High resolution compact vertical inertial sensor for atomic quantum gravimeter hybridizing

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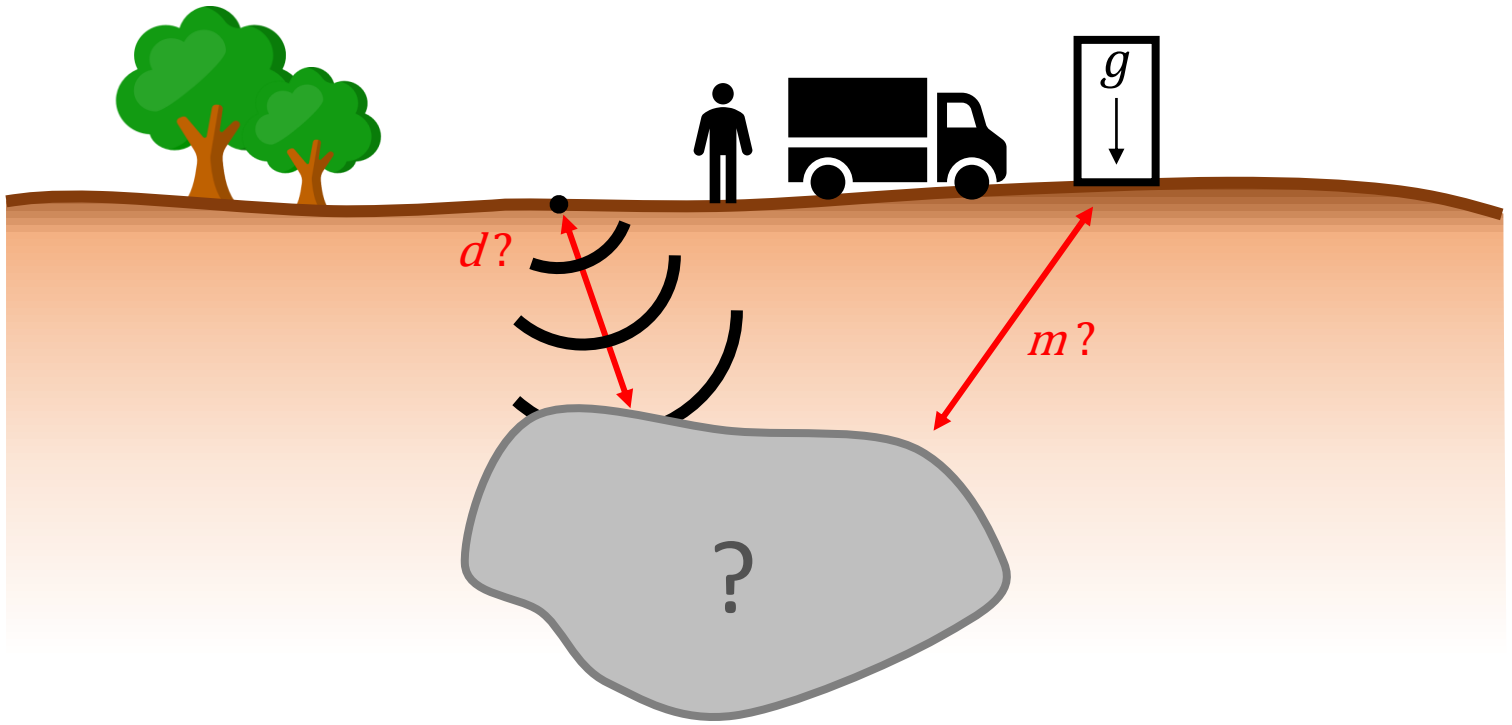
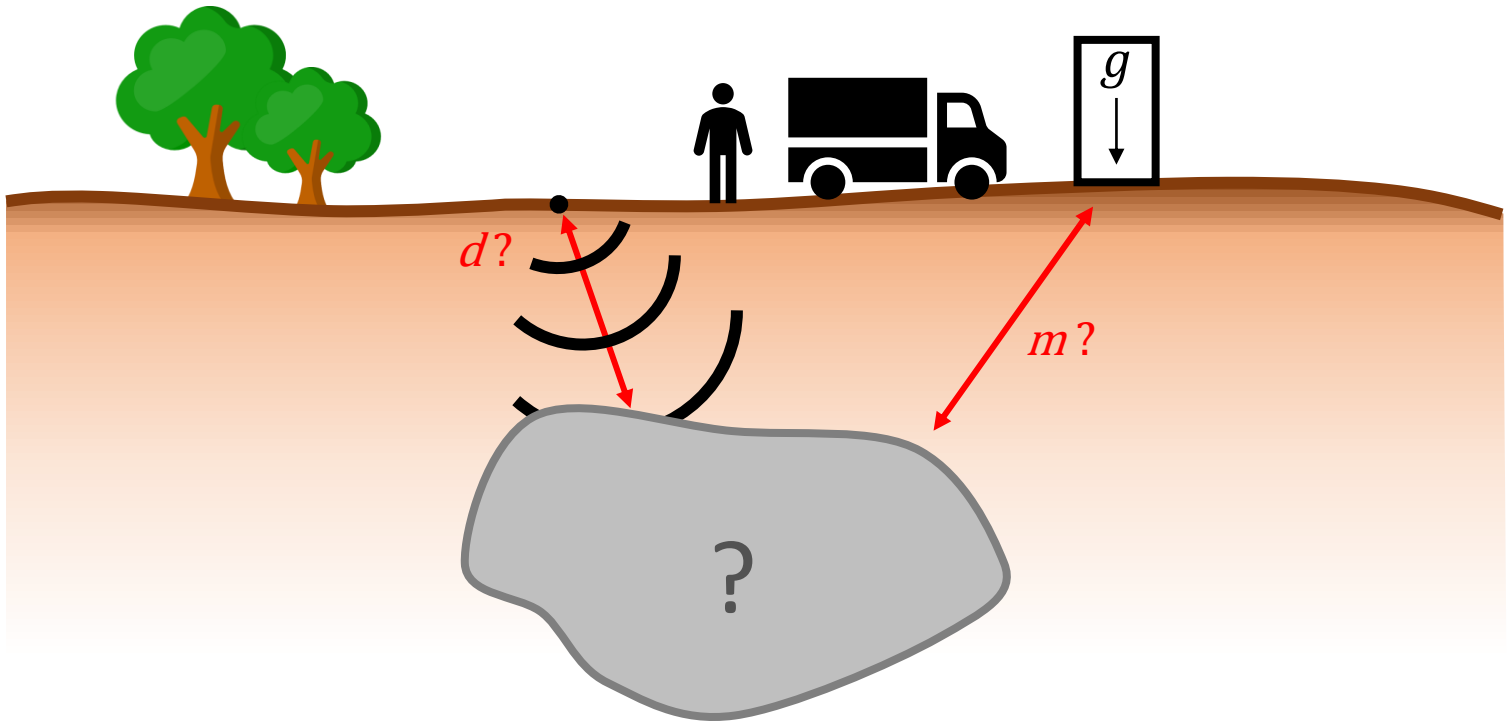
Gravimetry



Gravimetry



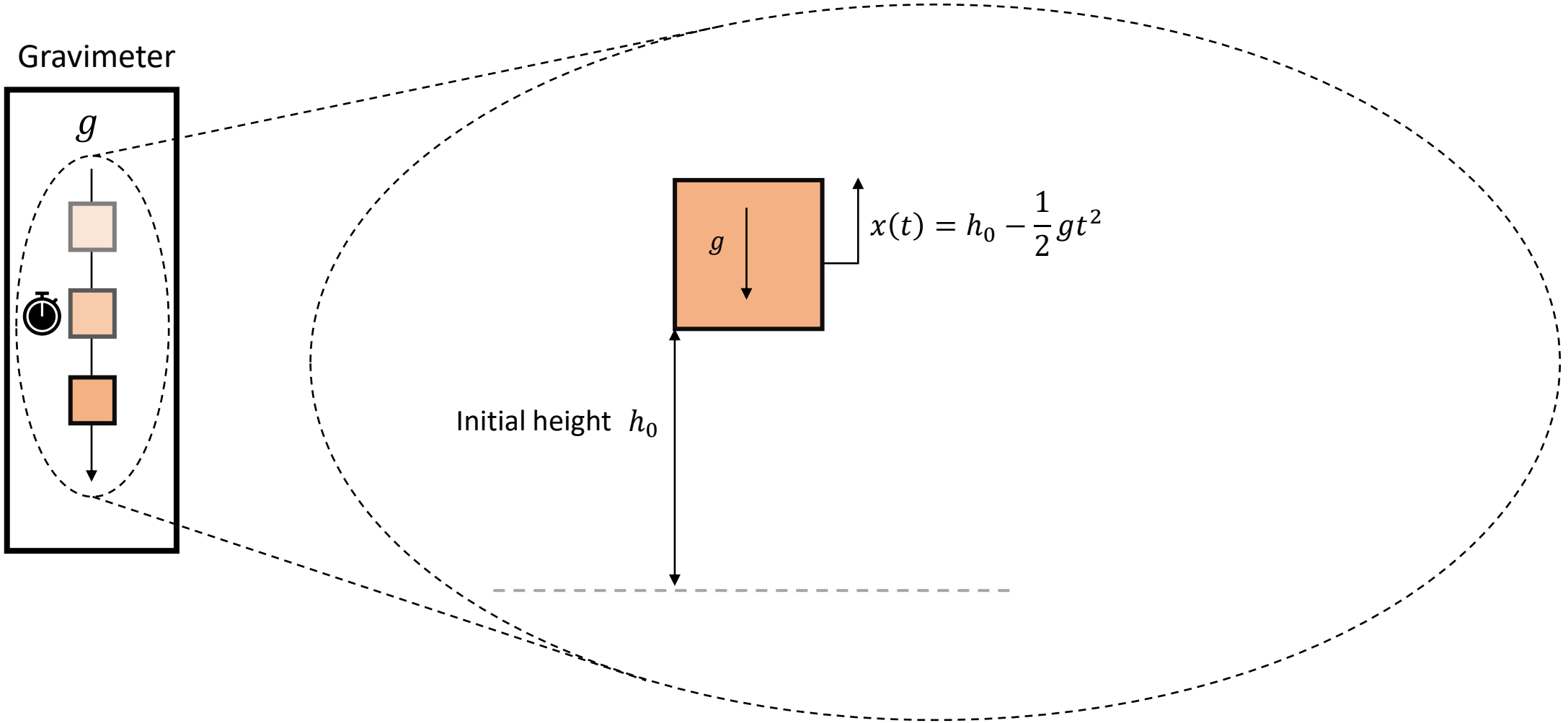
Deployment of the AQG on Mount Etna, [a]

Groundwater storage studies using USGS A10 absolute gravimeter, [b]

