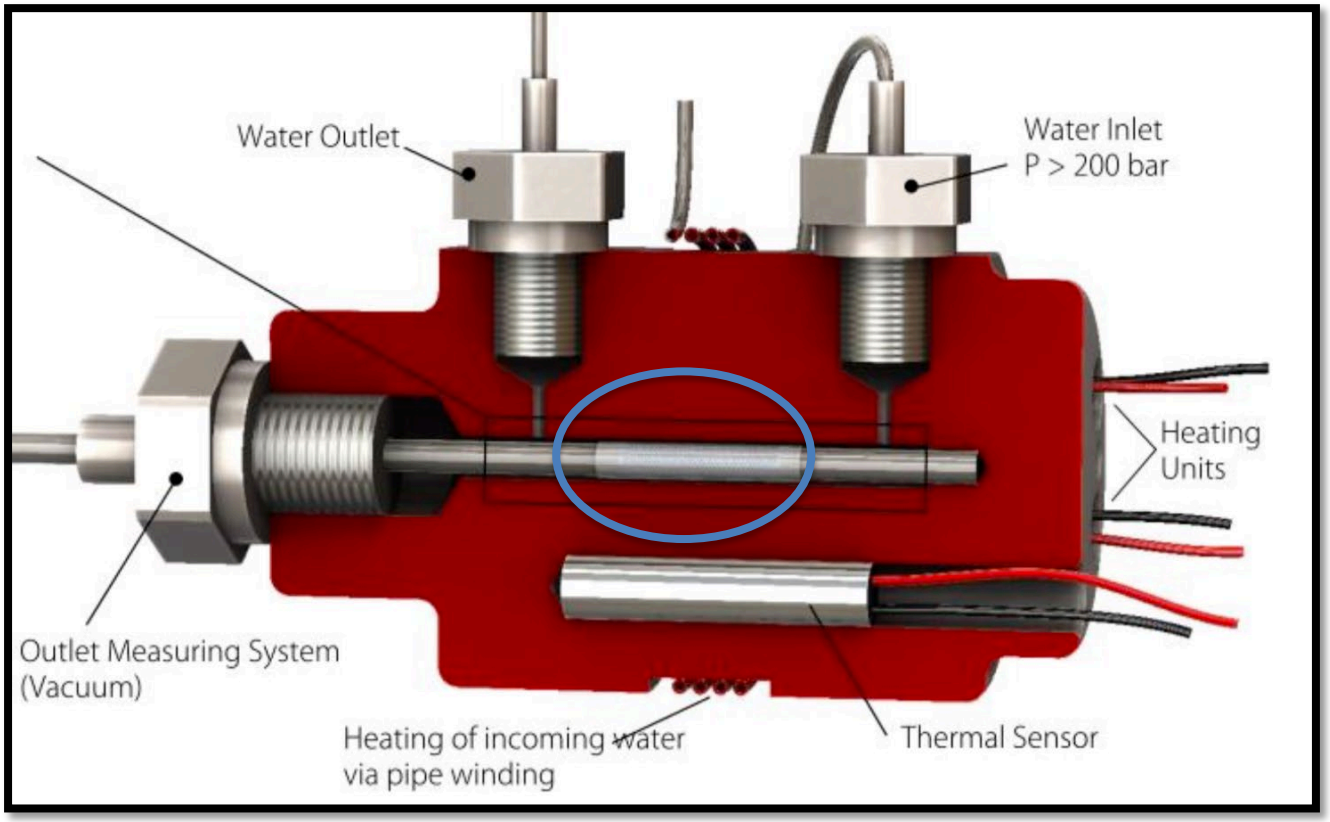


SubSeaSpec: UWMS3000

Pro Ozeanus:
Mini CH_4

https://www.franatech.com/img/products/pdf/franatech_METSsensor_productsheet.pdf
https://pro-oceanus.com/images/pdf/PSIInstrumentSheets2021MiniCH4.pdf
https://www.picarro.com/support/library/documents/gasscoutertm_g4301_analyzer_datasheet#
https://www.4h-jena.de/wp-content/uploads/2020/03/hydroc-ch4-accurate-long-term-stable-methane-sensor.pdf

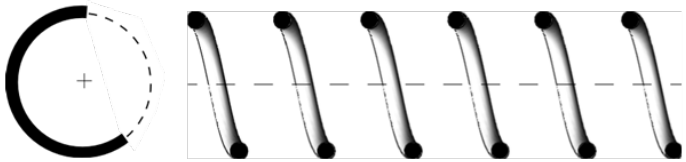
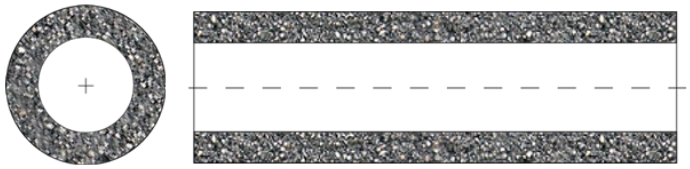
MEMBRANE INLET SYSTEM (MIS)

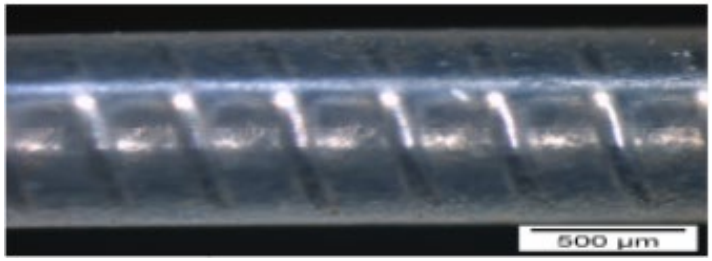


- PDMS membrane
- Supporting structure

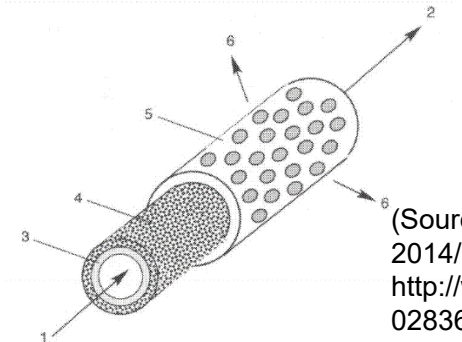
SUPPORTING MATERIAL

Advantages / disadvantages

Supporting structure		Pressure	Permeability	Reproducibility	Heating
Steel spring		↯	✓	✓	↯
Sintered		✓	↯	↯	✓



(Source: Gentz and Schlueter)



(Source: Mcmurtry Patentnumber: US 2014/0283626 A1; http://www.freepatentsonline.com/20140283626.pdf)

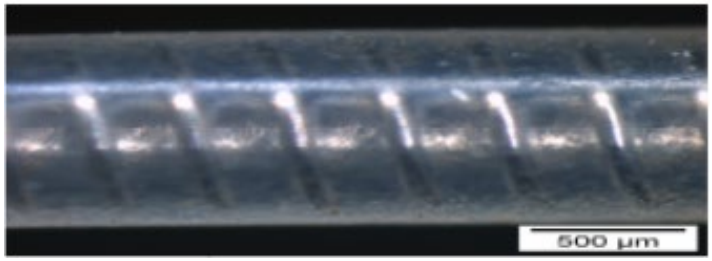
HELMHOLTZ

SUPPORTING MATERIAL

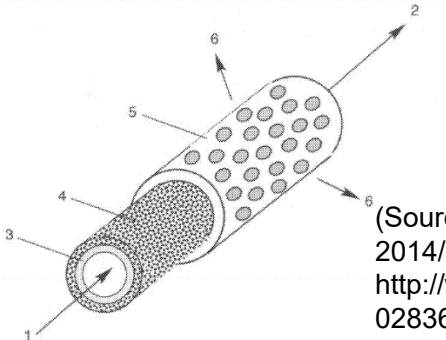
Advantages / disadvantages

Combine the best properties?

