Sub-nanometer displacement measurements in seismic sensors.

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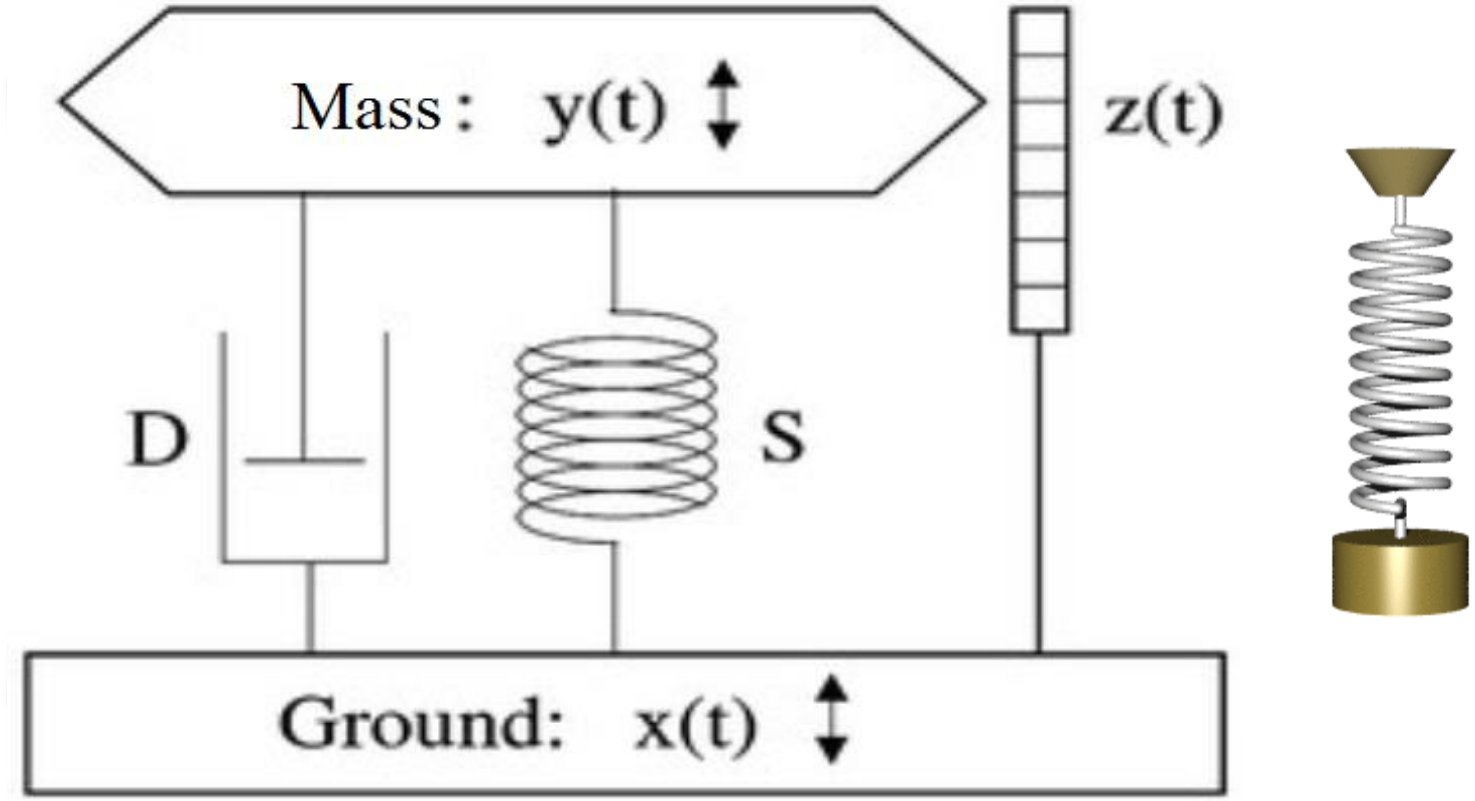
Content

- What are seismic sensors.
- Seismic sensors in PACMAN.
- Limitations of state of the art sensors.
- Understanding the sensor resolution.
- Measurement of the sensor resolution.
- How to improve sensor resolution.

What are seismic sensors and their working principle.