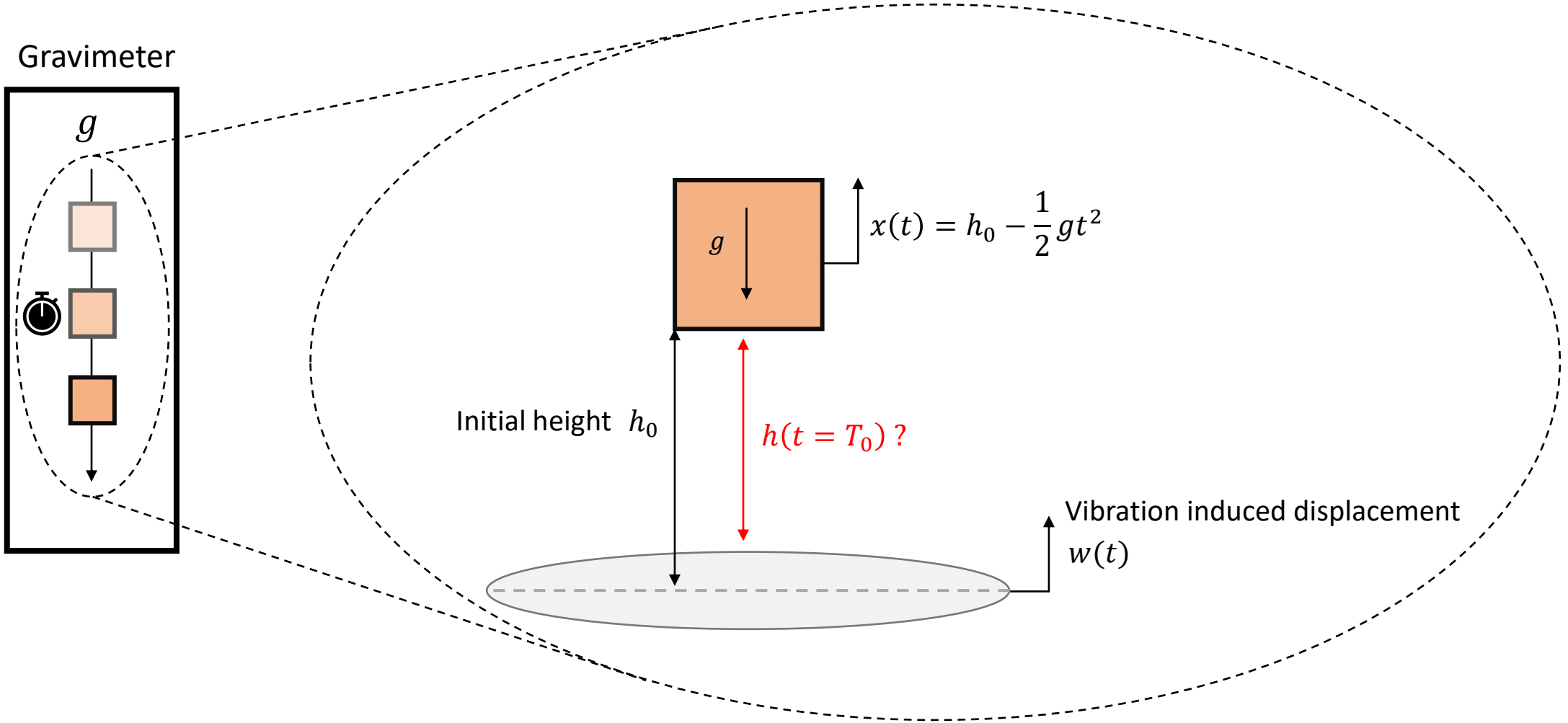
Outline

- Gravimeters and effects of ground vibrations
- Compact Vertical INterferometric Sensor (μVINS)
- Conclusion and future work

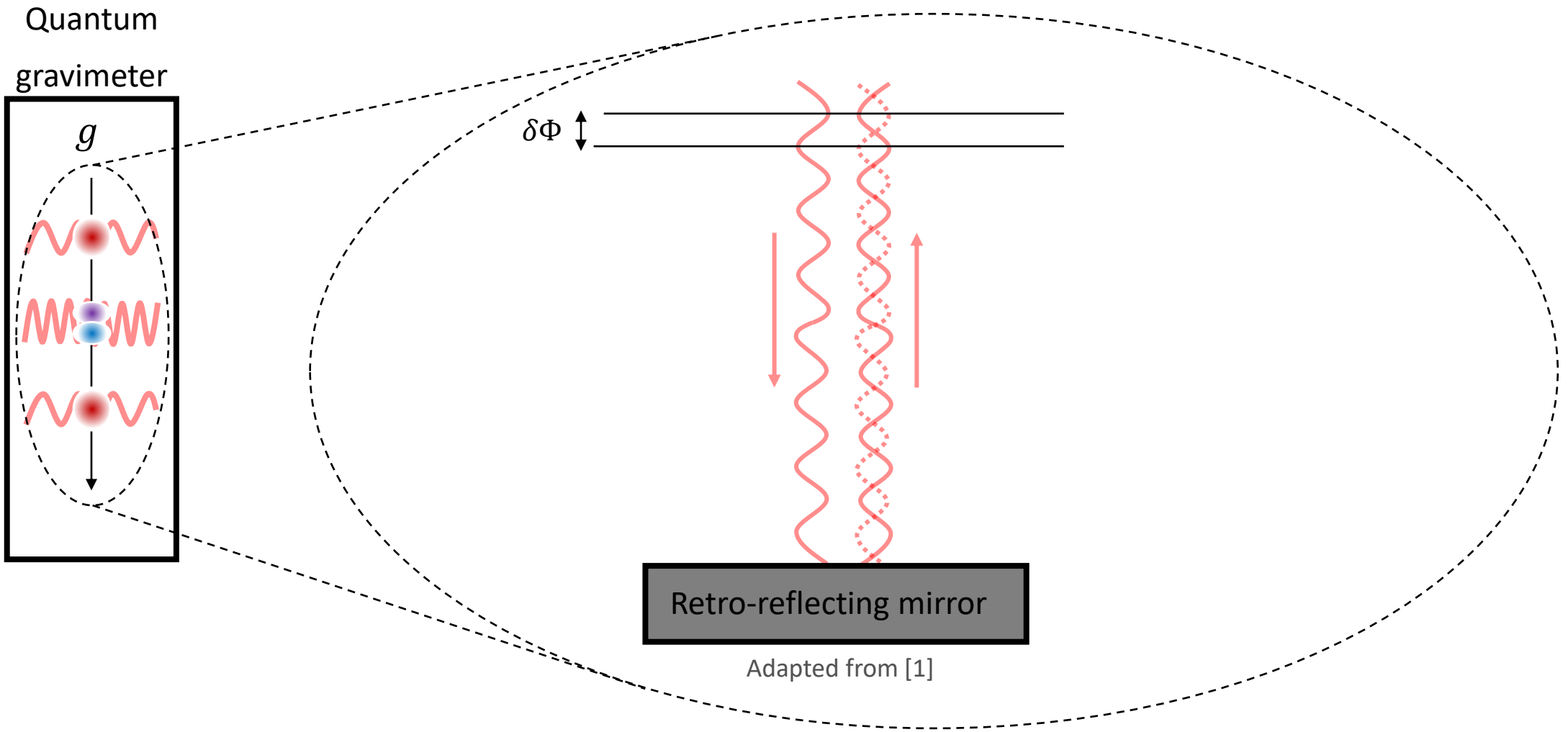
Gravimeter



Gravimeter

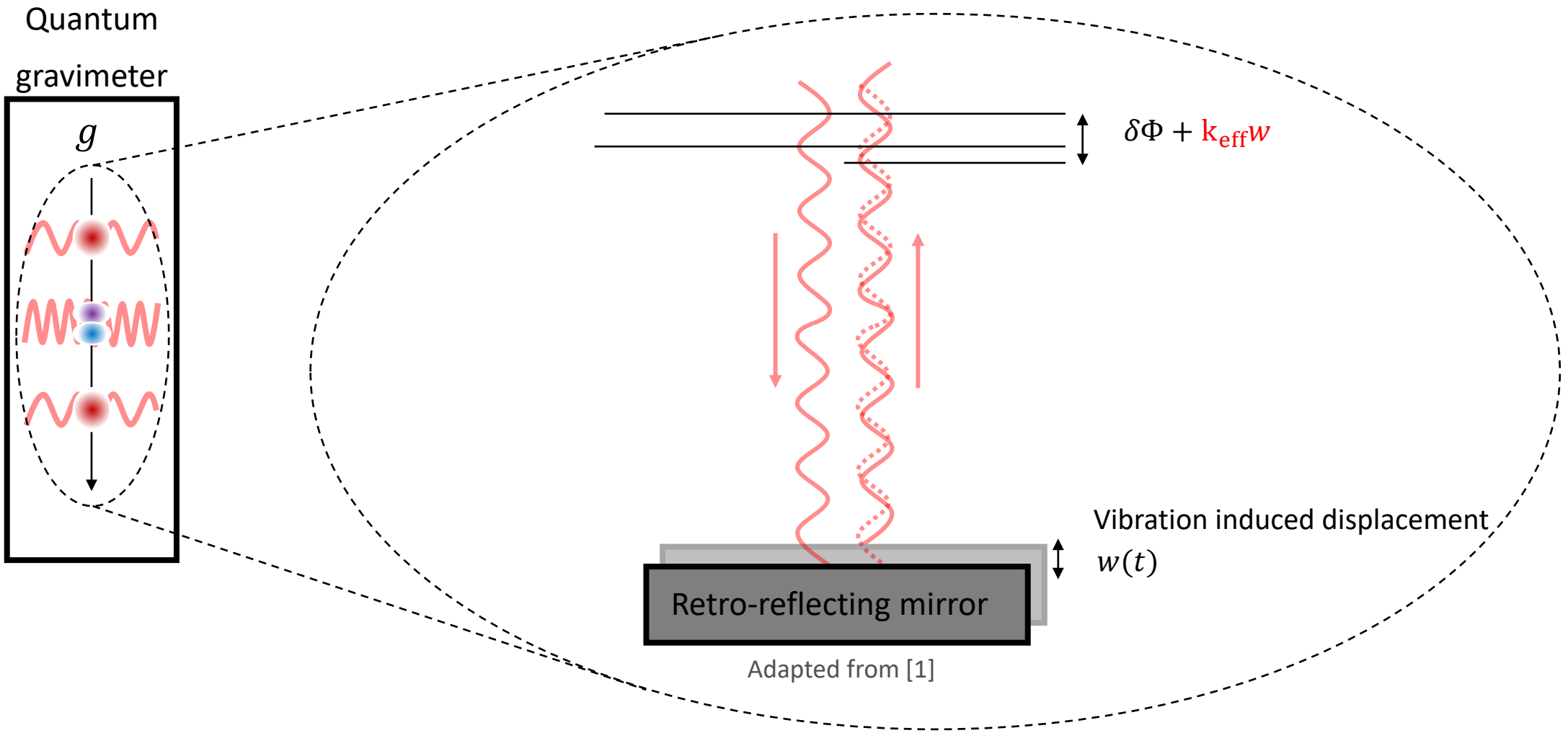

Gravimeter
g
g
$x(t) = h_0 - \frac{1}{2}gt^2$
Initial height h_0
$h(t = T_0)$?
Vibration induced displacement
$w(t)$

Quantum gravimeter



Adapted from [1]

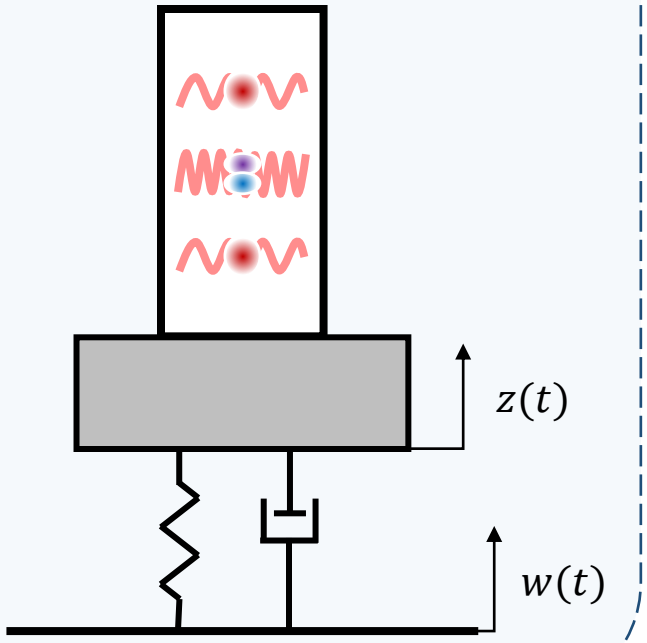
Quantum gravimeter



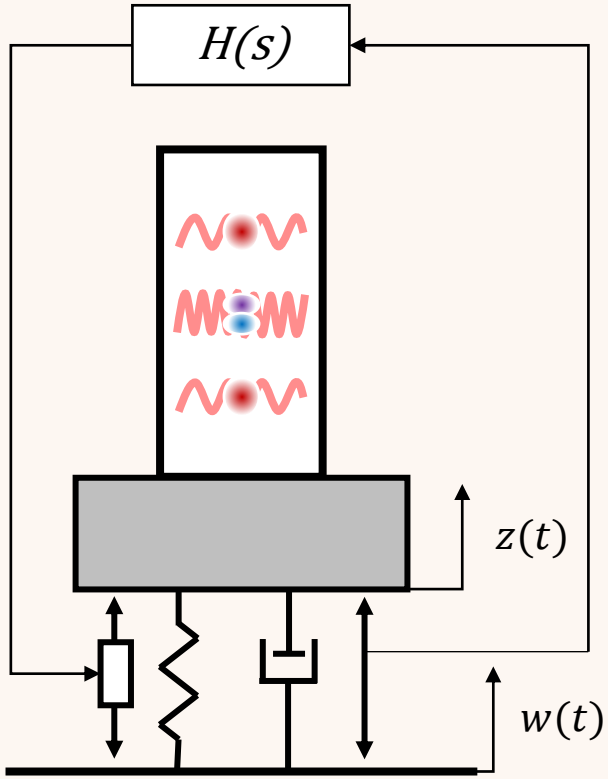
Adapted from [1]

