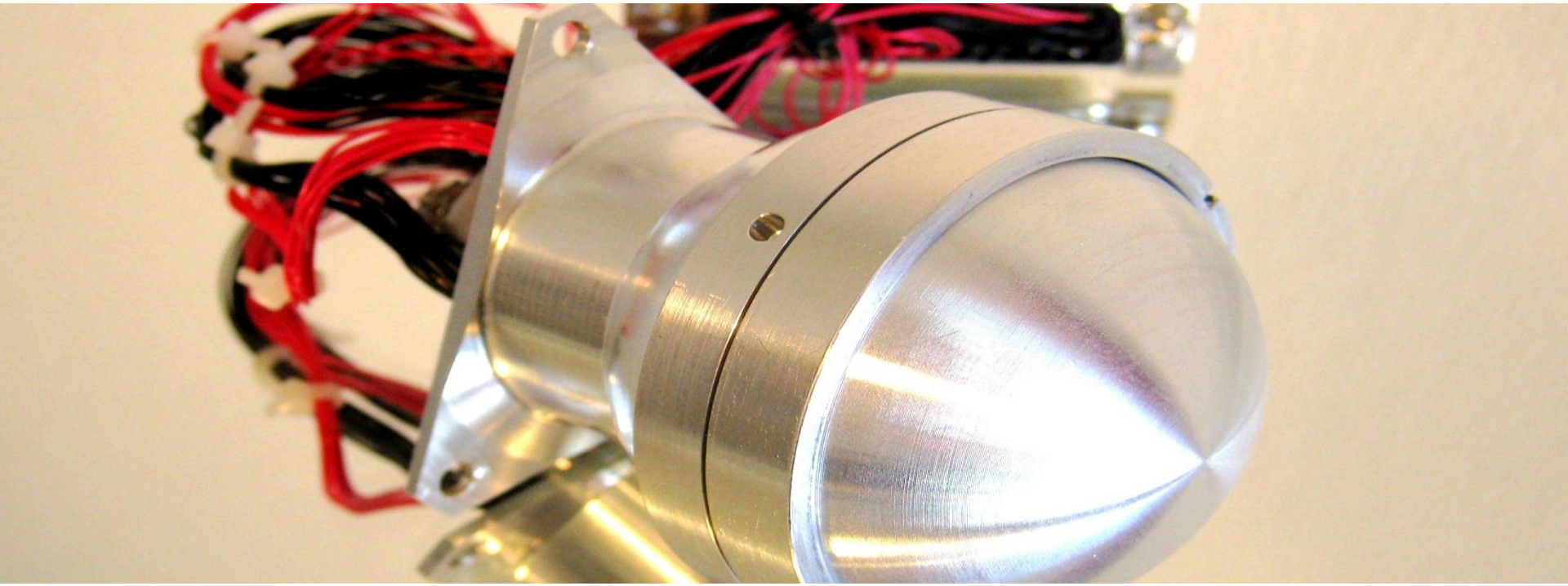
MINIATURIZATION OF COMPONENTS AND SYSTEMS FOR SPACE APPLICATIONS



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READY TO HELP YOU GET MORE FROM SPACE

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- Universal Space Network
- Aurora Technology
- ECAPS
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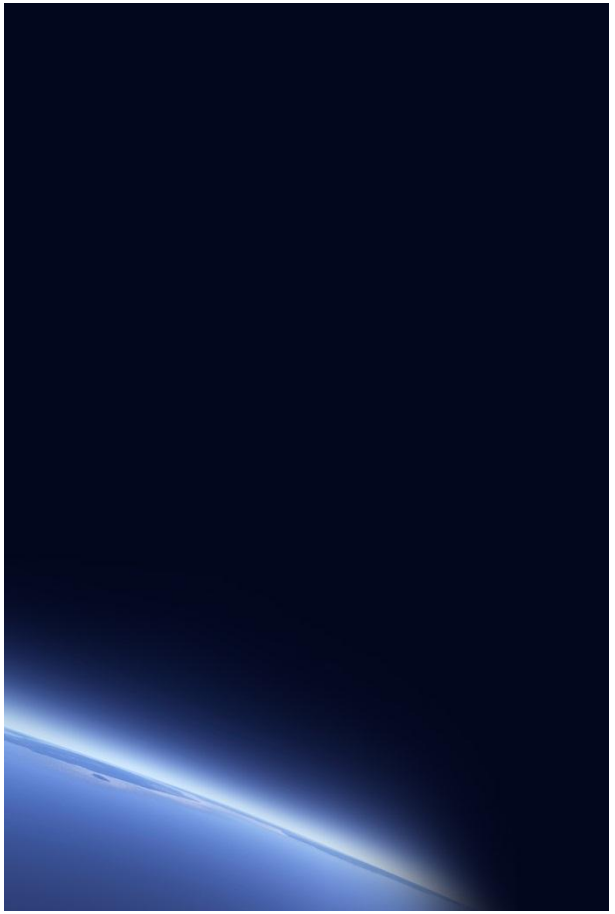

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GLOBAL PRESENCE

NanoSpace

- a subsidiary to Swedish Space Corporation (SSC)

Background

Spin-off company from Uppsala university.
Founded in 2005.
Located in Uppsala.

Business Idea

NanoSpace provides products and services for the space market based on novel MEMS technology
NanoSpace customer are the system integrators, i.e. the ”Prime contractors”

IPR and know-how

NanoSpace has 15 patents (granted or pending)
NanoSpace has its own staff of MEMS R&D engineers and an extensive process database

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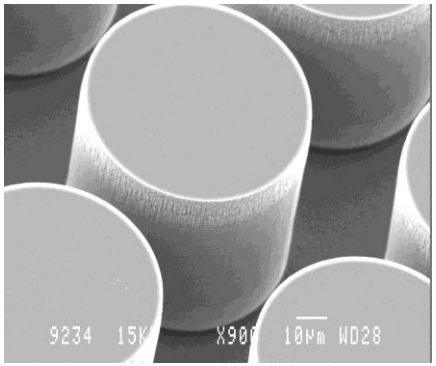
MEMS Manufacturing Services