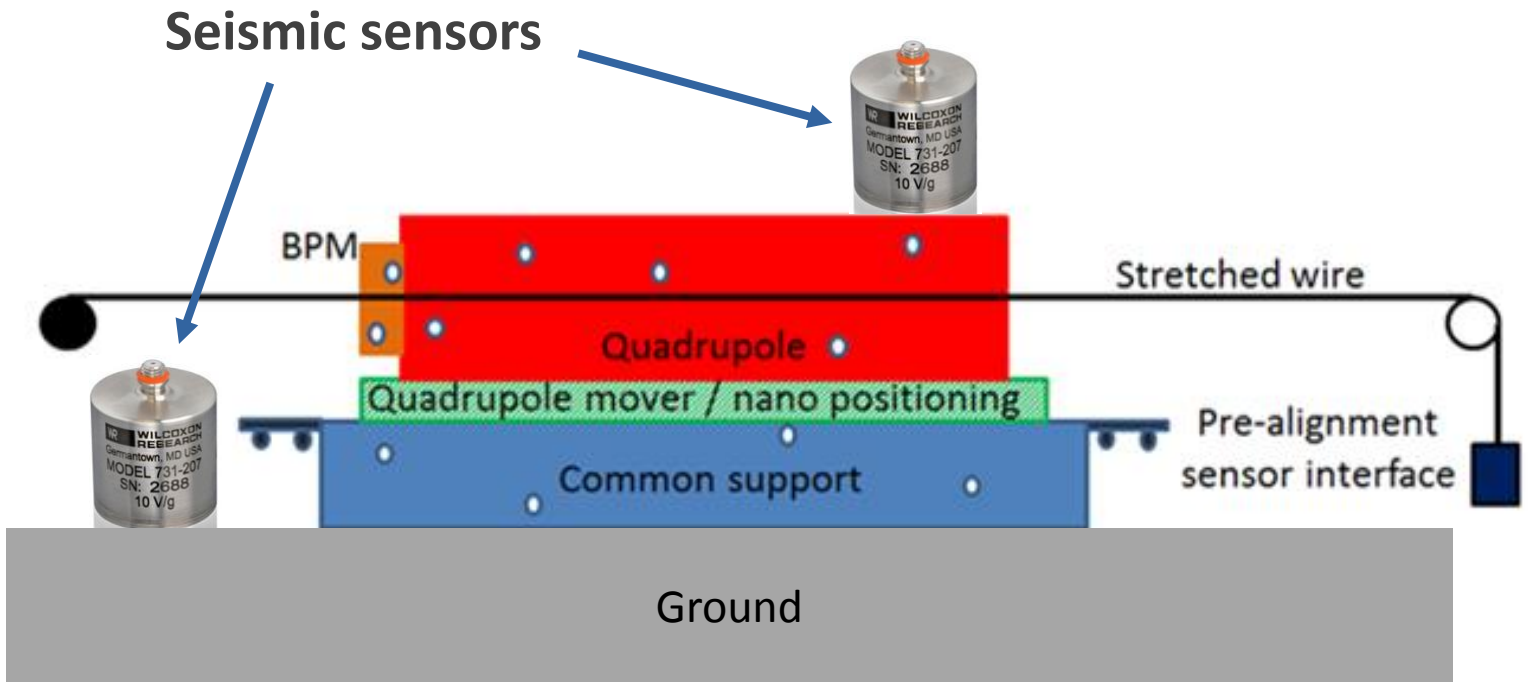
Instruments which measures ground motion.



Not only earthquakes but also motion in nanometres.

Why do we need seismic sensors in PACMAN?

- **To know how ground motion influences characterization of BPM.**



Limitations of state of the art sensors for PACMAN.

PACMAN requirements:

- **Bandwidth = 0.1 ~ 200 Hz**
- **Resolution ≤ 0.1nm RMS@1Hz**
- **Magnetic fields resistance**