Vibration compensation techniques

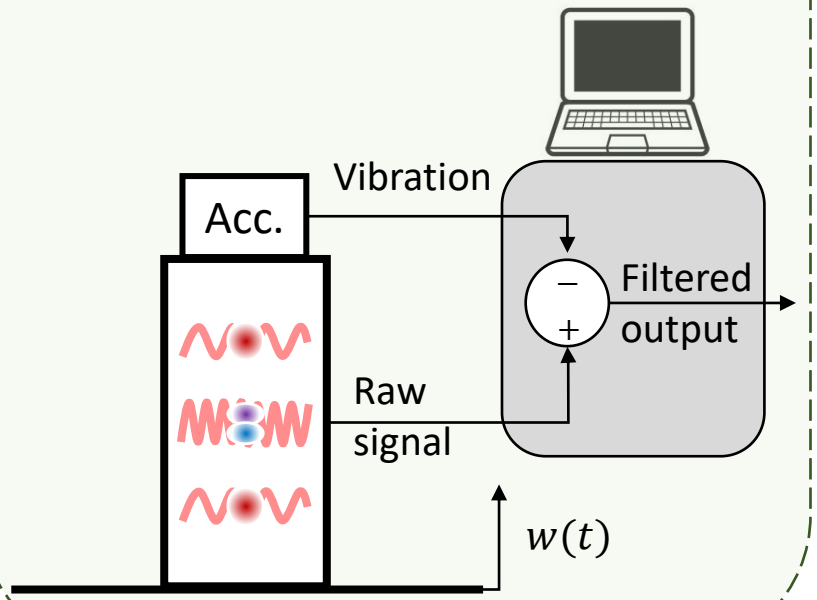
Passive vibration isolation



Active vibration isolation

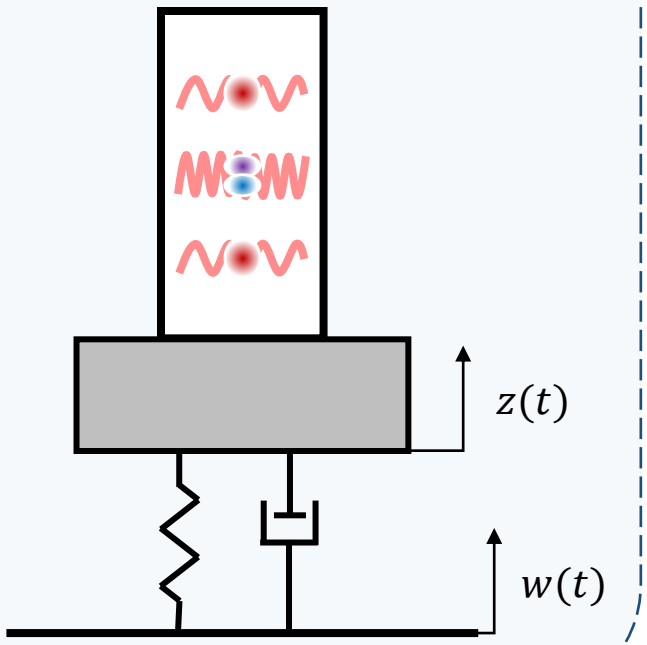


Software rejection

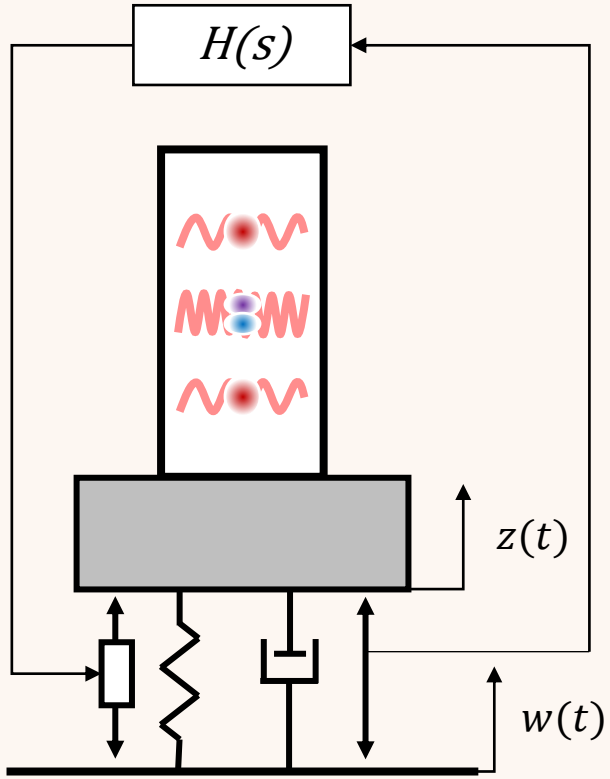


Vibration compensation techniques

Passive vibration isolation



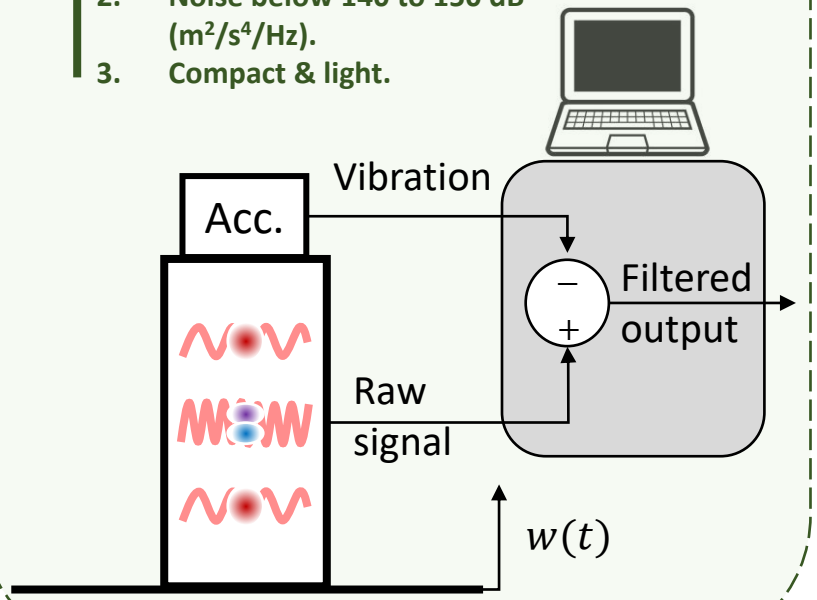
Active vibration isolation



Software rejection

Ideal sensor performance:

1. **Bandwidth from several seconds to 100 Hz.**
2. **Noise below 140 to 150 dB ($m^2/s^4/Hz$).**
3. **Compact & light.**



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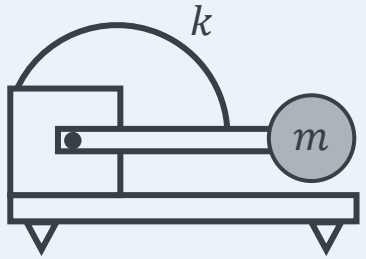
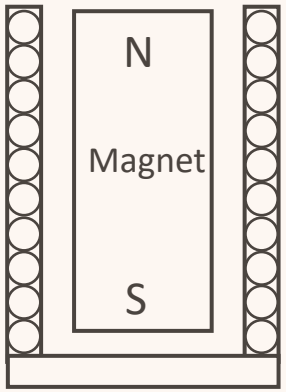
- Conclusion and future work

Vertical inertial sensor

Low stiffness mechanics and guidance



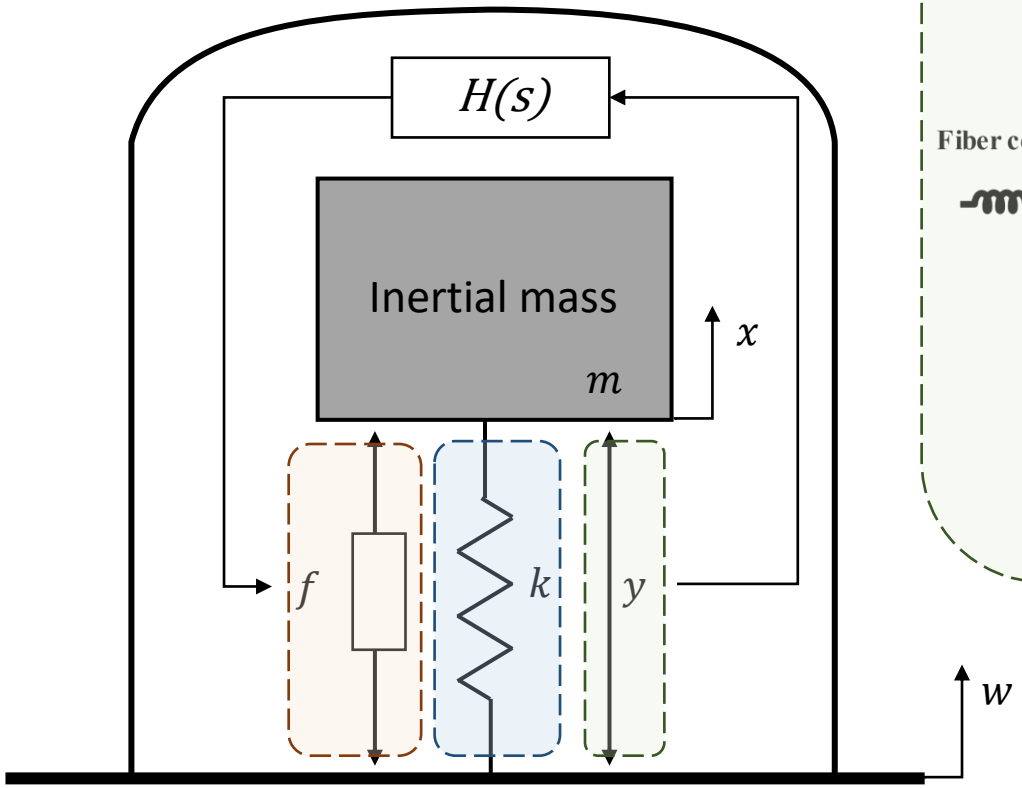
1. & 2. Low natural frequency.
3. Compact & light.