- Access to The Ångström Laboratory with our own staff
- Automatic DRIE equipment owned by NanoSpace
- A huge process database under configuration control

> A number of novel and patented processes

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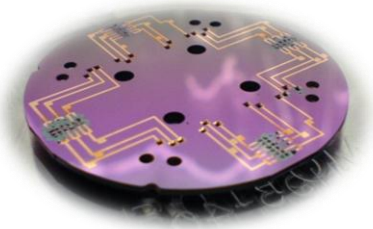
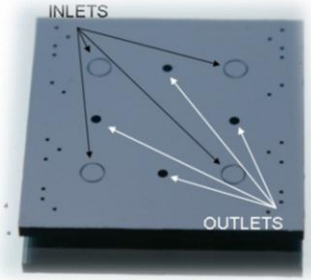
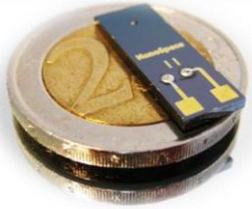
SMÖRGÅSBORD [ˈsmœrgɔsˌbuːd]
Miniaturised MEMS Micropropulsion Components

Thrusters



Flow Control Valves





Filters

Pressure Sensors

Presens (N)

MEMS Isolation Valve

Pressure Relief Valve

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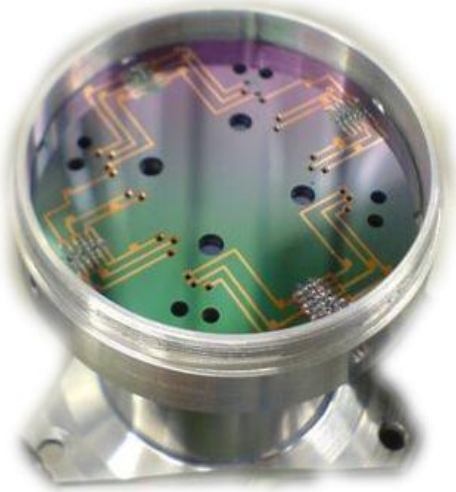
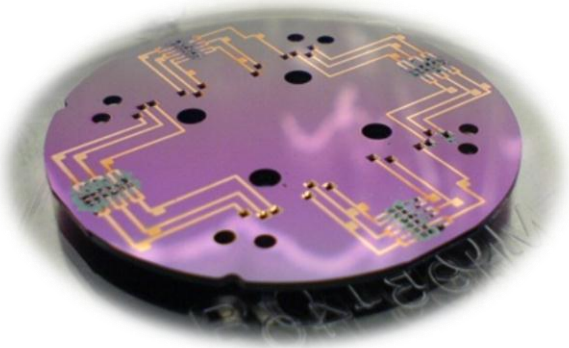
Thruster Pod Assembly – Plenty of MEMS inside

∅= **44 mm (1.73”)**
Four thrusters per pod
10 µN – 1 mN
Mass: 115 g





Six-wafer-stack MEMS Thruster Chip

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MEMS Micropropulsion Components

•First generation MEMS micropropulsion:

– *Miniaturised, accurate and open-loop*

• Next generation MEMS micropropulsion:

– *Still small, but smarter i.e. Closed-loop control*

Xenon flow control module

CubeSat propulsion module

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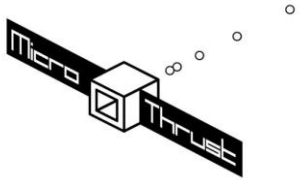
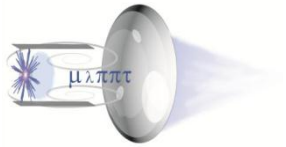
Miniaturisation of components in different micropropulsion projects and missions

- Electric micropropulsion:
  - *Colloid thruster, pulsed plasma thrusters, electric sail, RF ion thruster (RIT)*





- Chemical micropropulsion
  - *Monoprop hydrazine, resistojet, and cold gas*

Motivation

Offer propulsion to enable new missions

- *Advanced Nano- and Cube Sats*
- *Larger spacecraft with stringent requirements*
  - Drag free flights, Orbit change, FF & RV , docking, de-orbit…

-> New scientific results

-> Commercial applications

-> Space debris mitigation

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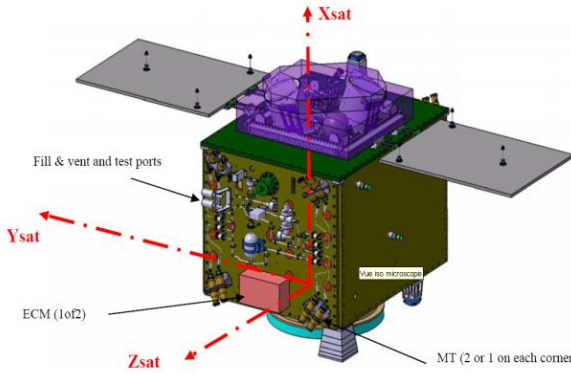
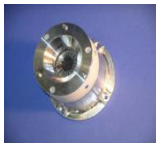
Challenging requirements

Mission thrust requirements given by CNES for MICROSCOPE	
Thrust range	1 – 300 µN
Thrust resolution	0.2 µN
Response time	250 ms



MICROSCOPE by CNES

Flow Control Requirements for next generation mini Ion engines	
Flow rate range	5 – 50 µg/s
Flow rate control accuracy	+/- 5% across the flow range +/- 5% above 25 µg/s and +/- 10% below 25 µg/s
Flow rate control resolution	+/- 0.5 µg/s



