Contactless Handling of Thin Substrates using Air Bearing Technology

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Mechatronic System Design and Tribology,
Dep. of Precision and Microsystems Engineering

KIVI Mechanics Symposium “To grease or not to grease”
November 3, 2016

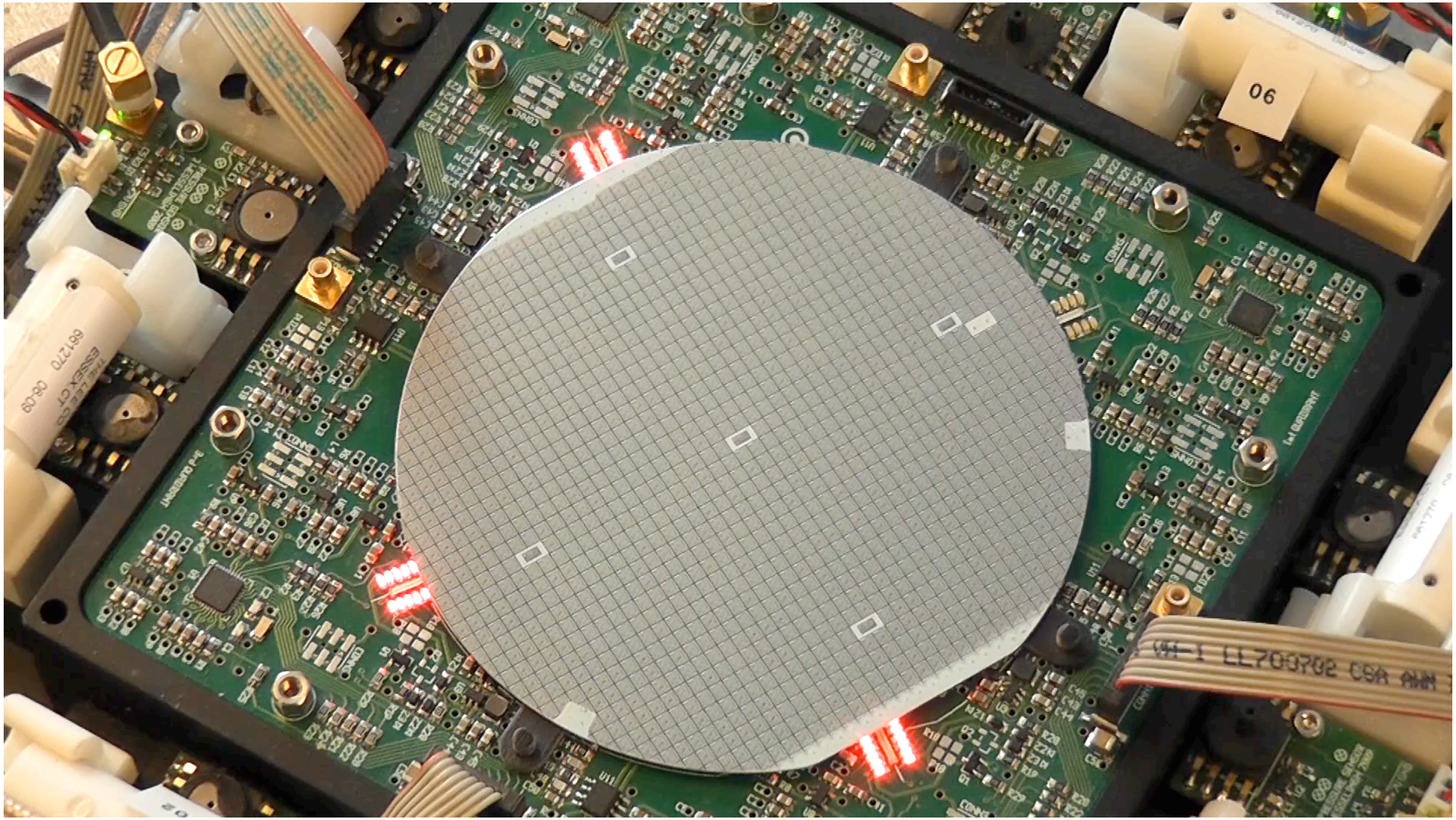
Delft University of Technology

Challenge

Thin, fragile, substrates are susceptible to contamination, damage or even breakage at every occurrence of mechanical contact.

So: Is it possible to carry, transport, and position, thin, fragile, substrates, without any mechanical contact? (2006)

YES!



J. Wesselingh, e.a., Euspen, 2008, 2009, 2010, 2011
J. van Rij, e.a., Tribology International, 2009
J, Wesselingh, TU Delft PhD-thesis, 2011

Contents

A living campus

TU Delft

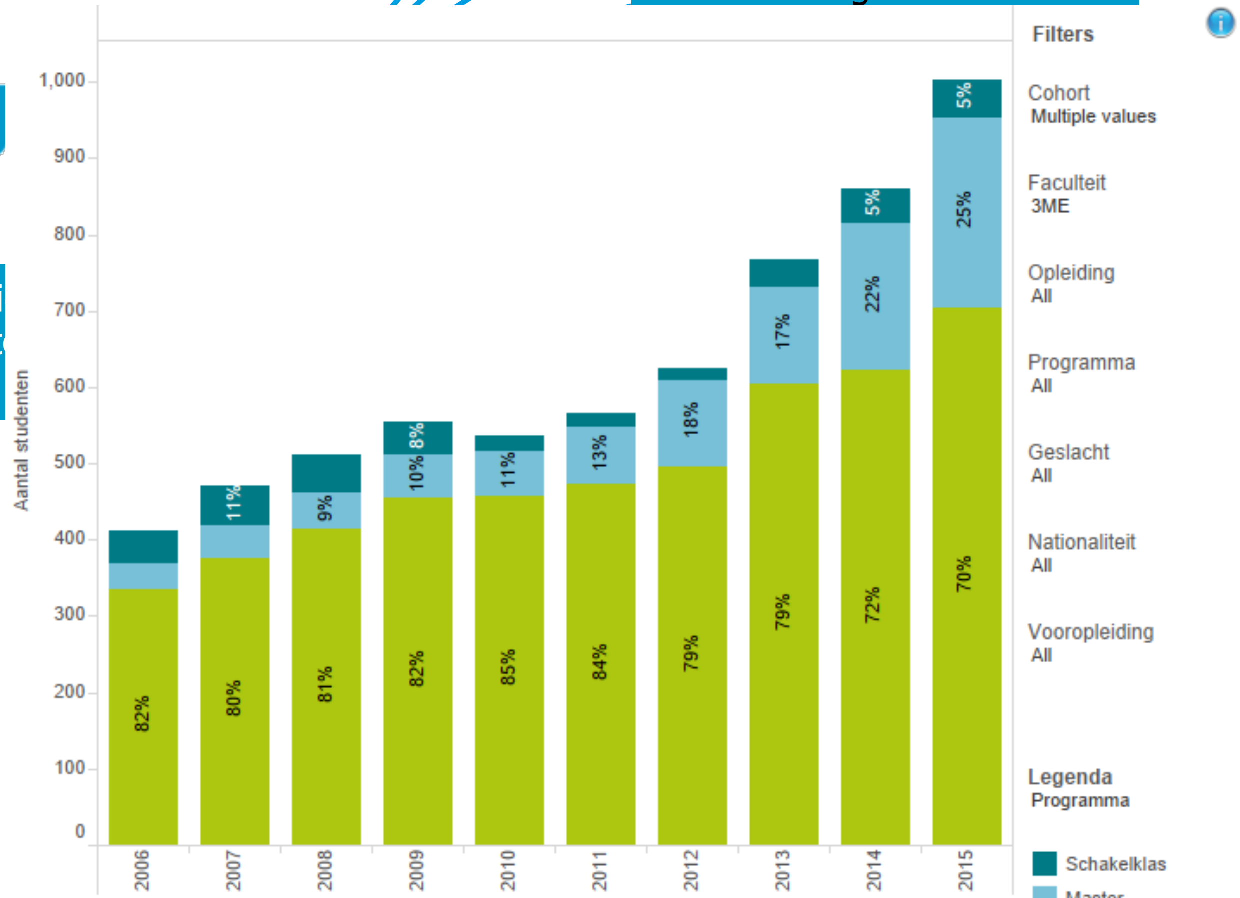
Aerospace Eng.

Applied Sciences

Architecture

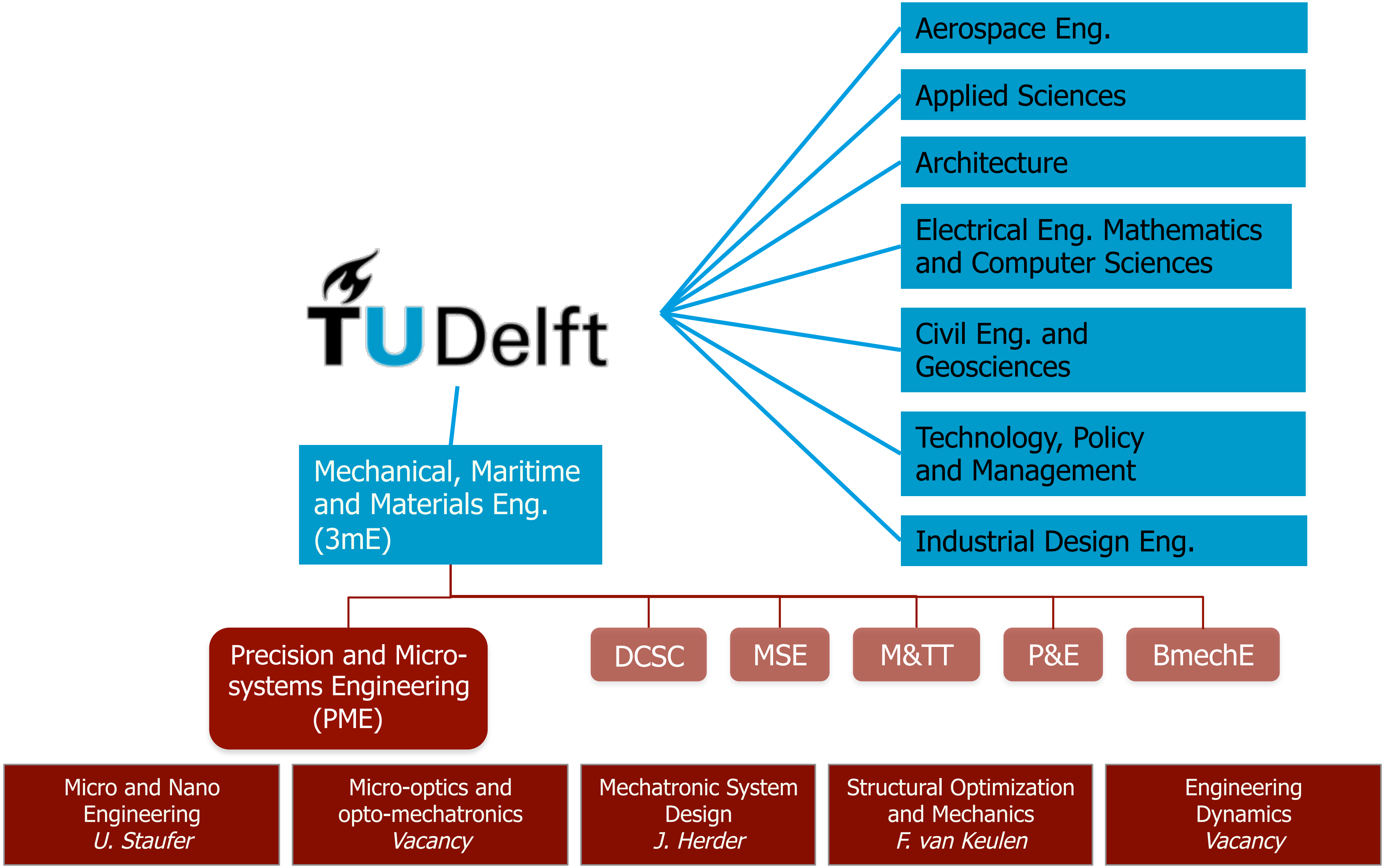
Electrical Eng. Mathematics

Mechani
and Mat
(3mE)



Instroom (aantallen studenten) verdeeld naar Programma.
Gefilterd voor: faculteit (3ME), opleiding (All), programma (All), geslacht (All), nationaliteit (All) en vooropleiding (All).