Supporting structure	Pressure	Permeability	Reproducibility	Heating
Steel spring	↯	✓	✓	↯
Sintered	✓	↯	↯	✓

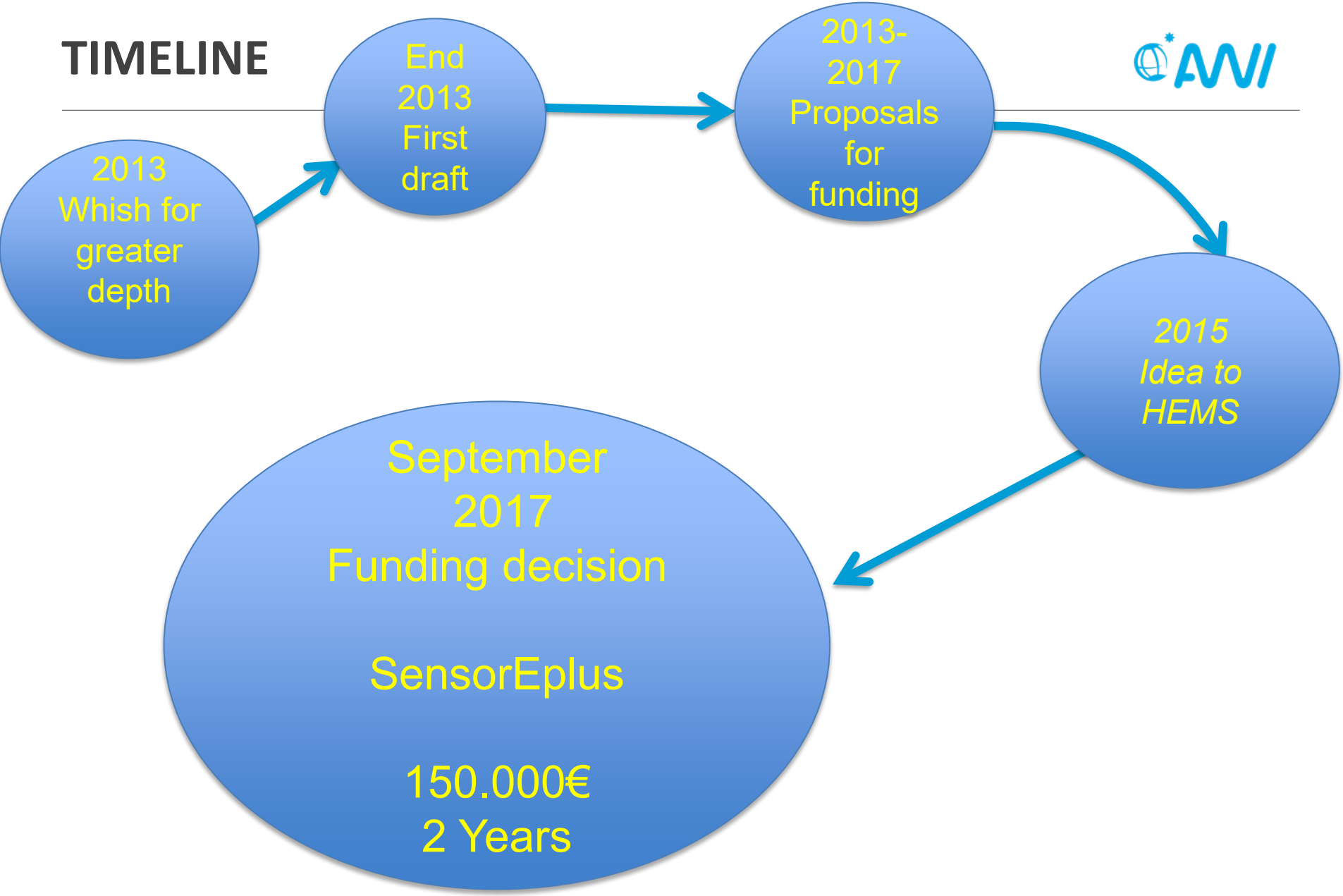


(Source: Gentz and Schlueter)



(Source: Mcmurtry Patentnumber: US 2014/0283626 A1; http://www.freepatentsonline.com/20140283626.pdf)

TIMELINE

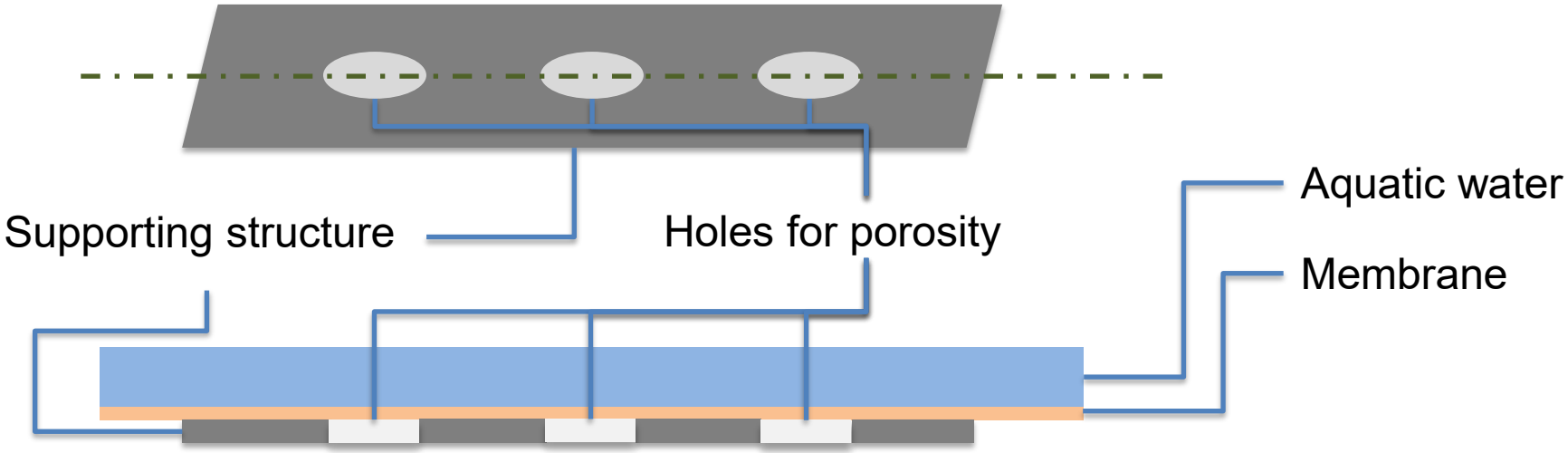

2013
Whish for
greater
depth
End
2013
First
draft
2013-
2017
Proposals
for
funding
2015
Idea to
HEMS
September
2017
Funding decision
SensorEplus
150.000€
2 Years