RIT-µX by Astrium

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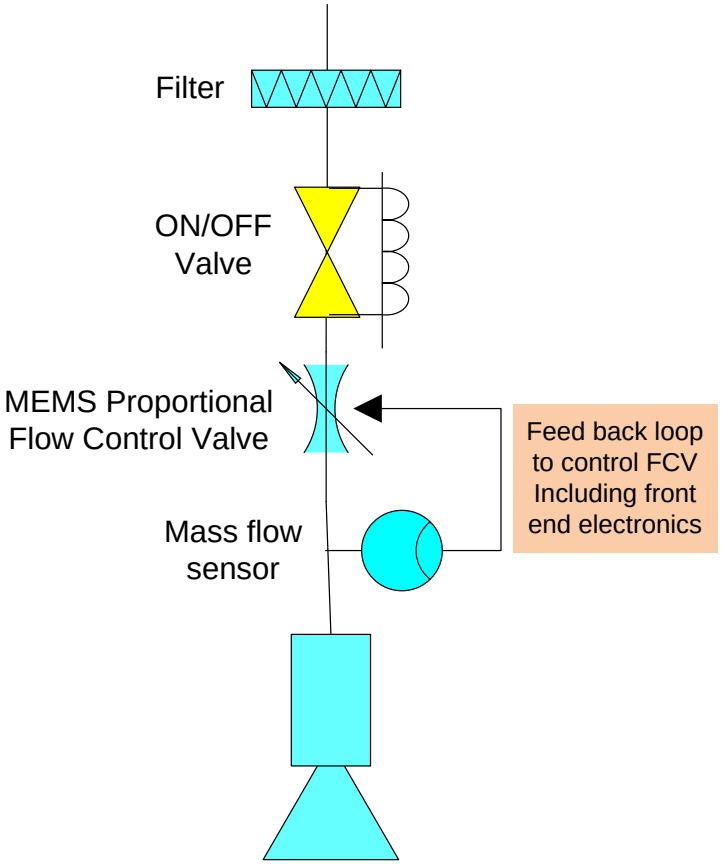
Closed–Loop Flow Control



Integrated mass flow sensor provides control signal to the proportional flow control valve

⇒ Closed-loop flow control

Schematic view of a complete closed -loop control thruster.

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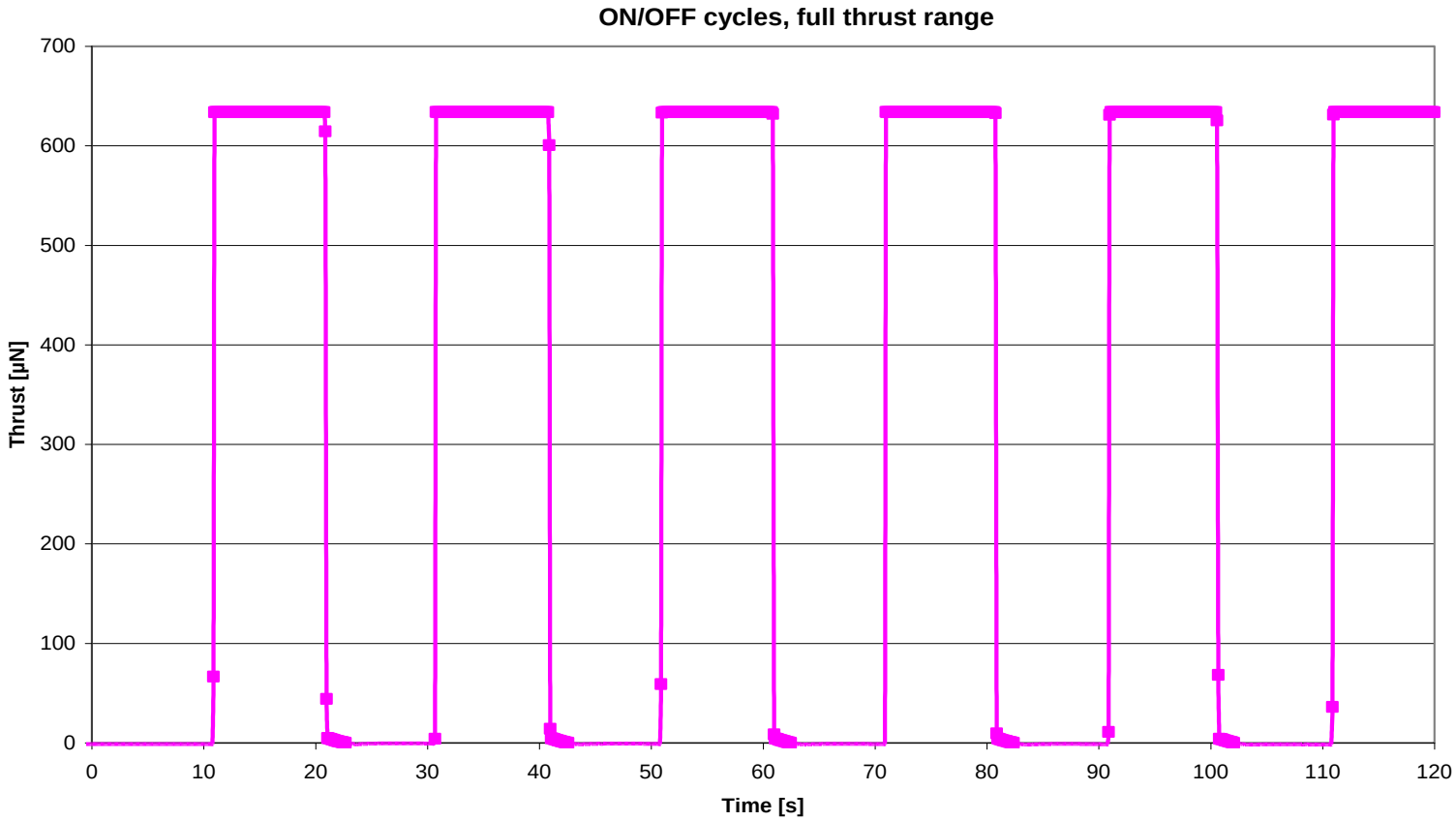
Key capabilities – Like any other



Test result of MEMS thruster operating in ON/OFF mode
(open loop, using solenoid valve only) to show thrust range.
Full thrust can be set in the range **50 micro-Newton** to **5 milli-Newton**