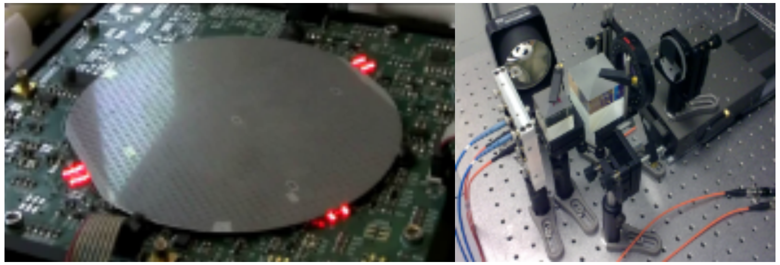
TU Delft



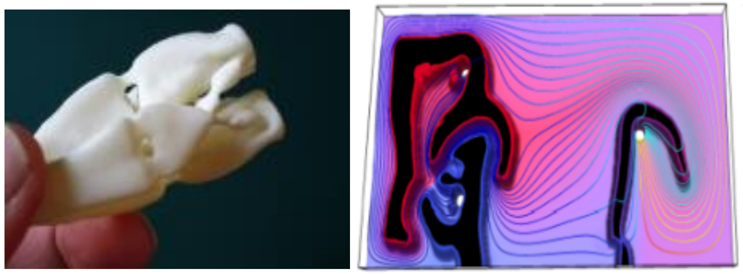
- PME is a Department within the Faculty of Mechanical, Maritime and Materials Engineering, and is focused on high-tech systems and materials

PME research program

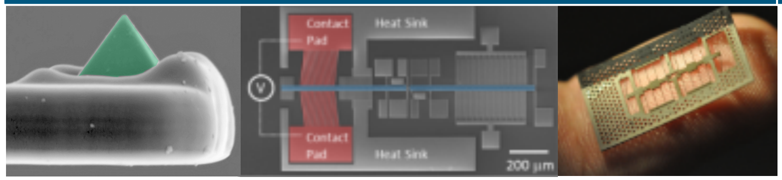
Systems



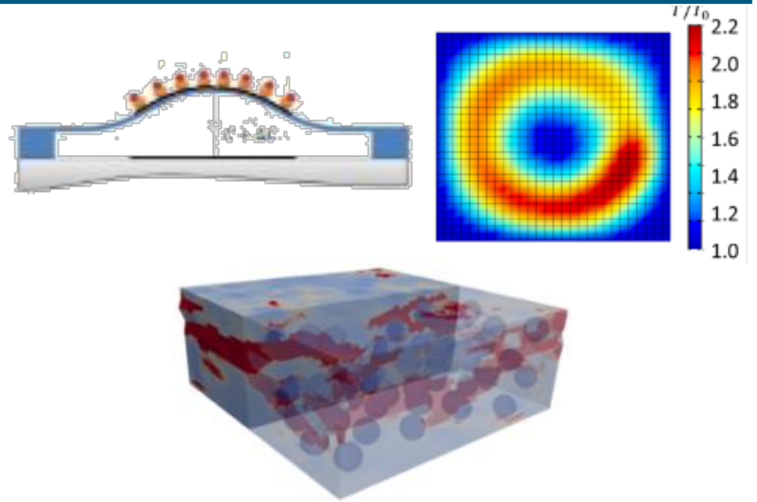
Design optimization



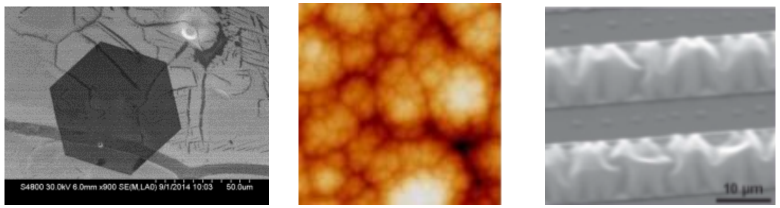
Devices and processes



Numerical modelling



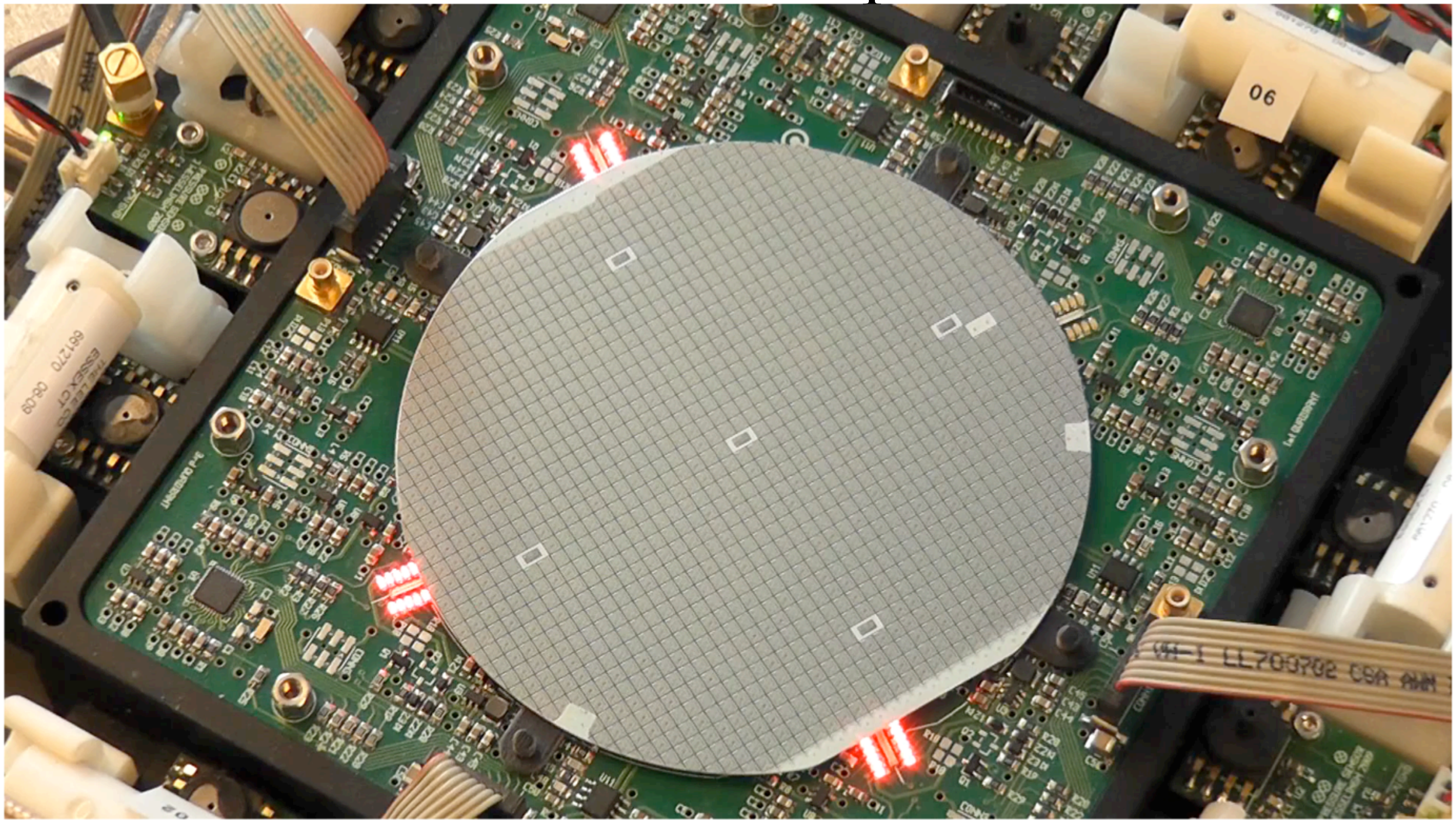
(Nano)material structures



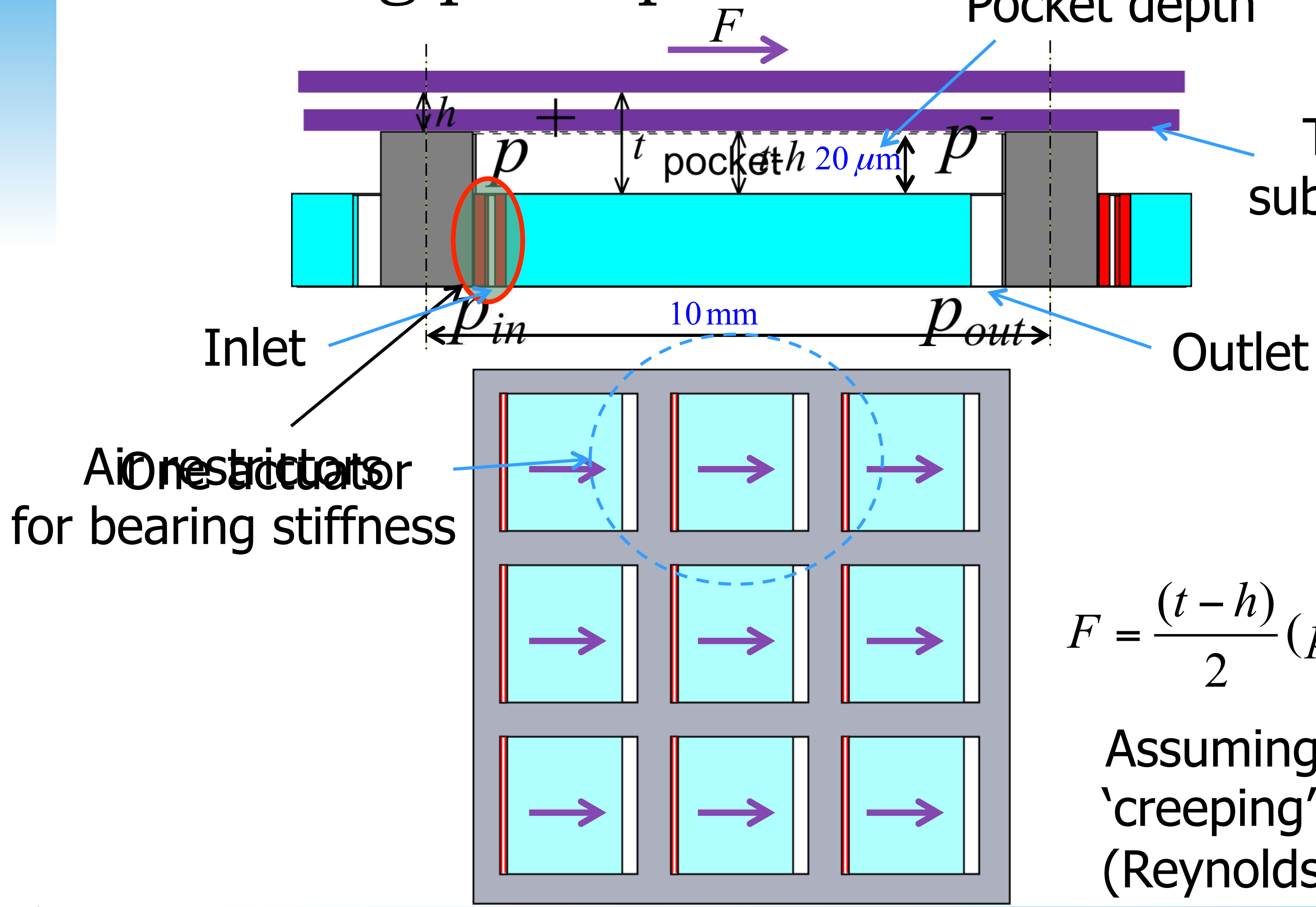
PME is focused on the **high-tech systems and materials domain**,

and has the mission to **integrate micro/nano-science into Mechanical Engineering**

Viscous traction concept: Intro



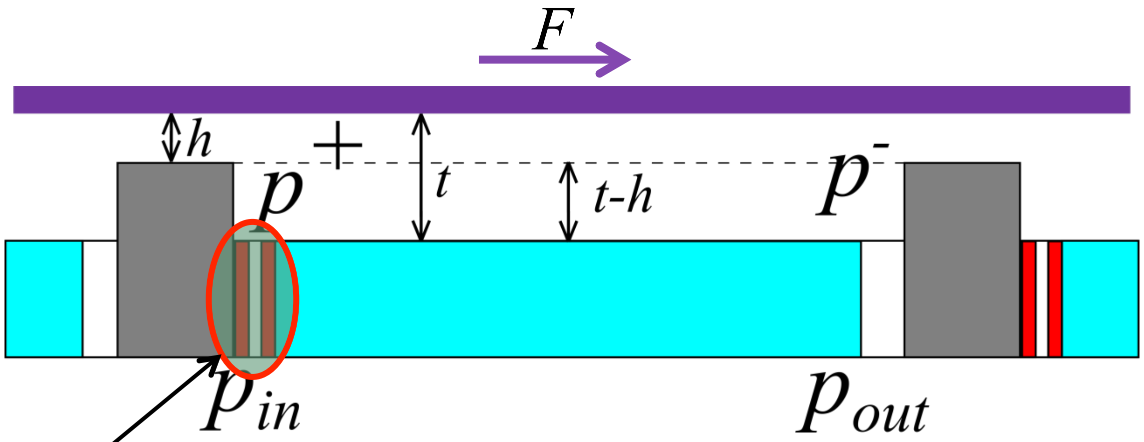
Working principle



$$F = \frac{(t-h)}{2}(p^{+} - p^{-})$$

Assuming thin 'creeping' flow (Reynolds eq.)