Seismometers

× Bandwidth

✓ Resolution

PZT Accelerometers

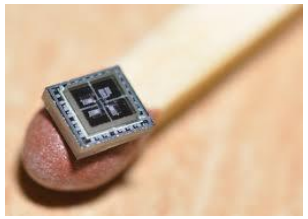
✓ Bandwidth

× Resolution

Geophones

× Bandwidth

× Resolution



MEMS accelerometers

✓ Bandwidth

× Resolution

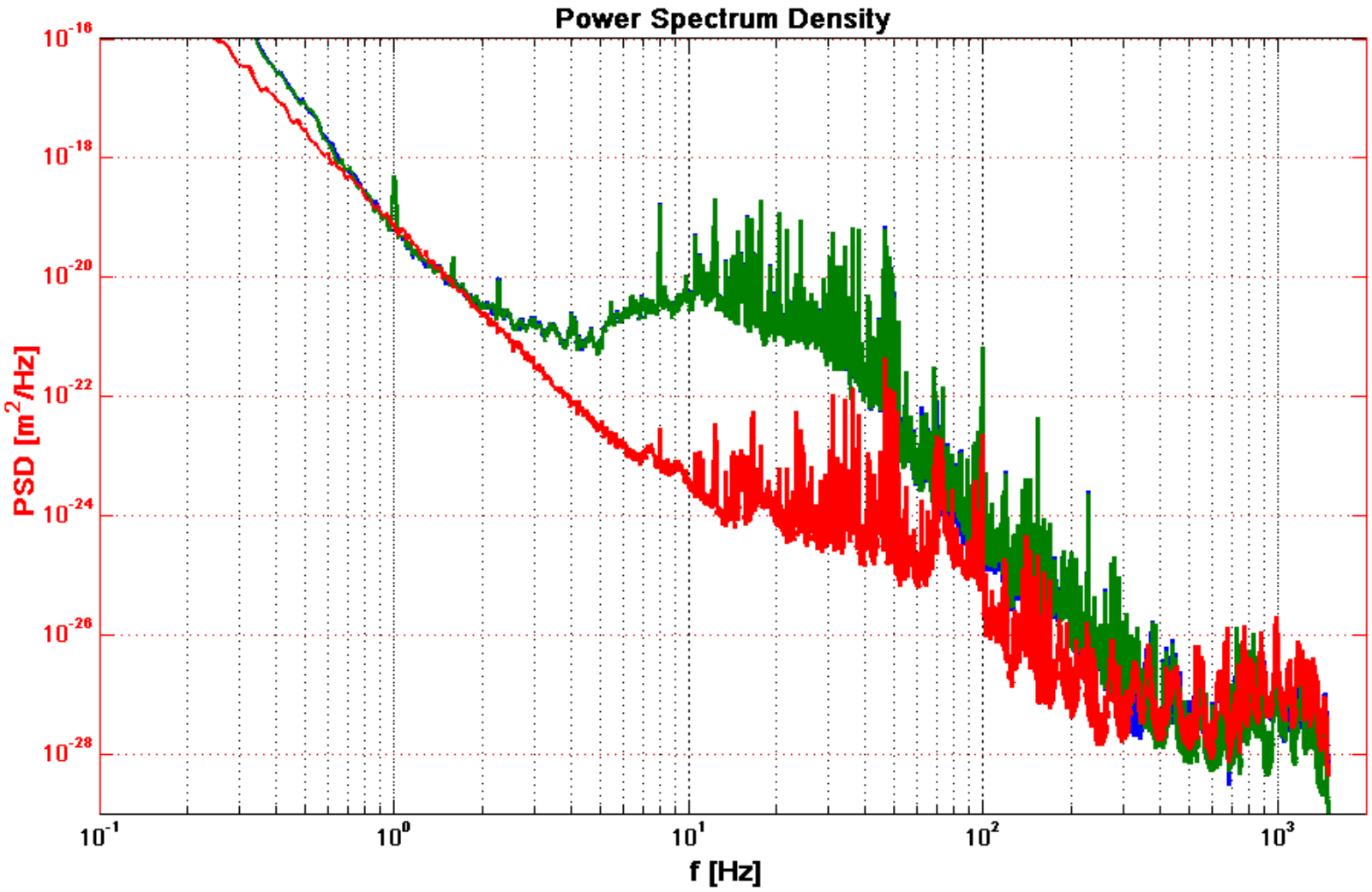
Force Balanced optical accelerometers

✓ Bandwidth

≈ Resolution

Main problem is that perfect quiet place doesn't exist!

How do we measure sensor's resolution?