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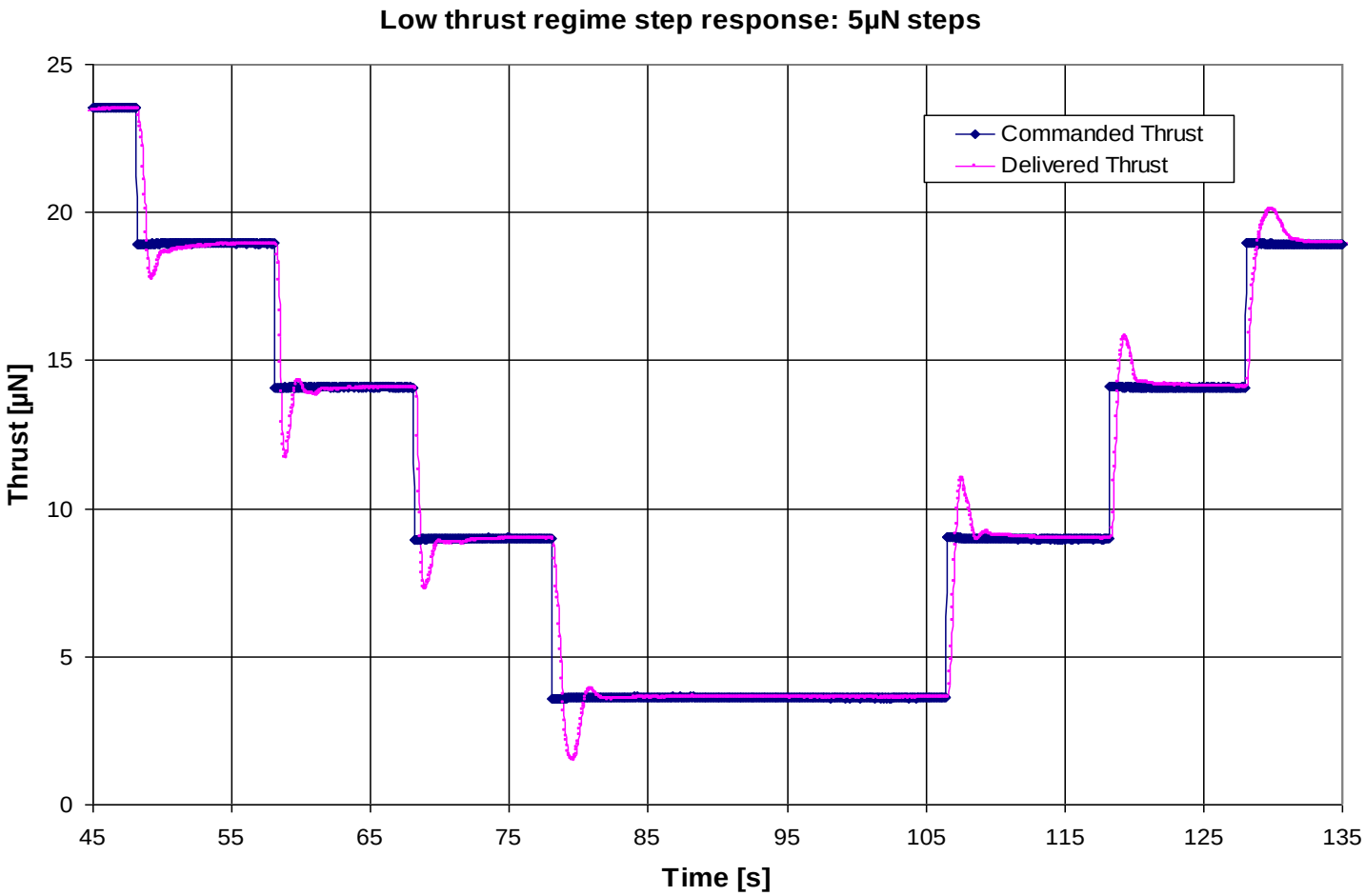
Key capabilities – Unlike any other



Test result of a MEMS valve operating in closed-loop control mode showing the thrust response to commanded steps of 5 μN.

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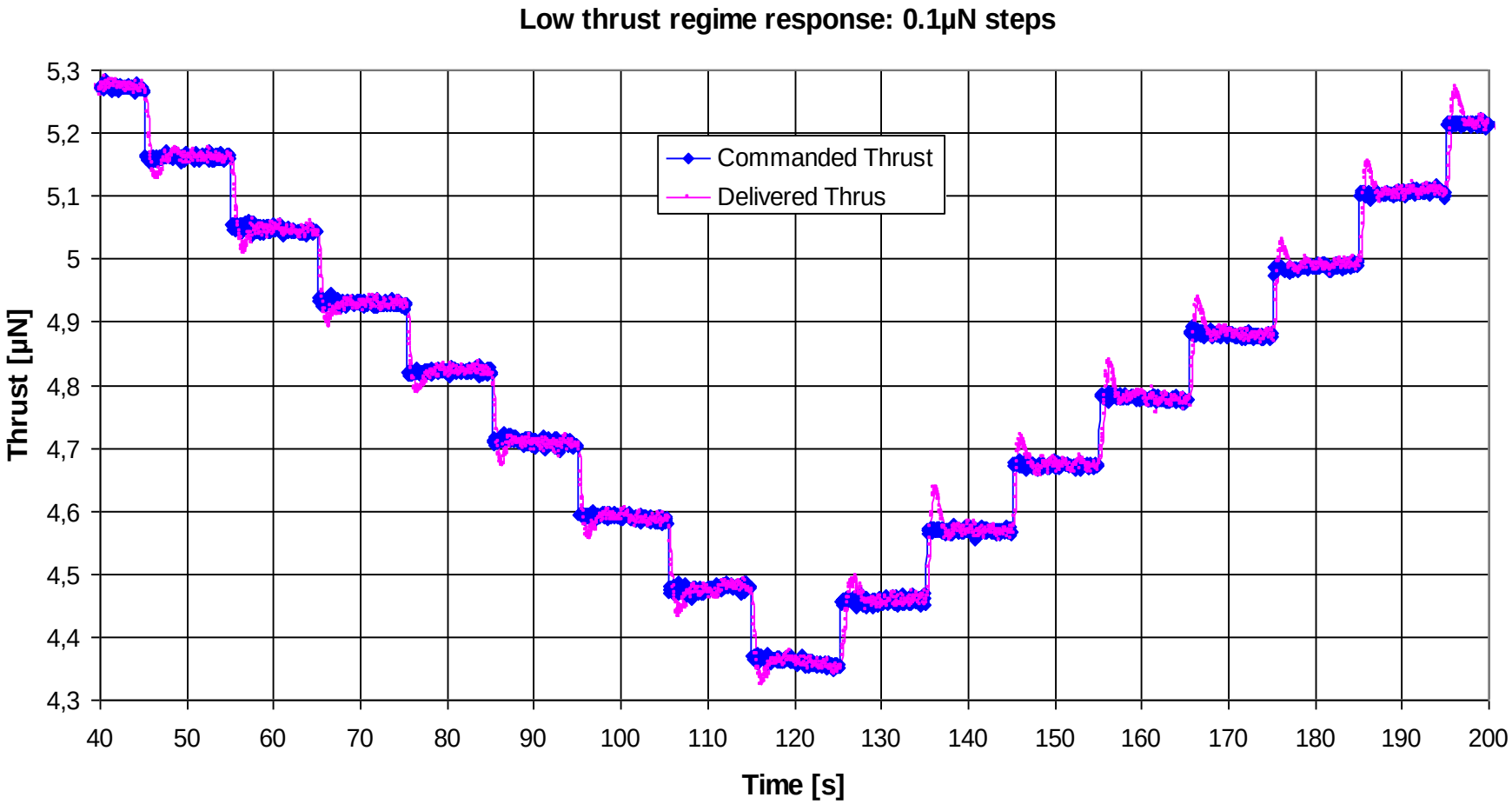
Unique performance