Position control



Air re
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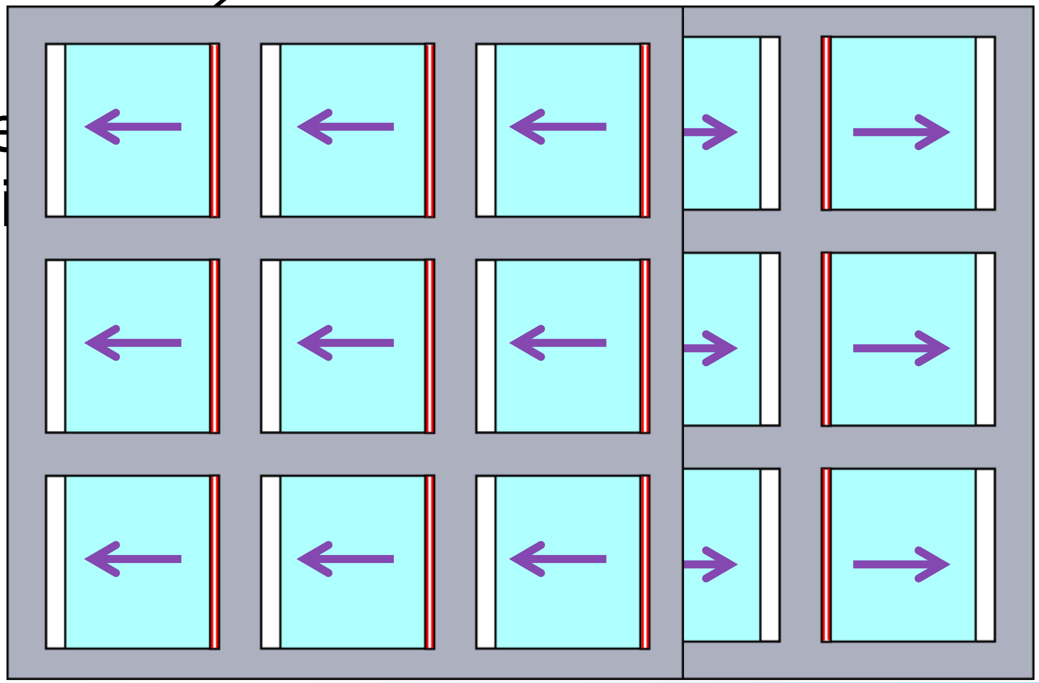

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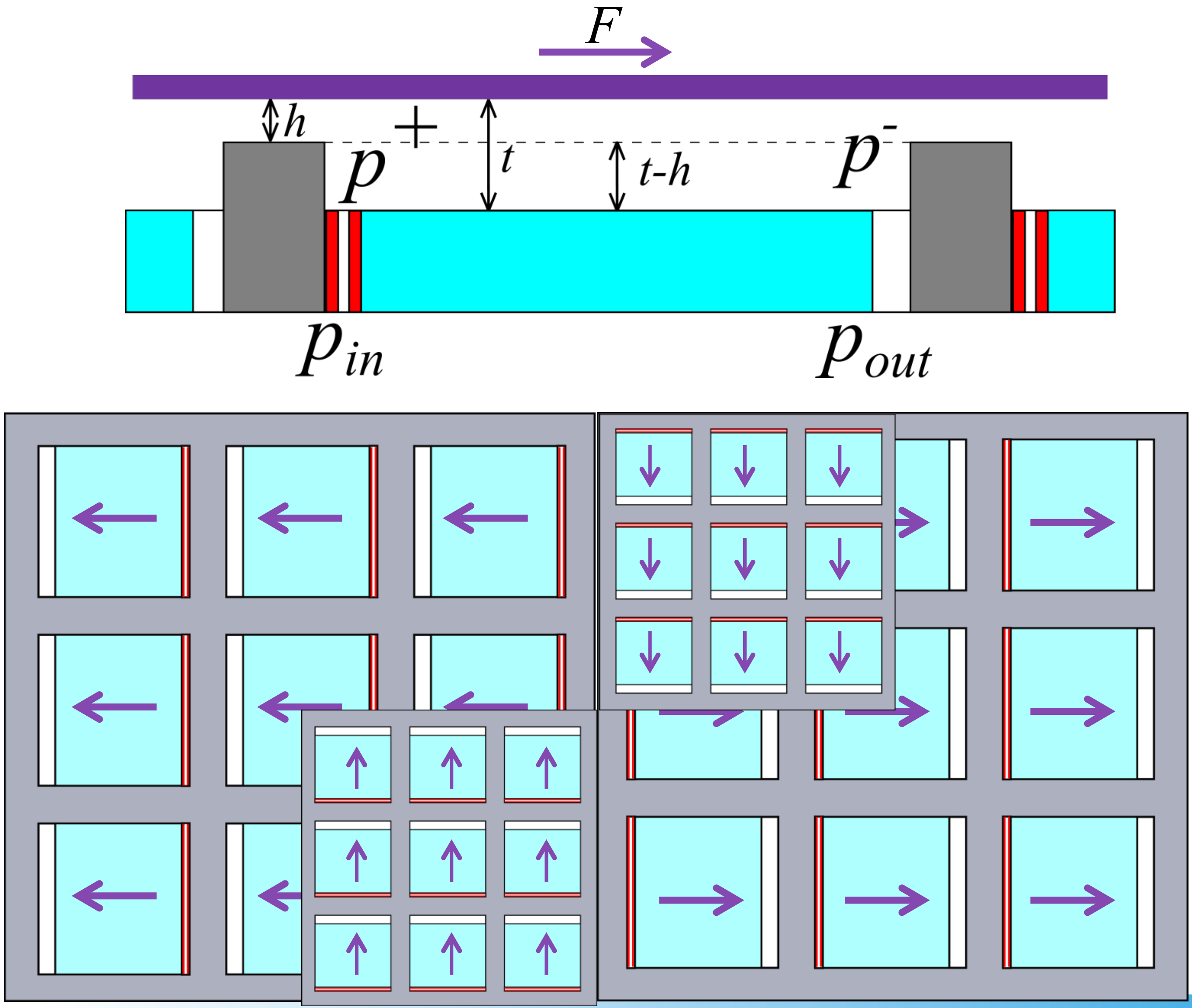
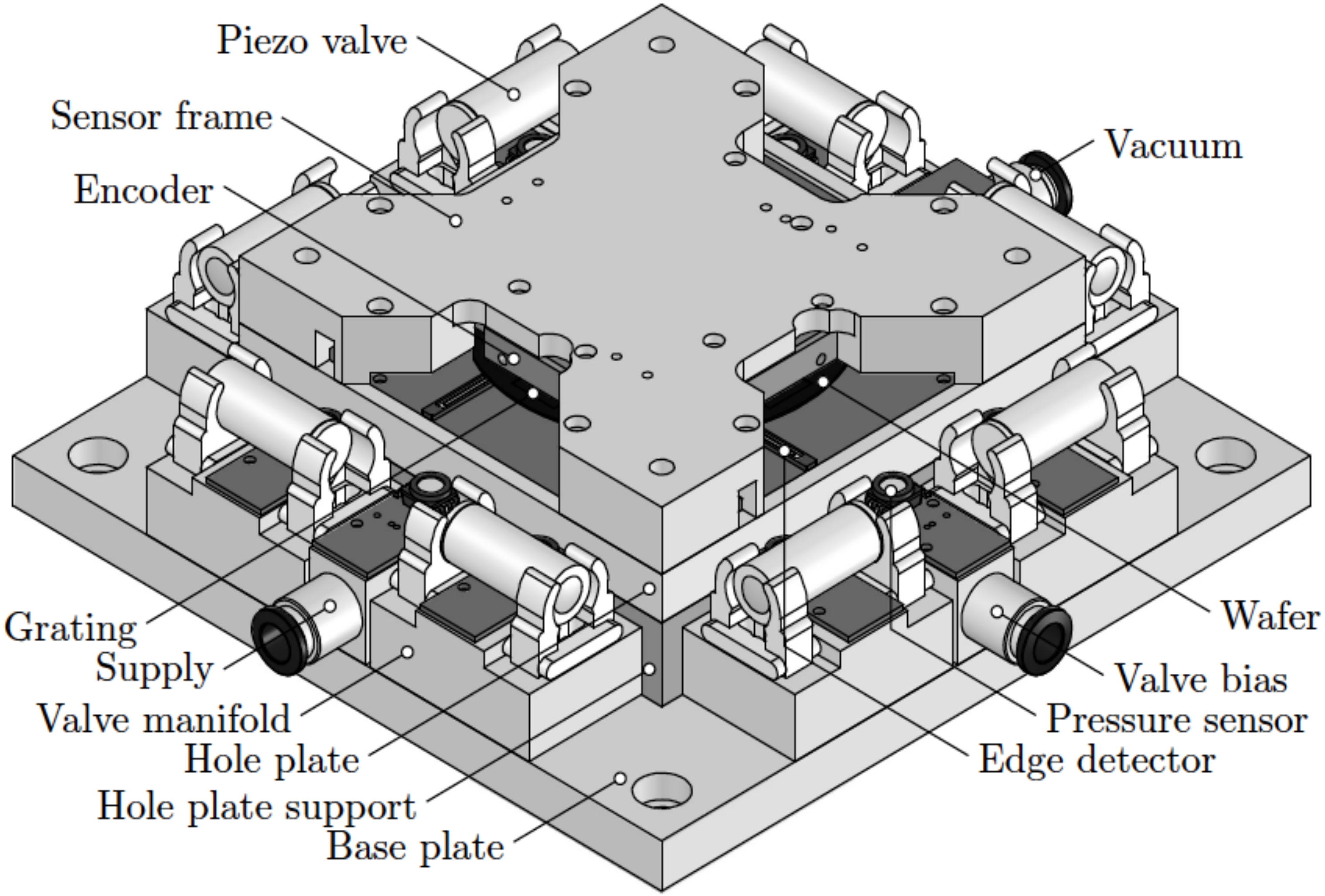
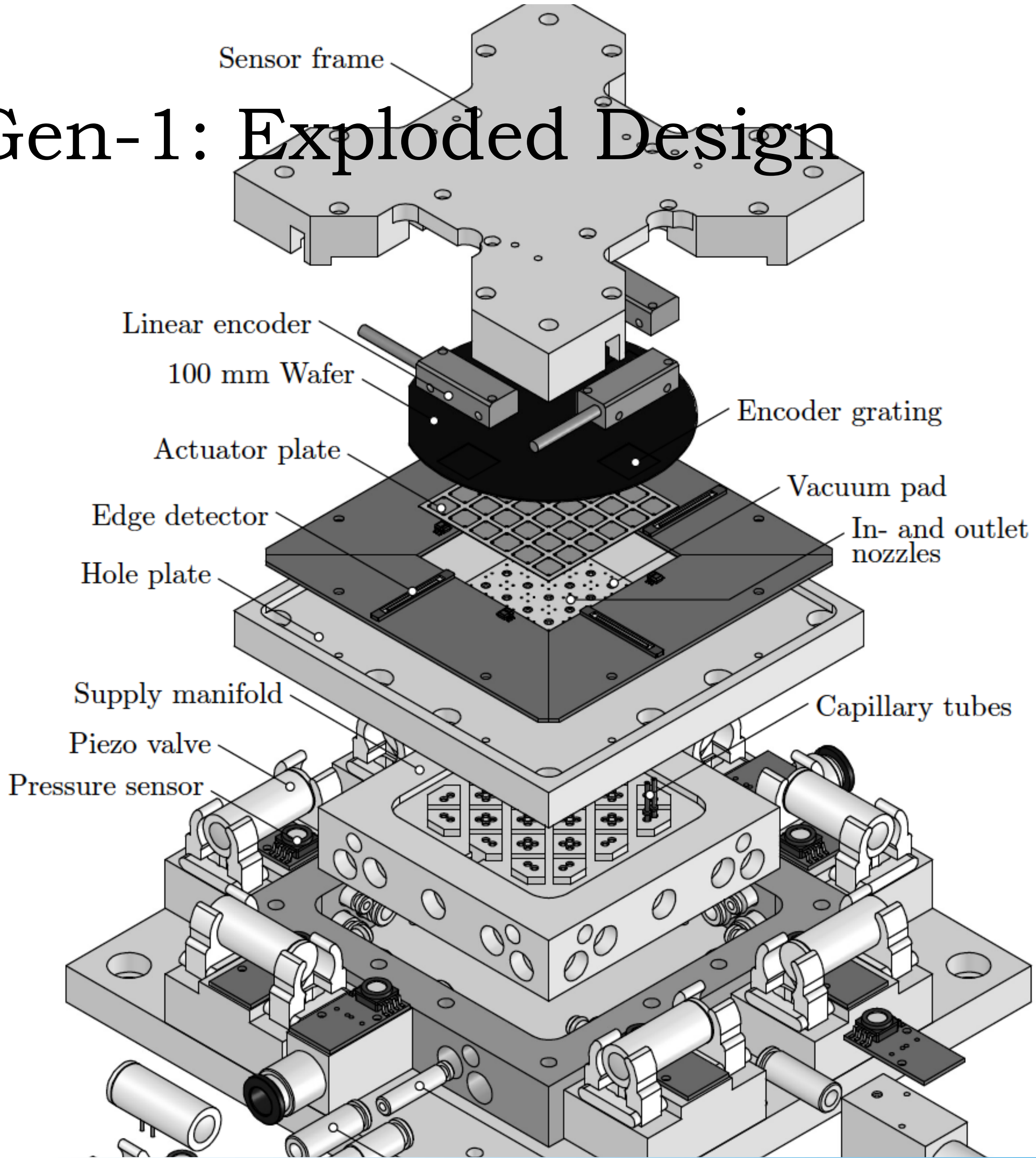


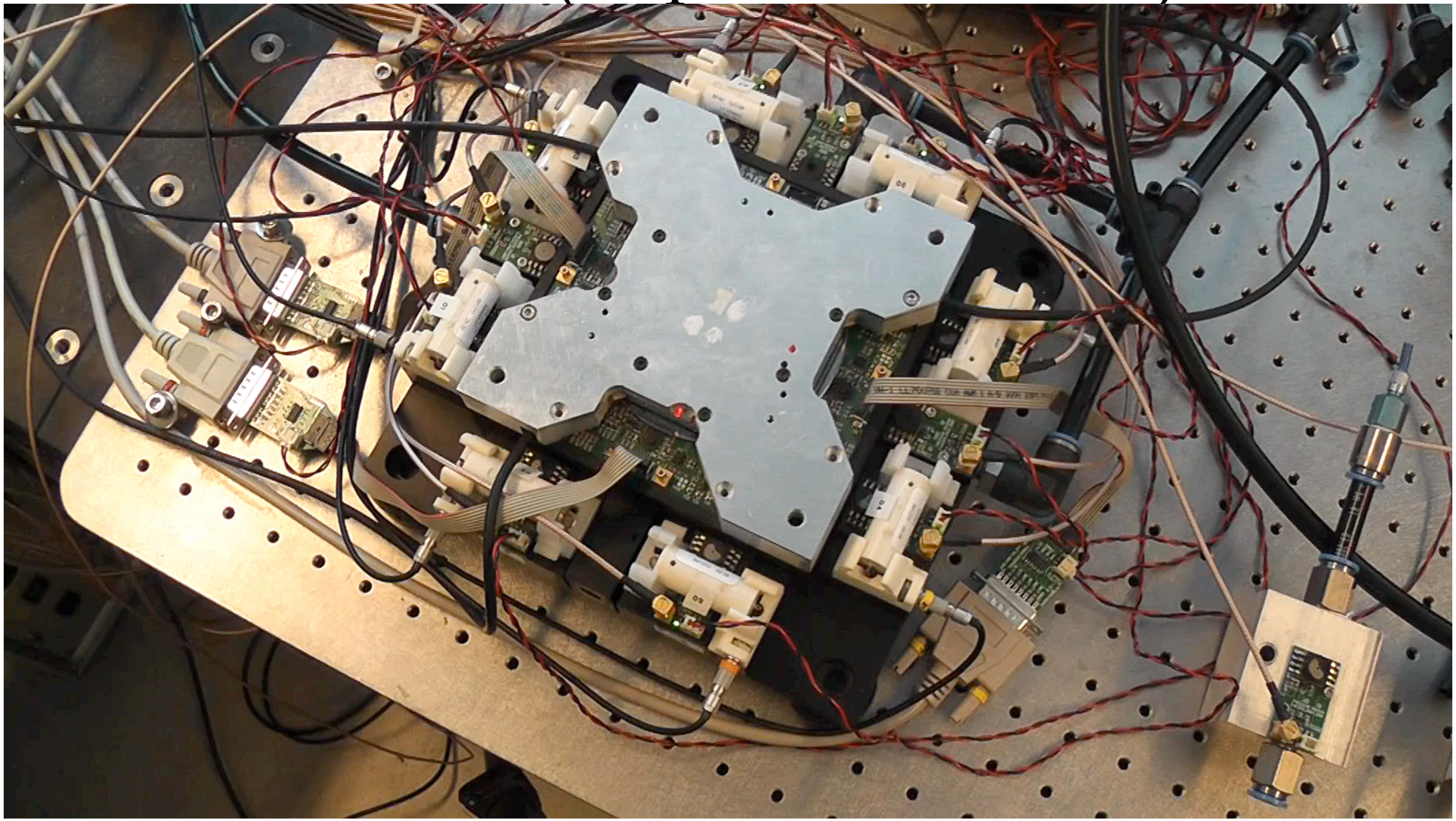
Gen-1: Design


Piezo valve
Sensor frame
Encoder
Vacuum
Grating
Supply
Valve manifold
Hole plate
Hole plate support
Base plate
Wafer
Valve bias
Pressure sensor
Edge detector

