Quantum Delta
the Netherlands

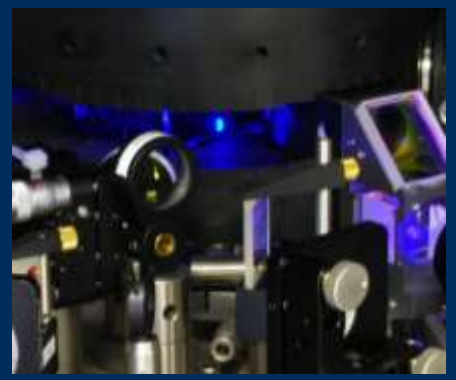
Quantum Sensing Applications

CAT-3

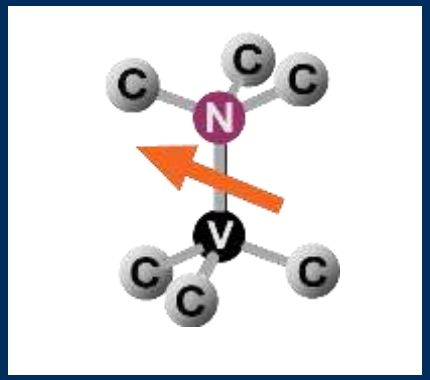
CAT3 - Quantum sensing applications

Four quantum sensing testbeds

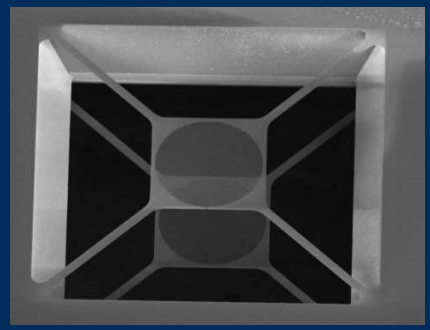
Ultracold atom sensors



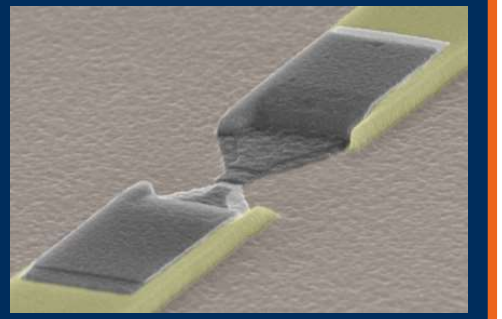
Spin sensors



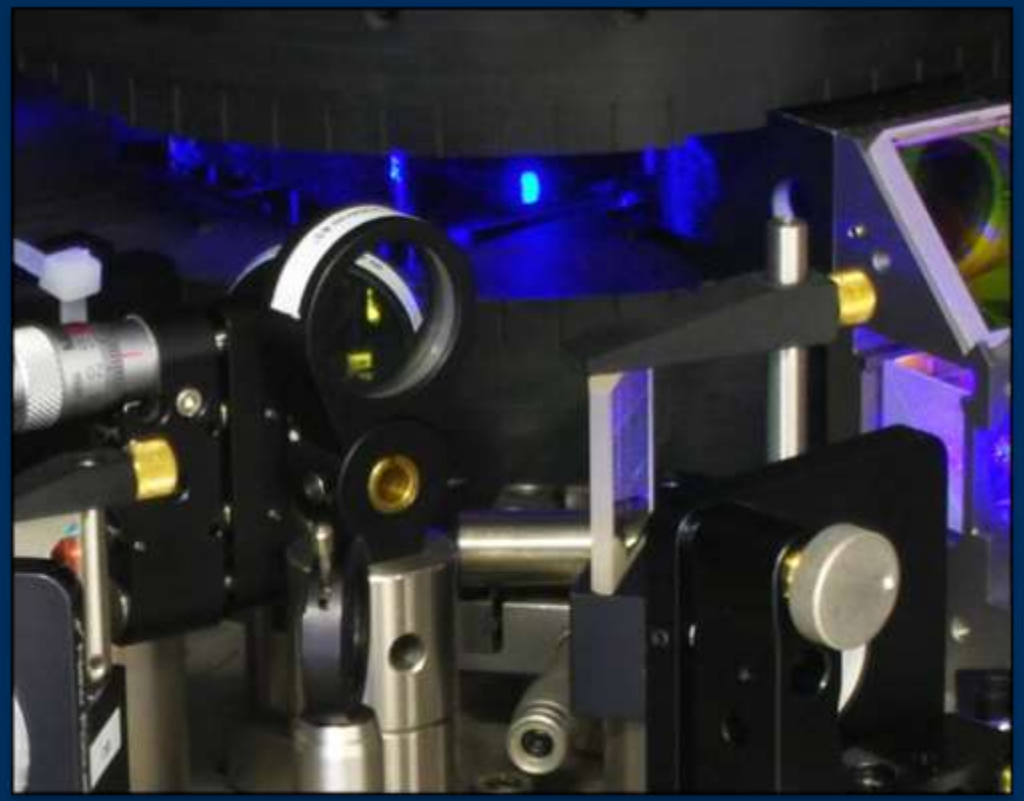
Mechanical quantum sensors



Superconducting sensors



- **Open calls** for new quantum sensor components and wider range of sensors



1

Ultracold quantum sensing testbed

Ultracold quantum sensors

Acceleration

redbubble.com

- Underground exploration

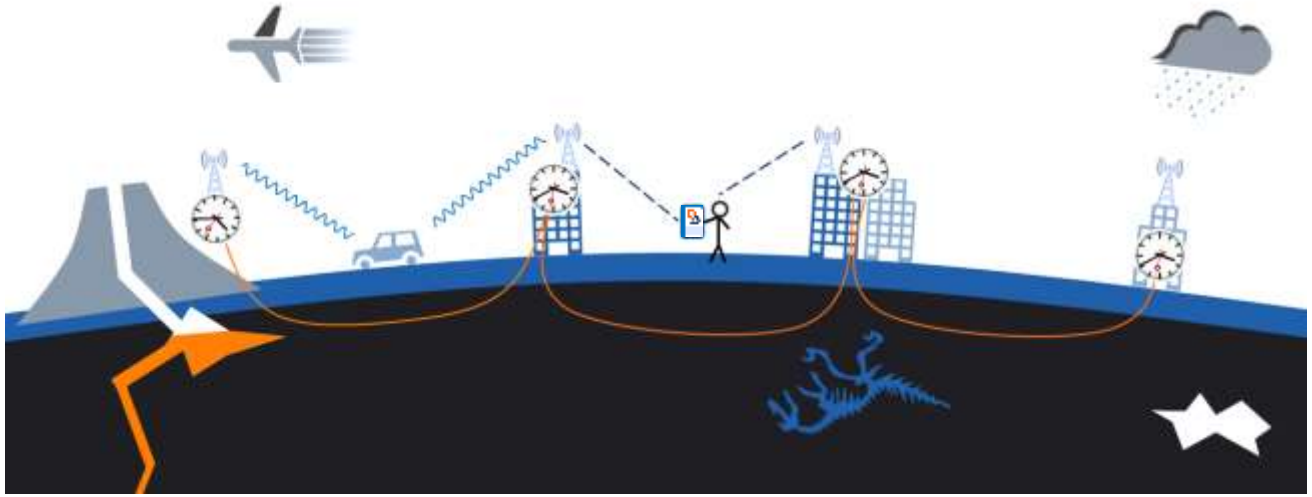
Teledyne e2v

- Inertial navigation

defensie.nl

- Network synchronization and positioning

Time

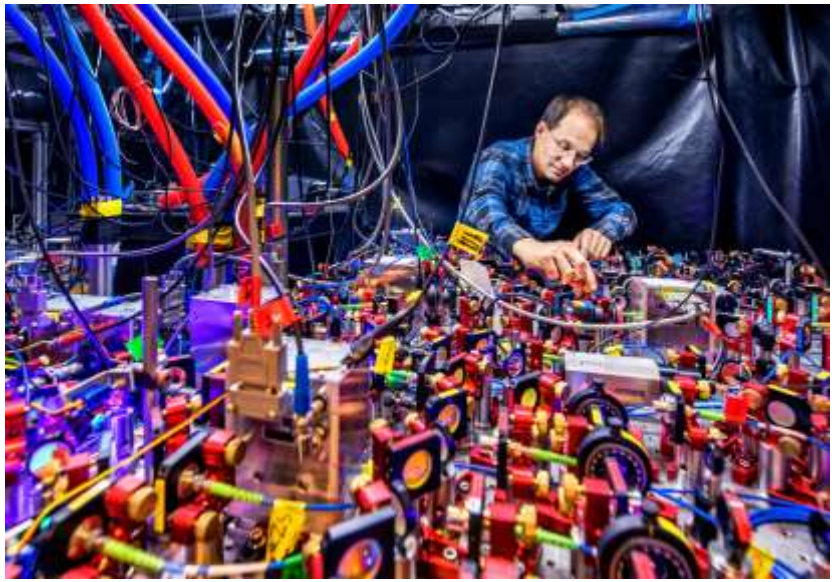