Test result of a MEMS valve operating in closed loop control mode responding to the commanded steps of 0.1 µN.

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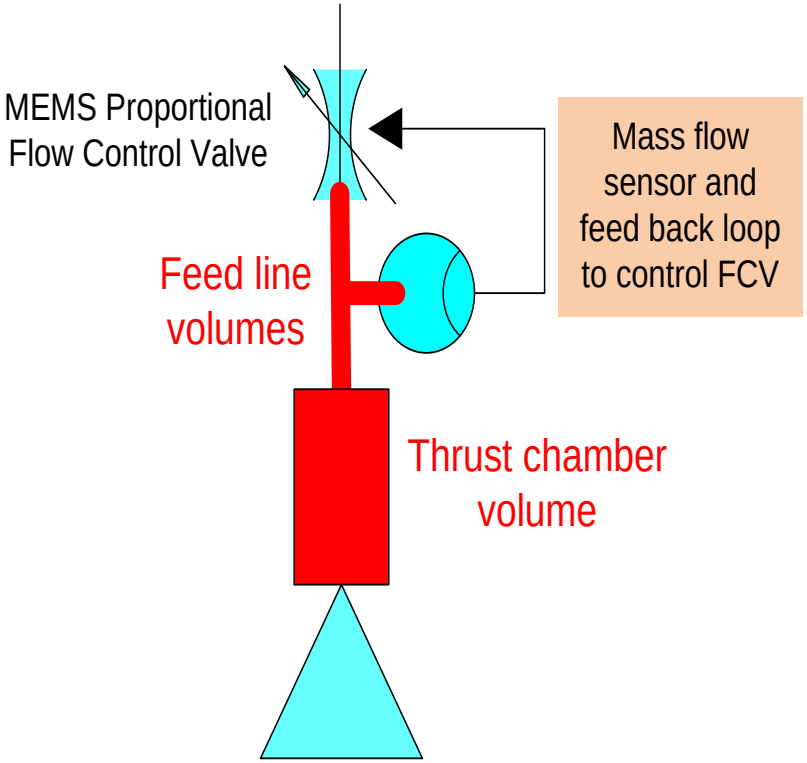
Physics problem

Low flow rates in combination with the wish for fast response



Thruster case:
Requirement: 250 ms in response time
Flow rate: 5 µg/s

Response time increases linearly with the internal dead volume

Simplified estimate: V ~ 10 mm^3

Tubing	Length	Volume
1/8”	5 mm (0.2”)	9 mm^3
1/4”	0.62 mm (0.025”)	10 mm^3

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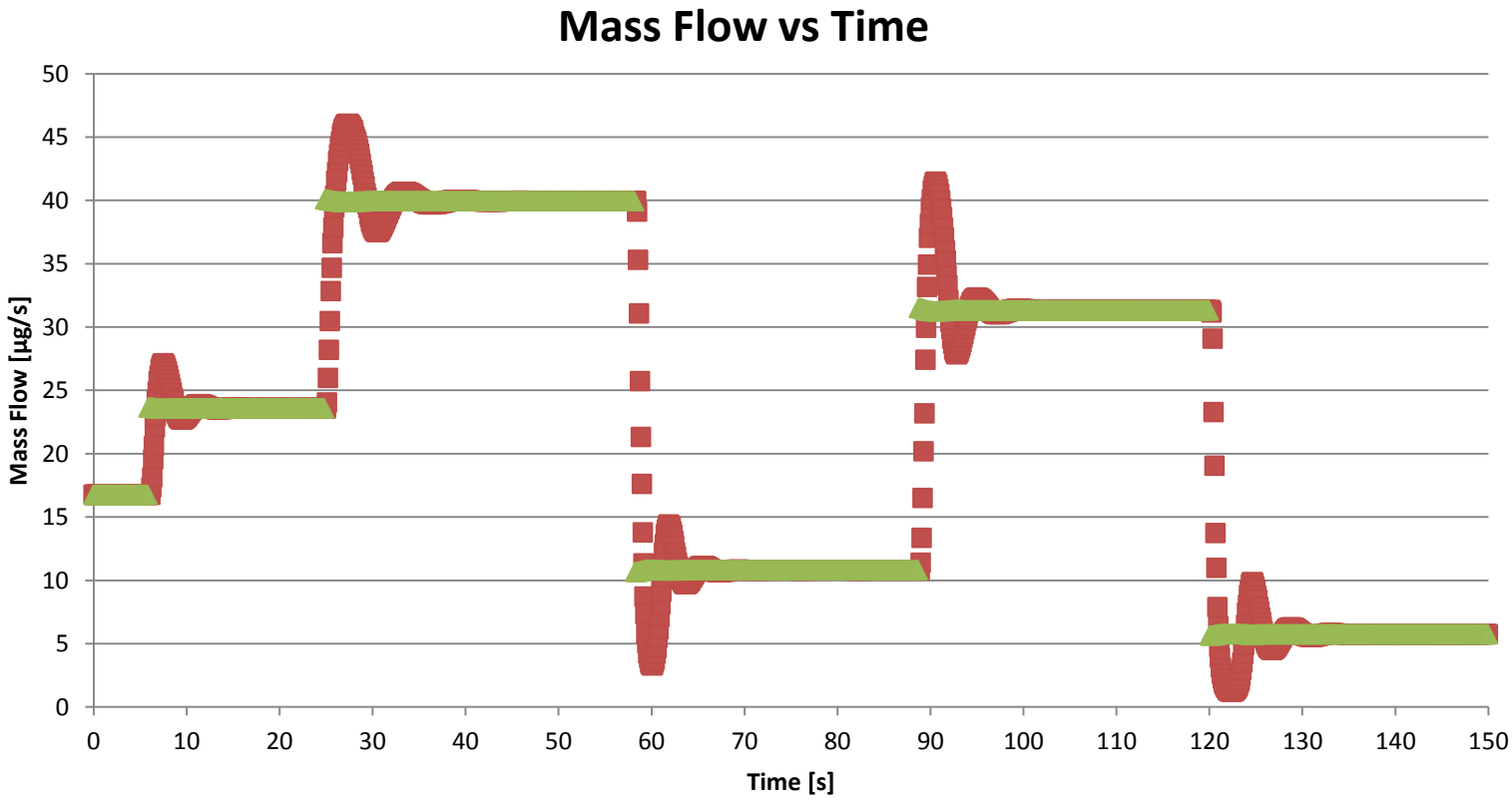
The Solution - MEMS