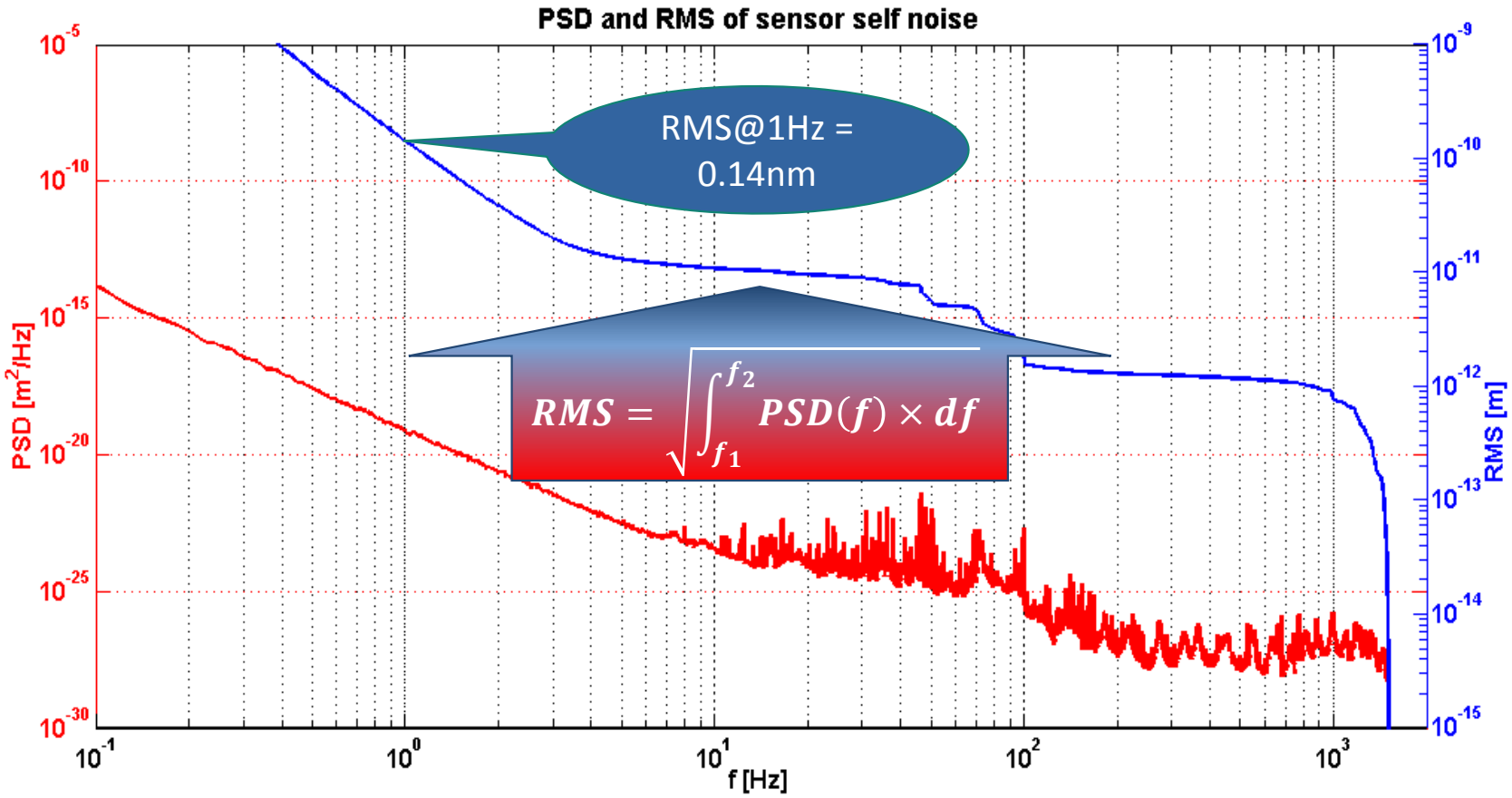


How do we understand resolution.