Adapted from Teledyne e2v

Ultracold quantum sensing testbed

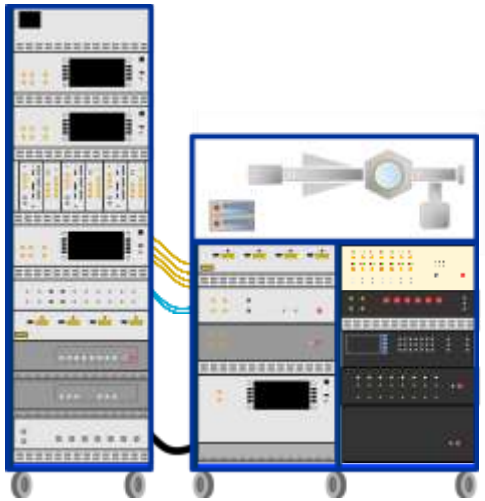
UNIVERSITY OF AMSTERDAM

QUANTUM FLAGSHIP

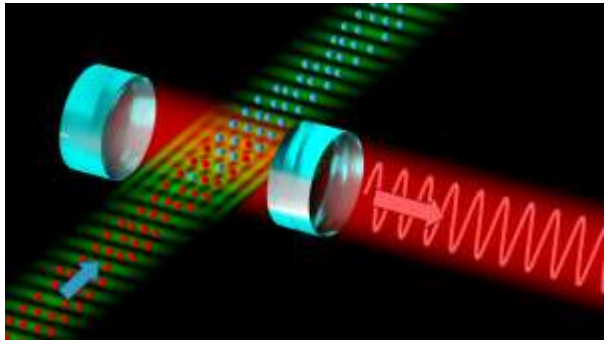


smaller

simpler



easy access



Compact ultracold quantum sensors

UNIVERSITY OF AMSTERDAM

- Industry testbed for Sr optical clocks and atom interferometers

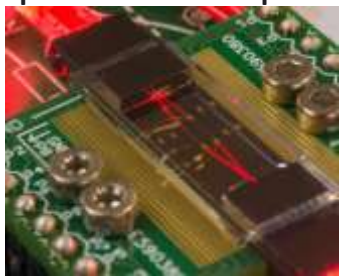
PhotonDelta
Gateway to Integrated Photonics

free space laser

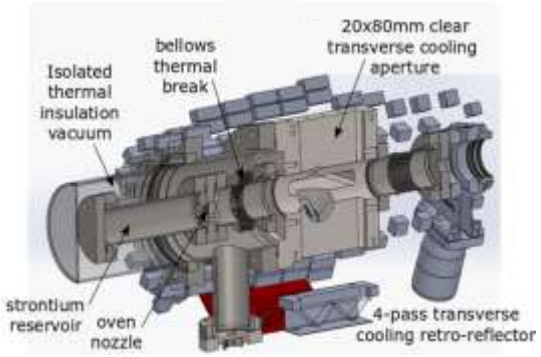
LioniX INTERNATIONAL

QuiX

photonic chips



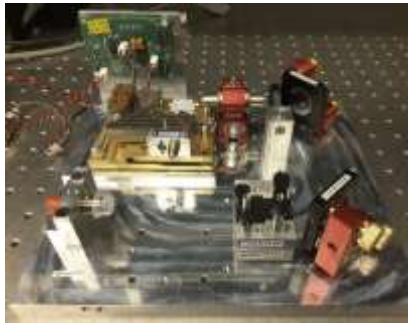
compact atom sources



esa ESTEC

space optical clocks

standard lasers



UNIVERSITY OF TWENTE.

Klaus Boller:
chip scale lasers

- Inertial navigation

acceleration

redbubble.com

TNO

defensie.nl

Easy access

UNIVERSITY OF AMSTERDAM

- Reference Sr optical clock and time+frequency distribution system

VSL — Long-term operation of National Sr Optical Clock

SURF eurofiber — Fibre network

} Time and frequency as a service

opnt. — Time and frequency distribution equipment

VU — Jeroen Koelemeij: time and frequency distribution research

- Support application development
  - Terrestrial navigation
  - Security
  - Neutral atom quantum computing
  - Fundamental research

European network (Paris)

2 Spin sensors testbed

Spin sensors

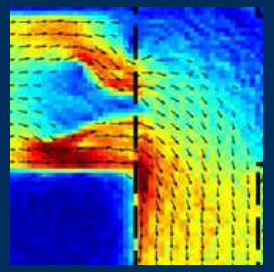
- ‘Spin’ is the quantum mechanical counterpart of light’s polarization
- Some of the earliest quantum sensors have been based on ensembles of nuclear spins
- Technologically, they tend to be simpler and more robust than other (quantum) sensors

