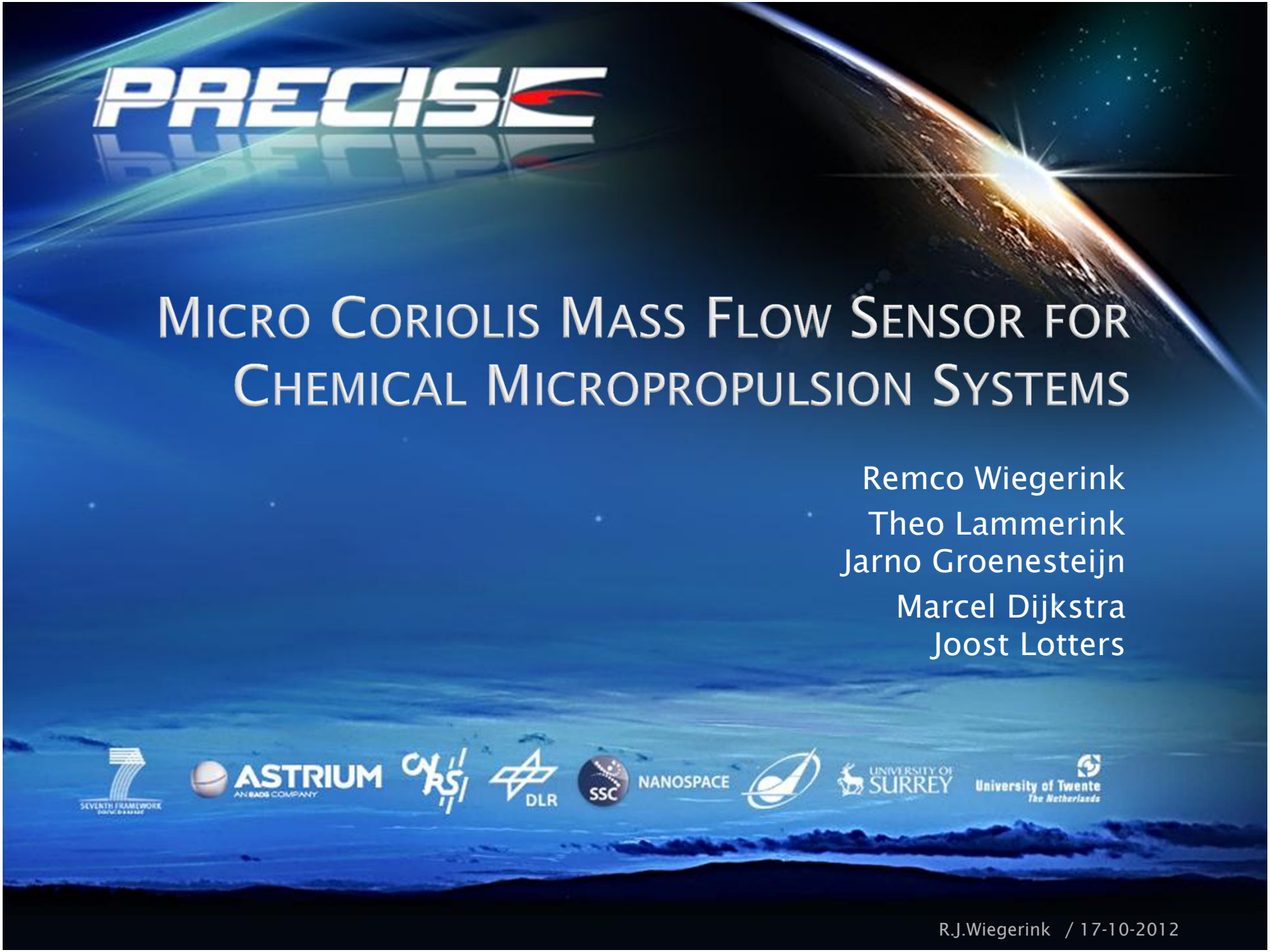
PRECISE
MICRO CORIOLIS MASS FLOW SENSOR FOR CHEMICAL MICROPROPULSION SYSTEMS
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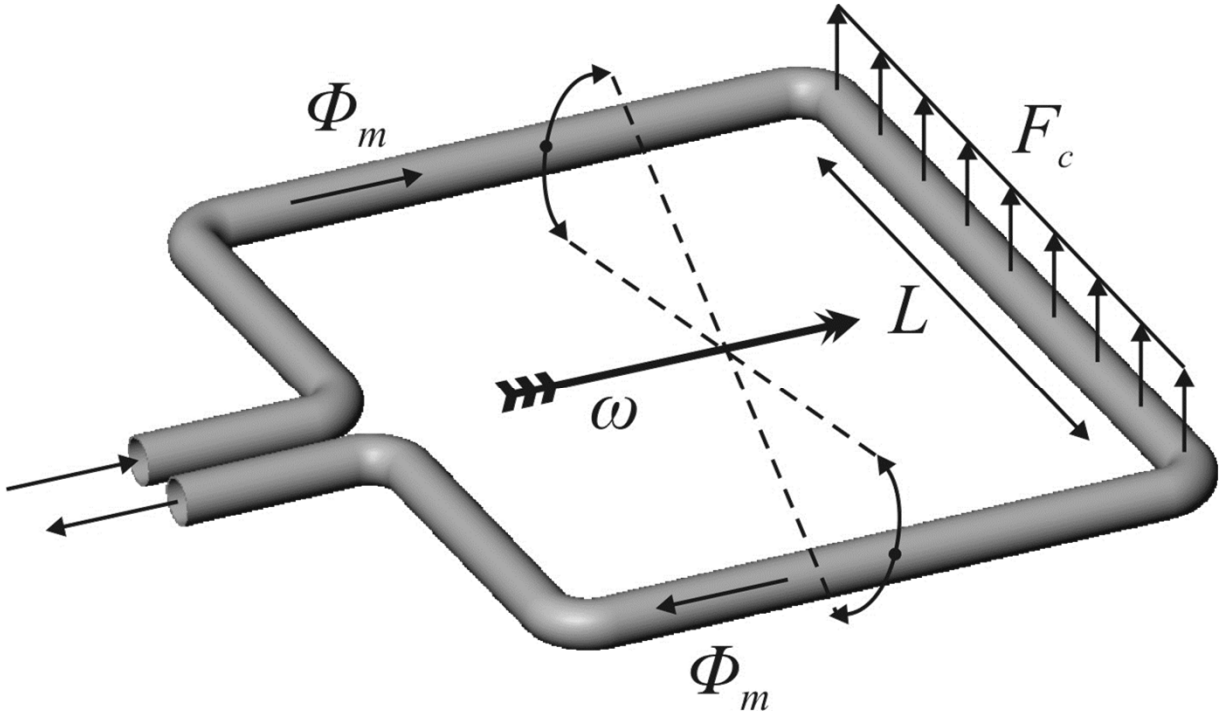
Contents