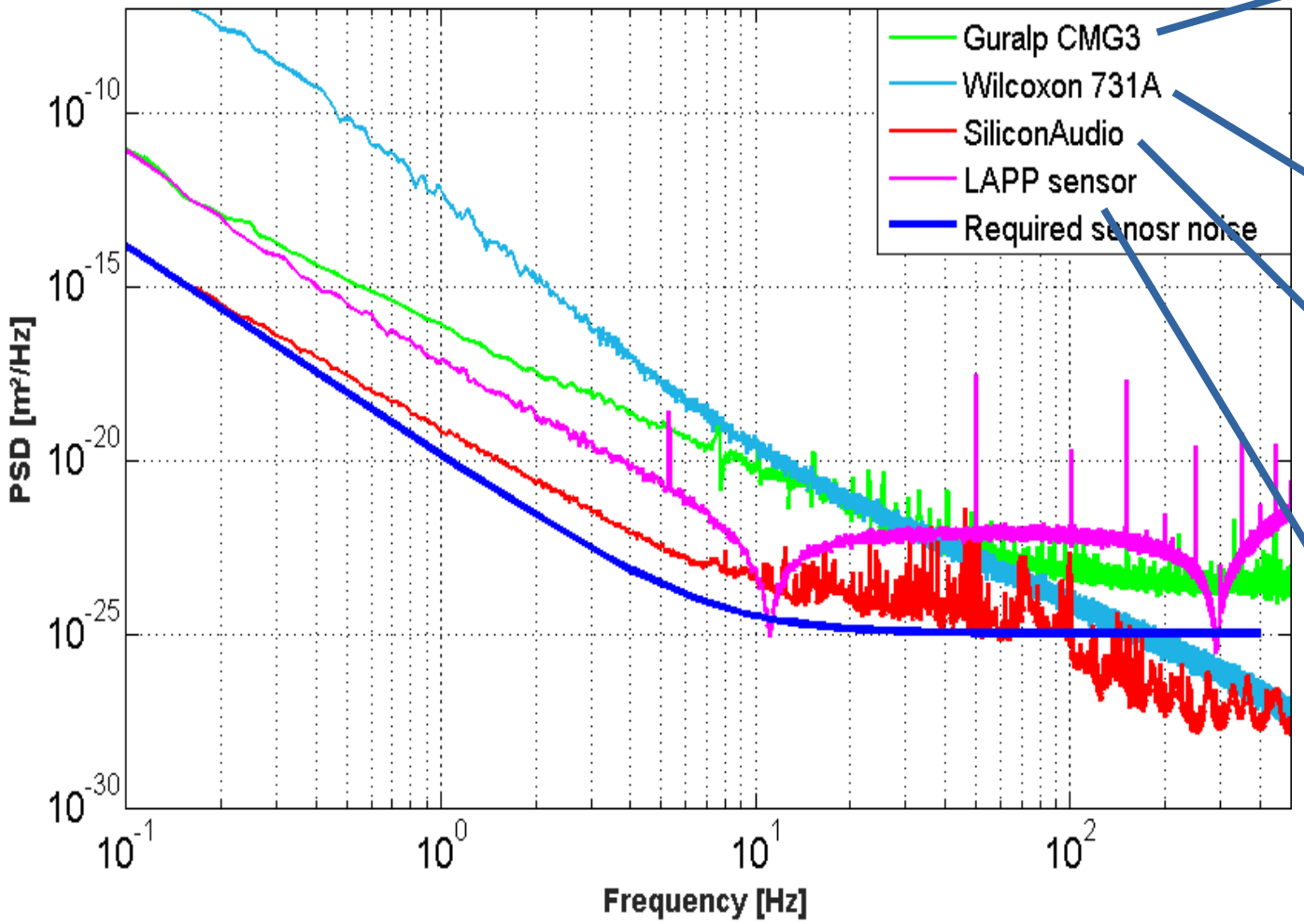
Bandwidth = 0.1 ~ 200 Hz

Resolution ≤ 0.1nm RMS@1Hz

RMS or “average” motion in the bandwidth of interest.

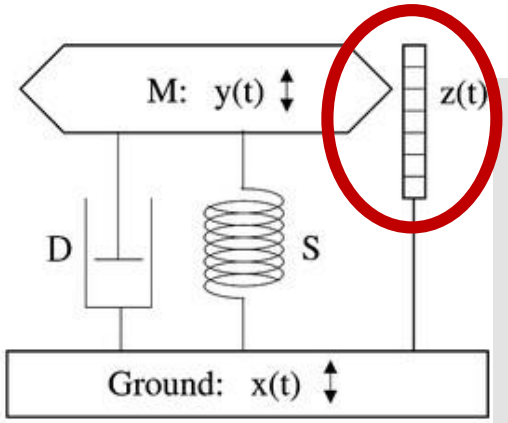


PSD resolution of different sensors.