In our view, **using MEMS technology and integrating the flow control valve, mass flow sensor and chamber/nozzle on a single chip is the best –if not the only- way to realise a closed-loop control thruster that can meet the challenging requirements with low flow rates in combination with fast response**.

Results – Xenon Flow Control



Capable to operate in full flow regime

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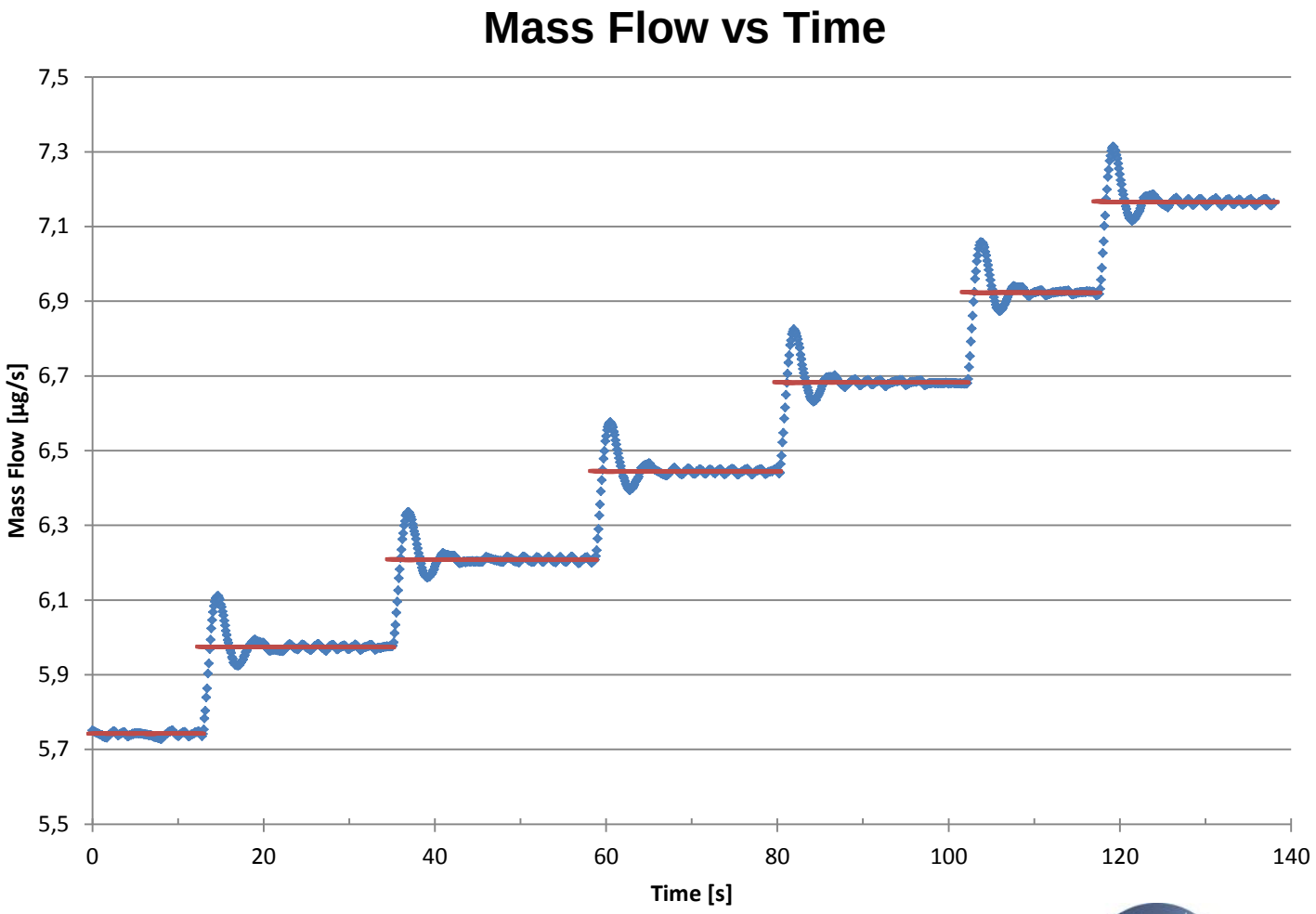
Results – Xenon Flow Control