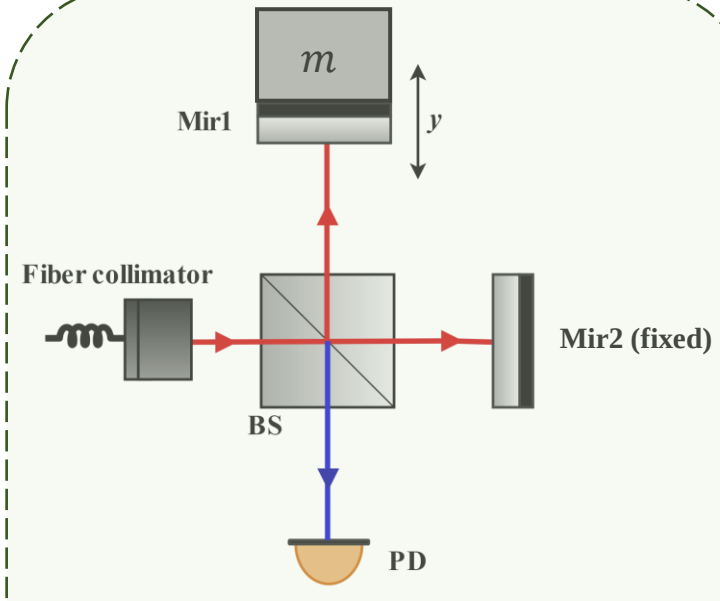


2. Low noise injection.
1. Improved linearity and bandwidth.

Contactless actuation

Inertial sensor



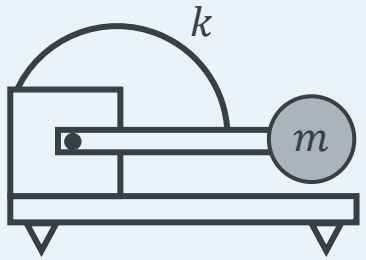


2. High resolution.

Contactless readout

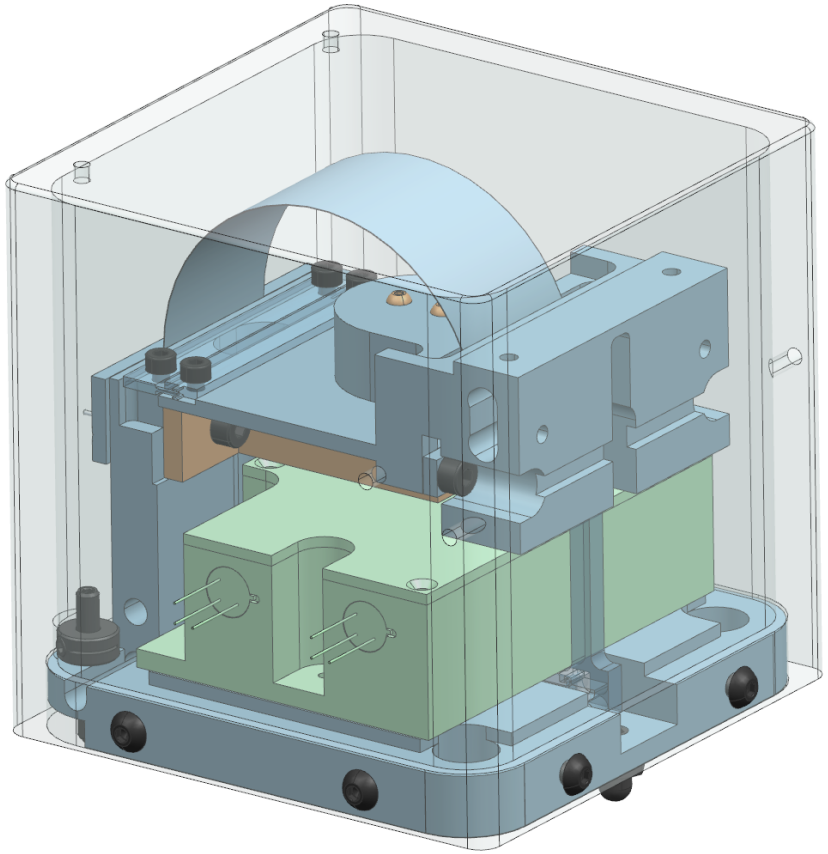
µ - Vertical INterferometric inertial Sensor

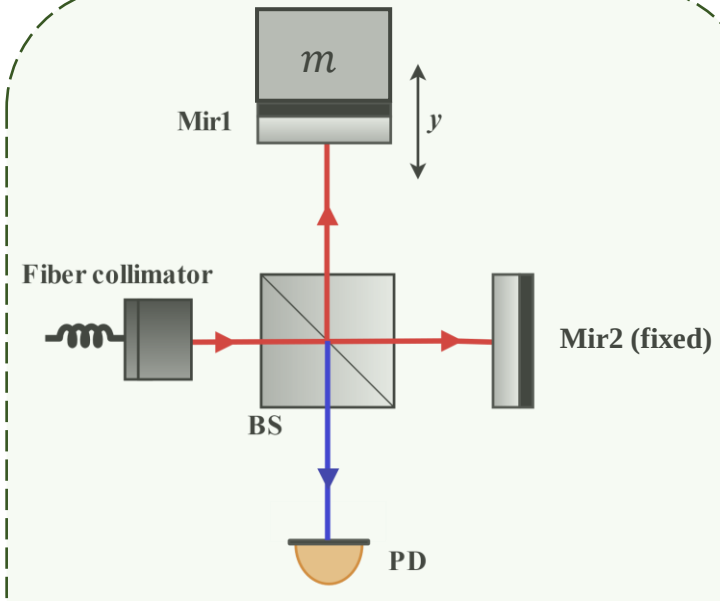
Low stiffness mechanics and guidance



1. & 2. Low natural frequency.
3. Compact & light.

µVINS





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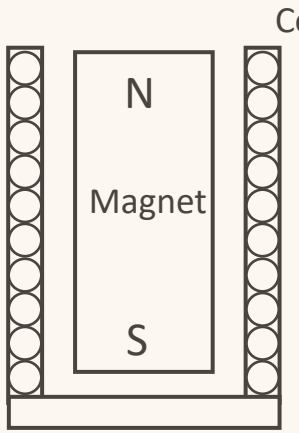
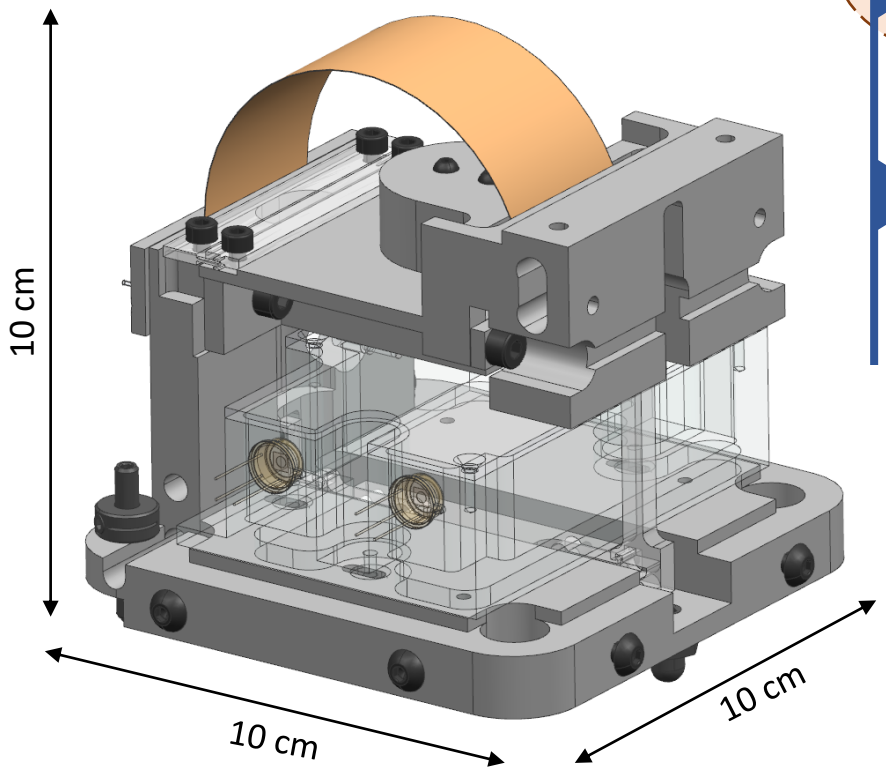
Contactless readout



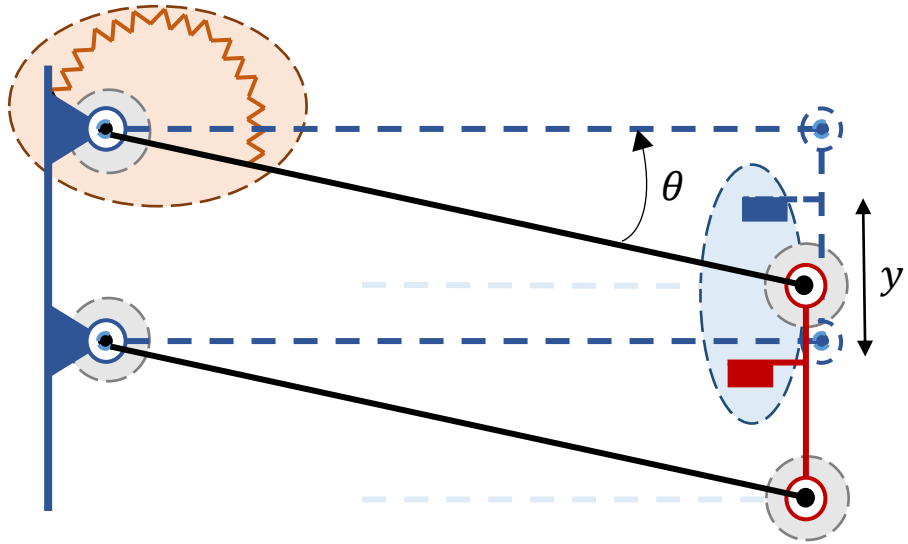
2. Low noise injection.
1. Improved linearity and bandwidth.

Contactless actuation

Low stiffness mechanical guide



CuBe leaf-spring

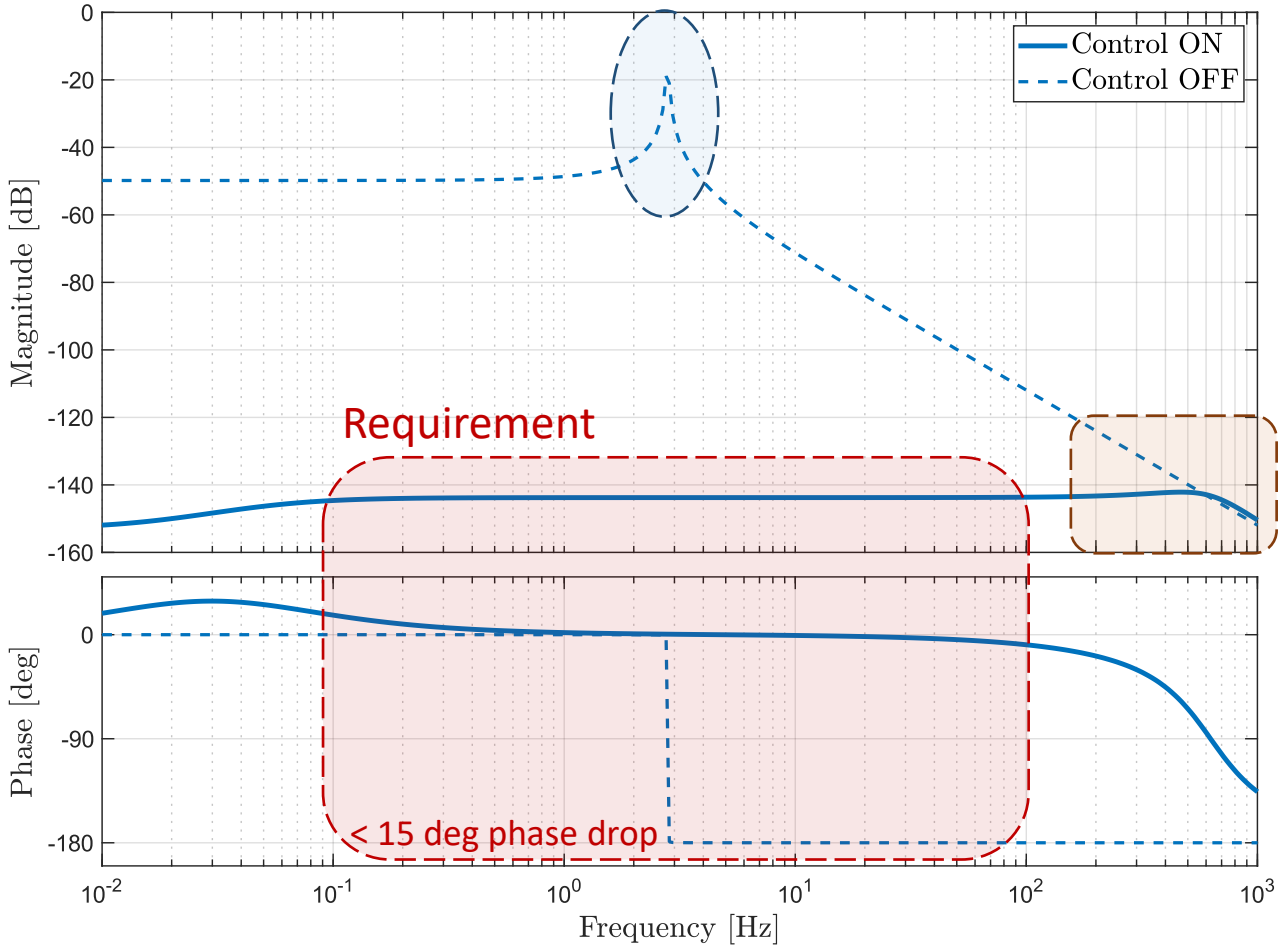


2.8 Hz natural frequency suspension.

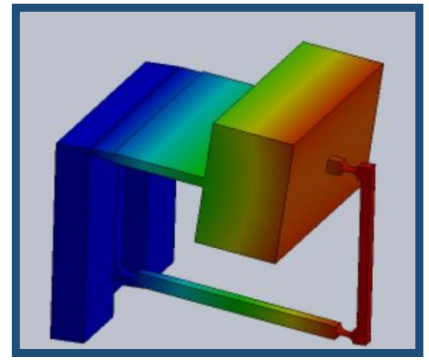
Linear, angle-maintaining, motion of the mirror.