INVOLVED AND INTERESTED PARTIES

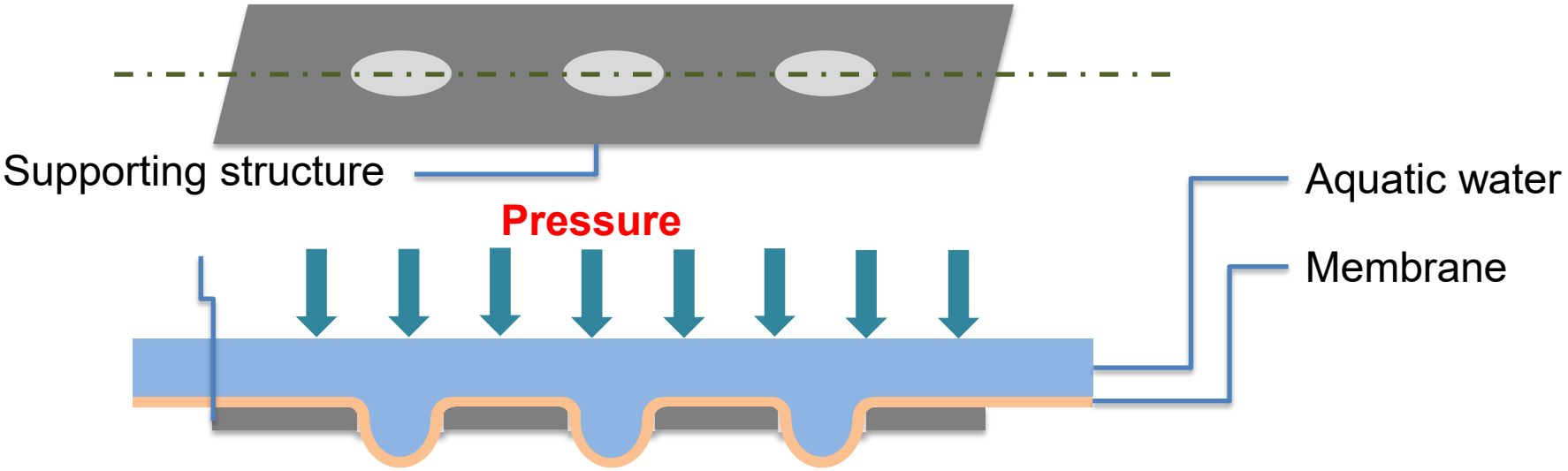
Involved

Interested

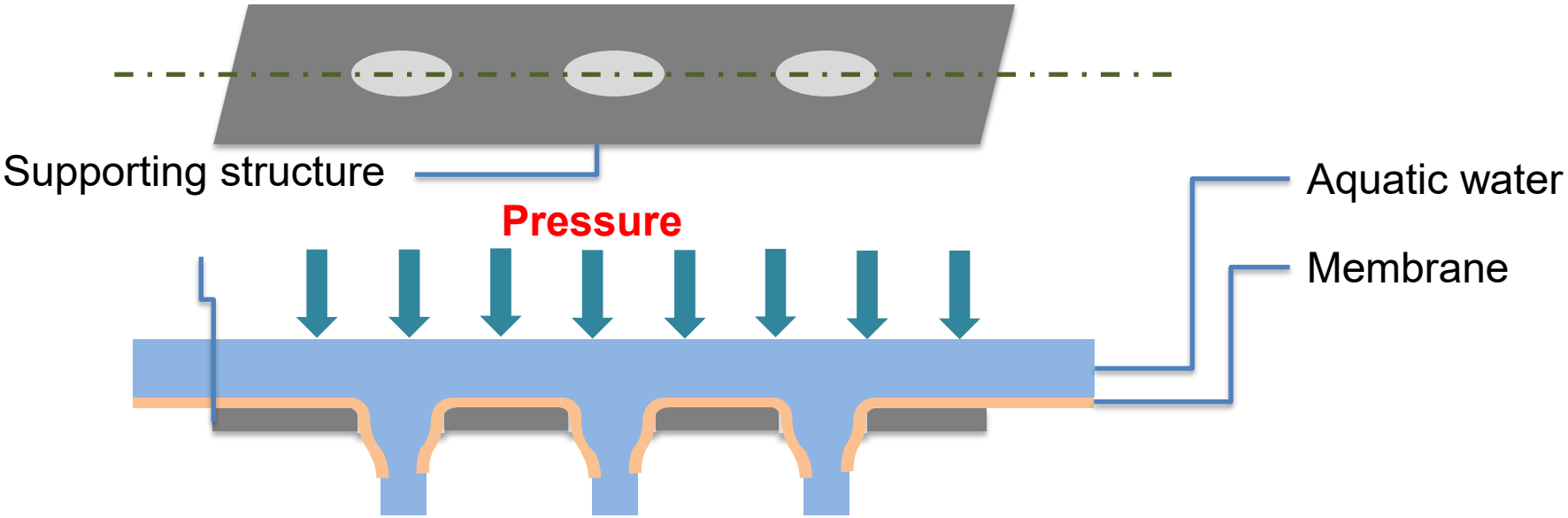
THE STRUCTURE



THE STRUCTURE

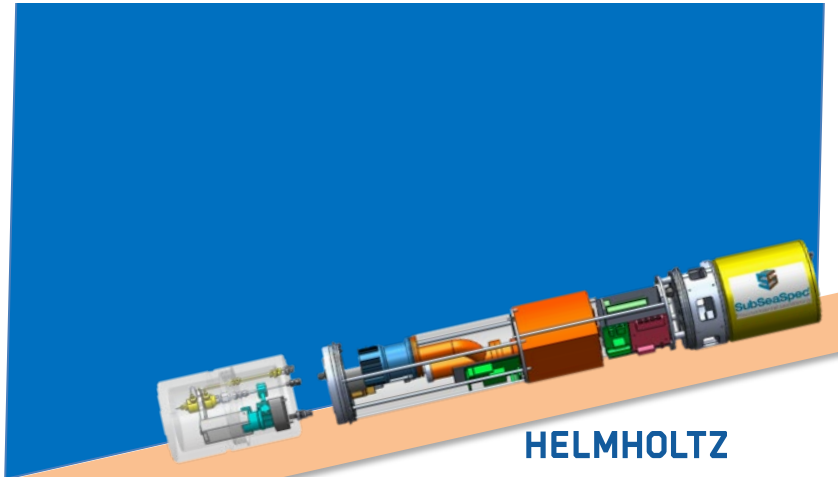


THE STRUCTURE

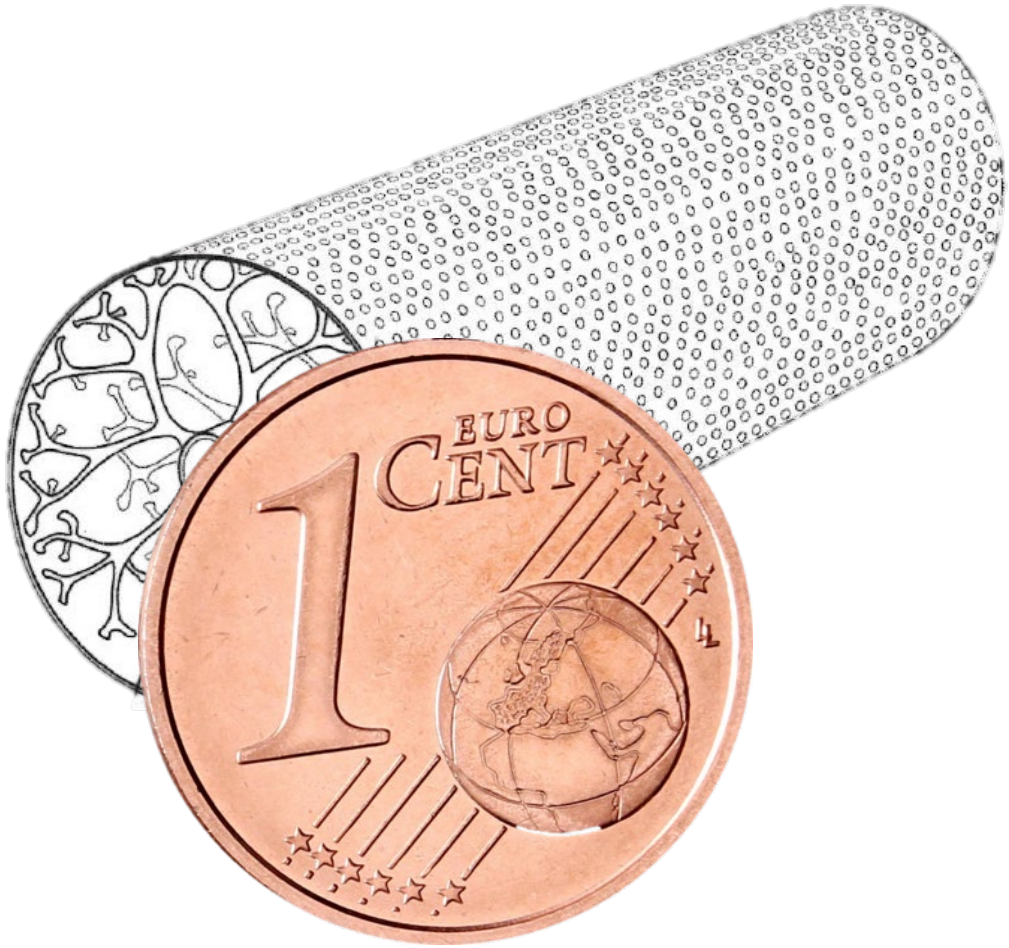


Too high pressure / oversized holes

Cut rope and leave at ground



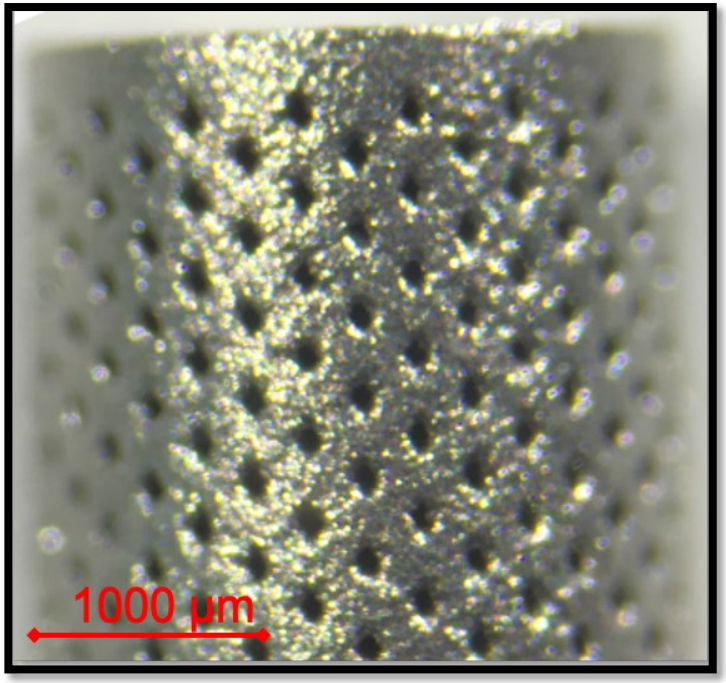
THE STRUCTURE



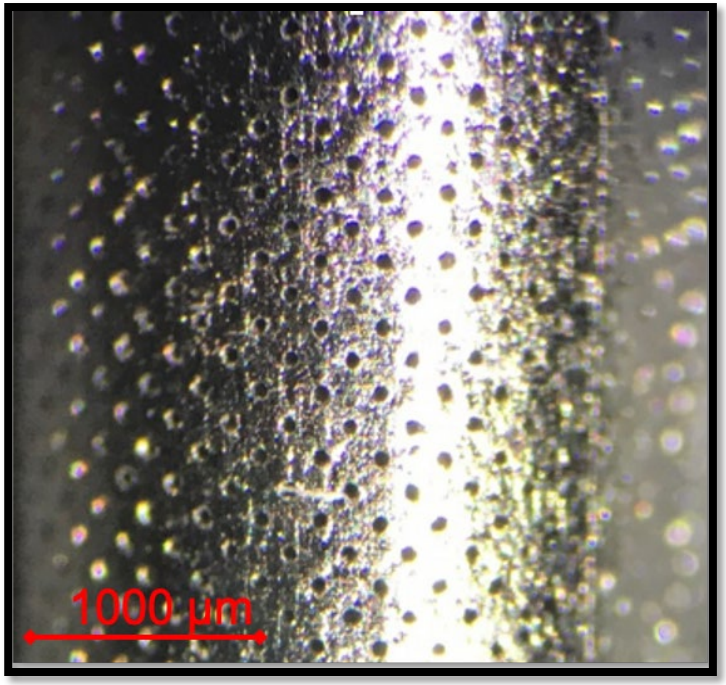
- Reproducibility
- High porosity
- Depth up to 4000 m