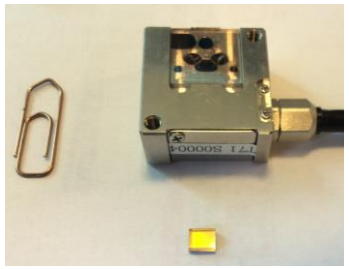
How to improve sensor resolution?

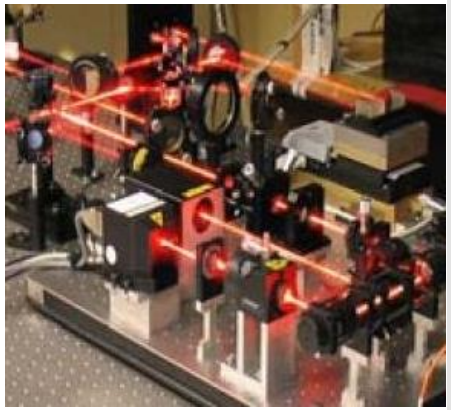
- **Implement high resolution sensor for displacement measurement**



- Options:
  - Resistive, Capacitive, LVDT, Optical encoders, Piezoelectric, Eddy current, Interferometers, …

- After applying following requirements:
  - Contactless
  - Sub-nanometer resolution
  - Magnetic field resistance





How to improve sensor resolution?

All technologies implemented before but results are influenced by:

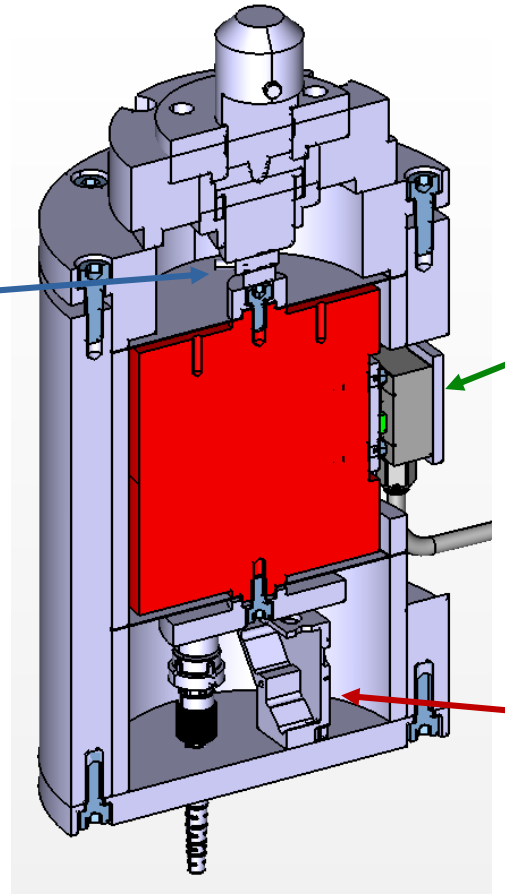
- Ambien environment (temperature, humidity, air refraction index, …)
- Mechanical design
- Data acquisition hardware
- Signal processing algorithm

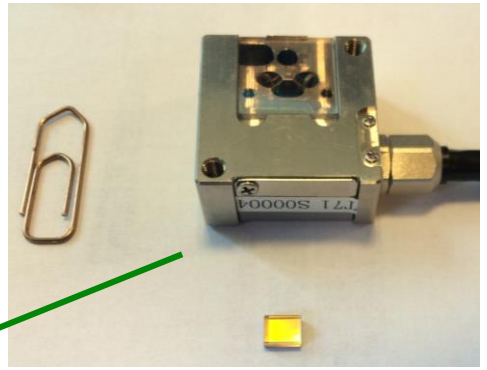
This makes comparison very difficult and unclear.