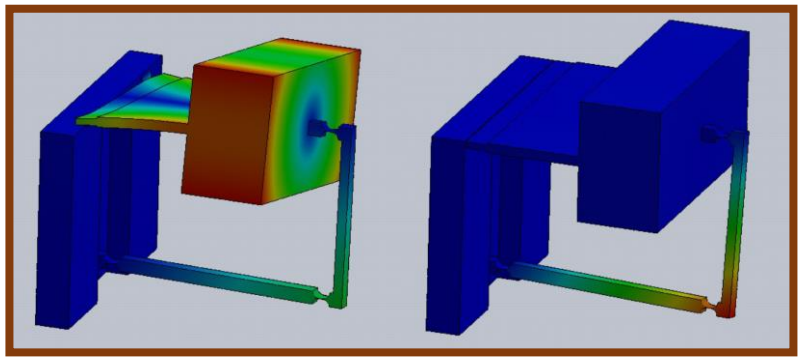
Low dissipation fused-silica joints.

Low stiffness mechanical guide



2.8 Hz

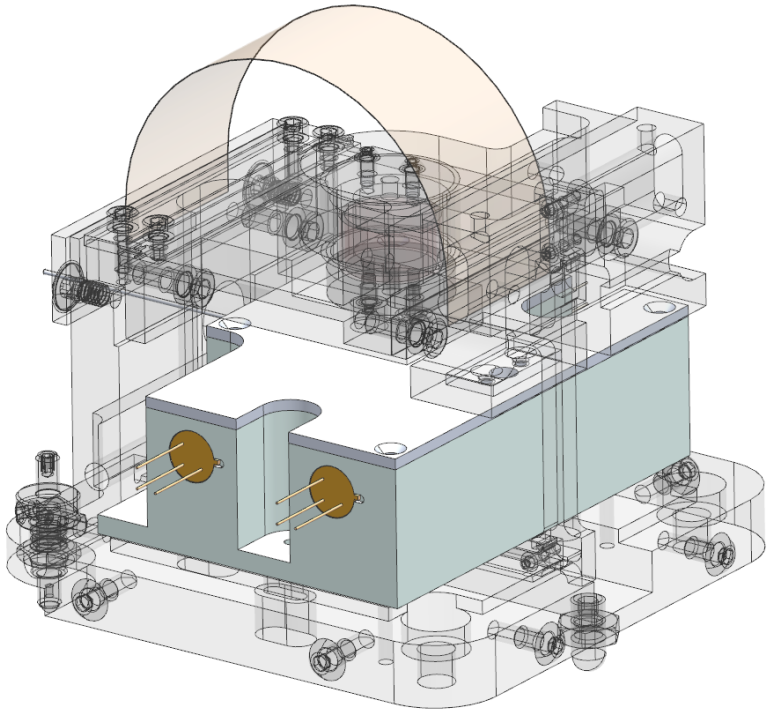


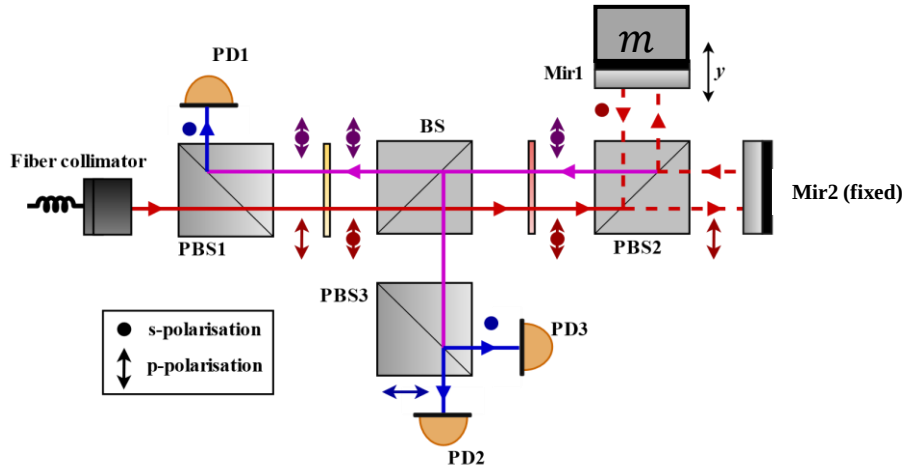


270 Hz

327 Hz

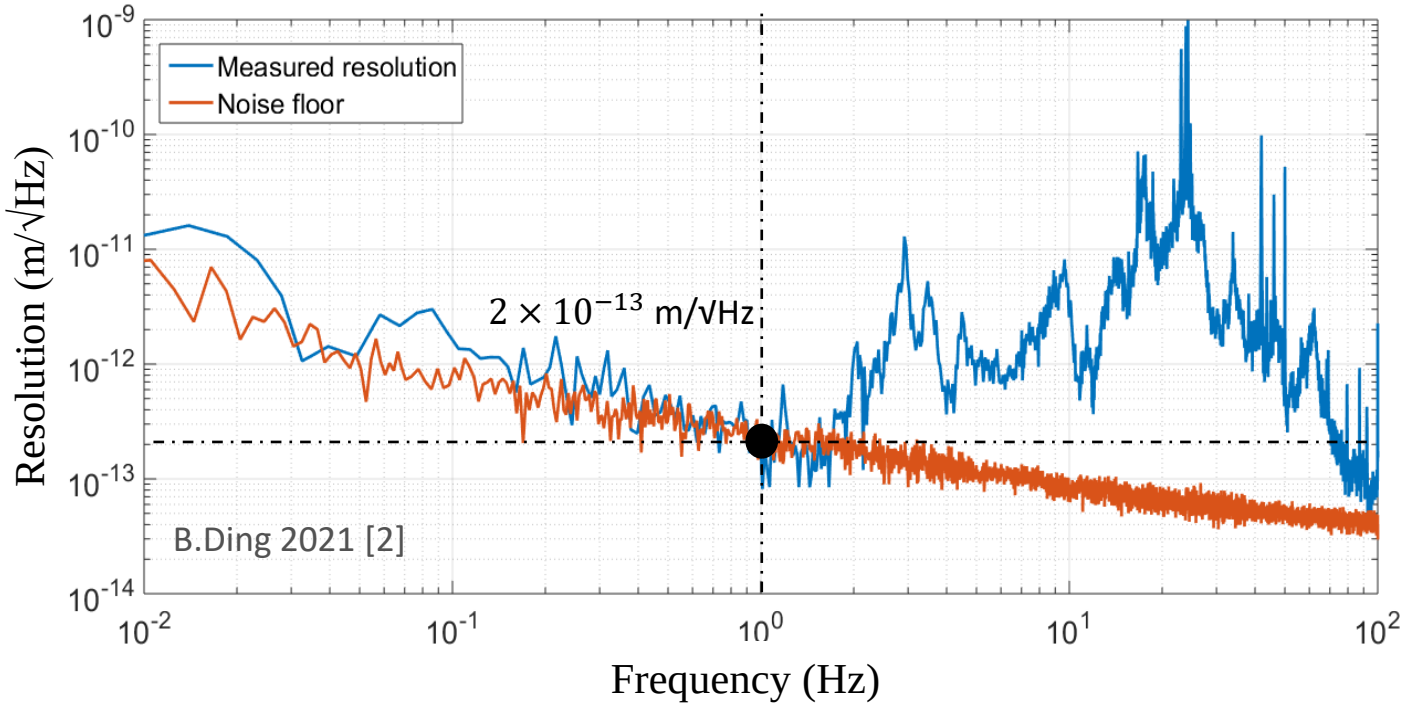
Interferometric readout



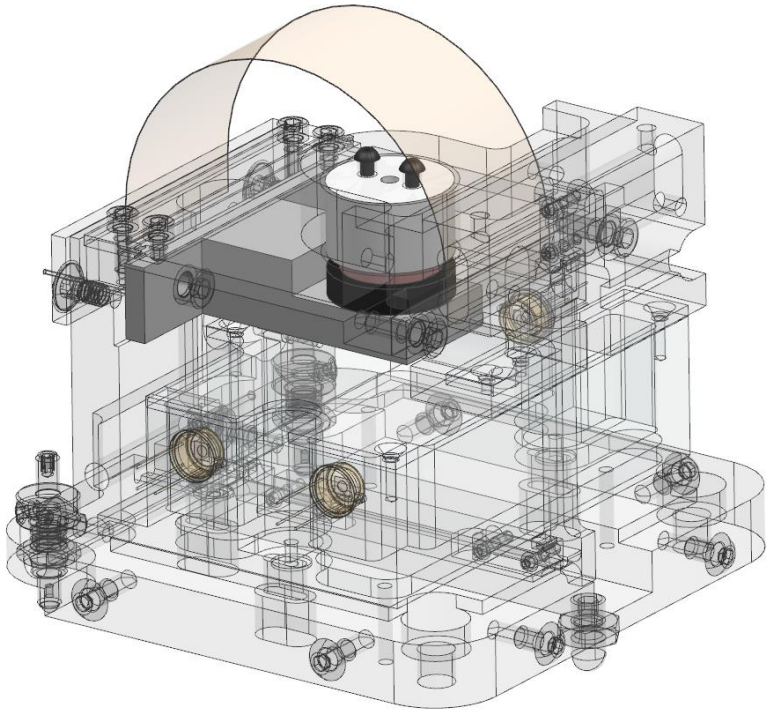


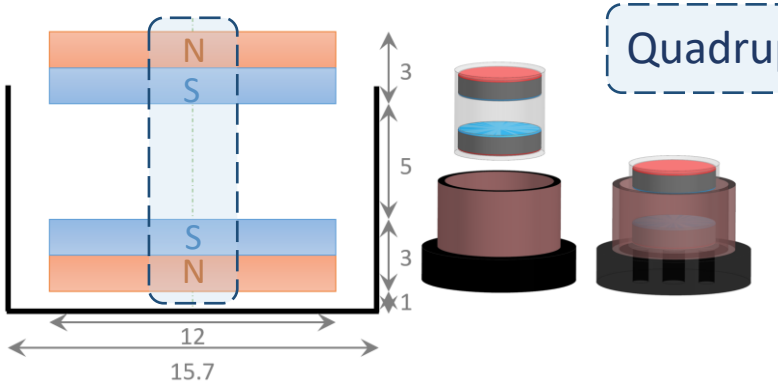
Long range readout.

Sub-pm resolution.