Gen-1: Exploded Design



Gen-1: Demo (improved sensor)



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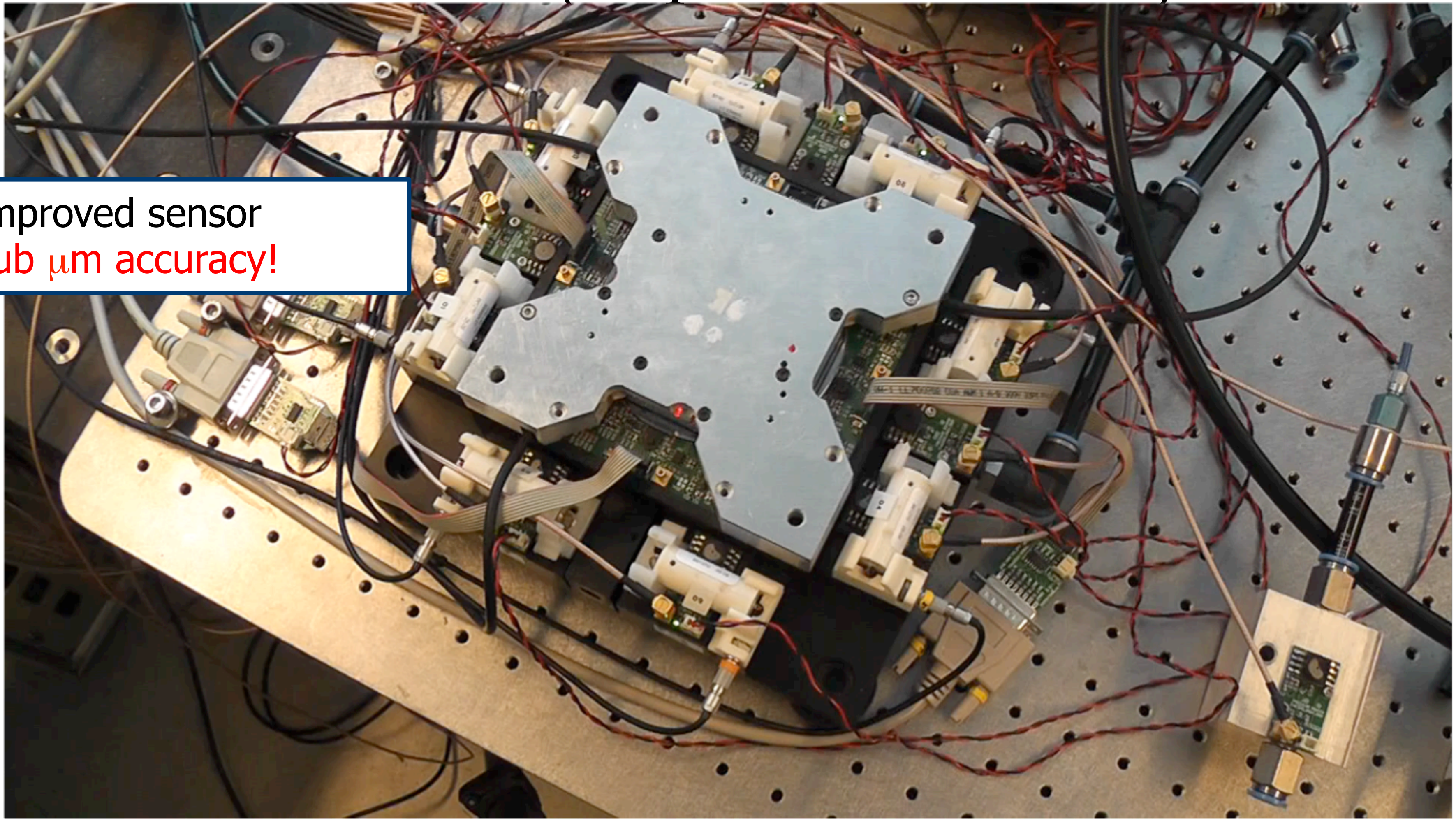
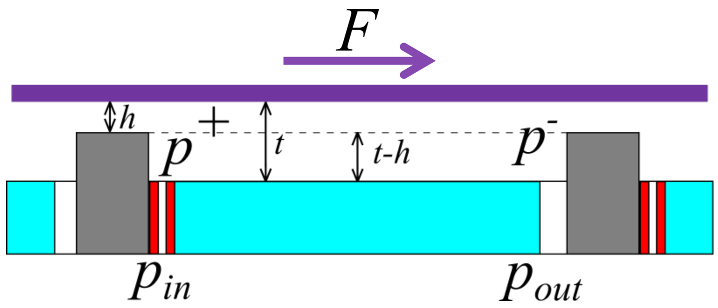
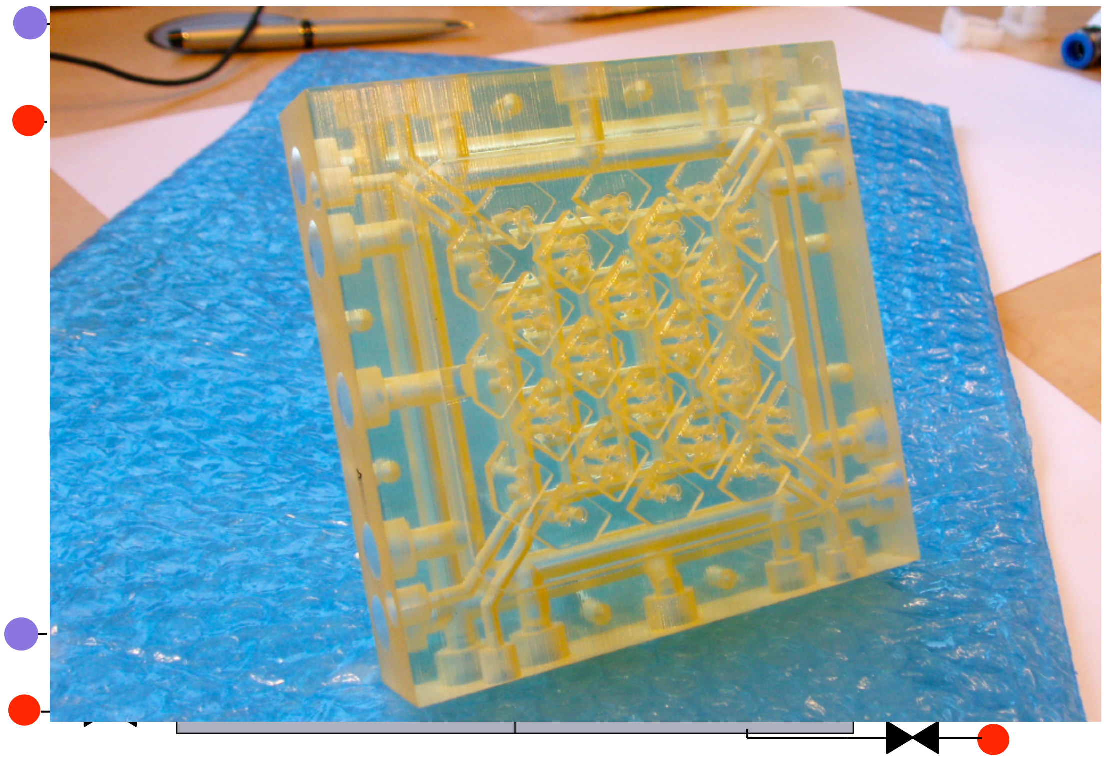


Improved sensor
Sub μm accuracy!

J. Wesselingh, e.a., Euspen, 2008, 2009, 2010, 2011
J. van Rij, e.a., Tribology International, 2009
J. Wesselingh, TU Delft PhD-thesis, 2011

Gen-1: Increased surface area?

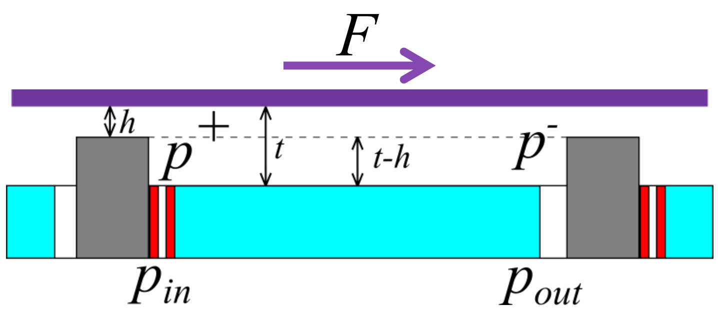


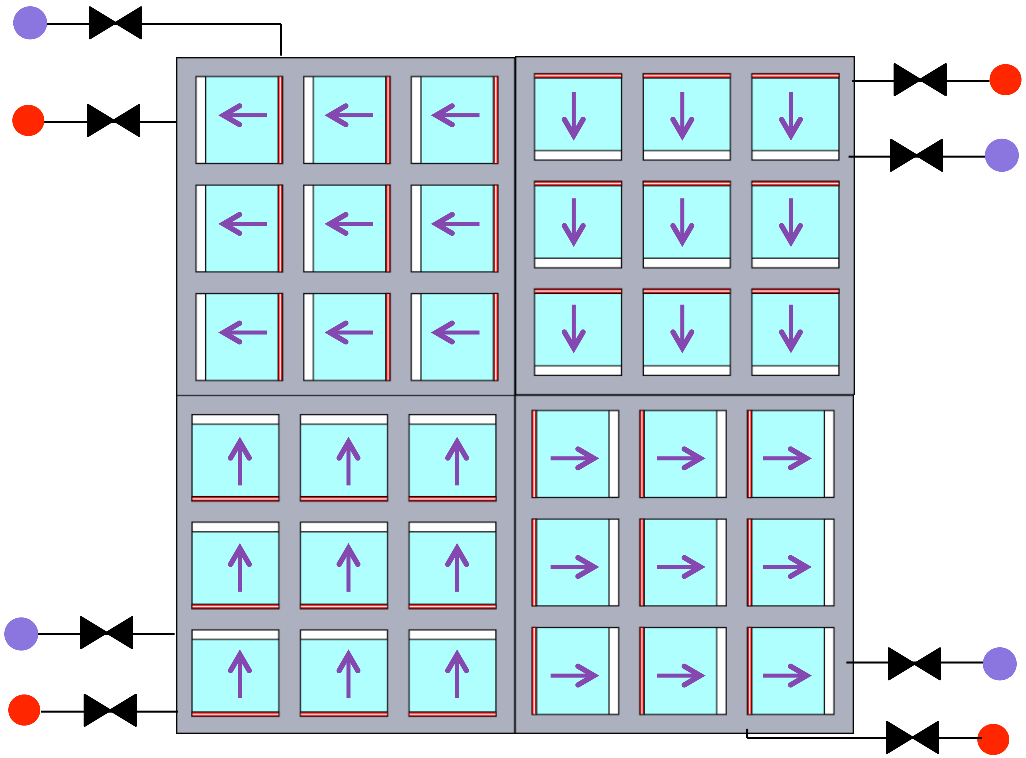


Limited number of valves controlling
large surface area:

- External placement, limiting bandwidth
- Big valves, limiting bandwidth
- Proportional valves combining high flow rate and high resolution, design challenge
- Snakes nest manifold design

Gen-1: Increased surface area?