Sensitive to a variety of quantities…

Magnetic fields

Maletinsky et al. Nat. Nano 7, 320 (2012)

Electric fields

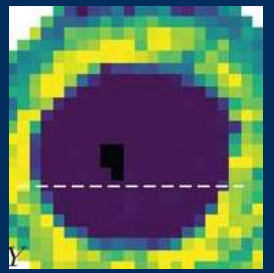


Tetienne, et al. Sci. Adv. 3, e1602429 (2017)

Temperature

Laraoui, et al. Nat. Comm. 6, 8954 (2015)

Pressure



Hsieh, et al. Science, 366, 1349 (2019)

Rotation

Soshenko, et al. arXiv:2009.0091

…with high sensitivity and single-atom resolution

CAT-3 spin sensor testbed

Develop + Test + Access

Some Technologies

- Quantum-enabled scanning probe microscopes
- High performance low cost diamond based sensors
- Silicon based quantum sensors

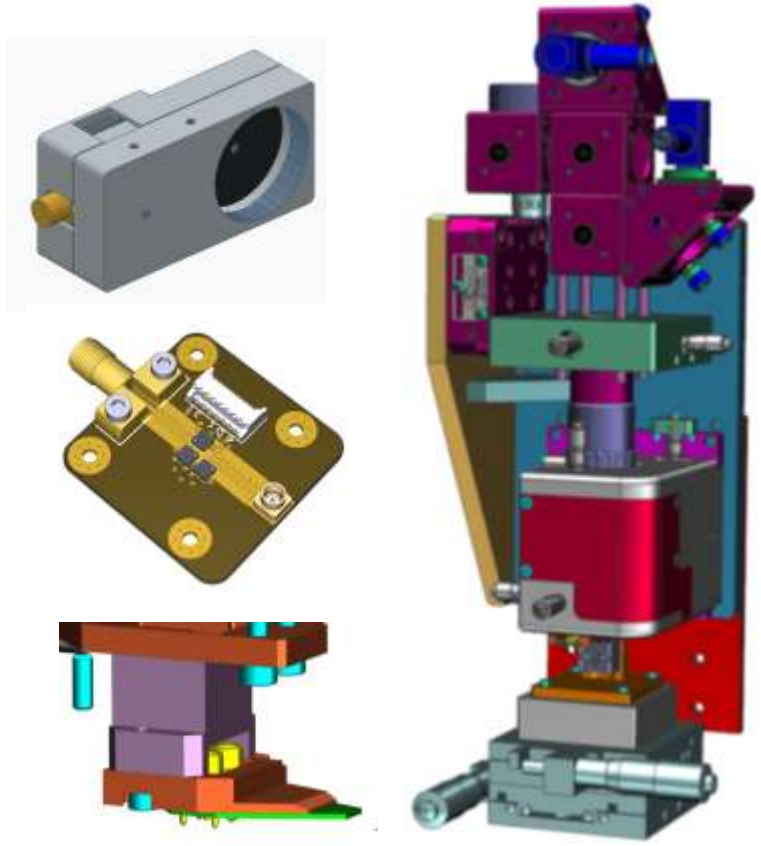
Potential applications

- Semiconductor metrology
- Biomedical research
- Positioning and navigation
- Defence