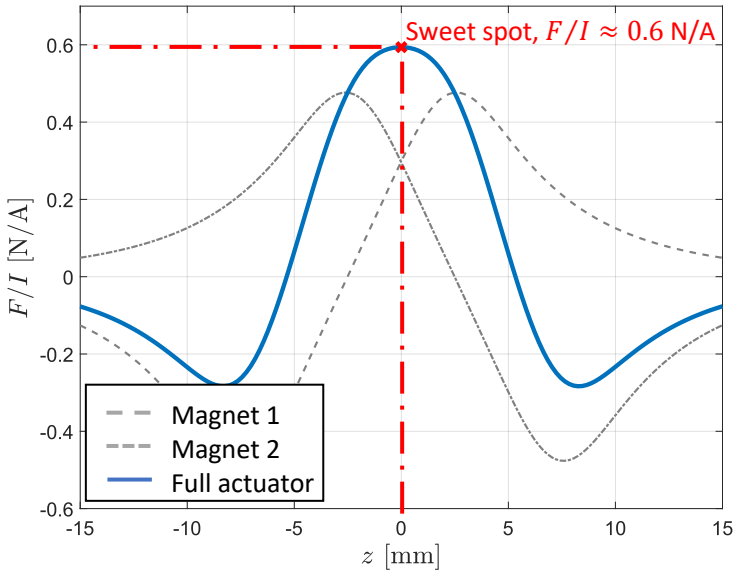


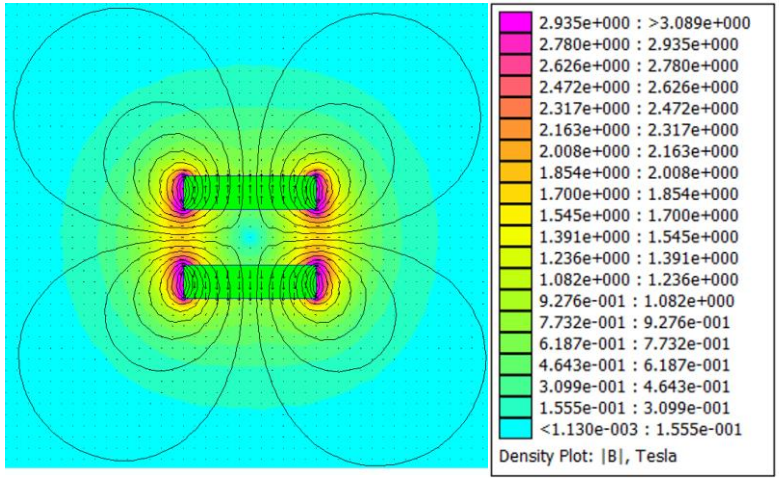
Quadrupole voice-coil actuator





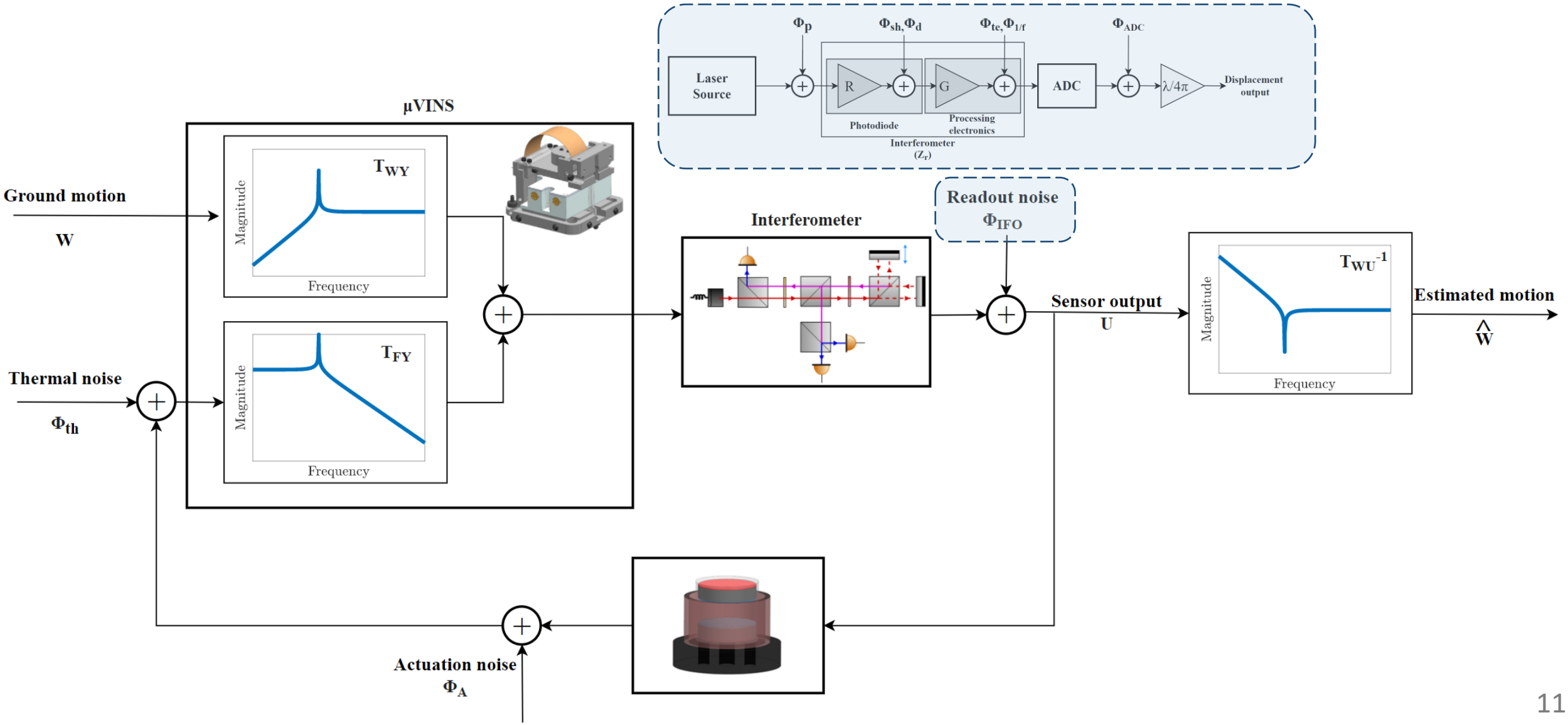
Quadrupole, selfshielded, magnet.



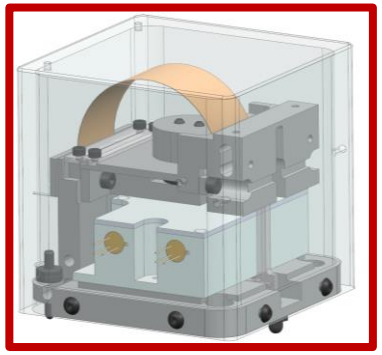


Numerical optimization of the geometry.