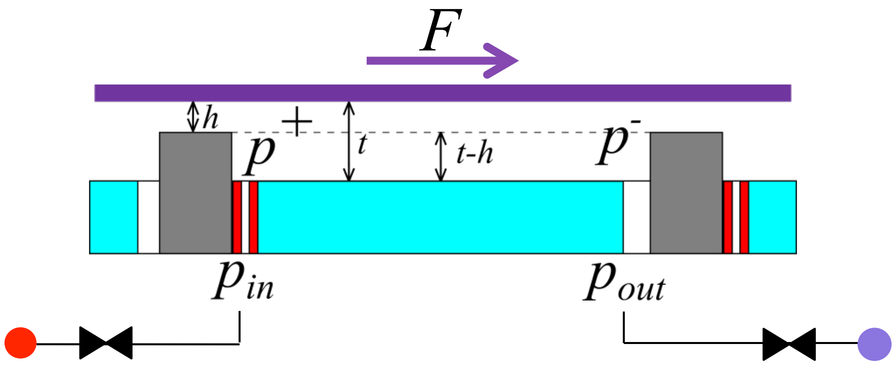




Large number of valves controlling
small surface area:

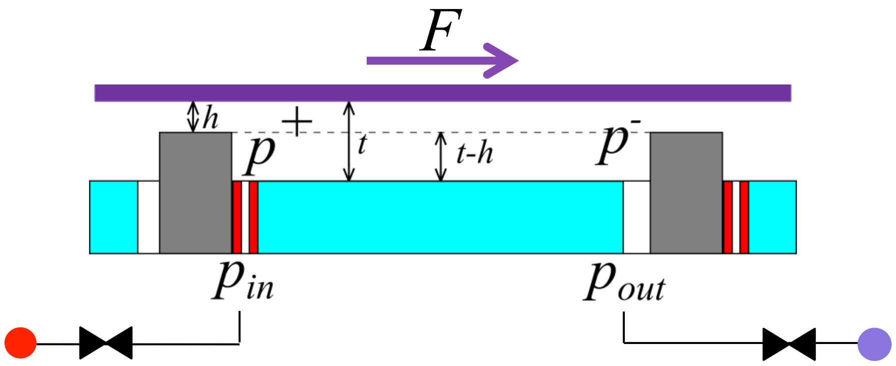
- Local, integrated valves
- On-going research..

Gen-1



$$F = \frac{(t-h)}{2}\left(p^{+} - p^{-}\right)$$

Gen-1 vs. Gen-2



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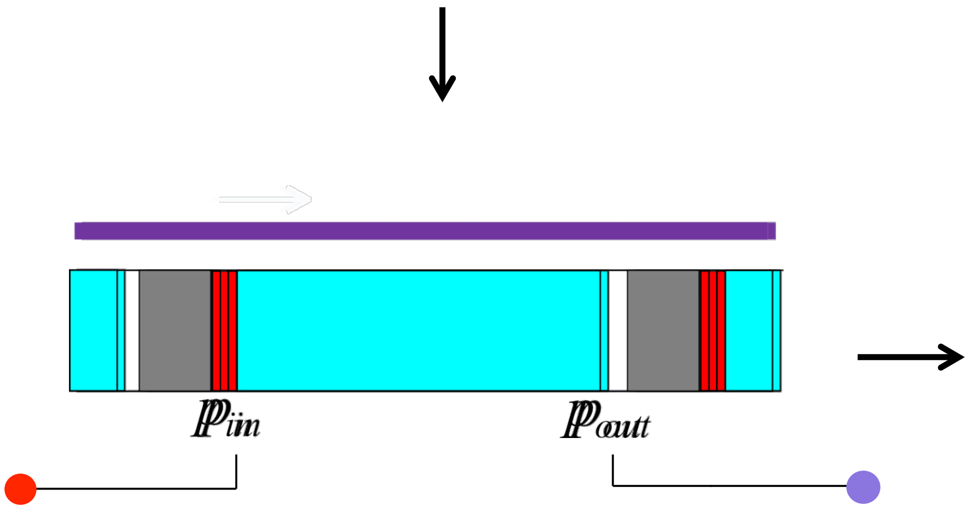
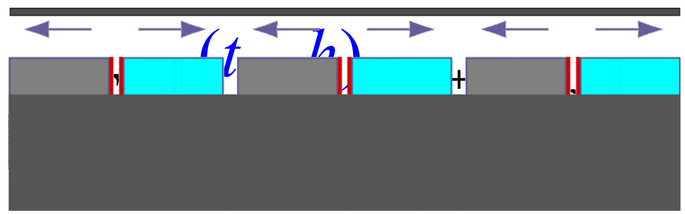
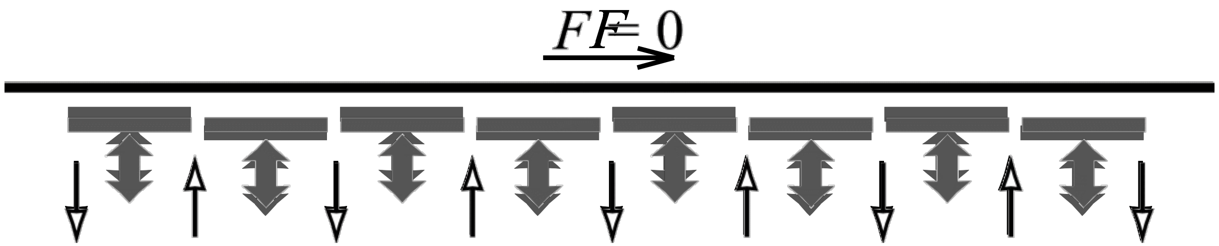


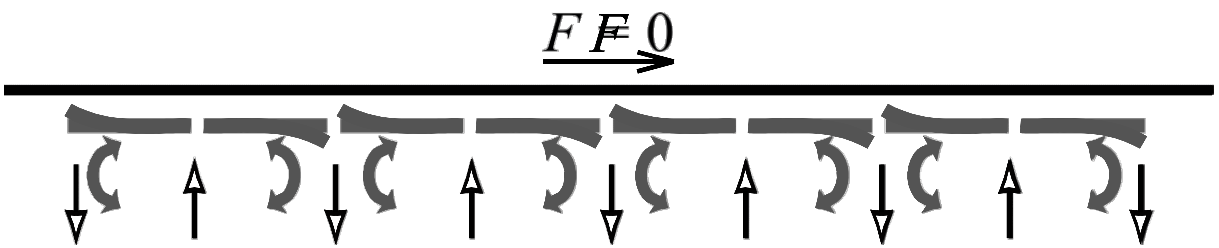


Gen-2: Different realizations

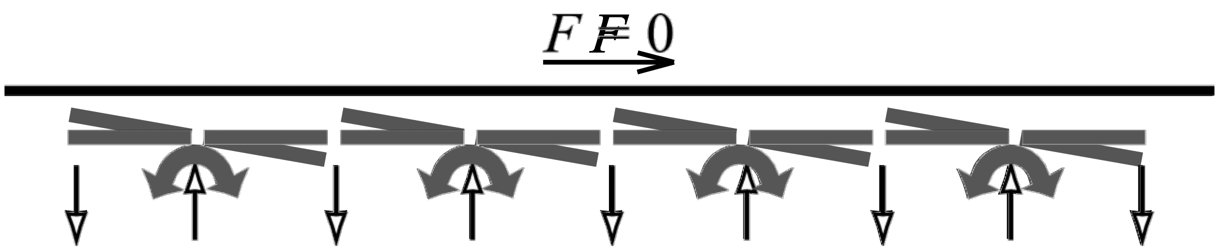
Up-down



Bending



Tilting



Gen-2: Different realizations

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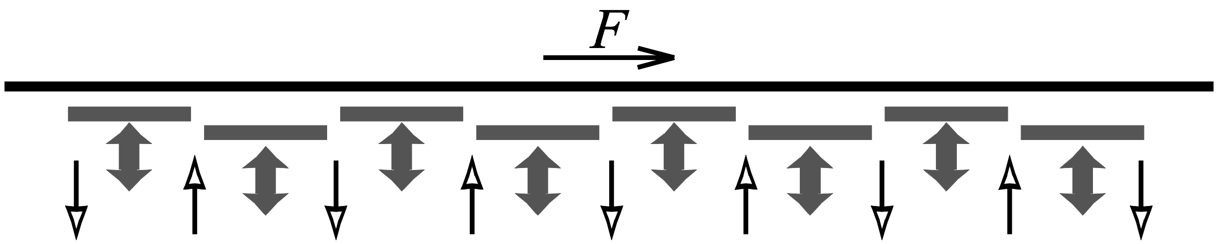

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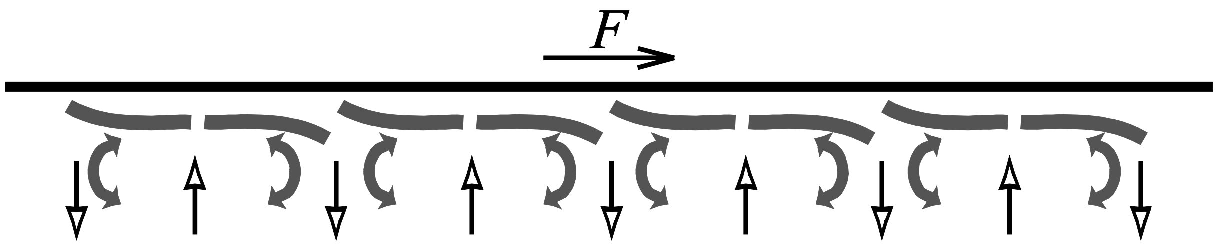

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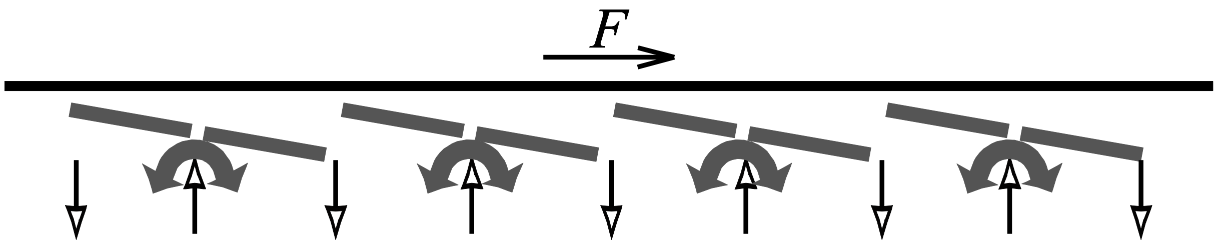
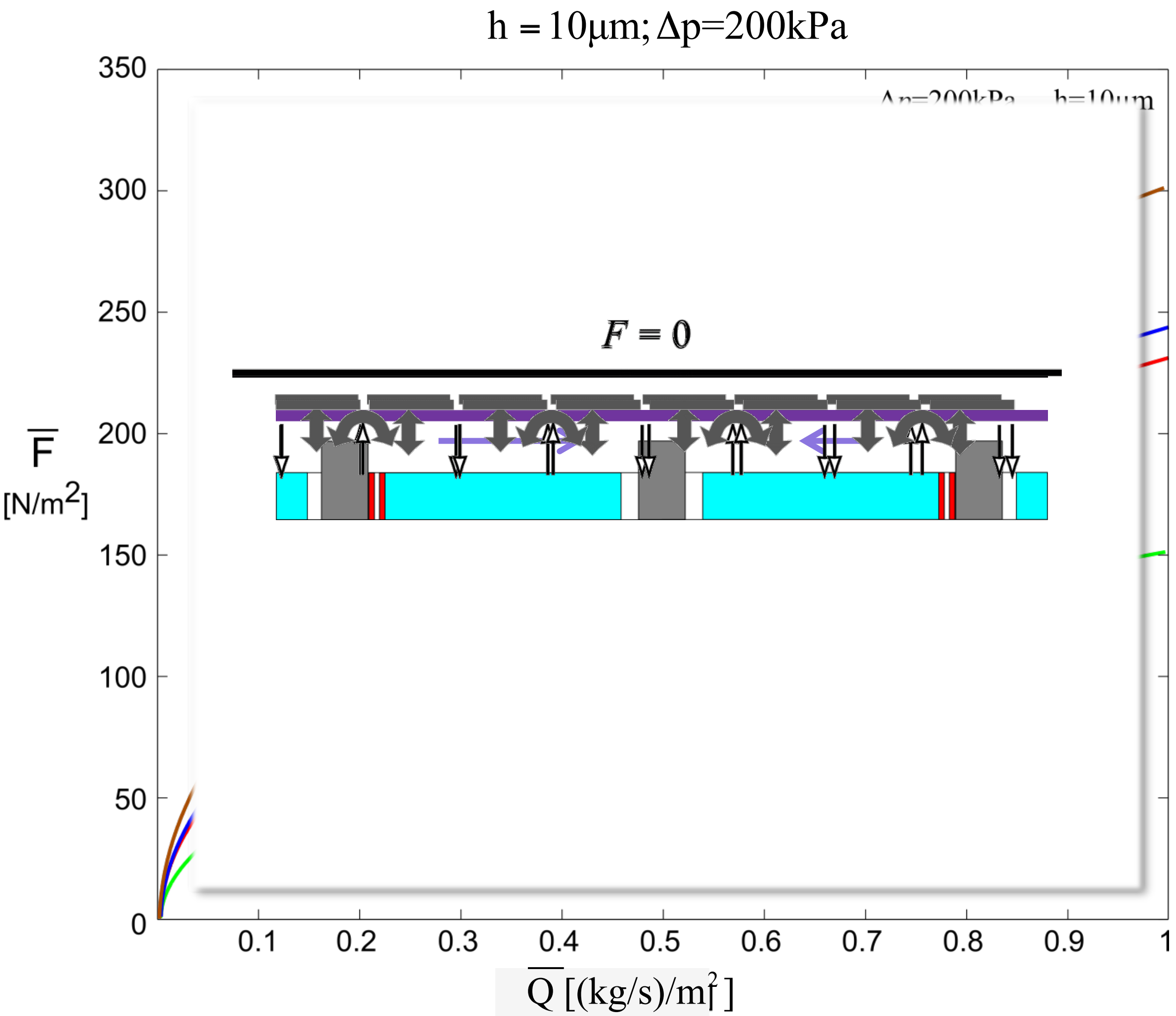
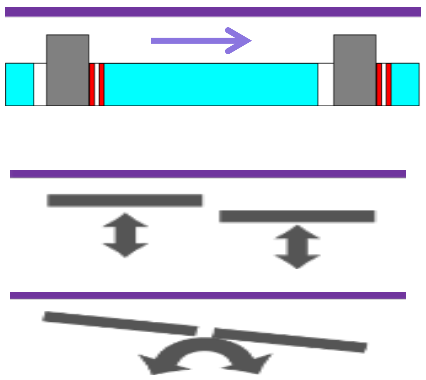