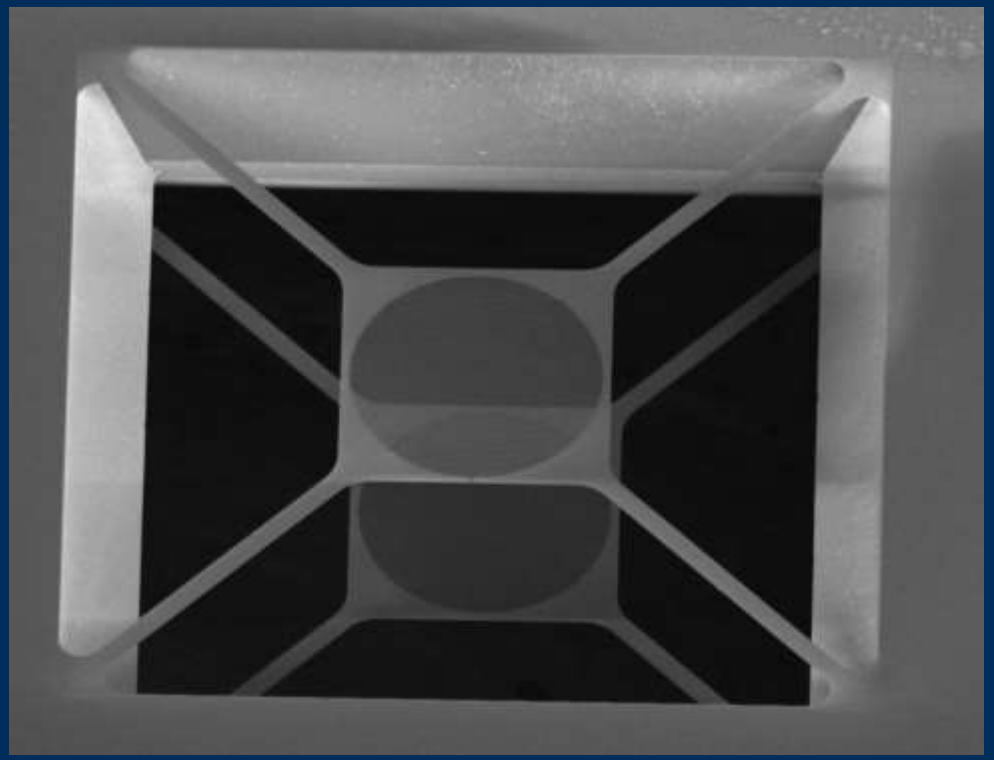
Initial partners

- TNO and its industrial partners
- QuTech
- TU Delft

TNO's quantum sensing technology



Contact: clara.osoriotamayo@tno.nl



3

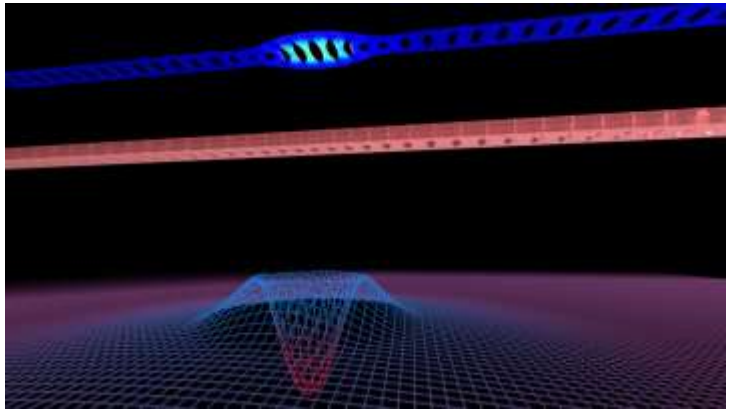
Mechanical quantum sensor testbed

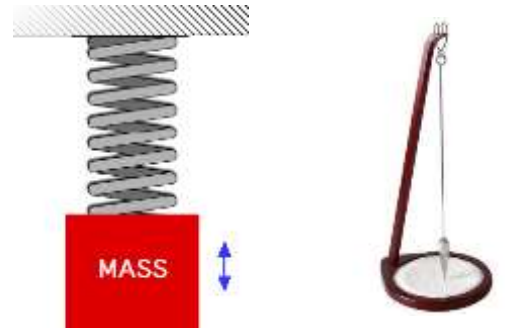
Mechanical quantum sensors

- Harnessing the versatility of mechanical oscillators

  Enhanced sensitivity through quantum *mechanics*

  Create a testbed for validation and benchmarking





Pressure

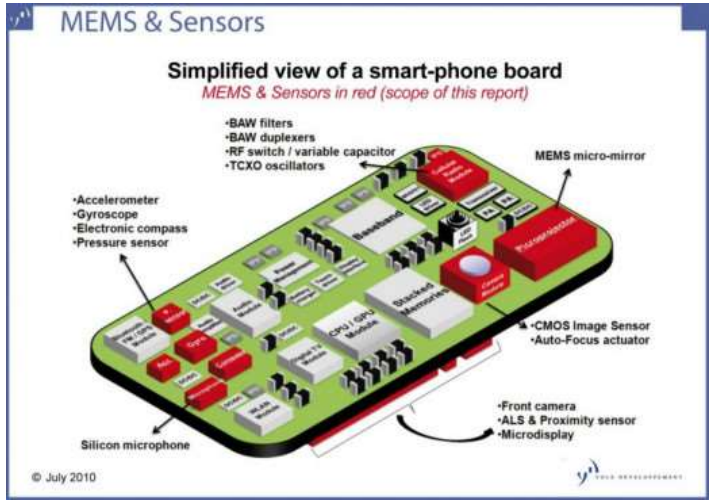
scubastore.com

Magnetic field

workshopplus.com

Acceleration

redbubble.com



10+ MEMS sensors in modern cell phones

Contact:
s.groeblacher@tudelft.nl