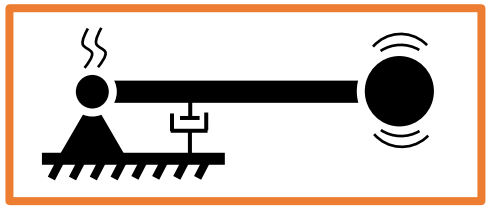
Noise budgeting

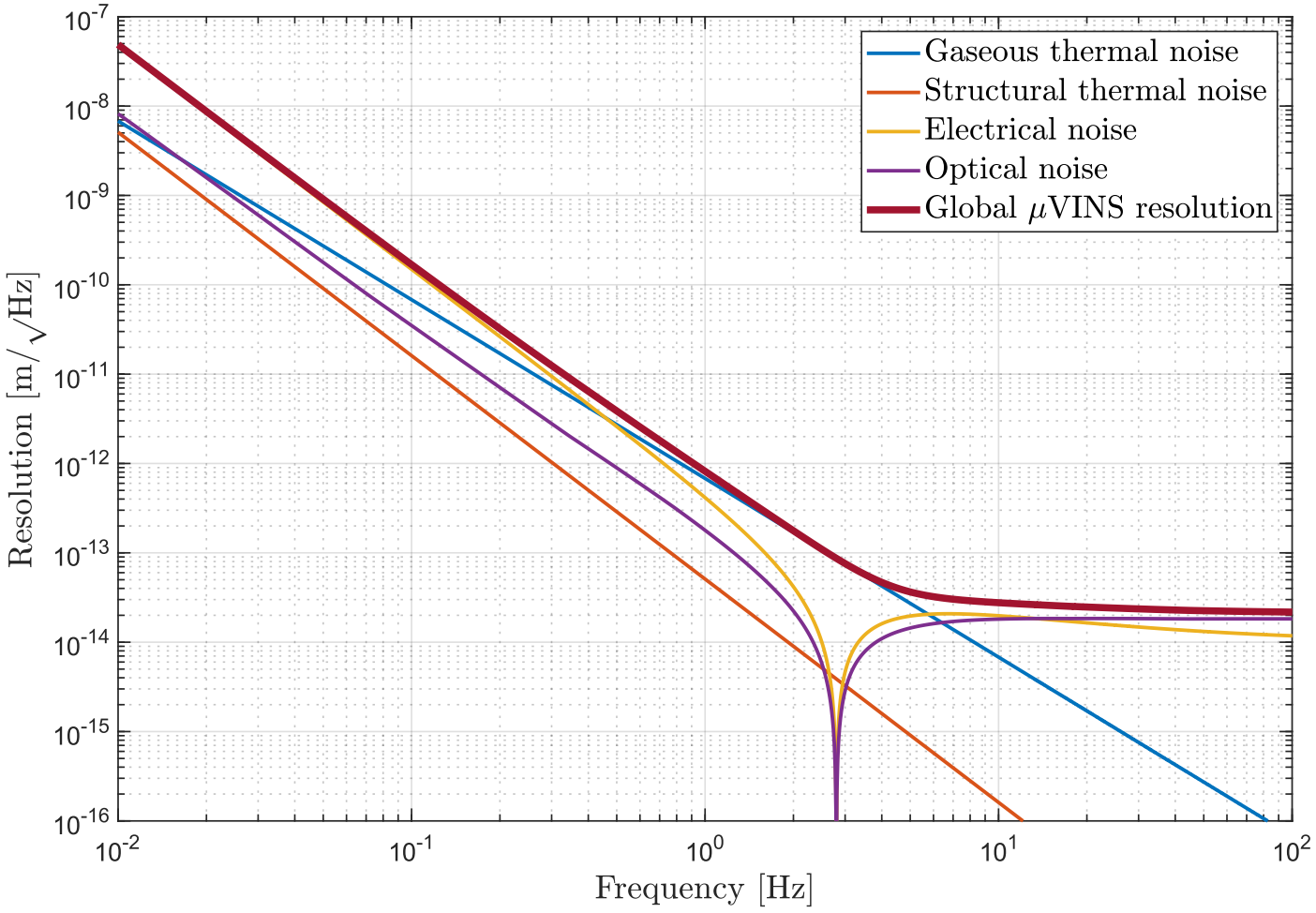


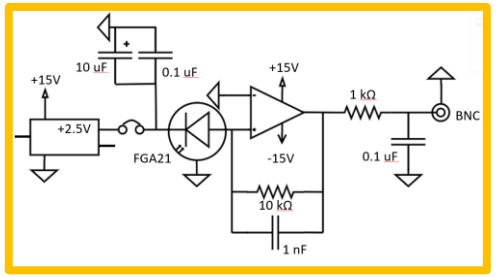
Noise budget

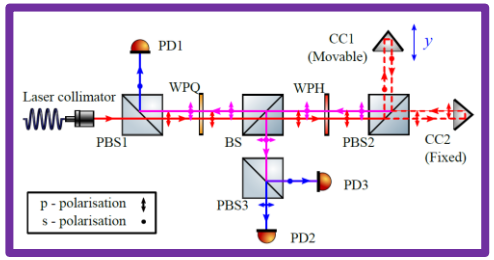


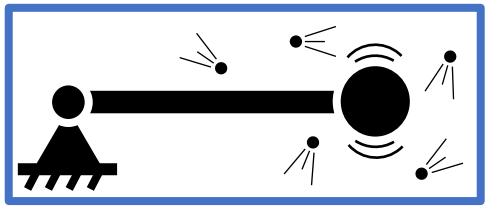
µVINS



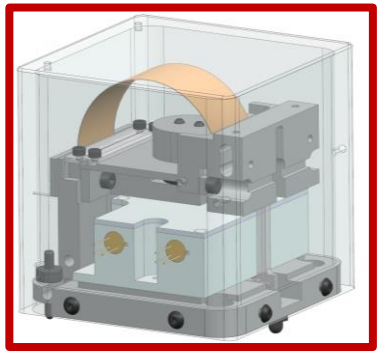






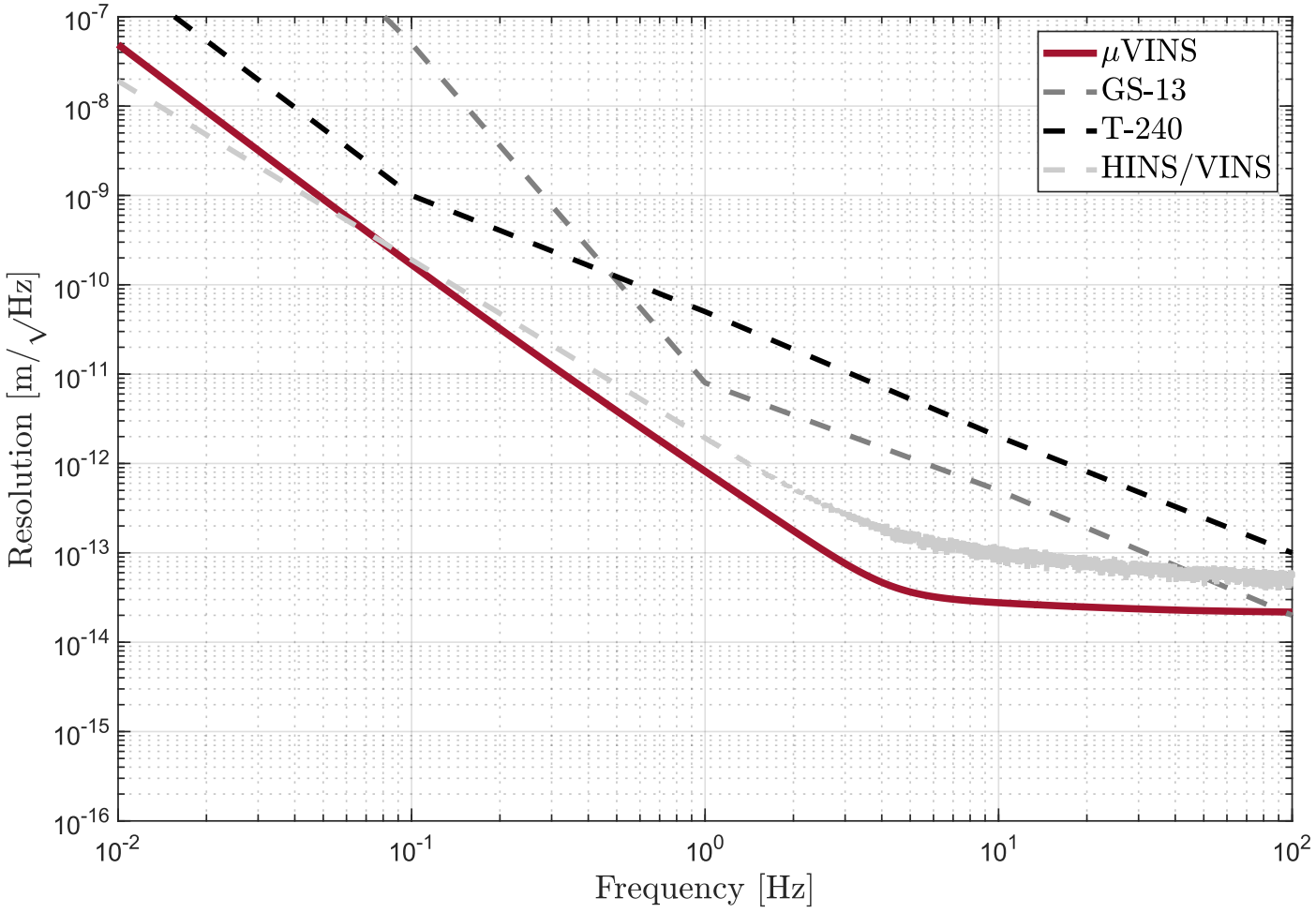


Noise budget



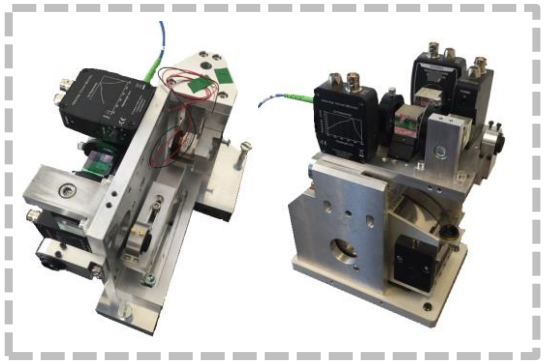
µVINS

T-240



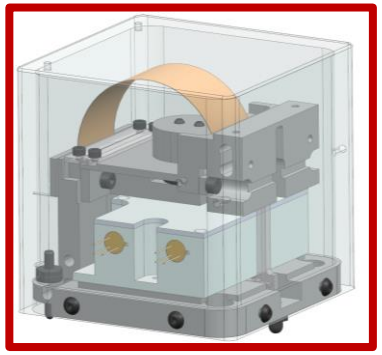
GS-13

VINS & HINS



B.Ding 2021 [2]

Noise budget

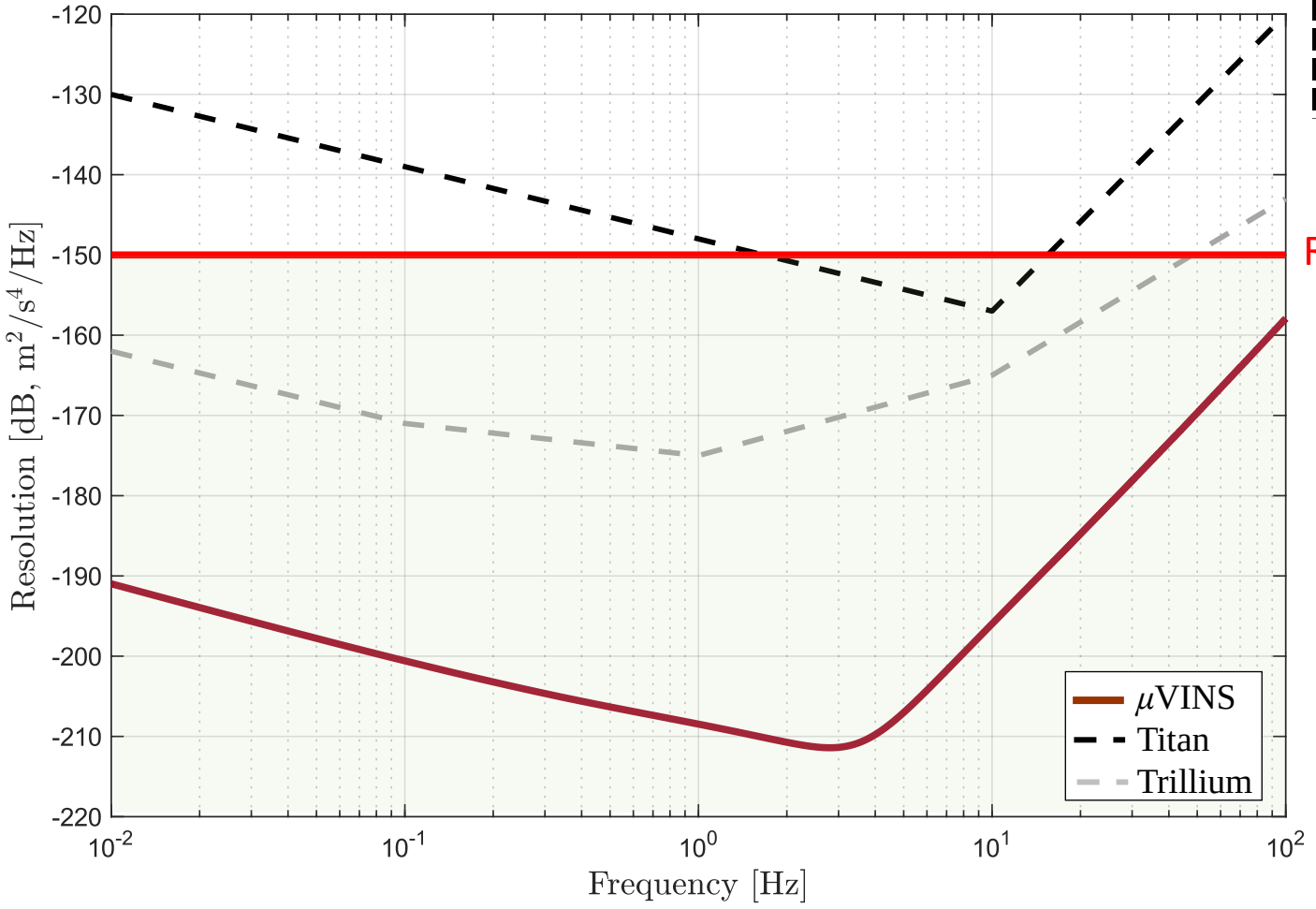


µVINS

Trillium

Titan

Requirement



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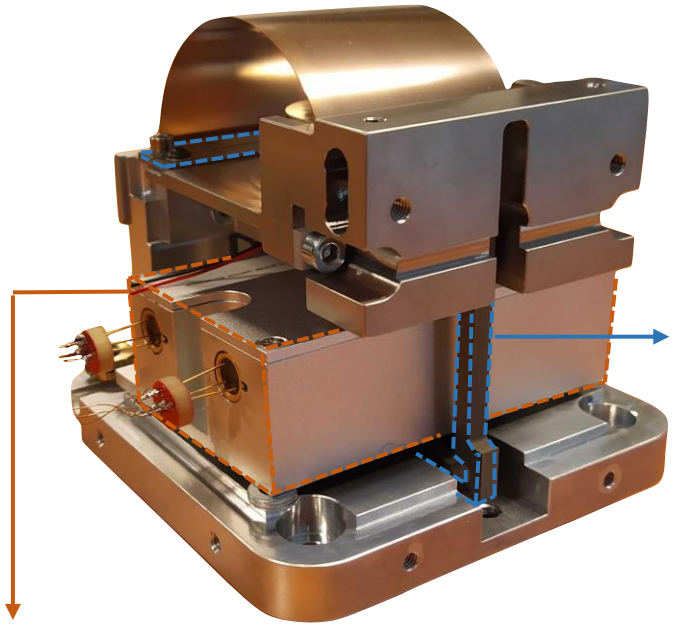
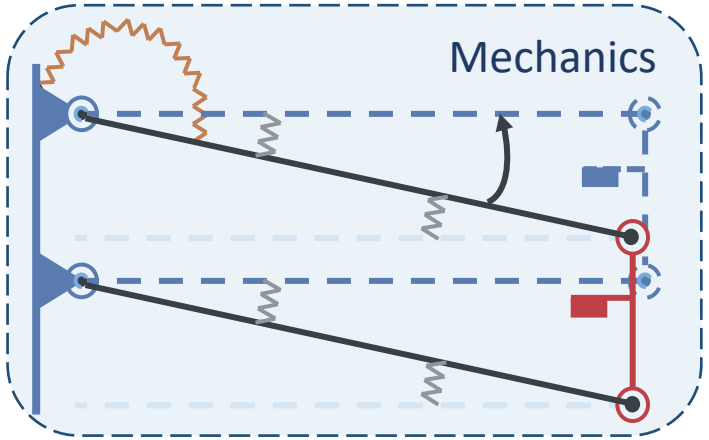
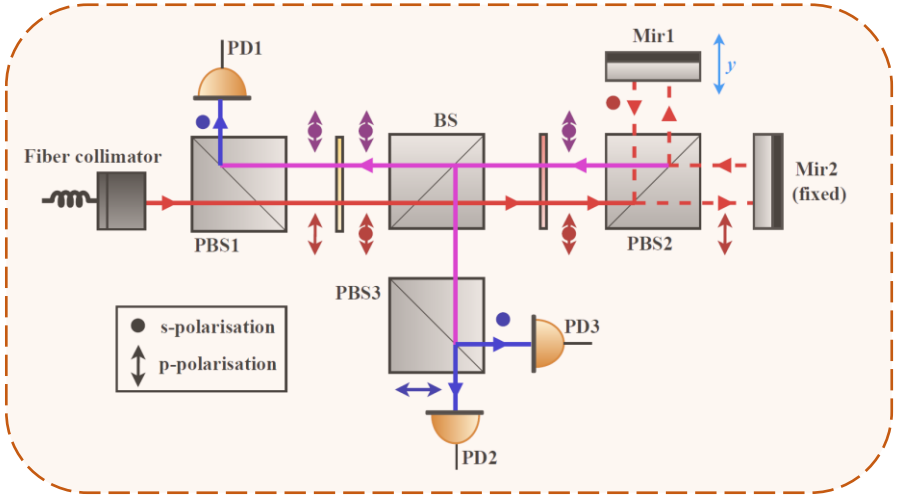
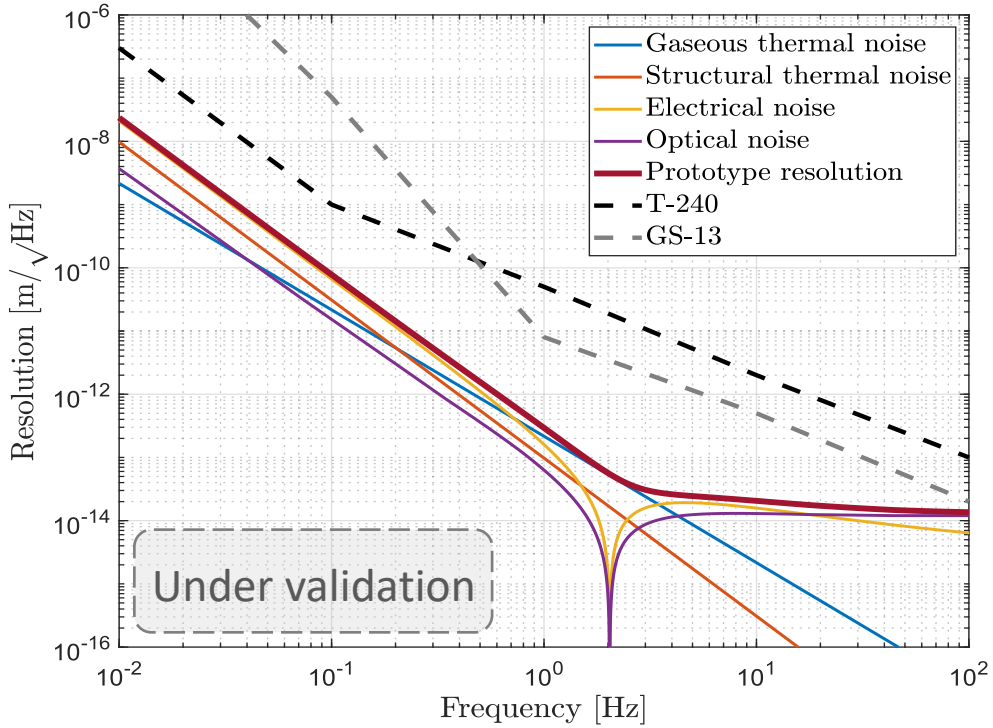
µVINS testing campaign