Gen-1 vs. Gen-2: Concept comparison metric

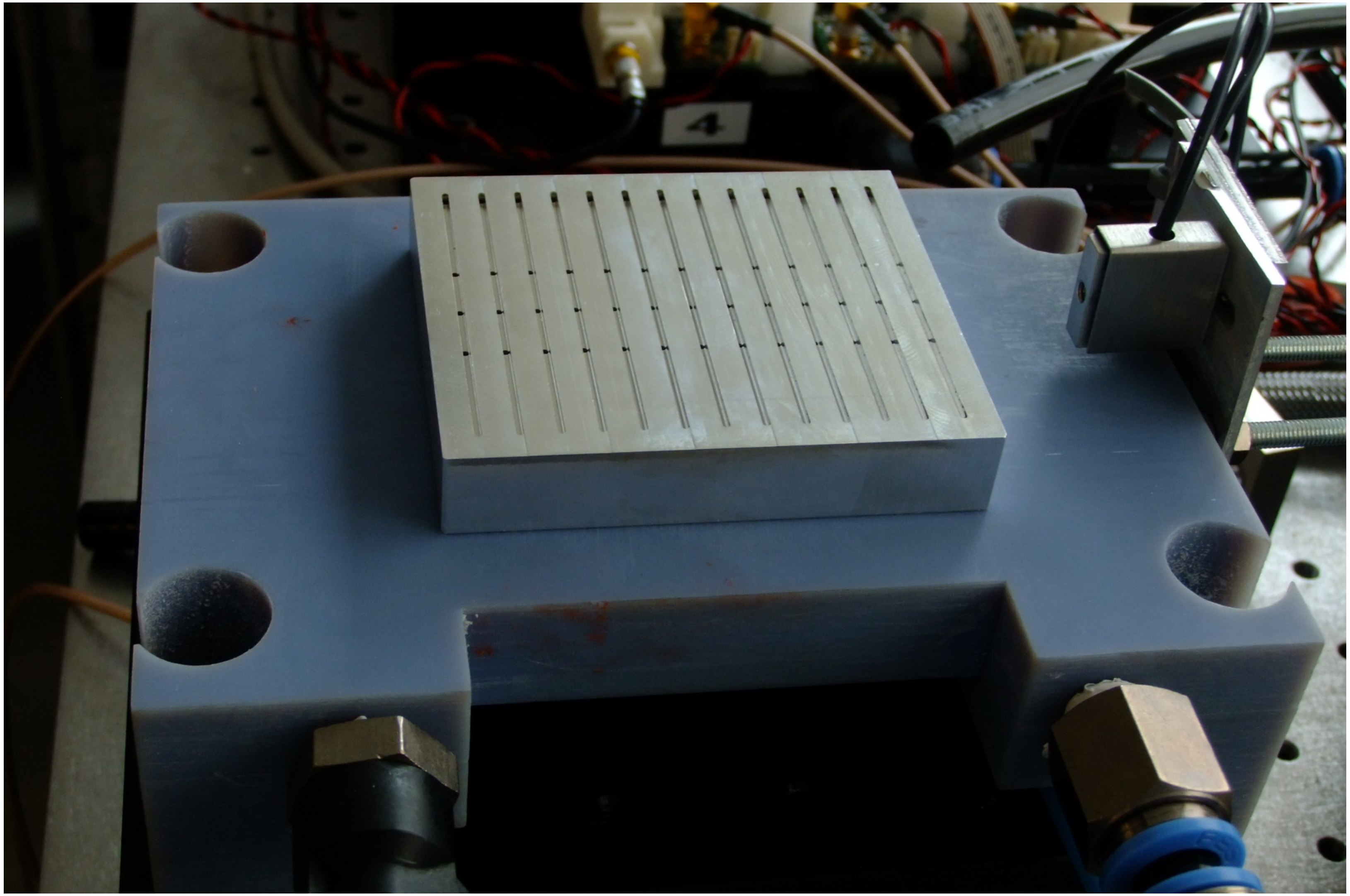
$$\frac{\text{Force density}\,[\mathrm{N/m^2}]}{\text{Flow density}\,[(\mathrm{kg/s})/\mathrm{m^2}]}$$

Traction vs. flow





Gen-2: Proof-of-concept



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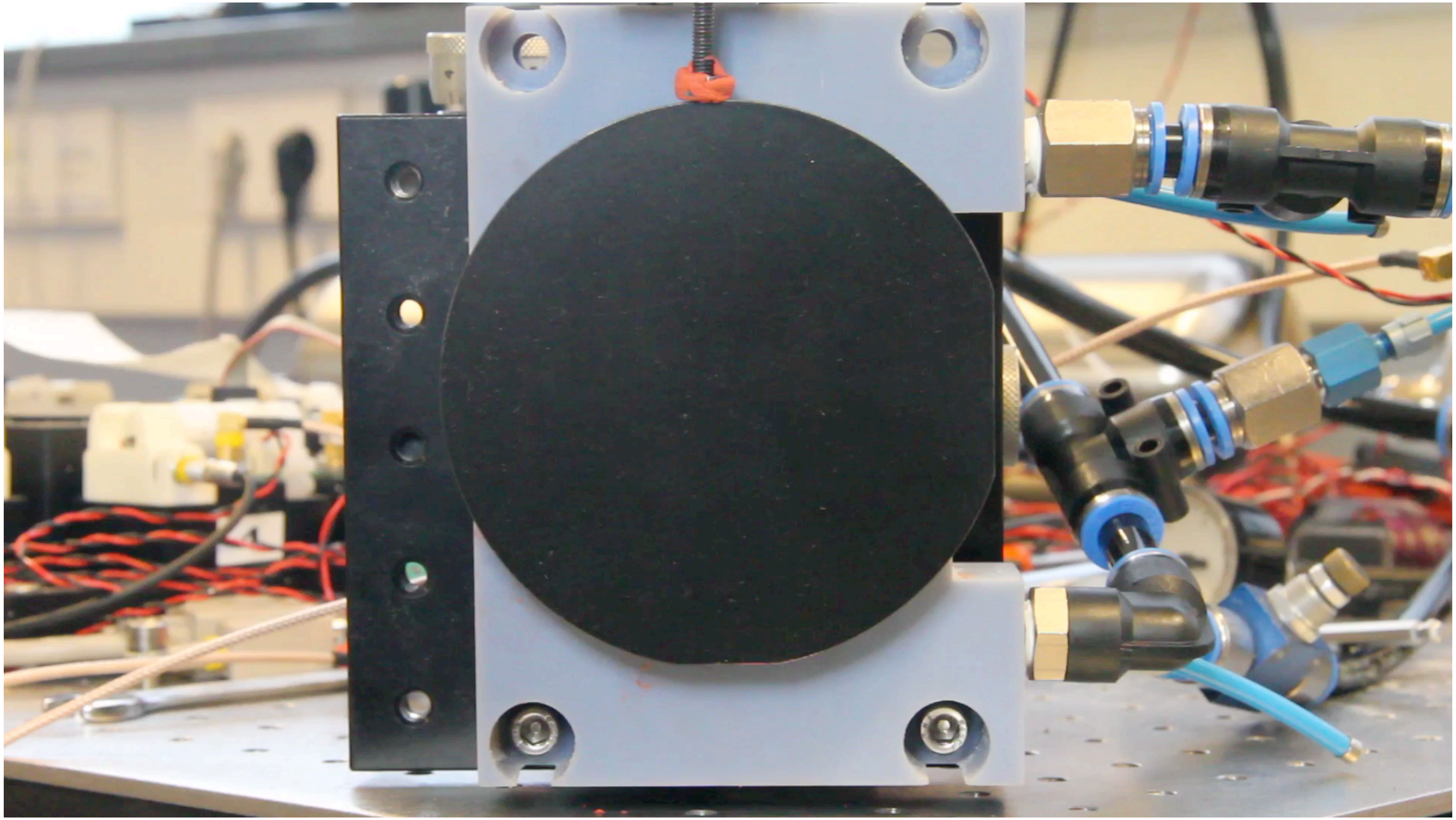
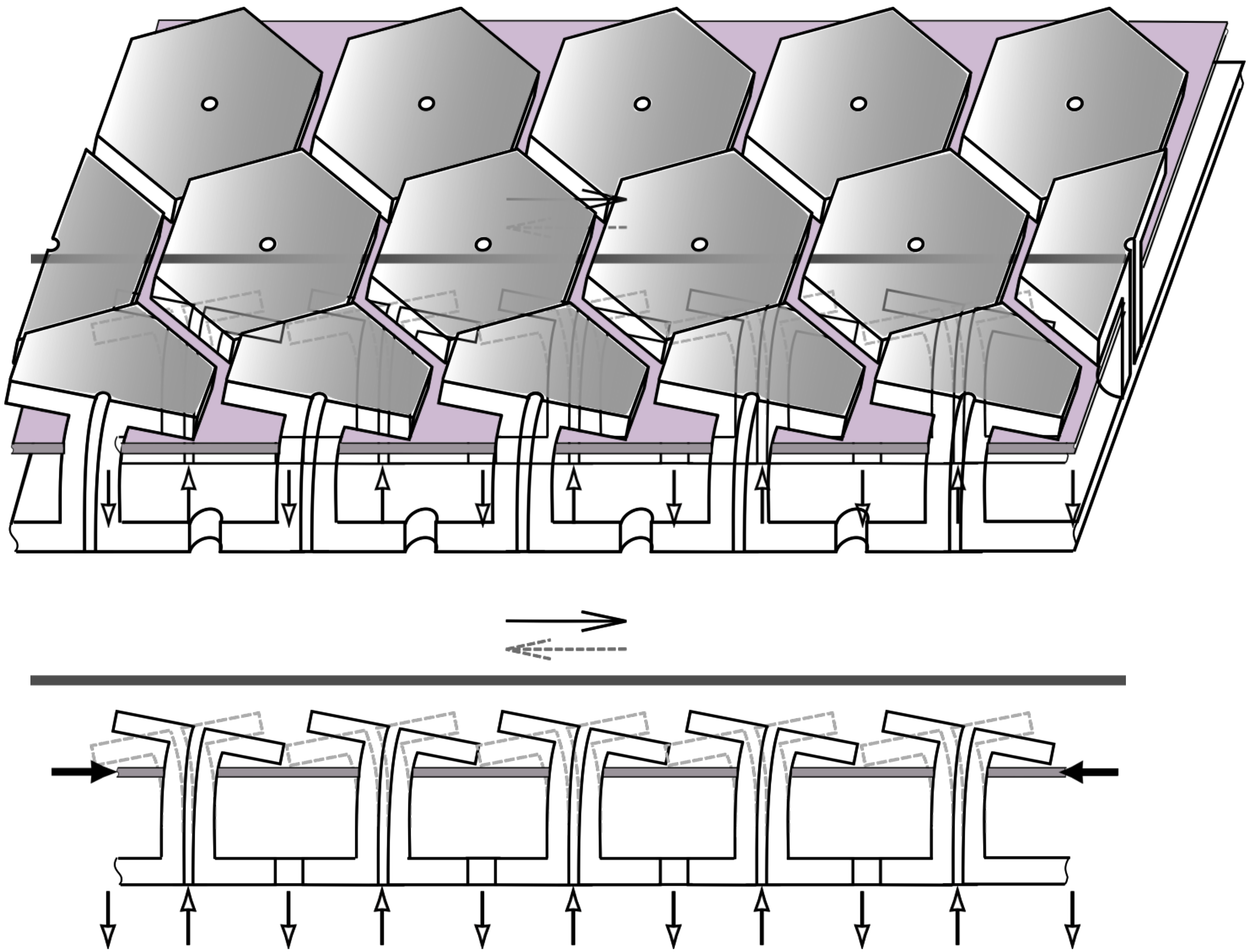
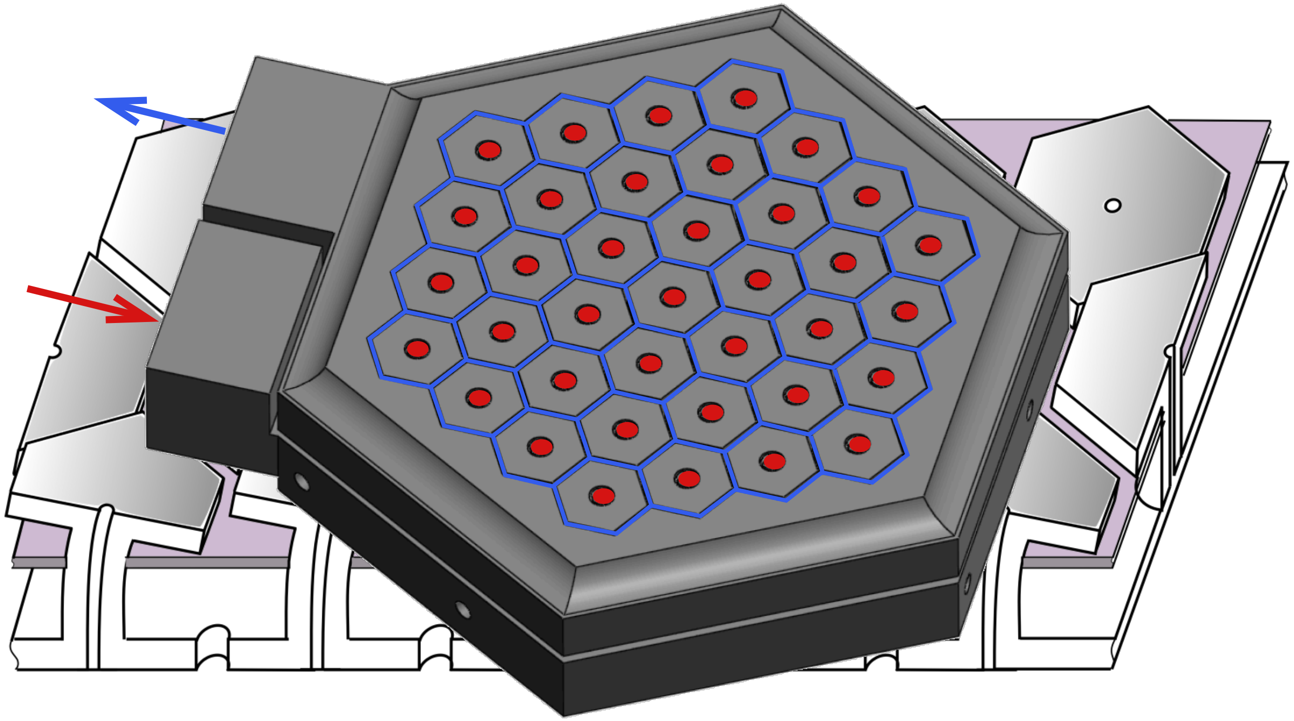