Two ways to get the structure we want

- 3D Micro printing



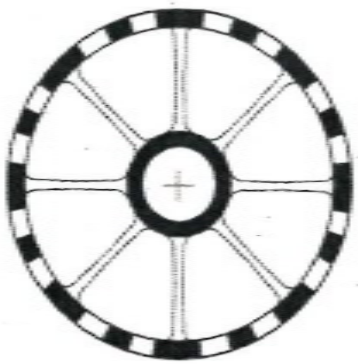
- Micro Laser Drilling



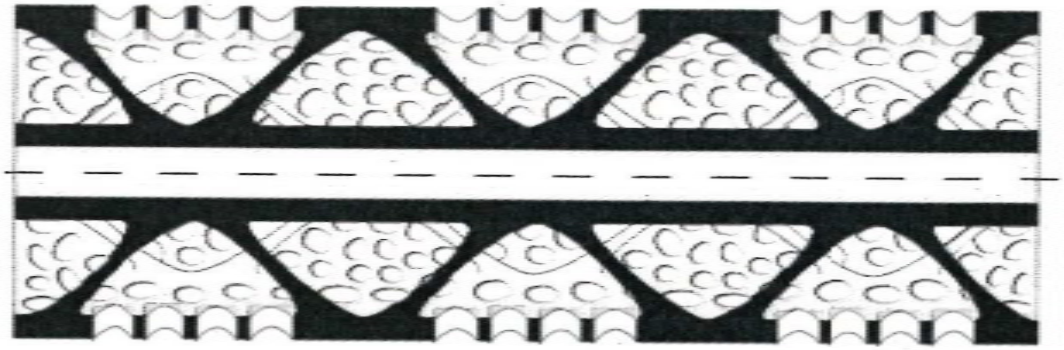
THE STRUCTURE

- Additive 3D-microprinting
  - Precision up to 50 µm
  - Complex structures possible
  - High reproducibility

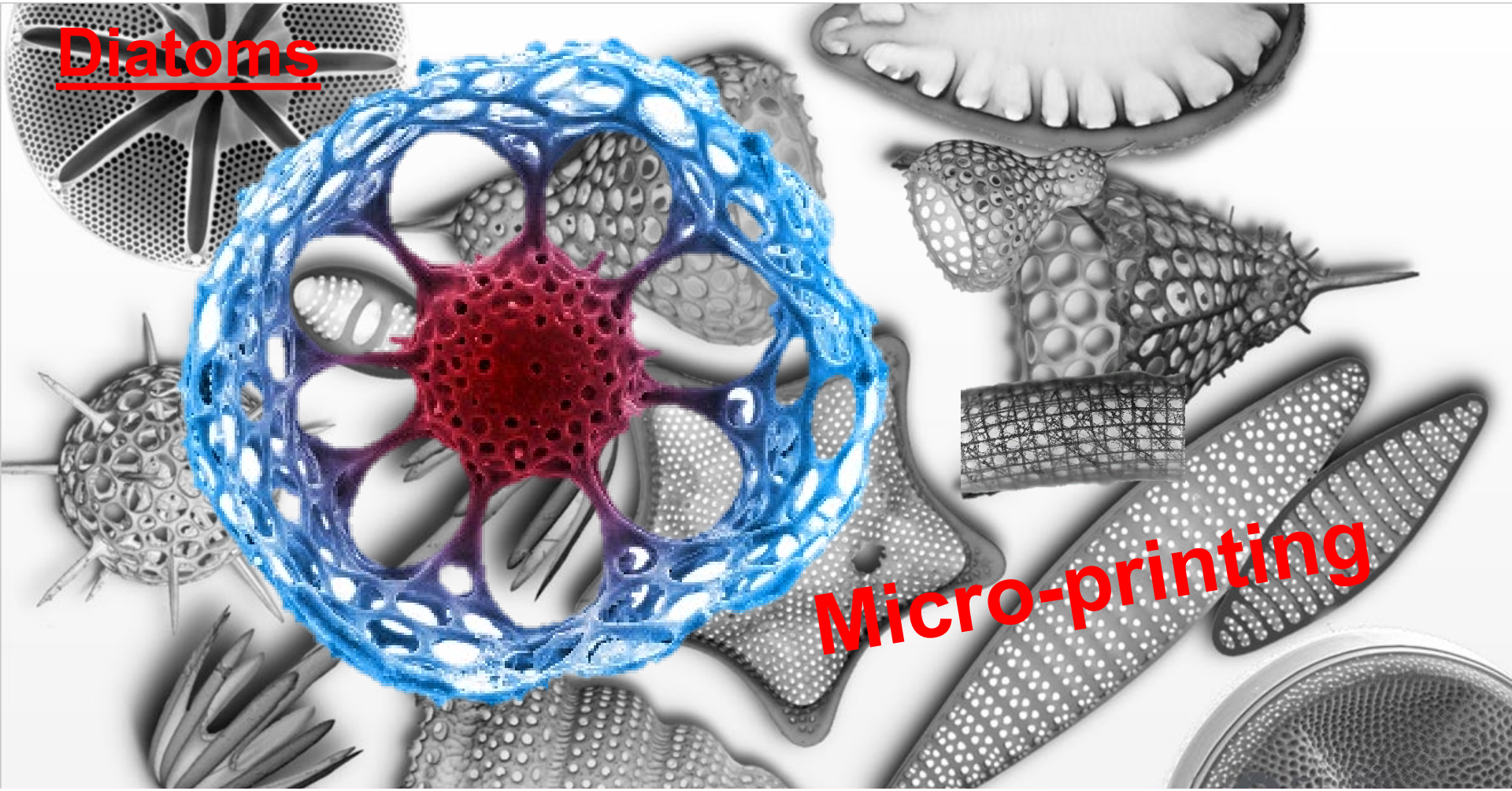
$\sim 1/8"\ (3mm)$



$\sim \frac{1}{2}$“(13mm)