Capable to performe minute flow changes

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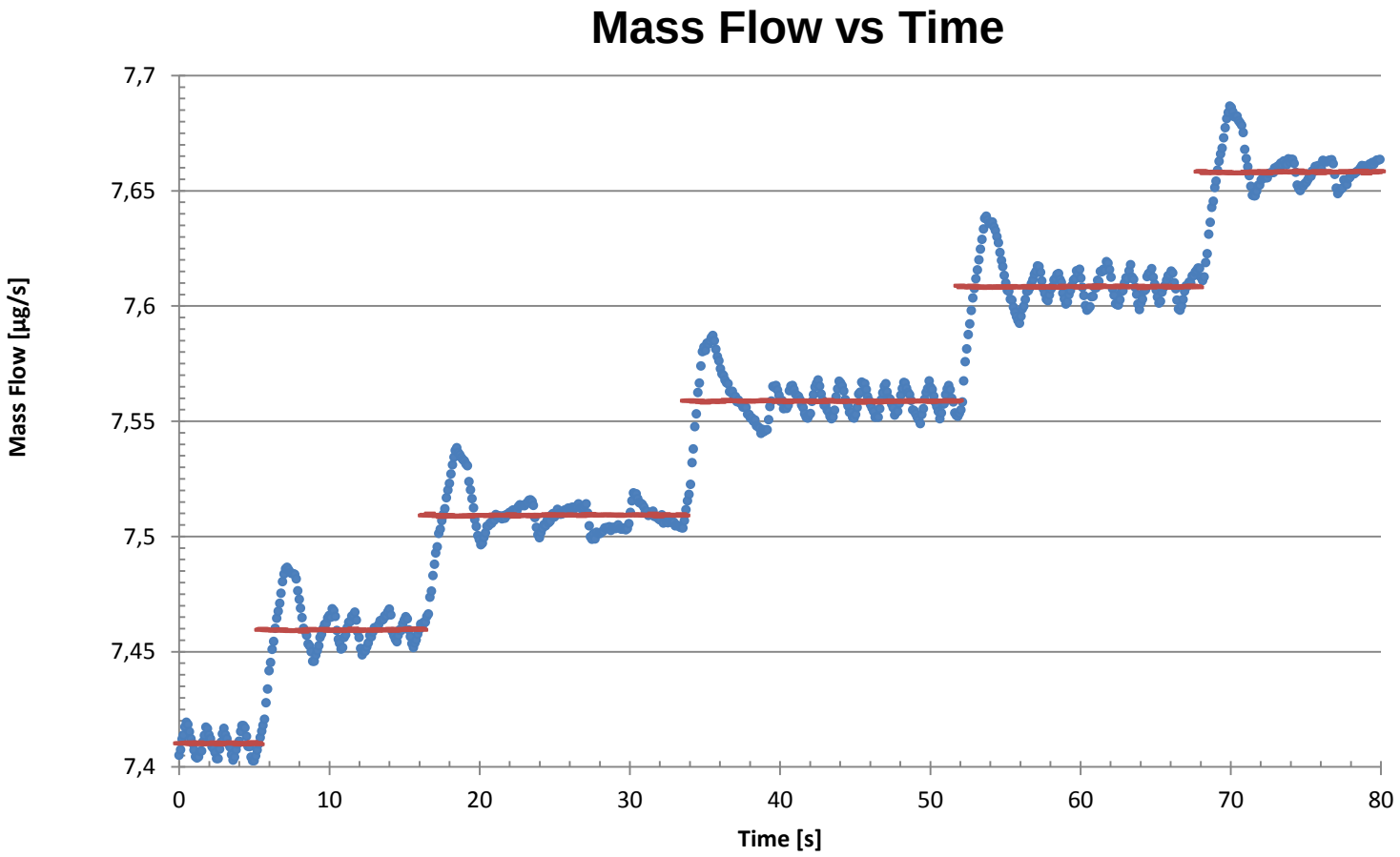
Record shattering resolution



Capable to resolve extremely small changes: 0.2 µg/s (200 ng/s)

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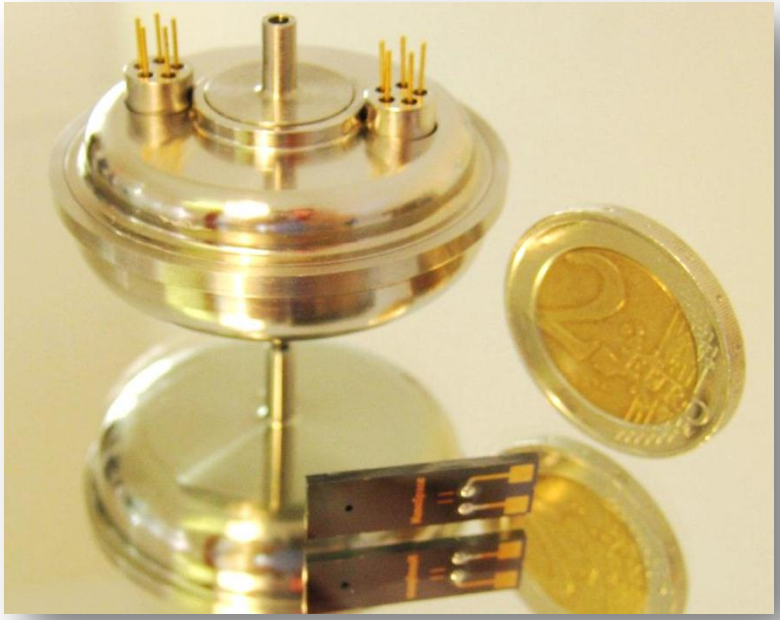
Summary – XeFCM H/W

- Designed, manufactured, and tested a Xenon closed-loop flow control module!
- Mass: 63 grams
- Excellent dynamic range
- Step regulation < 200ng/s
- Fast response time



Next step:

- Testing together with mini Ion engine (Astrium´s µN-RIT engine)

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Summary – Micro Thruster H/W

- Closed-loop thrust control demonstrated with unique performance (in terms of thrust and response time in the low thrust regime)
- Developing a CubeSat propulsion module

- Four 1mN thrusters with closed-loop thrust control
- Thrust resolution: <10µN
- Propellant: Butane
- Total impulse: 40Ns
- Size: 10*10*3cm
- Mass: 250g
- Operating pressure: 2-5 bar
- Power consumption: 2 W (average, operating)
- Mechanical interface: CubeSat payload I/F (Pumpkin)
- Electrical interface: 52 pins analog (0-12V) and digital (SPI)