- Operating principe
- Previous work / background
- Current status
- Fabrication process
- Characterisation results
- Towards hydrazine flow measurement
- Conclusions

Sensor structure and basic operating principle



$$\vec{F}_c = -2L \cdot \vec{\omega} \times \vec{M}_f$$

Why micro-Coriolis?

- Advantages:

Independent of:

- flow profile
- temperature
- pressure
- density
- viscosity
- homogeneity

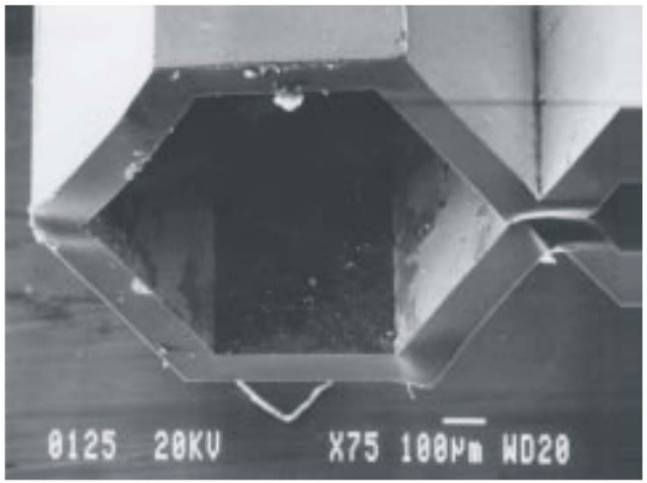
Less external mechanical influences due to low system mass / high resonance frequency

- Disadvantages:

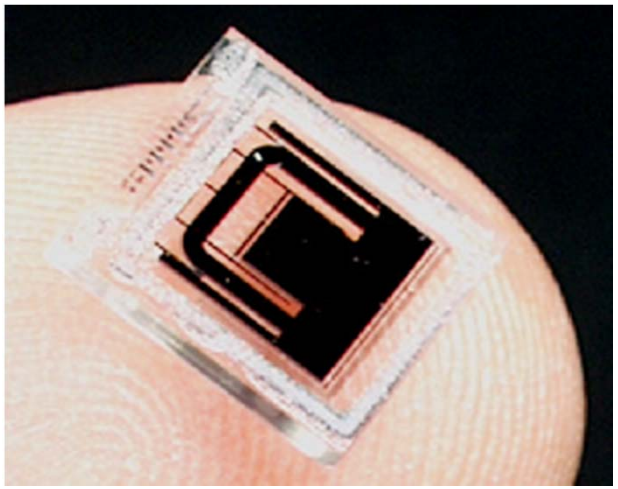
Higher stiffness + lower mass flow → lower signal
High manufacturing accuracy necessary

Previous work

- Worldwide 2 other groups active in the 'MicroCoriolis' field:
  - Enoksson, using silicon bulk micromachining and wafer bonding
  - ISSYS, using various bulk and surface micromachining techniques resulting in highly boron doped silicon tube walls



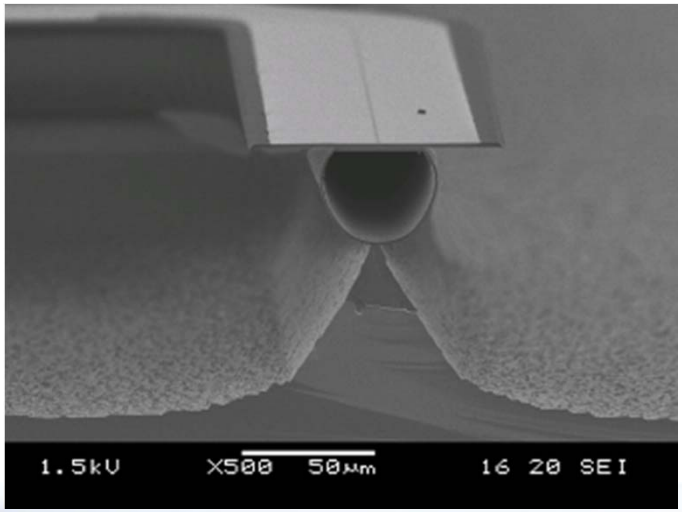
Silicon tube by Enoksson et al

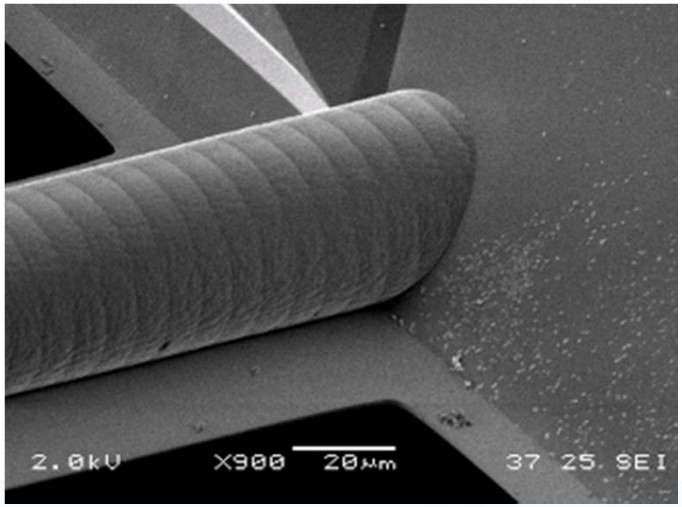


ISSYS sensor

Our approach

- Use LPCVD silicon nitride tube walls
  - Thin (1.2 um) but strong walls
  - Inert material
- Research started in 2006 within the MicroNed programme
- Continued in PIDON-HTF, NanoNextNL and PRECISE