Mechanical quantum sensing testbed

TU Delft
Delft University of Technology

- Build facility to support Dutch quantum sensing ecosystem

Multi-user facility for testing and benchmarking

Simulation of real world environment

Support to increase TRL level

Open to industry, academia & government

- Several initial partners

INNOSEIS

s[&]t
Science and Technology Corporation

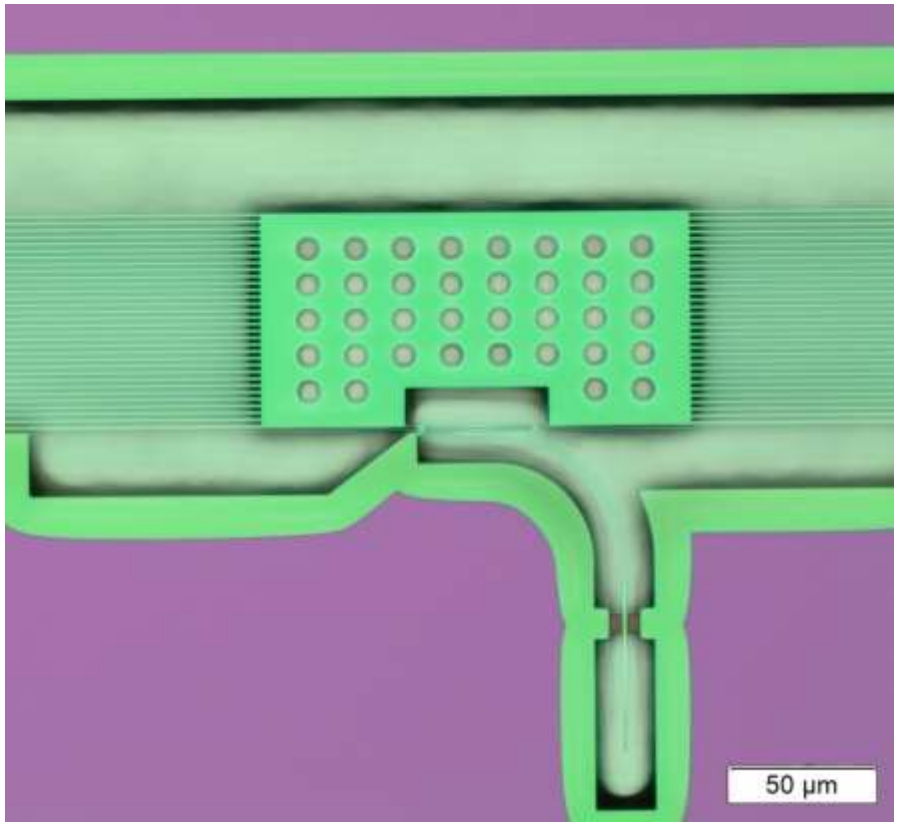
Technobis group

Somni
Somni Solutions

OPTICS11
Optics11

TNO
Netherlands Organisation for Applied Scientific Research

Mechanical Quantum Accelerometer



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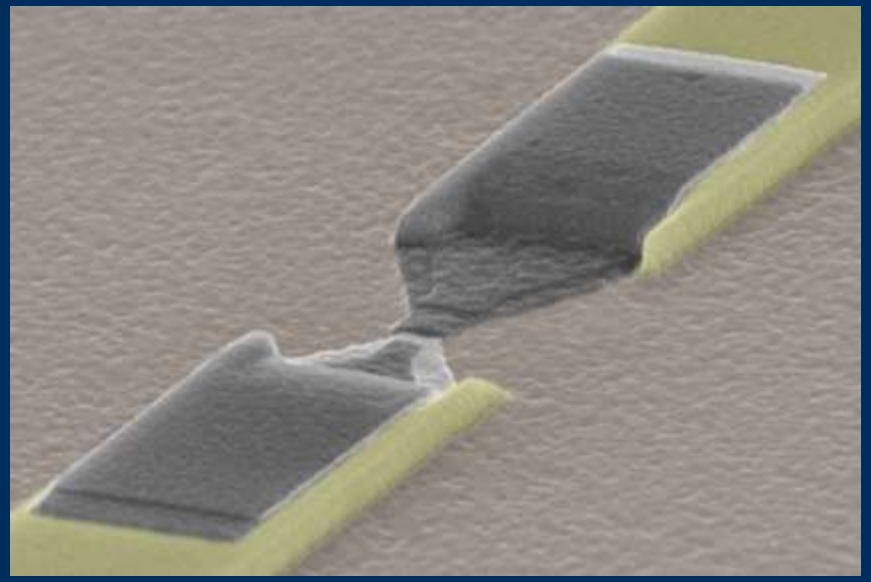
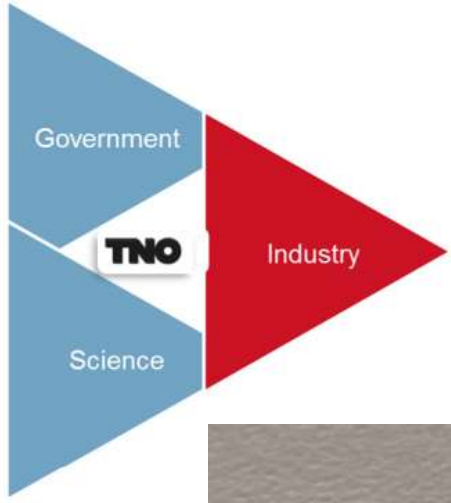