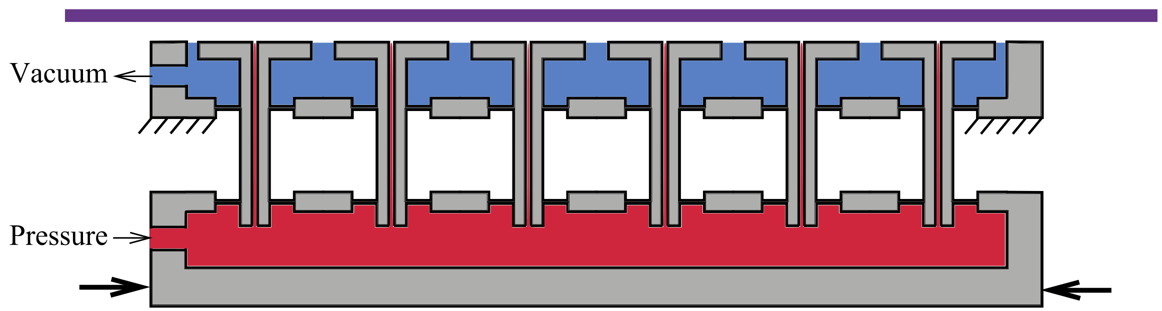
P. Vuong, e.a., ASPE Spring Topical, 2013

Gen-2: The Flower-bed

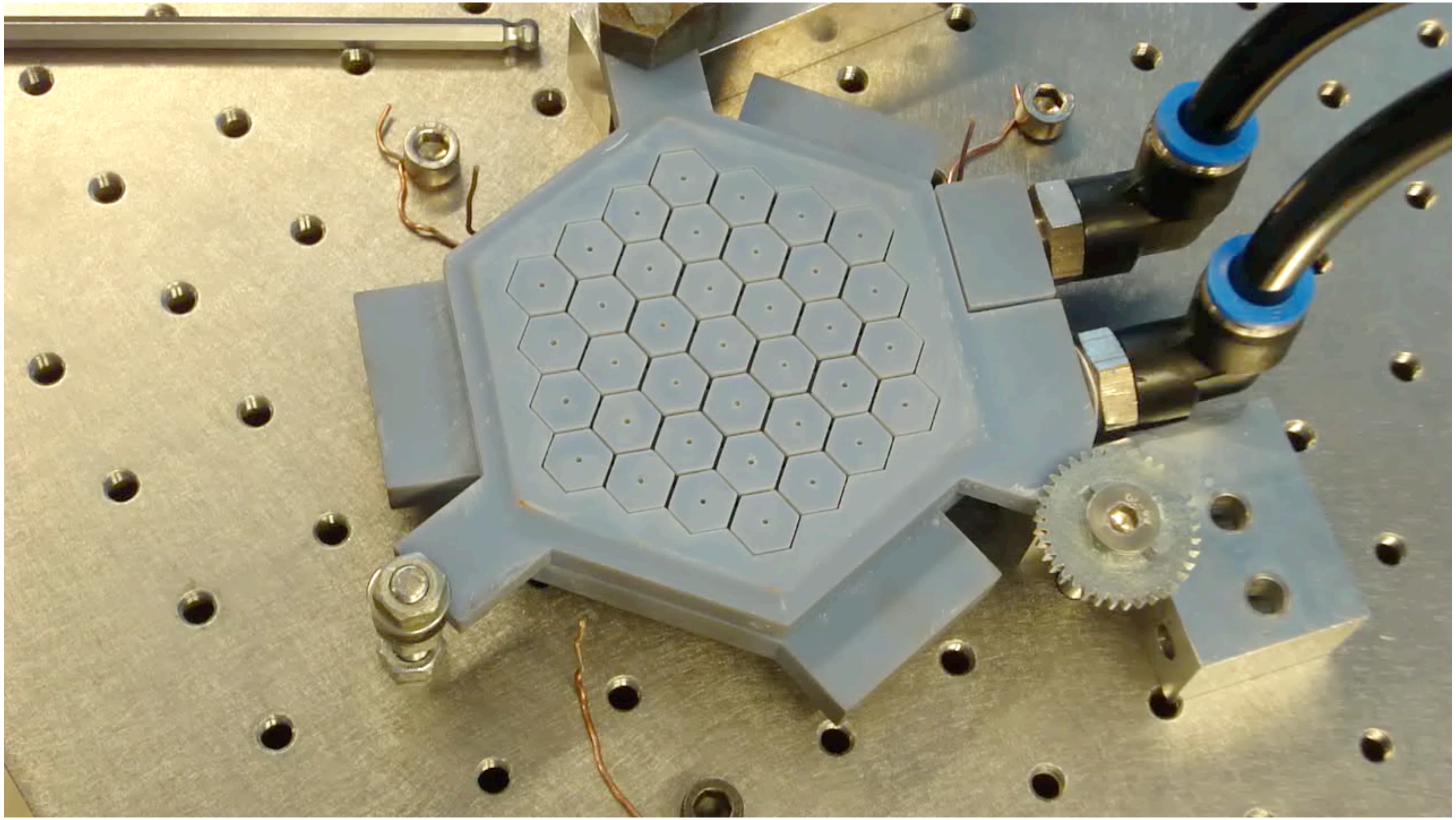


Gen-2: The Flower-Bed



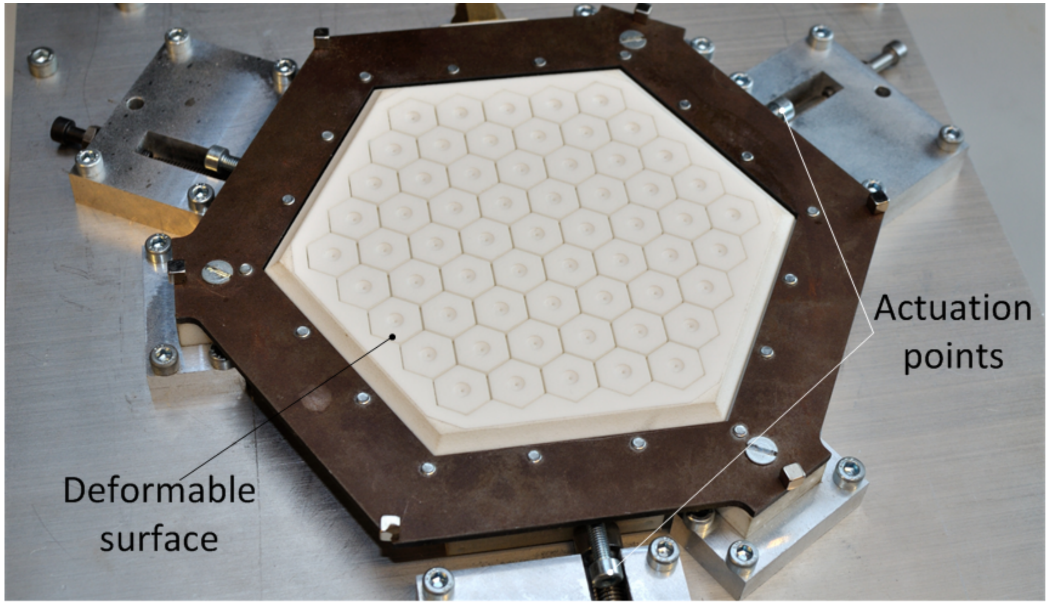


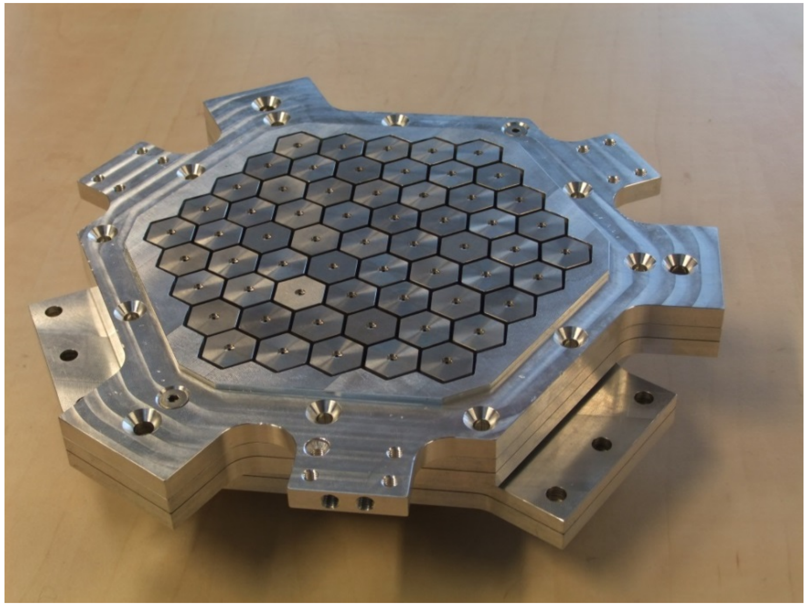
Gen-2: Flower-Bed demo 1



Gen-2: Flower-Bed demo 2, 3

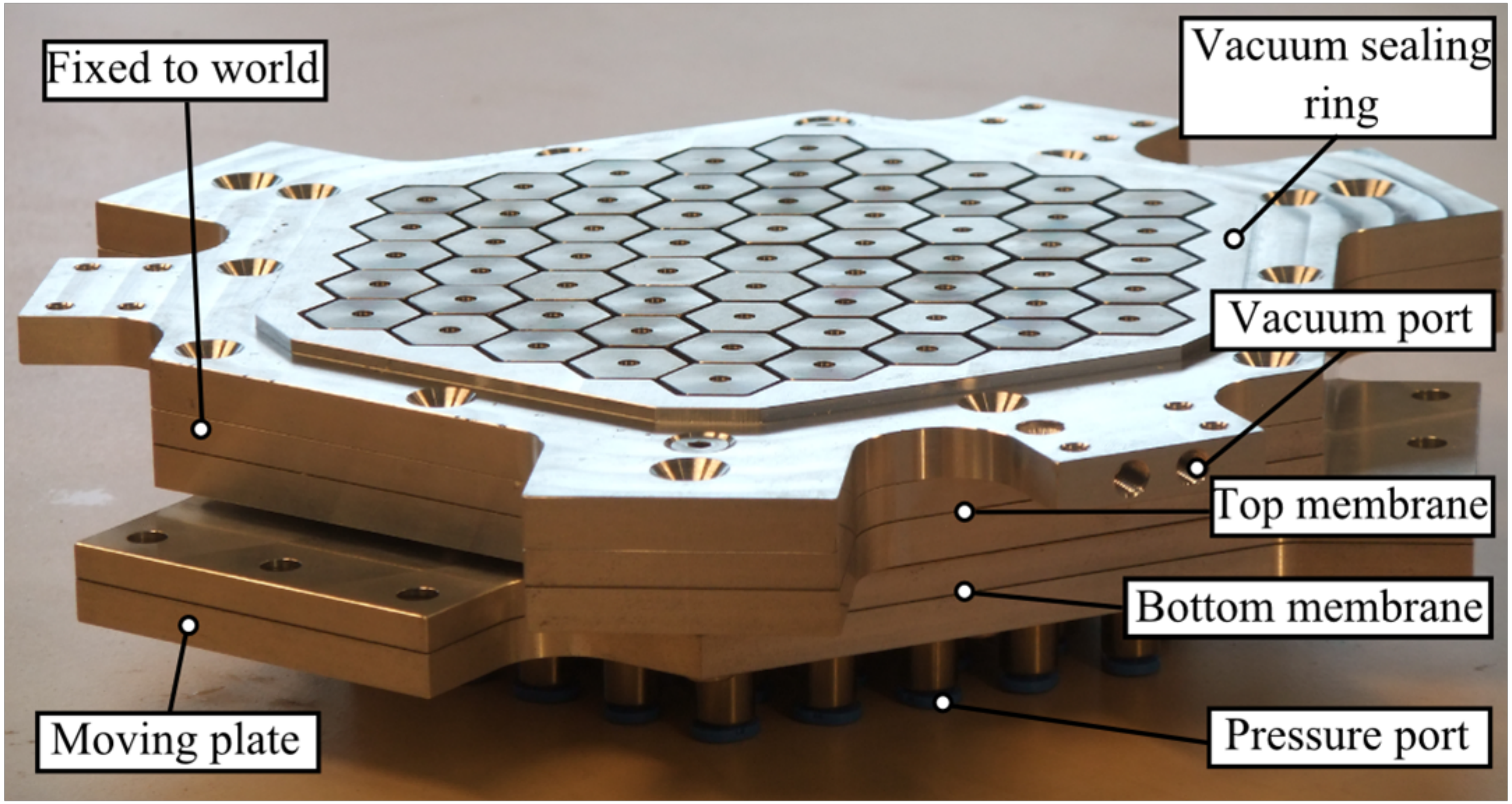
- Manufacturability improvements
- Polymer design → Metal design
  (higher accuracy, higher performance)