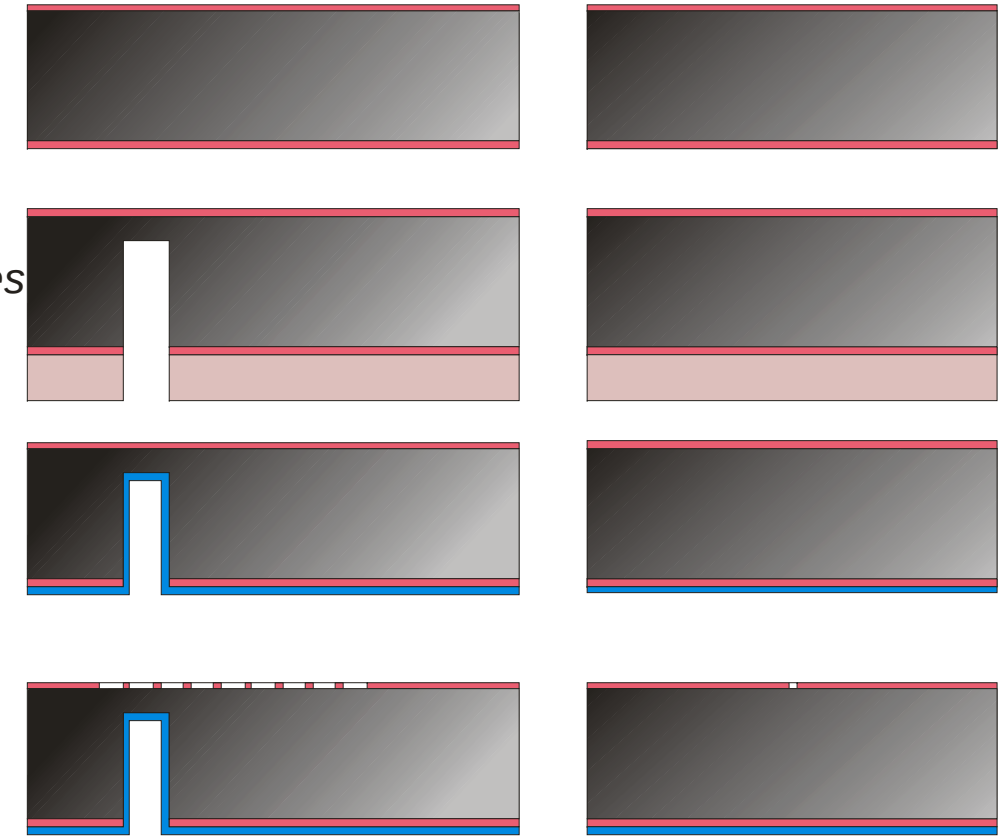
Process flow

deposit 500 nm SiRN

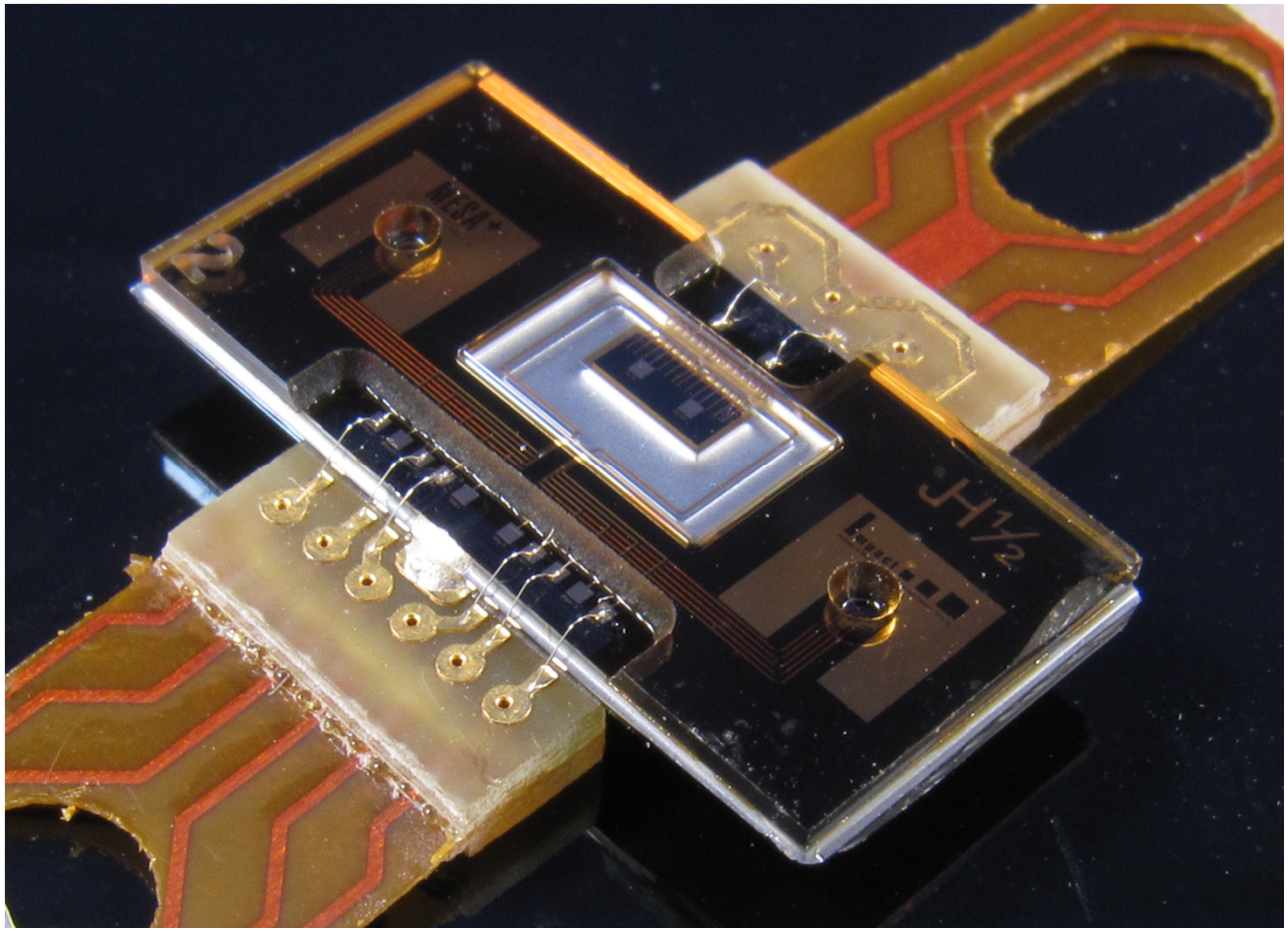
Etch back access holes

deposit 500 nm TEOS
remove from frontside

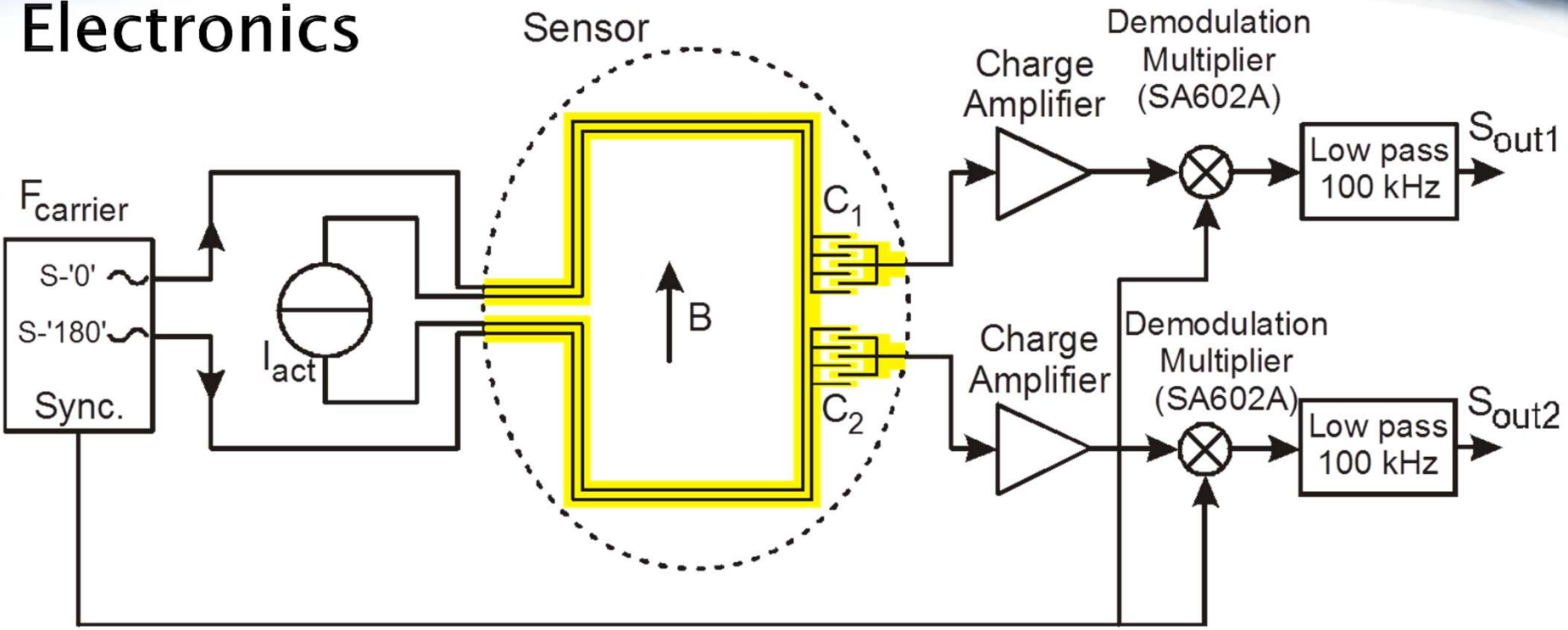
Pattern SiRN

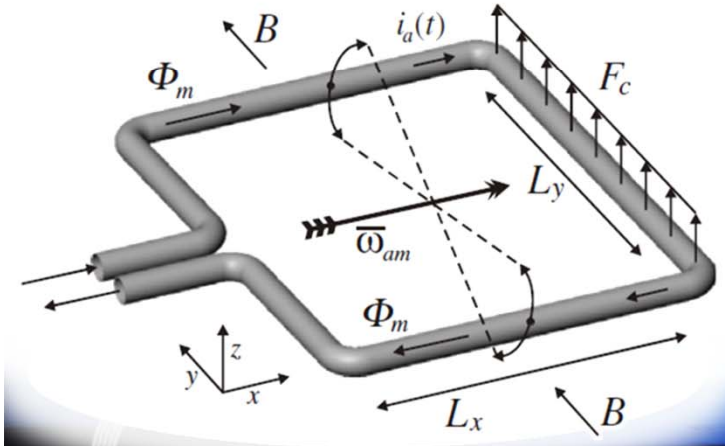


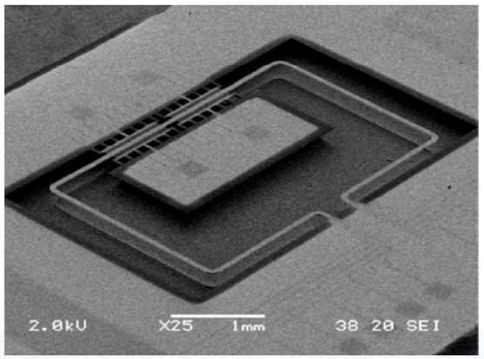
Current status

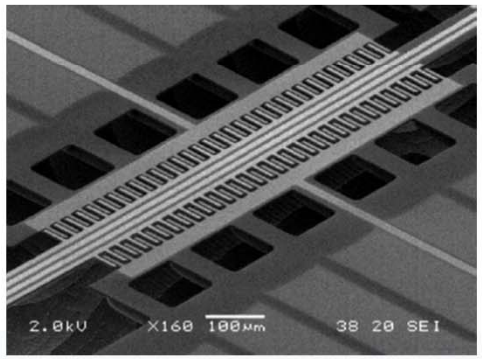