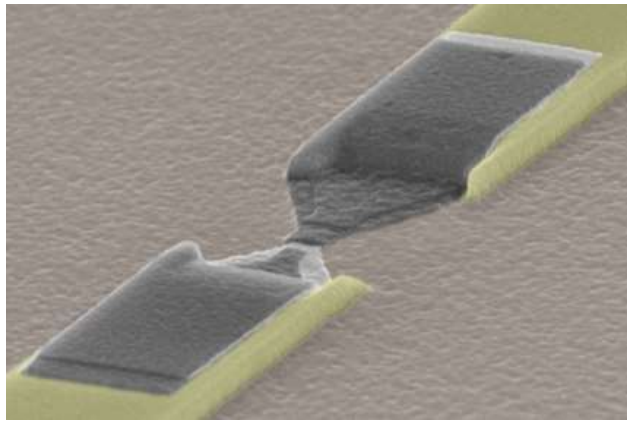
4

Superconducting sensor testbed

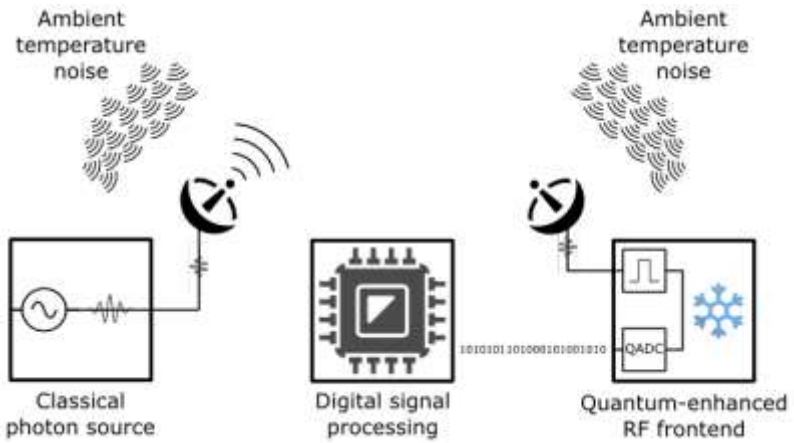
CAT-3 superconducting sensor testbed

- Development and evaluation of quantum sensing demonstrators relevant for Dutch military, national police and space industry
- Collaboration with Dutch universities, spin-offs and other research institutions to increase the TRL level of current quantum sensors
- Hands-on assessment and characterization of sensor arrays combined with superconductor electronics to enable the development of the next generation of quantum-limited sensor systems
- Design, fabrication and measurement expertise of superconducting devices within TNO