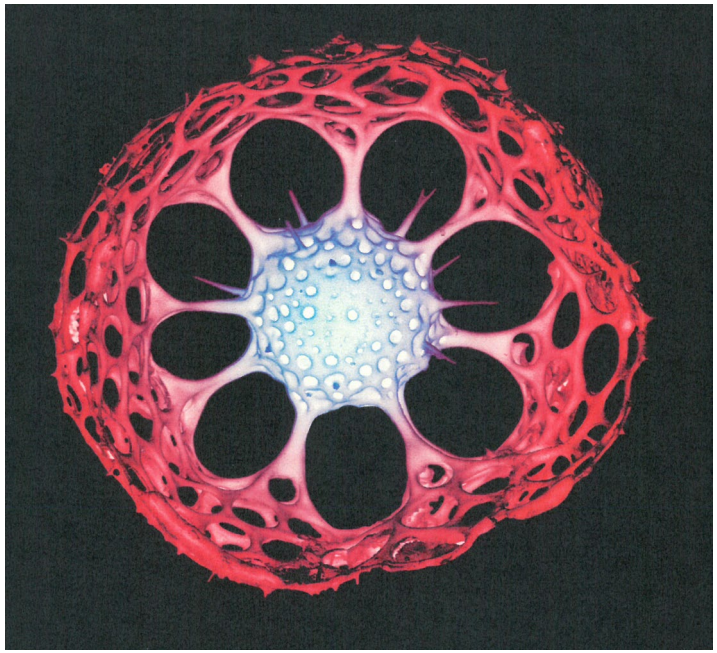


EliSE – BIONIC LIGHT WEIGHT

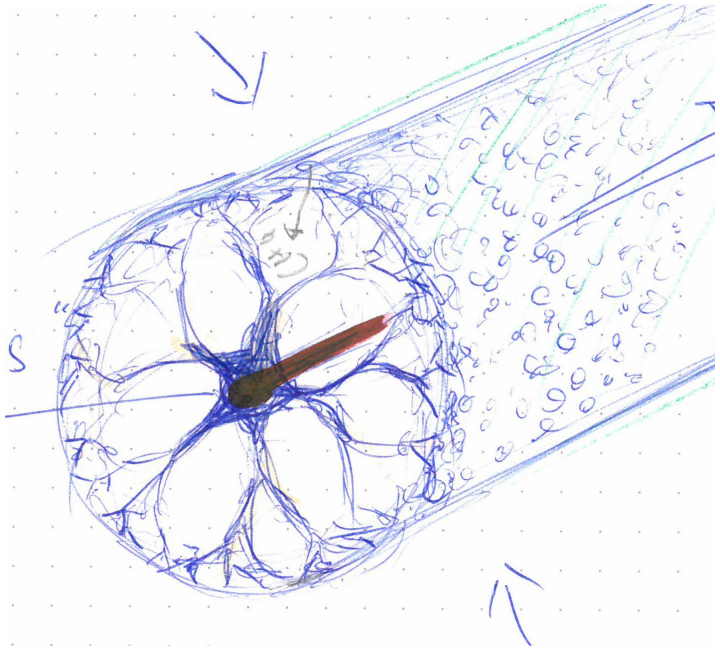


Adapt structures from organisms out of harsh environmental surroundings

THE STRUCTURE



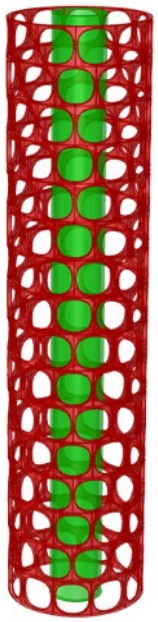
ELiSE



Additive manufacturing

3D microprinting

THE STRUCTURE

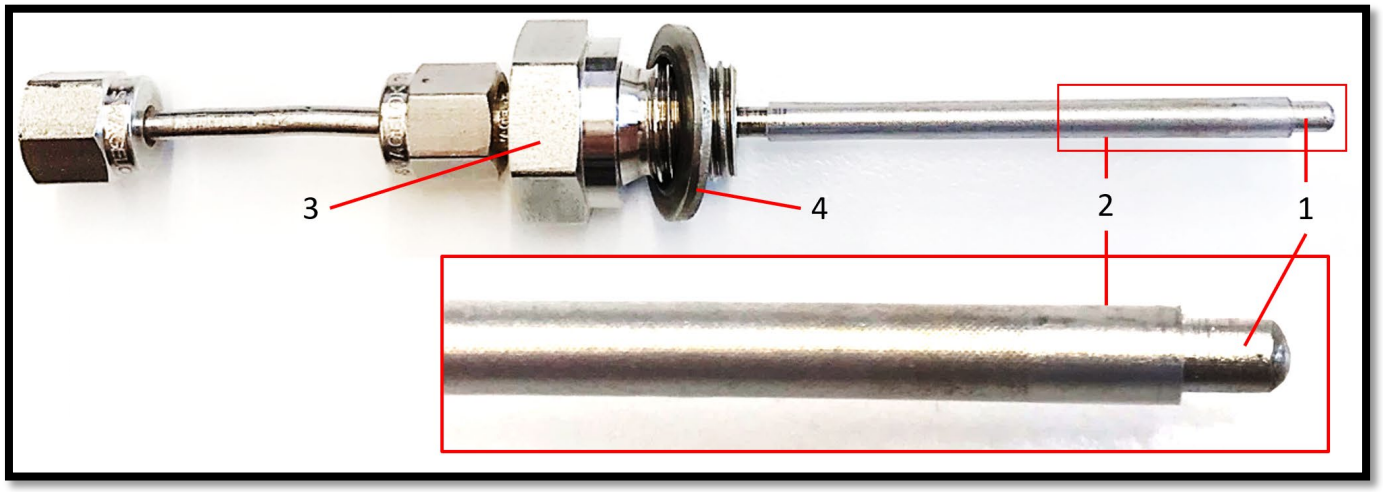


Concept ellipse

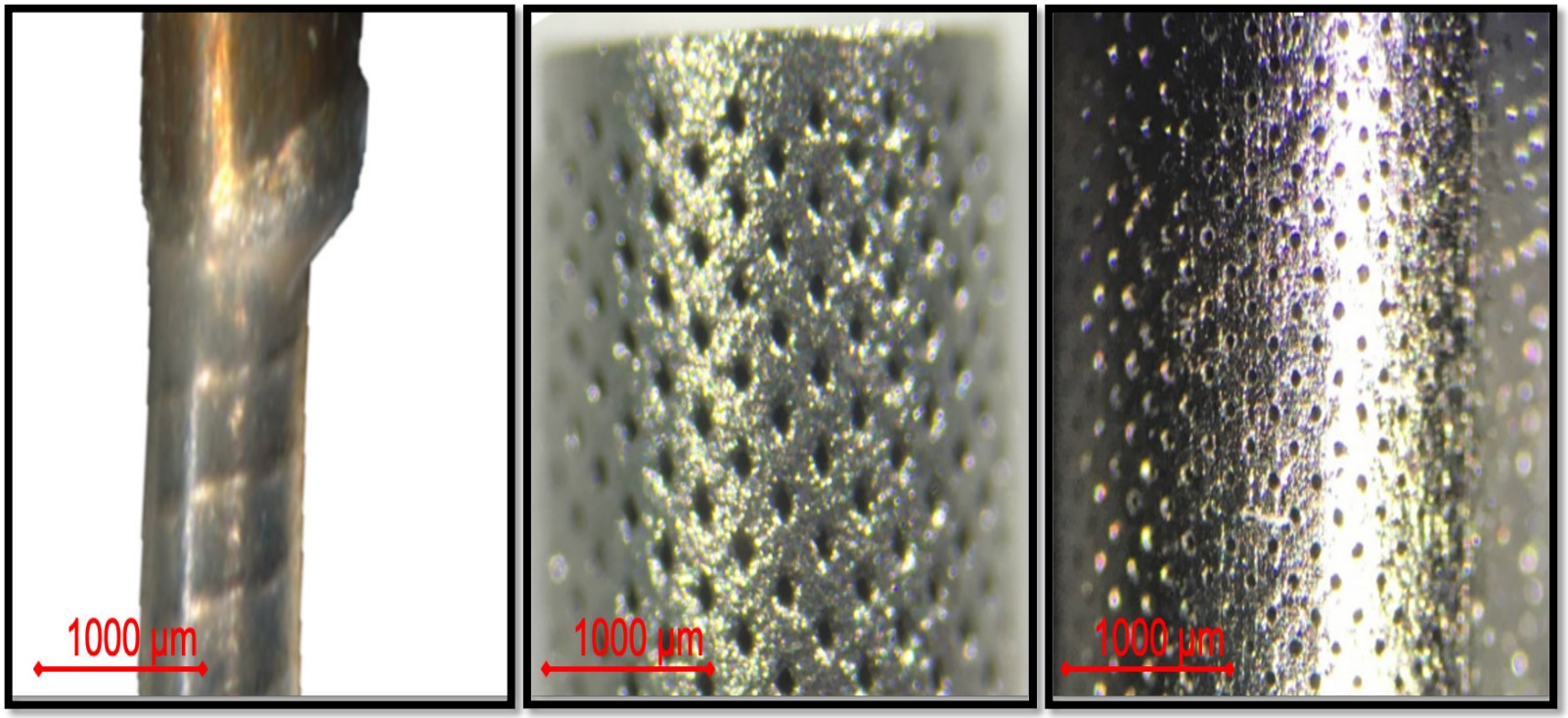
Not
for p

THE STRUCTURE

- laser drilling
  - Hole diameter down to 50µm (~12000 holes in 13mm length)
  - Complex structures not possible
  - High reproducibility



TESTED STRUCTURES



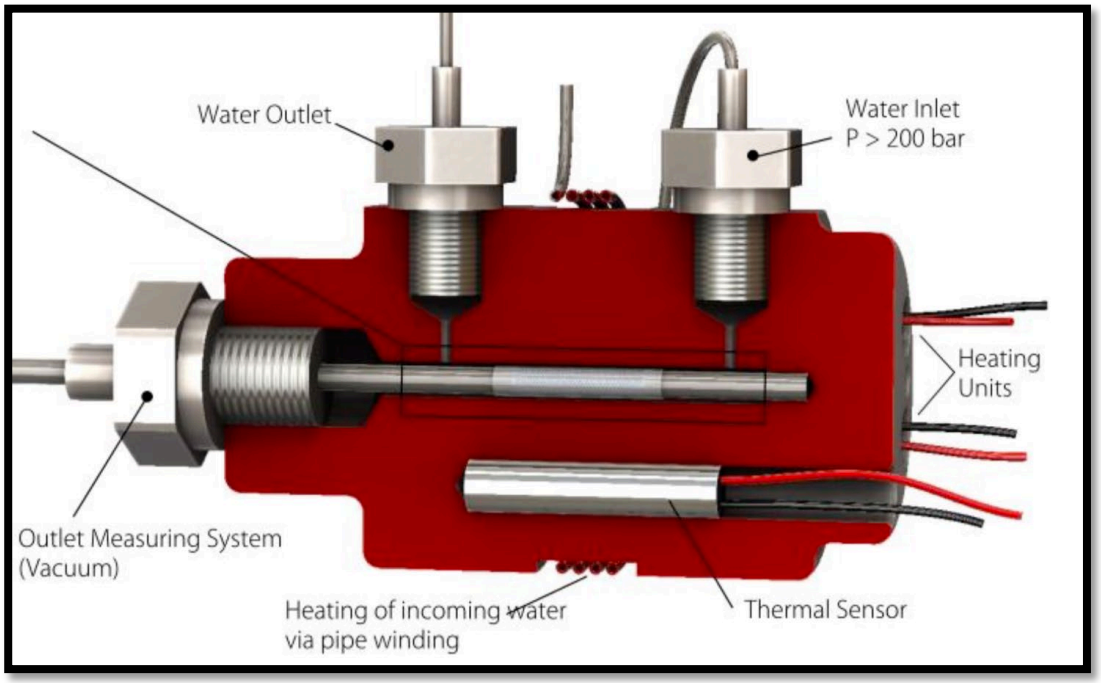
Spring (Reference)