Next step:

- Finalise the assembly, integration, and testing

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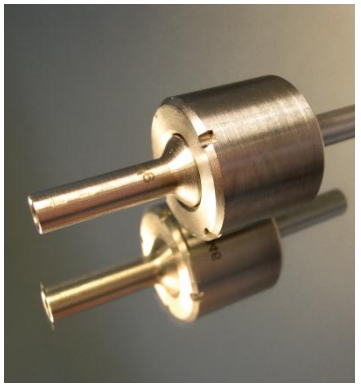
MEMS Filters

Etched disk technology

- Extreme dimension control
- Zero media migration
- Extreme cleanliness
- High element strength
- High quality coatings
- Compact integration of other components/functions
- Increased redundancy without mass penalty
- Batch processing

Gas Filters

- 5µm and 10 µm filtration rating
- Built-in filters down to 2 µm absolute filtration



Liquid Filters

- 20 µm filtration rating

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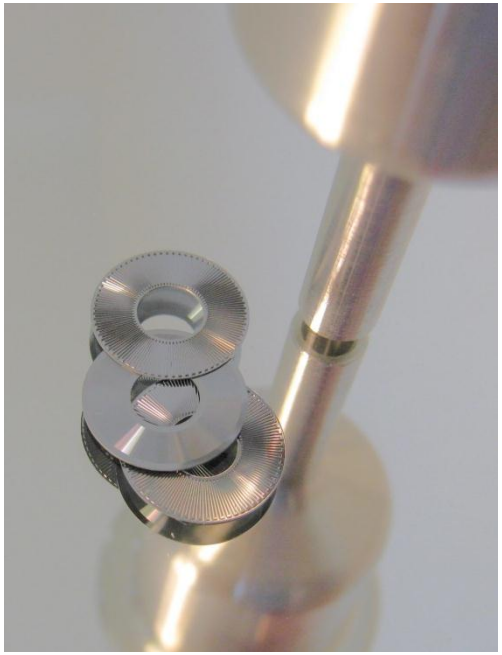
Summary - MEMS Filters

- Etched disk technology
- Both gas and liquid filters
- Built-in filters available
- 2, 5, 10 µm, and 20 µm filtration rating
- Extreme cleanliness and zero media migration
- High capacity filters (high flow rate/low pressure drop)
- Scalable design



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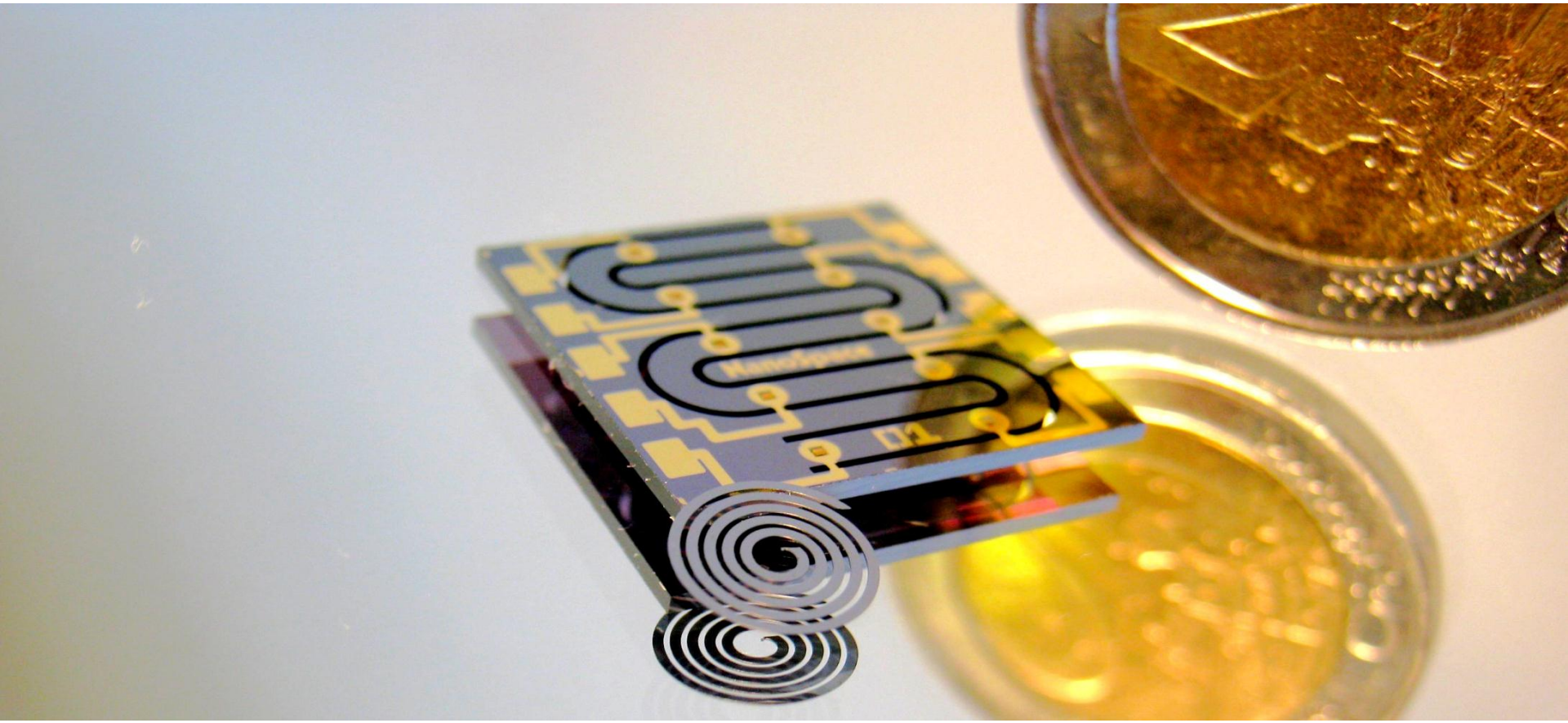
Thanks for your attention!



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