Electronics

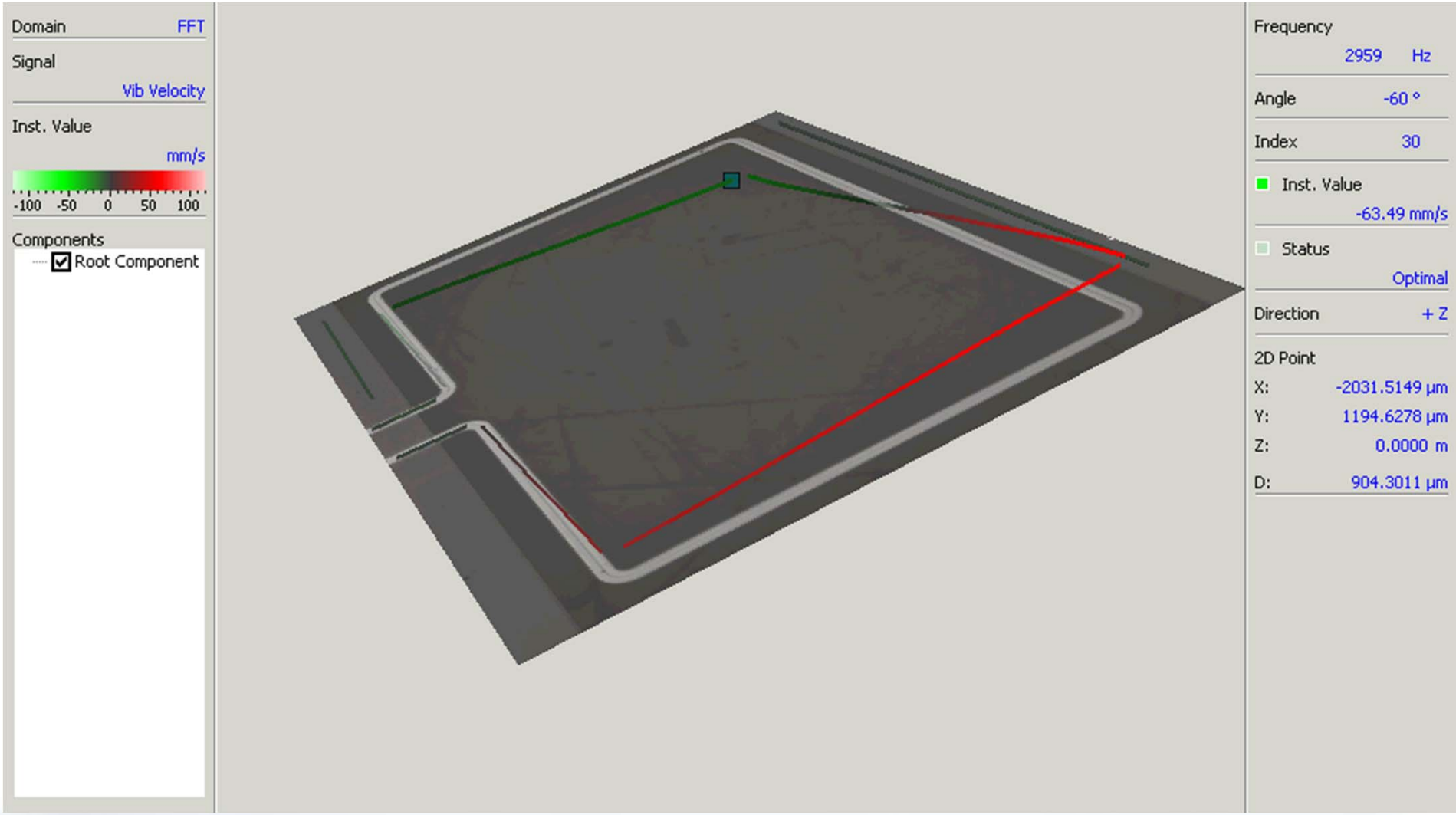


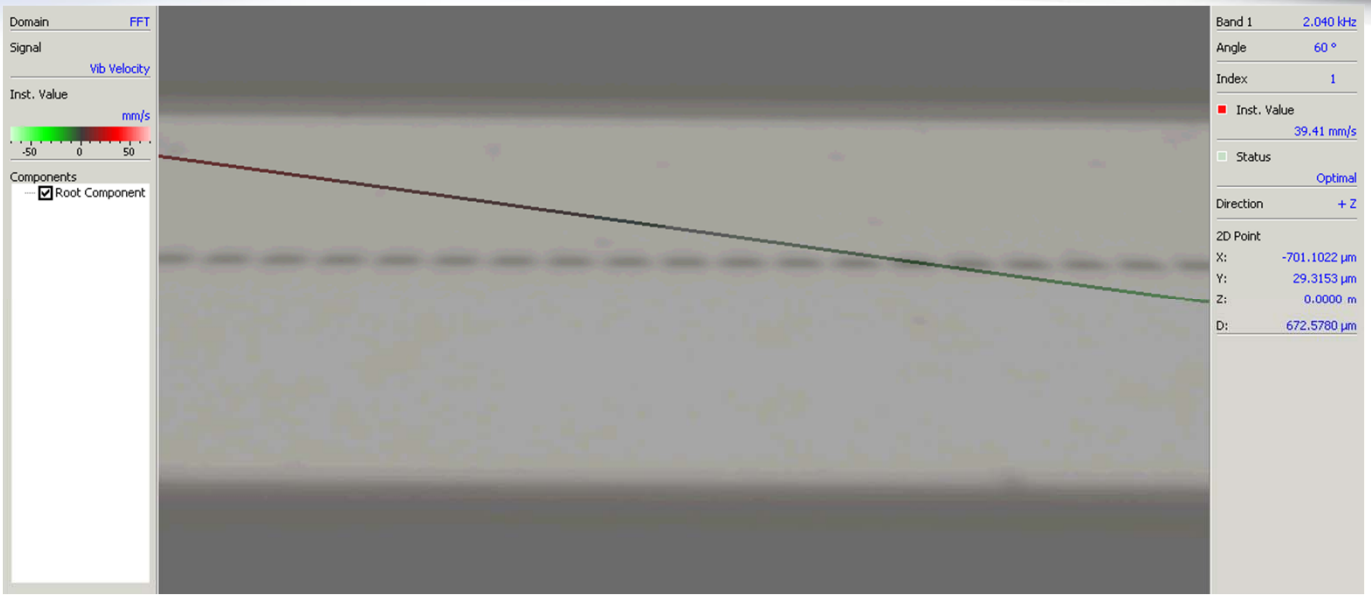




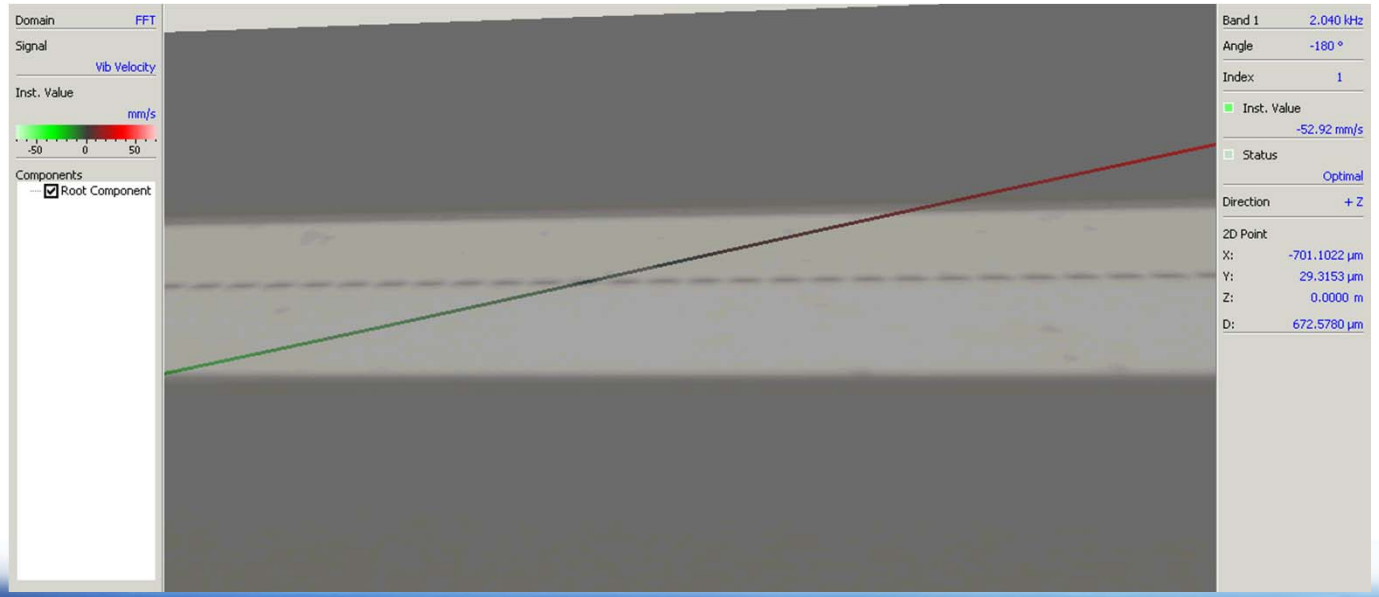


Vibrometer measurements



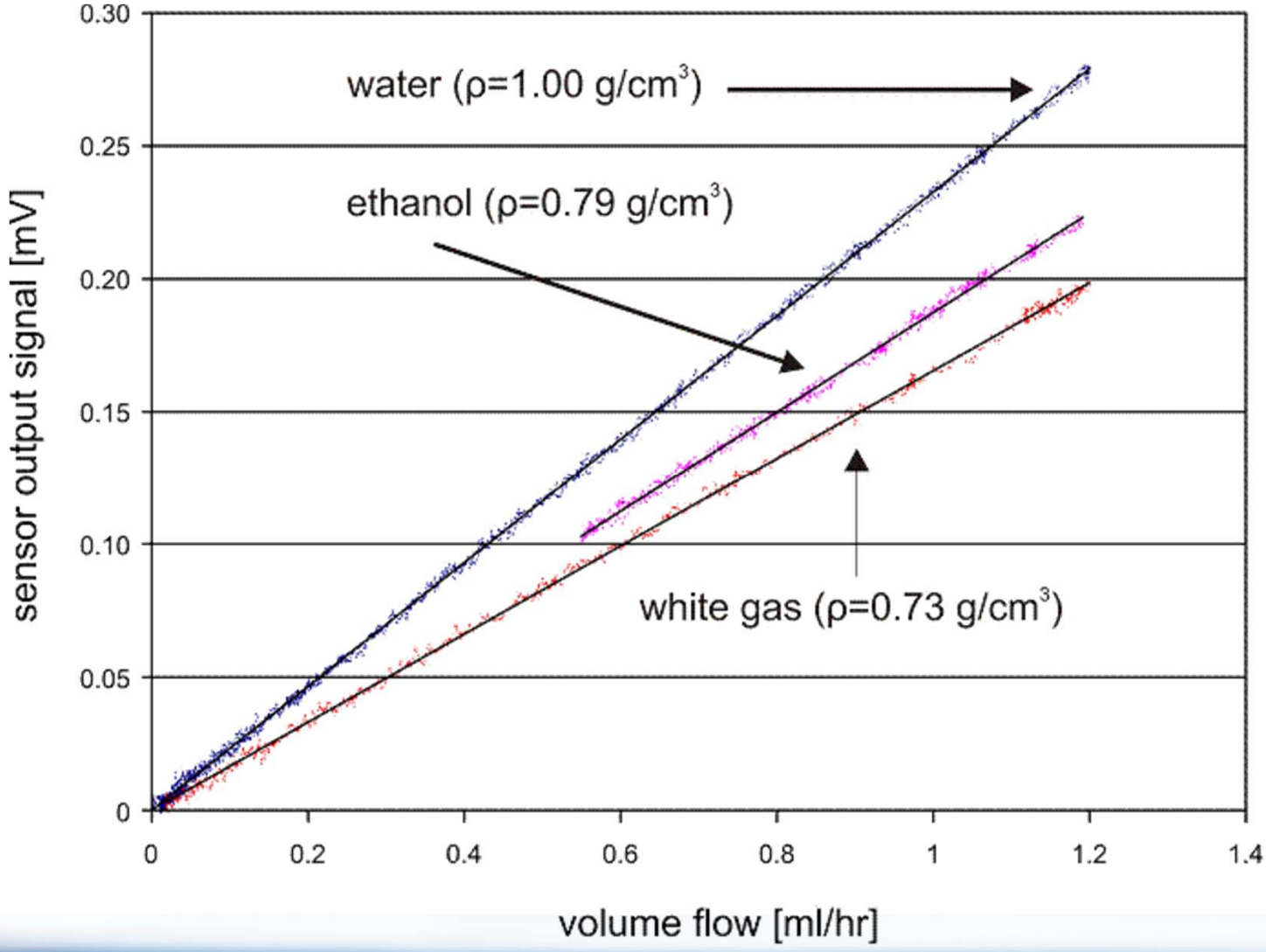


No flow

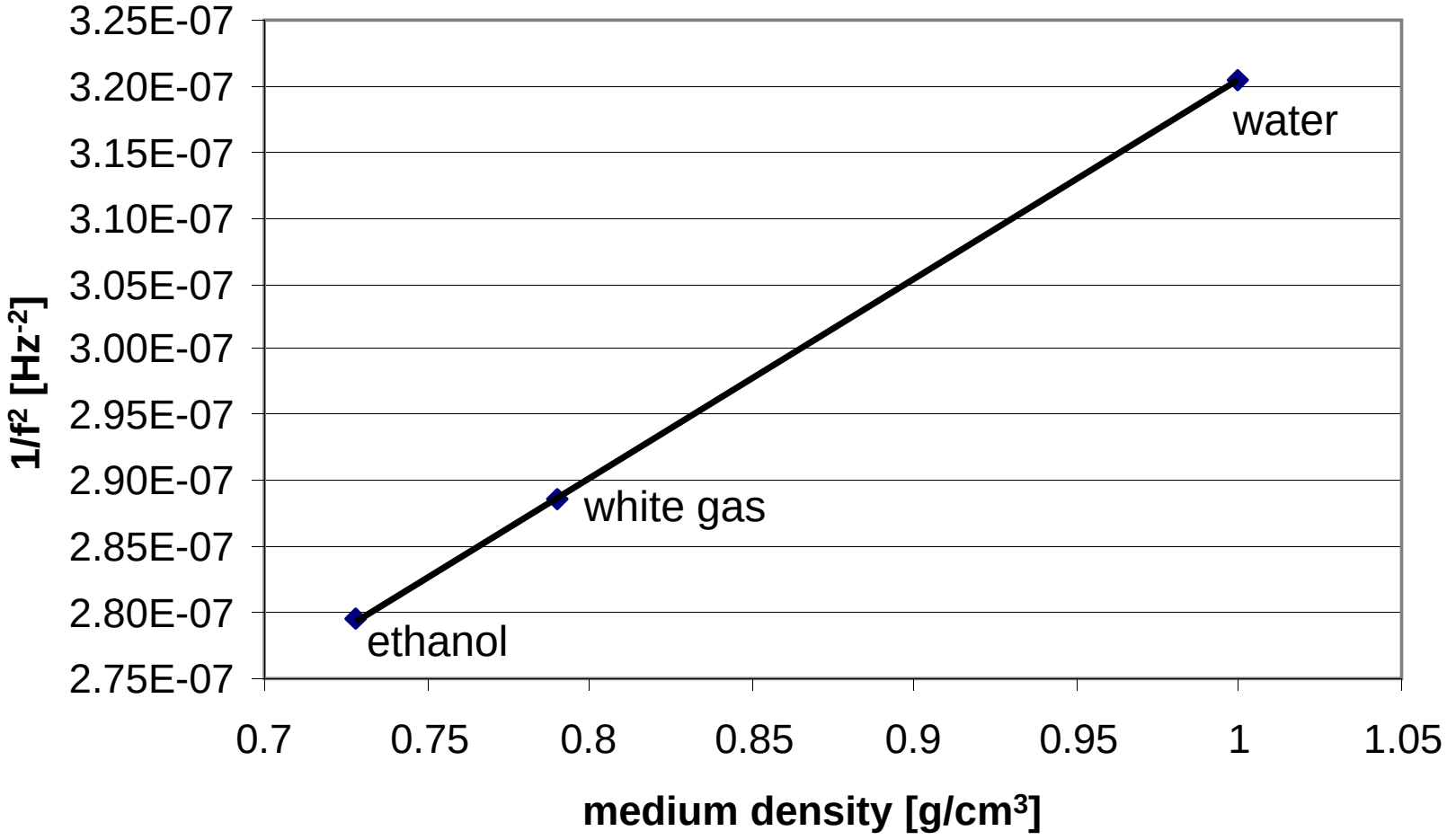


Max. flow

Mass flow measurements



Density measurements

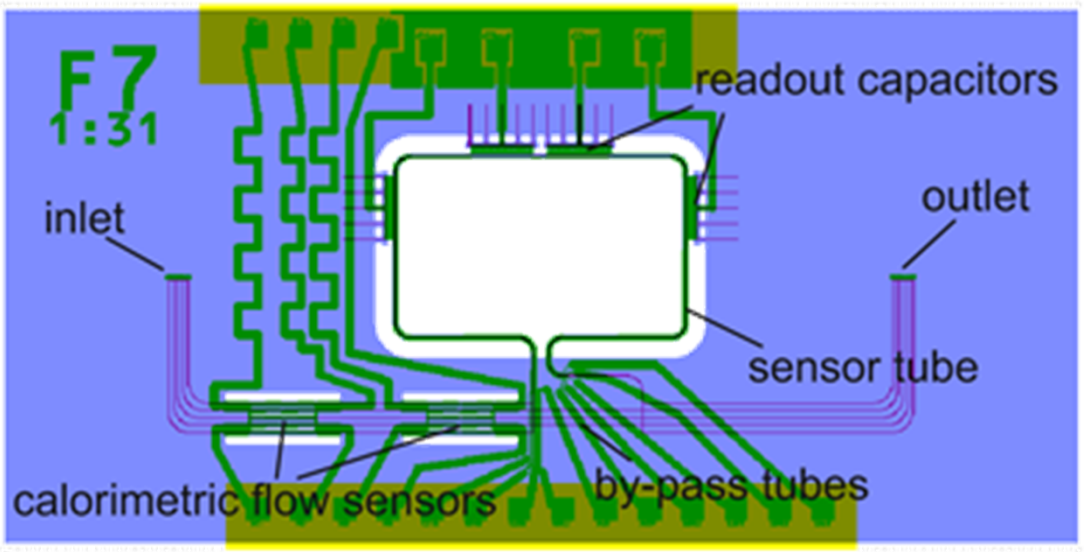