3D printed

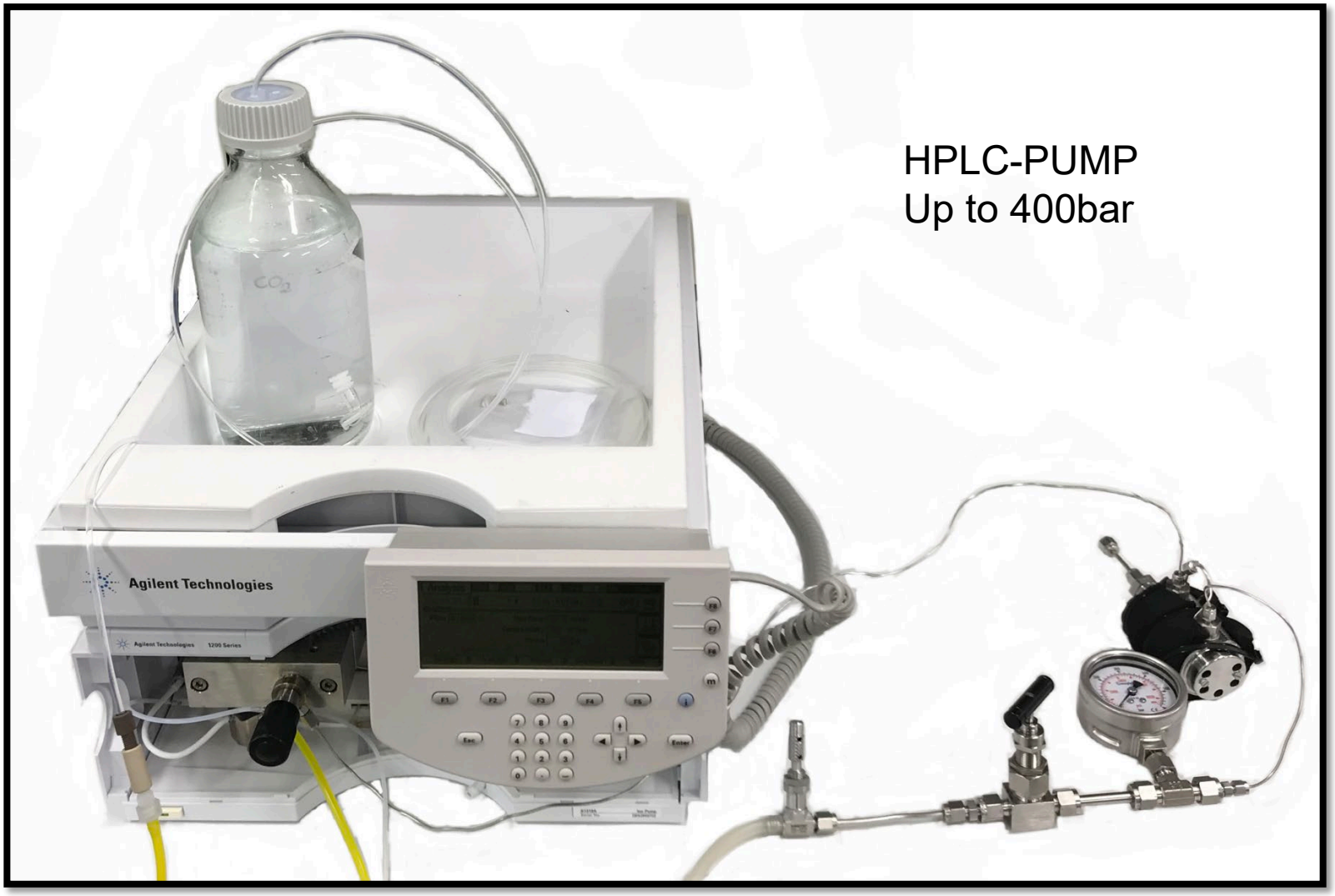
Laser drilled

TESTED STRUCTURES

Membrane Thickness (0,25 mm und 0,51 mm)
Attached to UWMS



PRESSURE RESISTENCE

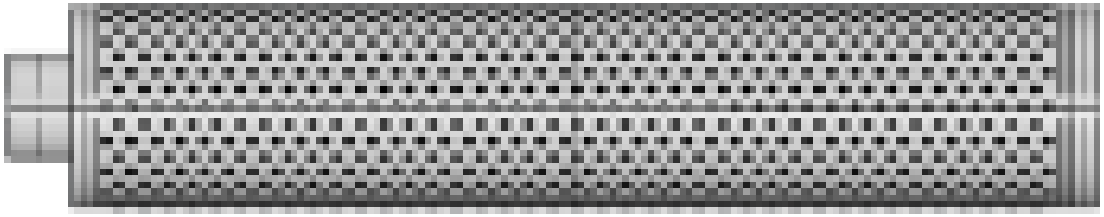


PRESSURE RESISTENCE

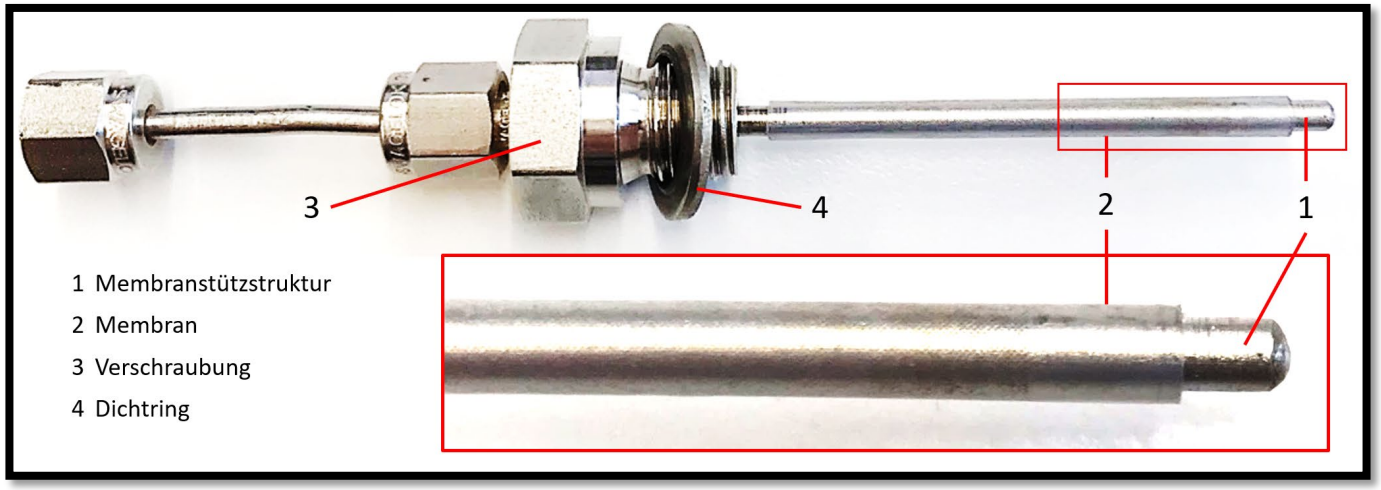
Structure Membrane thickness [mm]	**Max depth** [m] (safety 1.5)
Spring 0,28	100 - 200
3D-printed 0,25	470
3D-printed 0,51	3000
Laser drilled 0,25	2400
Laser drilled 0,51	>3000