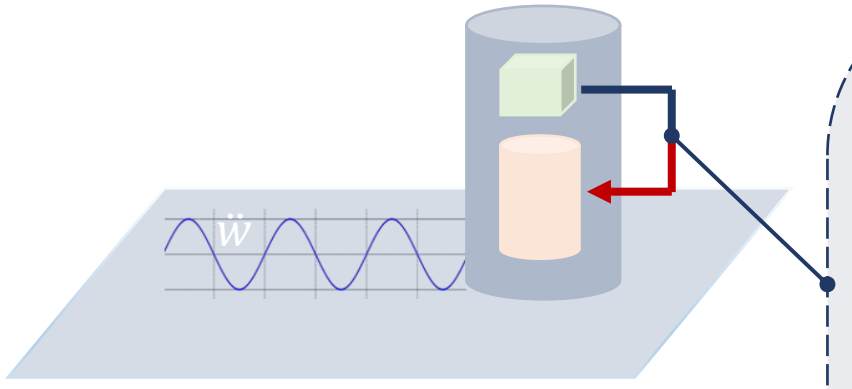


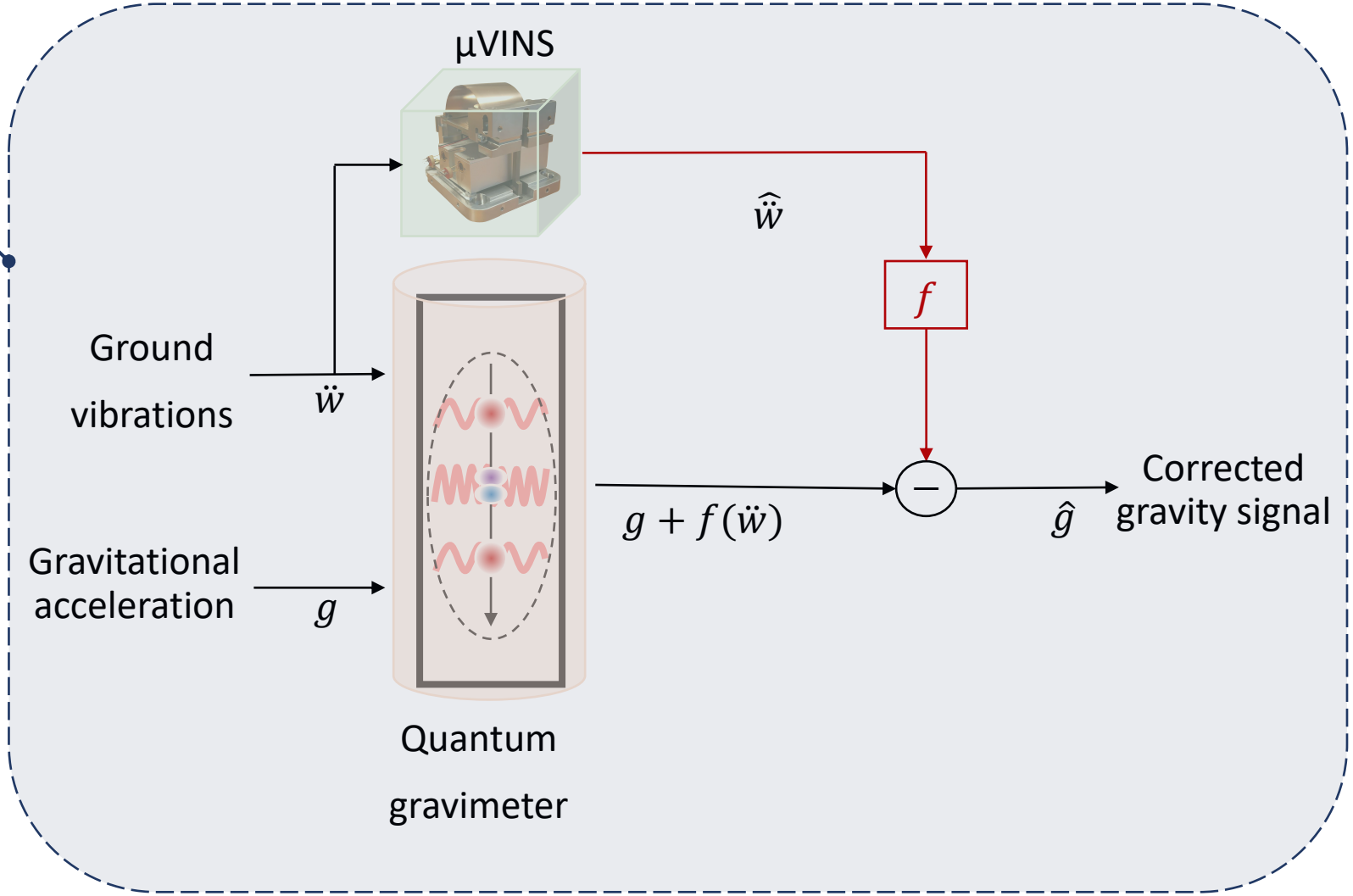
Quadrature optical readout





Vibration compensation

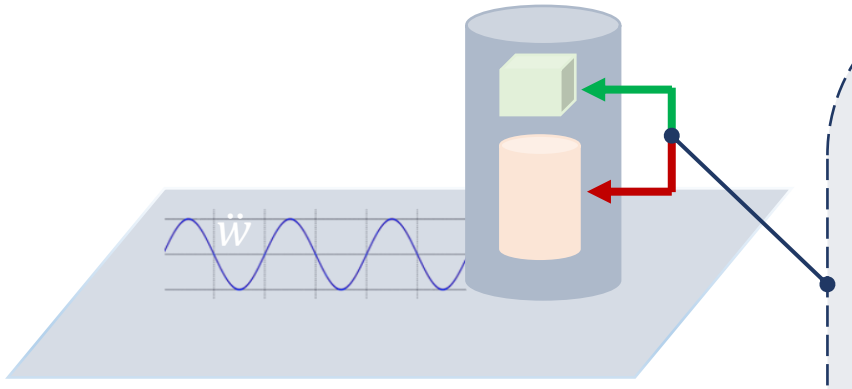


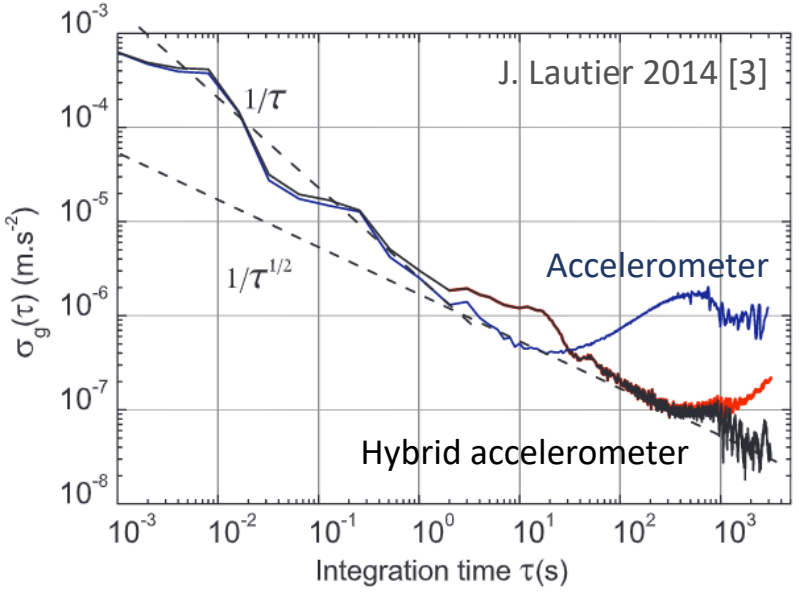


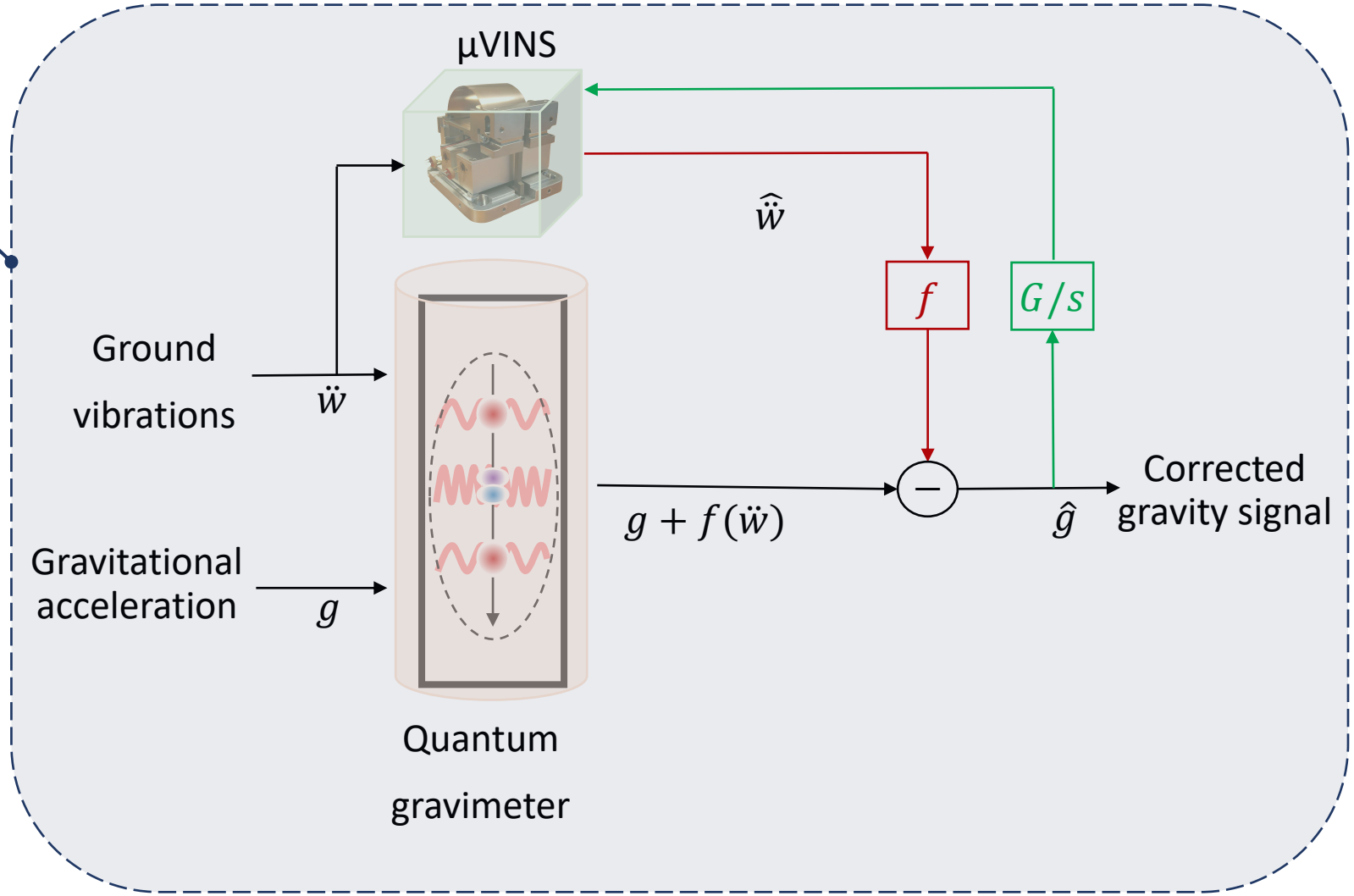
iXblue

µQUANS
PRECISION QUANTUM SENSORS

Full hybridizing







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[a] https://www.muquans.com/news/deployment-of-our-quantum-gravimeter-on-mount-etna/

[b] https://www.usgs.gov/media/images/changes-earths-gravity-reveal-changes-groundwater-storage-0

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Thank you for your attention!

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