Scanning-electron micrograph showing one of the fabricated Josephson Junctions

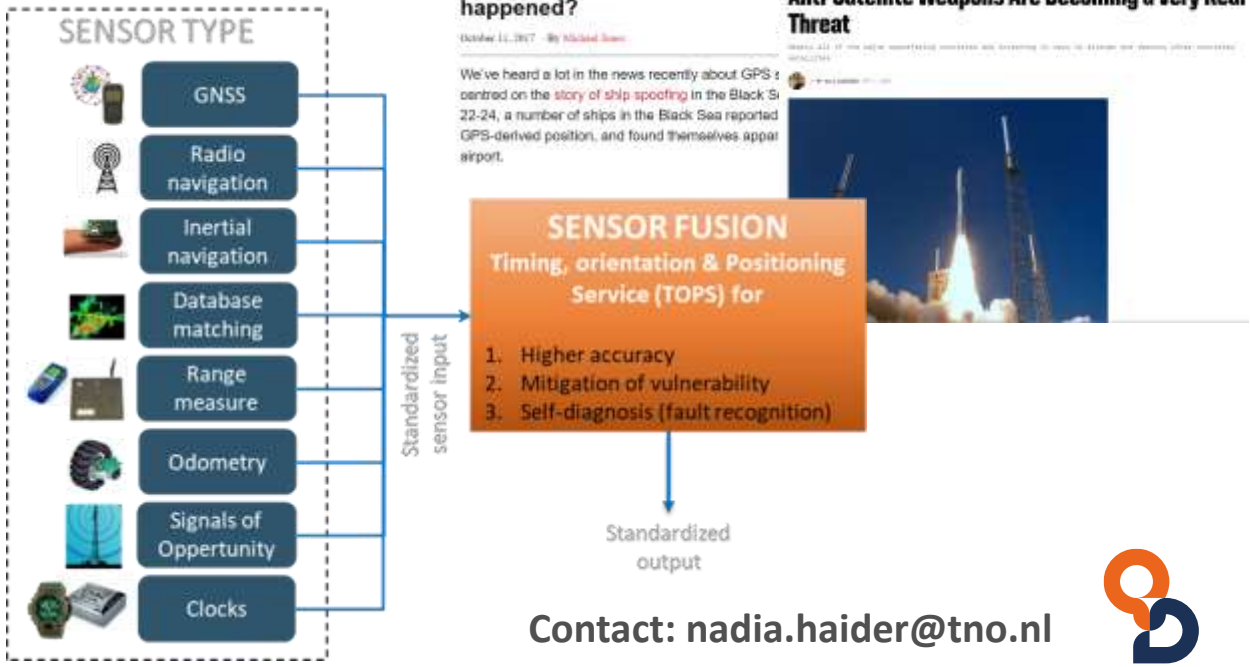


Quantum enhanced RF-frontend for wideband spectrum monitoring

Contact: nadia.haider@tno.nl

Quantum navigation: A challenging landscape

- PNT (position-navigation-timing) has a foundational role in the military and space domain
- Assured PNT cannot be delivered by Sat-NAV alone
- New focus on alternative solutions with high precision and challenging SWAP-C (size, weight, power & cost)
- Quantum sensors can fill capability gaps;
  - Mechanical quantum inertial navigation system - TUD
  - Atomic clock and quantum accelerometer - UvA
  - Magnetic sensors based on NV-centre – TNO + TUD
- TNO provides TOPS framework for navigation sensor fusion & PNT solution assessment



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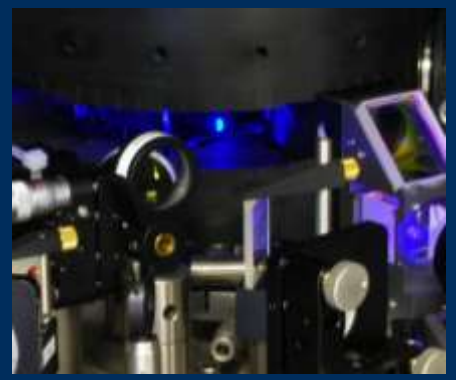
CAT3 - Quantum sensing applications

Four quantum sensing testbeds

Ultracold atom sensors



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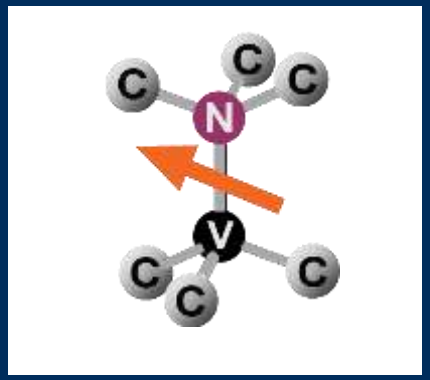

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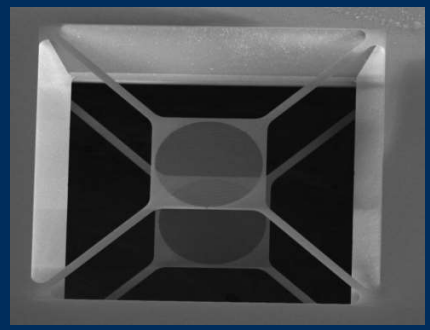
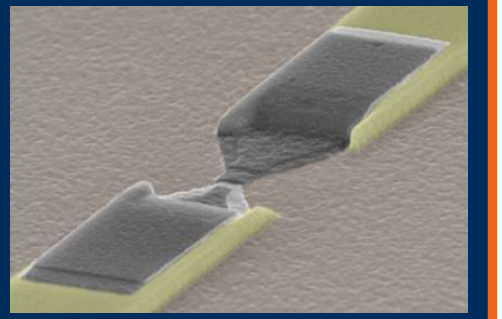


Superconducting sensors



- **Open calls** for new quantum sensor components and wider range of sensors