P. Vuong, et al., EUSPEN, 2014.
P. Vuong, TU Delft PhD-thesis, 2016

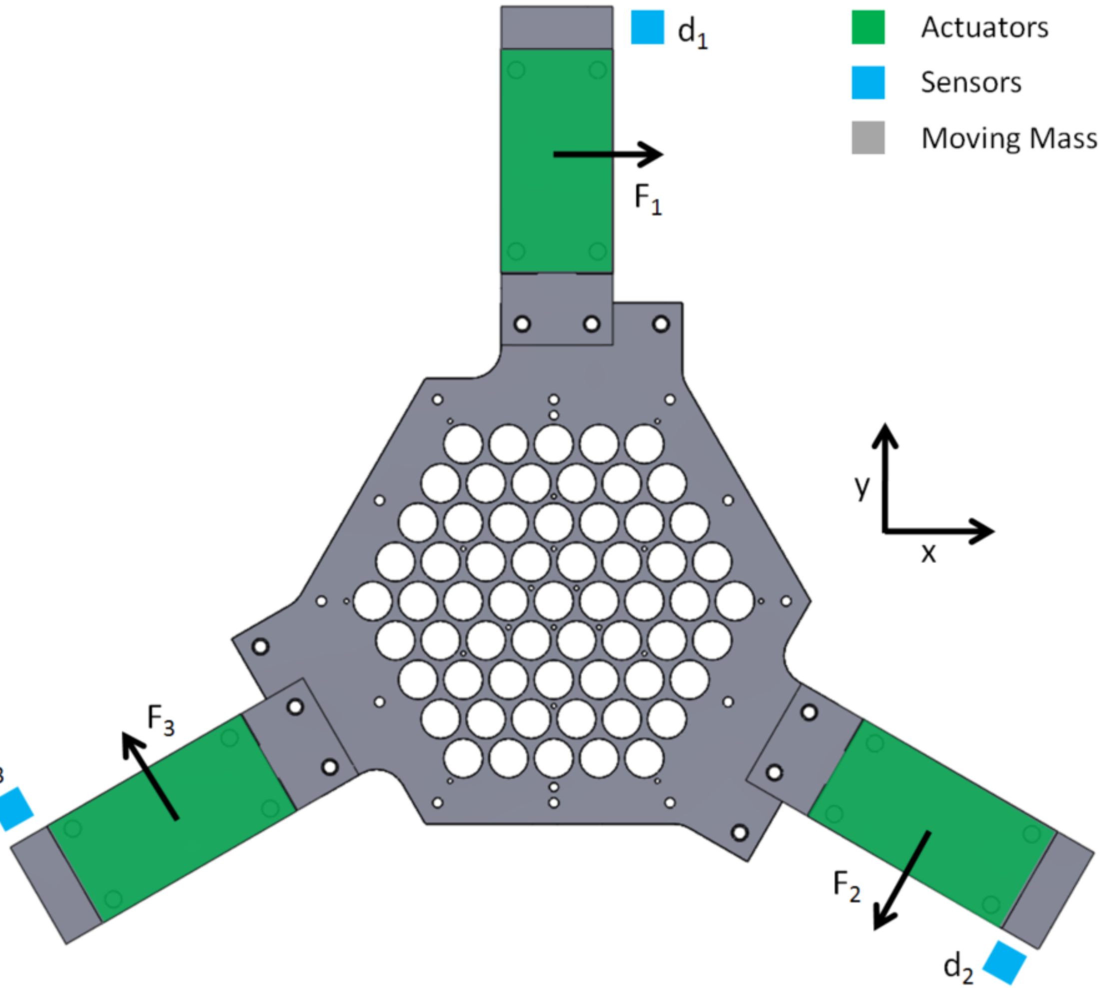
Gen-2: Flower-Bed demo 3



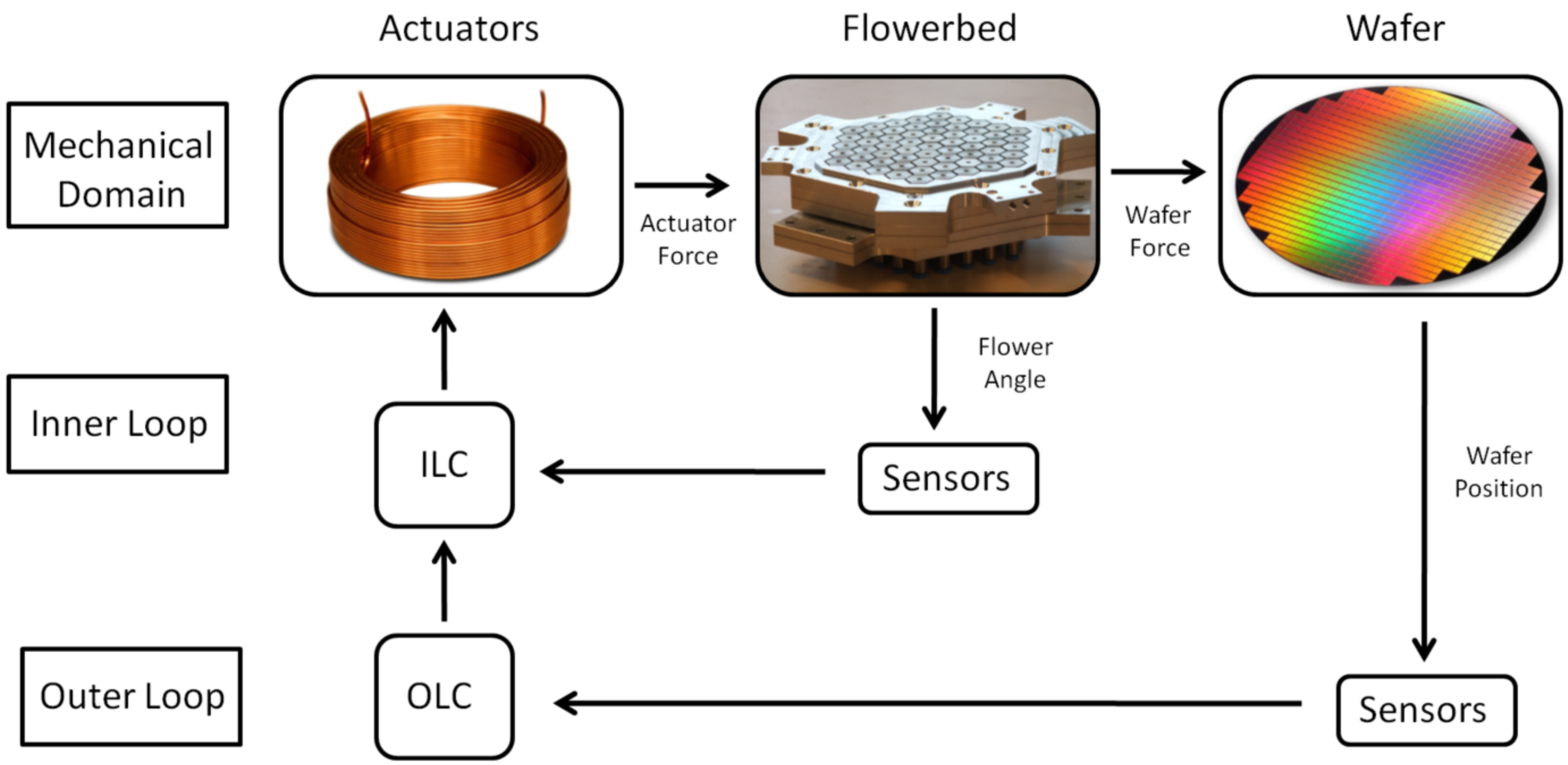
Gen-2: Flower-Bed demo 3

https://www.youtube.com/watch?v=Sl0hHmhfxFc

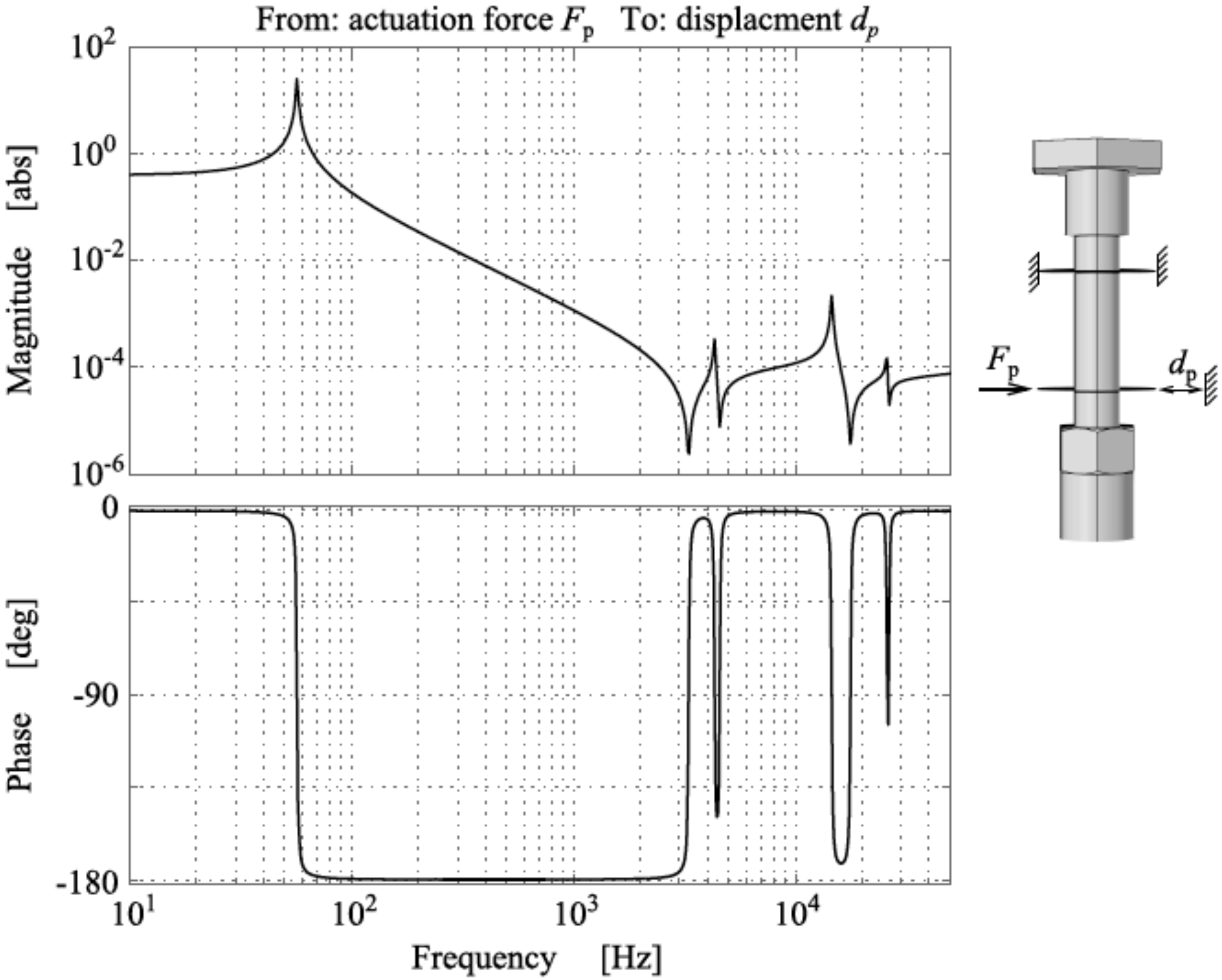
Gen-2: Flower-Bed actuation



Gen-2: Flower-Bed control design



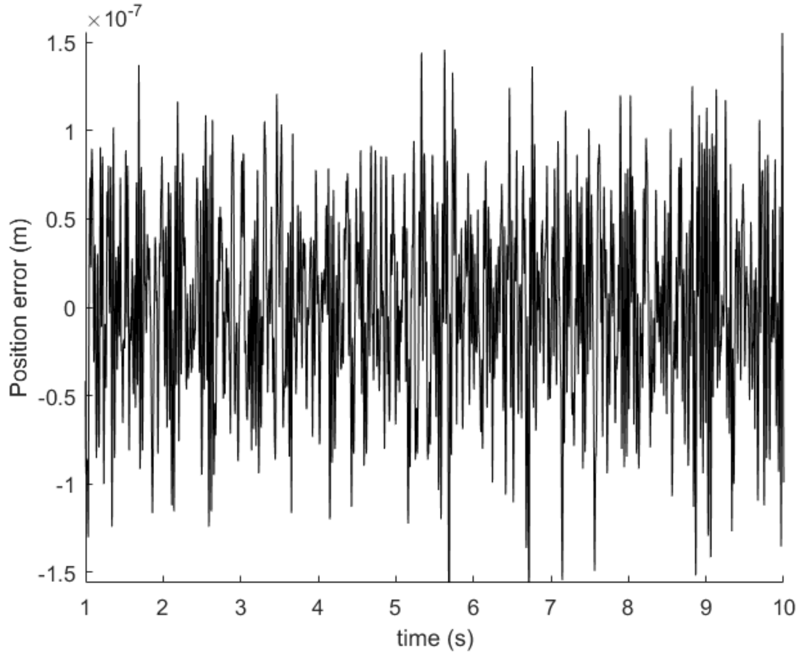
Gen-2: Expected performance



Gen-2: Actual performance

- Positioning BW: 60 Hz
- Positioning error: 50nm RMS

- Performance limitations:
  - **Actuator mass**
  - External vibrations
  - Pressure noise
  - **Sensor noise**



Recommendations

- Get closer to theoretical Flower-Bed performance:
  - Improve sensor
  - Improve actuation
- Improve Gen-2 design: Manufacturability
- Improve Gen-1 design: Micro-pneumatics
- Gen-3: Mixed control
- From positioning to transport
- Killer application (industrial partners)

Conclusion

- Validated the mathematical model of the viscous traction concept
- Determined the performance limit curves for different realizations, both Gen-1 and Gen-2
- Performed design and preliminary tests of both Gen-1 and Gen-2 designs
- Defined future research and development

Thank you