PRESSURE RESISTENCE

Micro printed frit

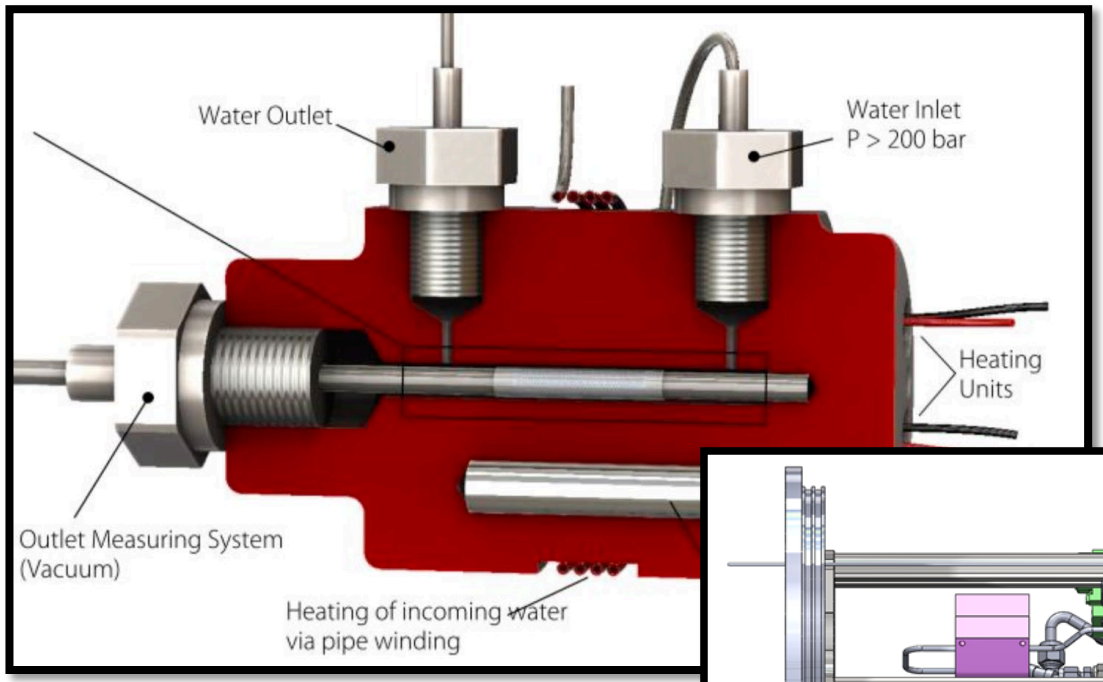


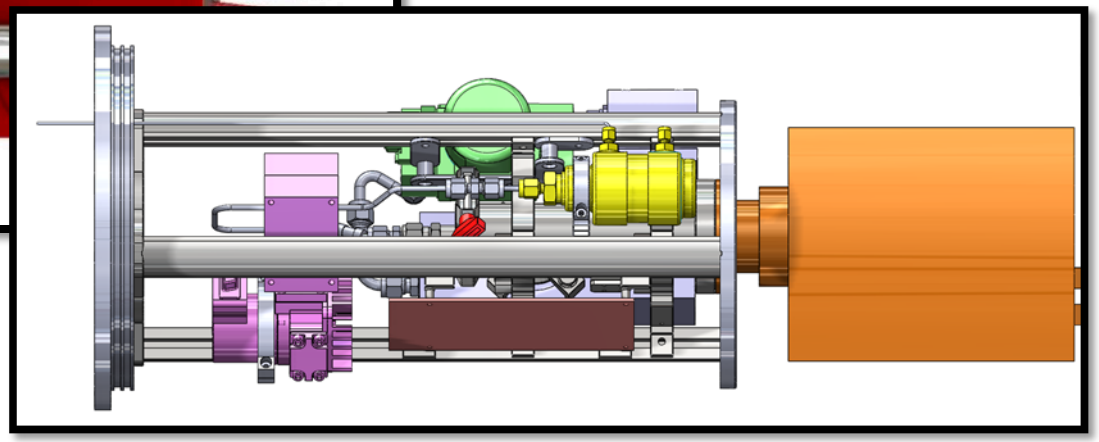
Laser drilled membrane



TESTED STRUCTURES

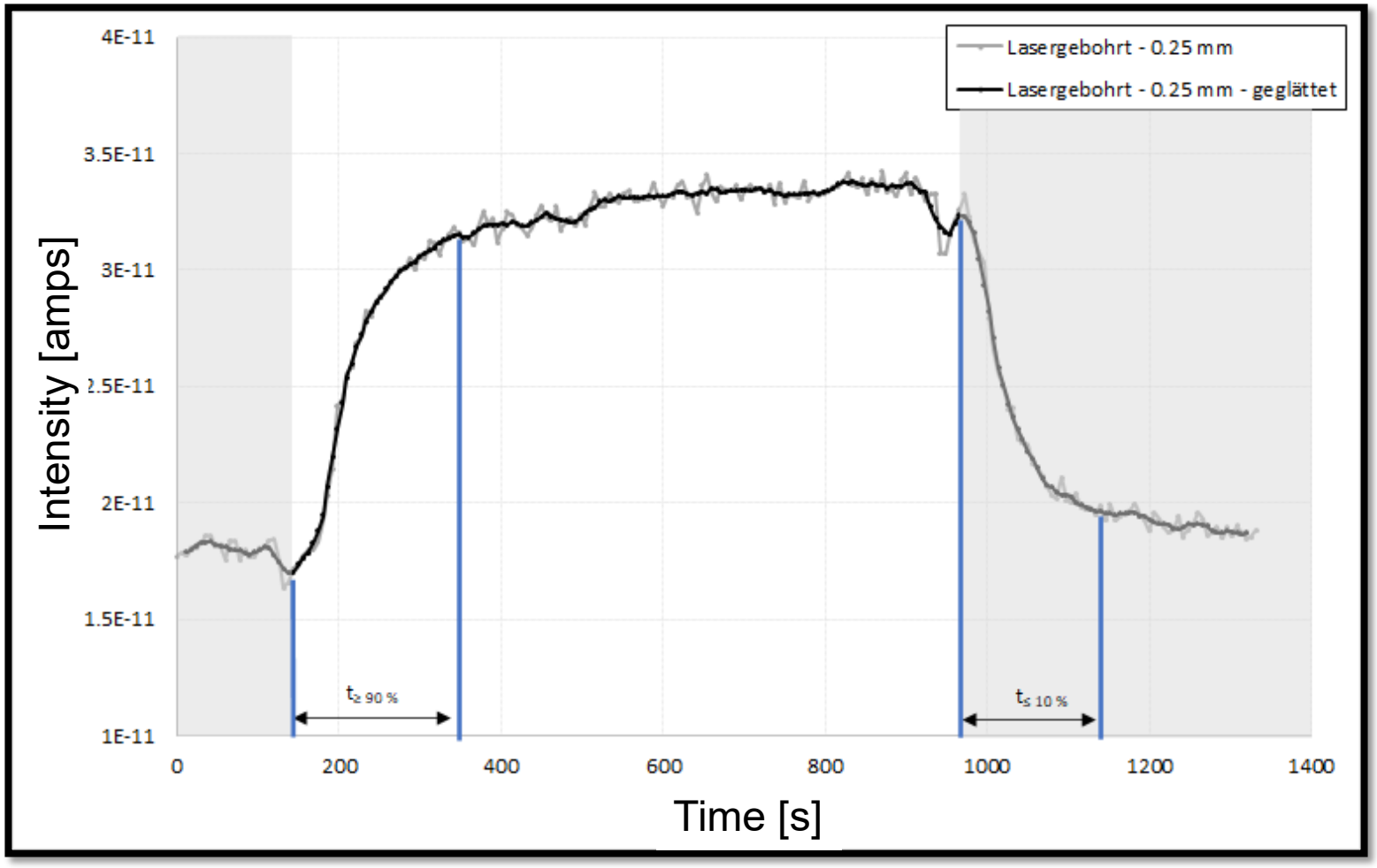
Membrane Thickness (0,25 mm und 0,51 mm)
Attached to UWMS





UWMS 3000

RESPONDS TIME



RESPONDS TIME

Structure Membrane thickness [mm]	**Responds time ($T_{\geq 90\ \%}$)** [s]	**Decay time ($T_{\leq 10\ \%}$)** [s]
Spring 0,28	89 ± 5	144 ± 5
3D-printed 0,25	83 ± 5	114 ± 5
3D-printed 0,51	215 ± 5	340 ± 5
Laser drilled 0,25	100 ± 5	110 ± 5
Laser drilled 0,51	275 ± 5	330 ± 5

DETECTION LIMIT

Structure Membrane thickness [mm]	**Limit of Detection** [nmol/L]	**Limit of determination** [nmol/L]	
Spring 0,28	5,21	17,08	
3D-printed 0,25	9,98	36,44	
3D-printed 0,51	5,44	17,45	
Laser drilled 0,25	1,68	6,88	
Laser drilled 0,51	4,50	14,67	
Sintered Structure k.A.	20		Cardenas-Valenzia et al. (2014)
Sintered Structure k.A.	30		