Towards hydrazine flow measurement

- Required full-scale mass flow 6 mg/s per thruster
- 24 mg/s for 4 thrusters
- Existing sensor has full-scale range of 0.3 mg/s
- We need to increase the flow range by a factor 20

New design uses on-chip by-pass channel

- Ratios ranging from 20 to 100 have been designed
- Designs with lowest sensitivity suitable for 4 thrusters together



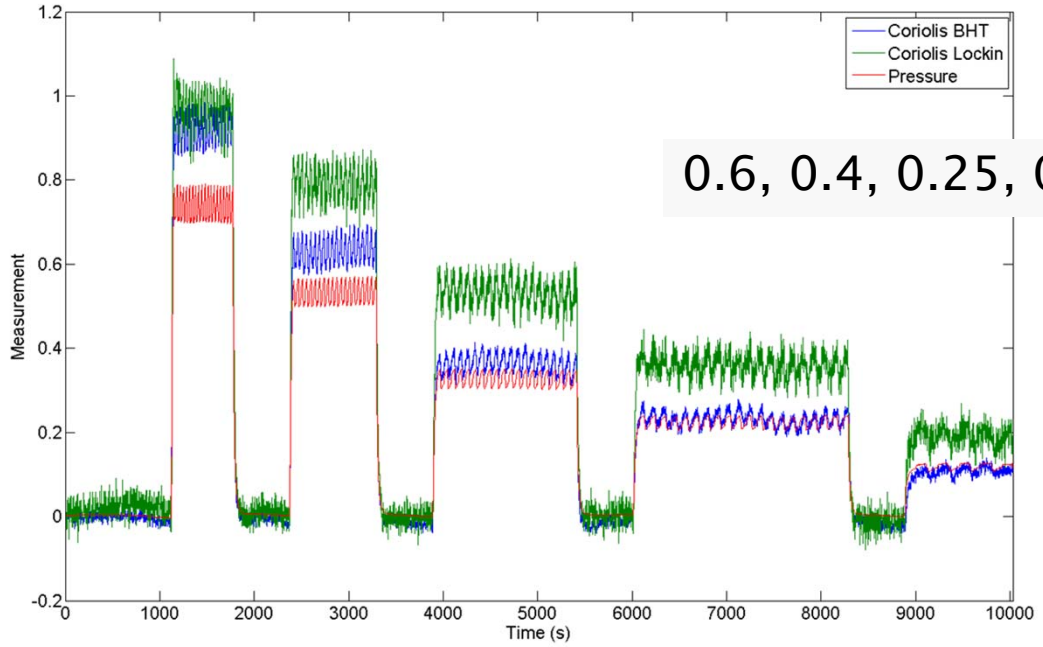
CleWin mask design

Other research topics

- Tube size and using parallel tubes
- Actuation
  - Using miniature magnets
  - Electrostatic actuation / parametric amplification
- Readout
  - Optimization of the capacitive readout
- Low-noise electronics
- Packaging / fluidic interconnects

First results

- First devices with by-pass channel have been fabricated.
- Filling of device with water did not give any problems.
- Further characterisation in progress



0.6, 0.4, 0.25, 0.17 and 0.08 µl/s

Conclusions

- Micro Coriolis flow sensors have been succesfully fabricated
- Progress is being made on all aspects of the device.
- A design was made for hydrazine flow using an on-chip by-pass channel to increase the full-scale flow to 6 µl/s
- First devices with by-pass channel were fabricated.
- Initial measurements/characterization has started.

Acknowledgements

*The research leading to these results has received funding from the **European Community's Seventh Framework Programme** ([FP7/2007-2013]) under grant agreement n° 282948*

Thank you for your attention!