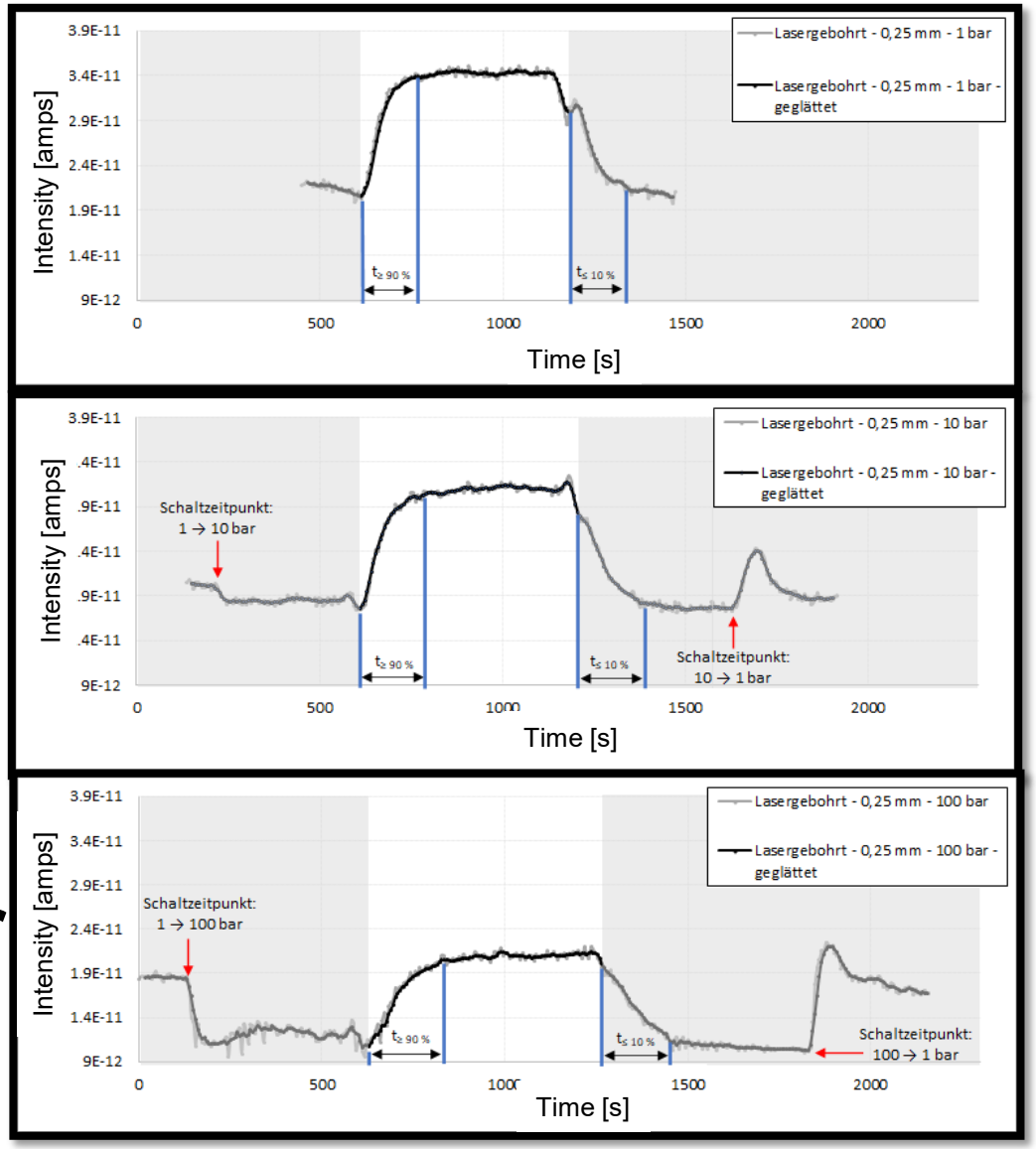
Calibrated by GC-Headspace

PRESSURE RESISTENCE

1 bar

10 bar

100 bar

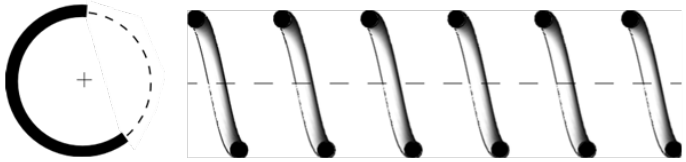
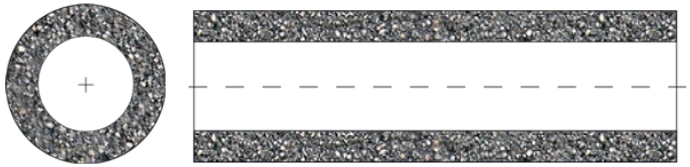
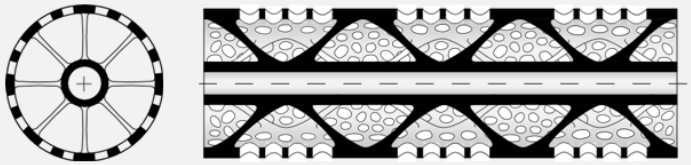


PRESSURE RESISTENCE

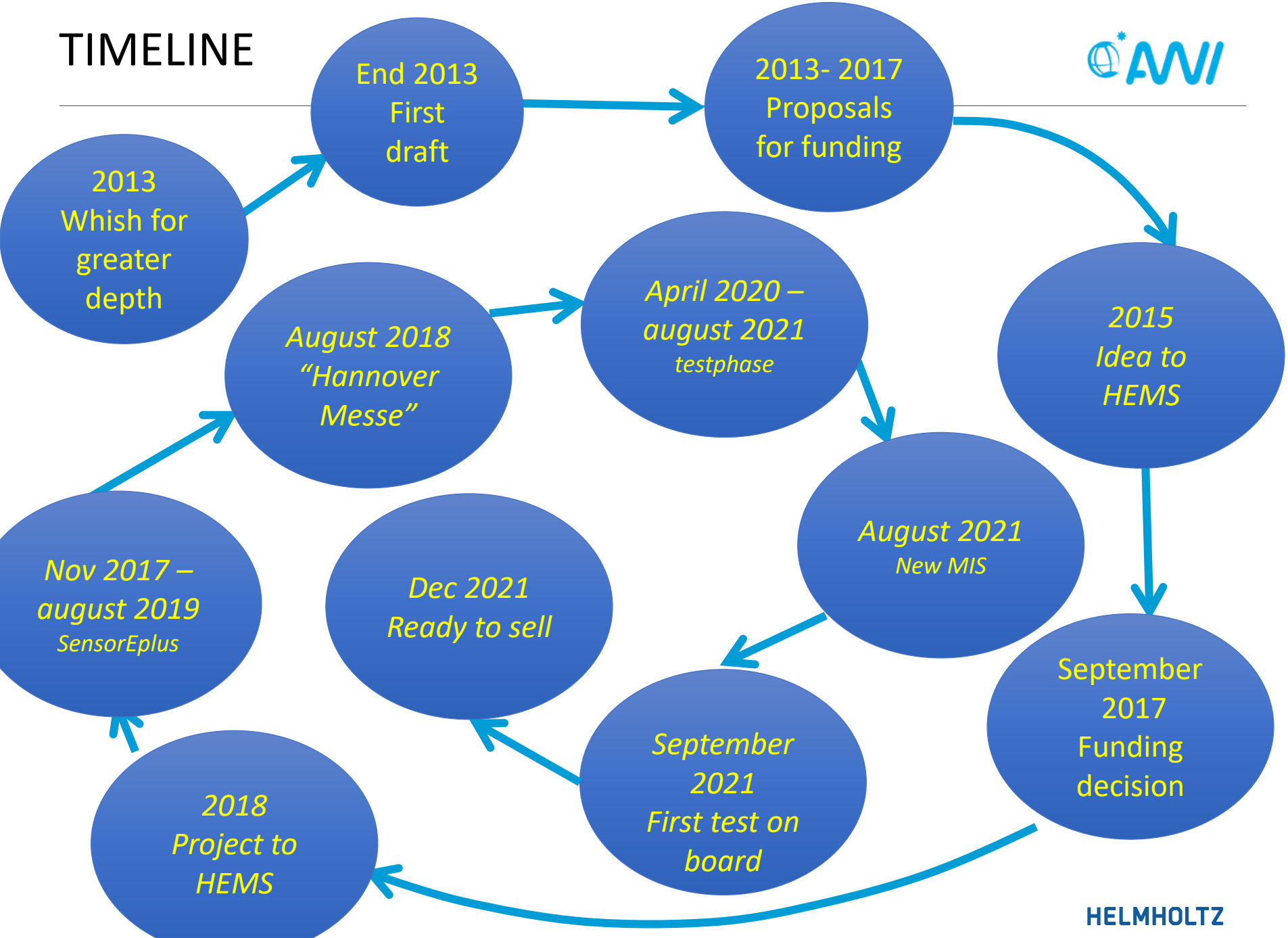
Structure Membrane thickness [mm]	p_{H2O} [bar]	C_{CH4} [nmol/L]	**ΔS** Related to 1 bar [%]
Spring 0,28	1 10	53,99 ± 5,11	/ 1,63
3D-printed 0,25	1 10	53,55 ± 7,83	/ 6,56
3D-printed 0,51	1 10 100	51,68 ± 7,57	/ 4,28 46,06
Laser drilled 0,25	1 10 100	51,22 ± 7,51	/ 9,34 37,28
Laser drilled 0,51	1 10 100	50,29 ± 7,38	/ 15,67 43,68

THE STRUCTURE

Advantages / disadvantages

Supporting structure		Pressure	Permeability	Reproducibility	Heating
Steel spring		↯	✓	✓	↯
Sintered		✓	↯	↯	✓
Developed		✓	✓	✓	opt.

TIMELINE


2013
Whish for greater depth
End 2013
First draft
2013- 2017
Proposals for funding
2015
Idea to HEMS
April 2020 – august 2021
testphase
August 2018
"Hannover Messe"
Nov 2017 – august 2019
SensorEplus
August 2021
New MIS
Dec 2021
Ready to sell
September 2017
Funding decision
September 2021
First test on board
2018
Project to HEMS

CLIENTS

SubSeaSpec®
Environmental Monitoring

contact@subseaspec.com

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UWMS IN ANTARCTIC

THE STRUCTURE