Implementation of displacement sensors to same mechanical body

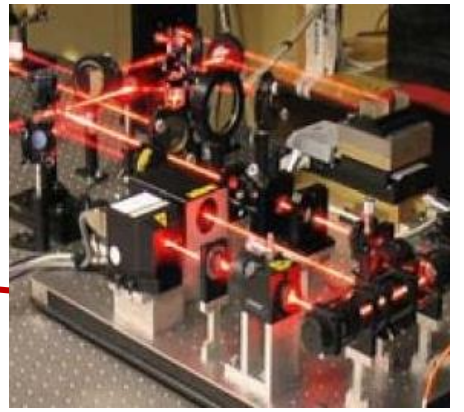
Direct comparison = no data ambiguity

Capacitive sensor





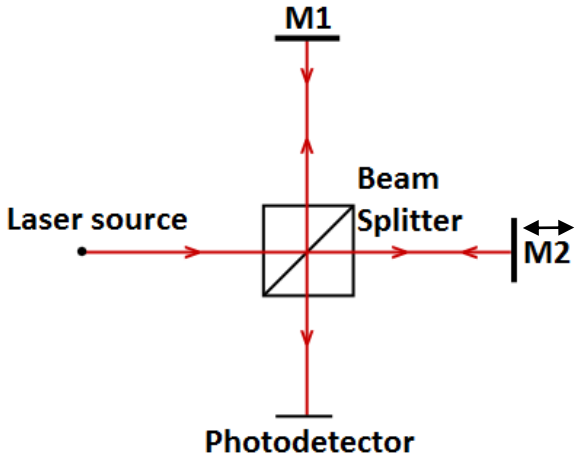
Optical encoder

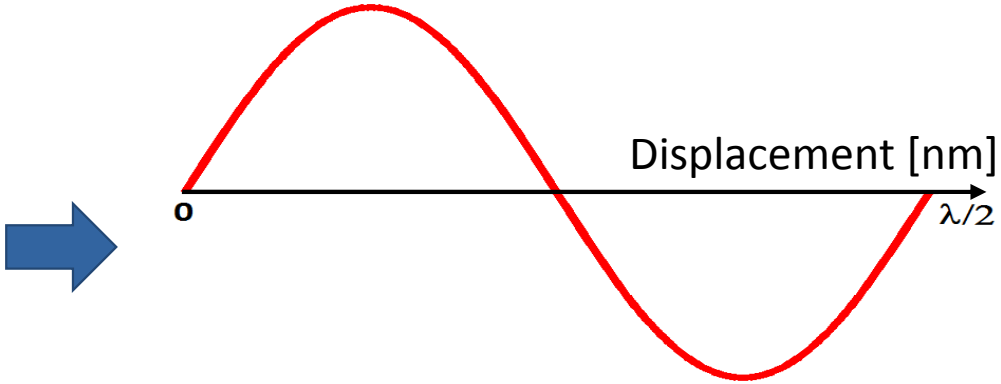


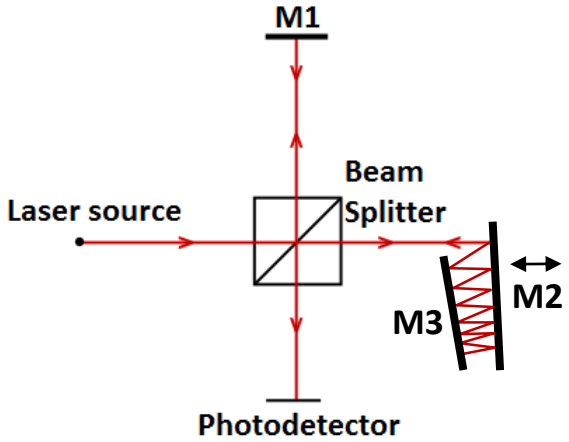
Interferometer

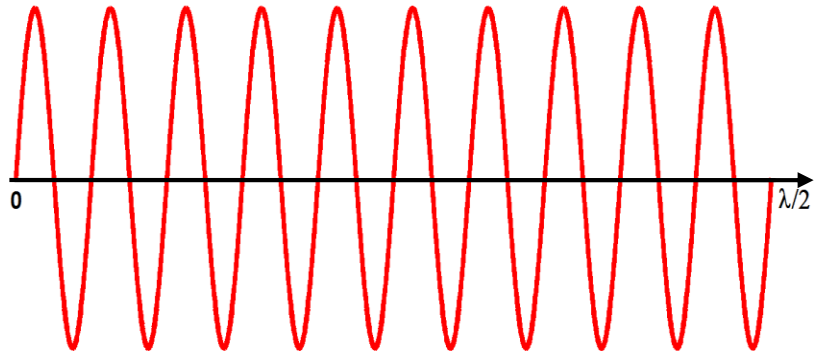
Increasing sensitivity to improve resolution

Implementation of multi-reflection Michelson interferometer







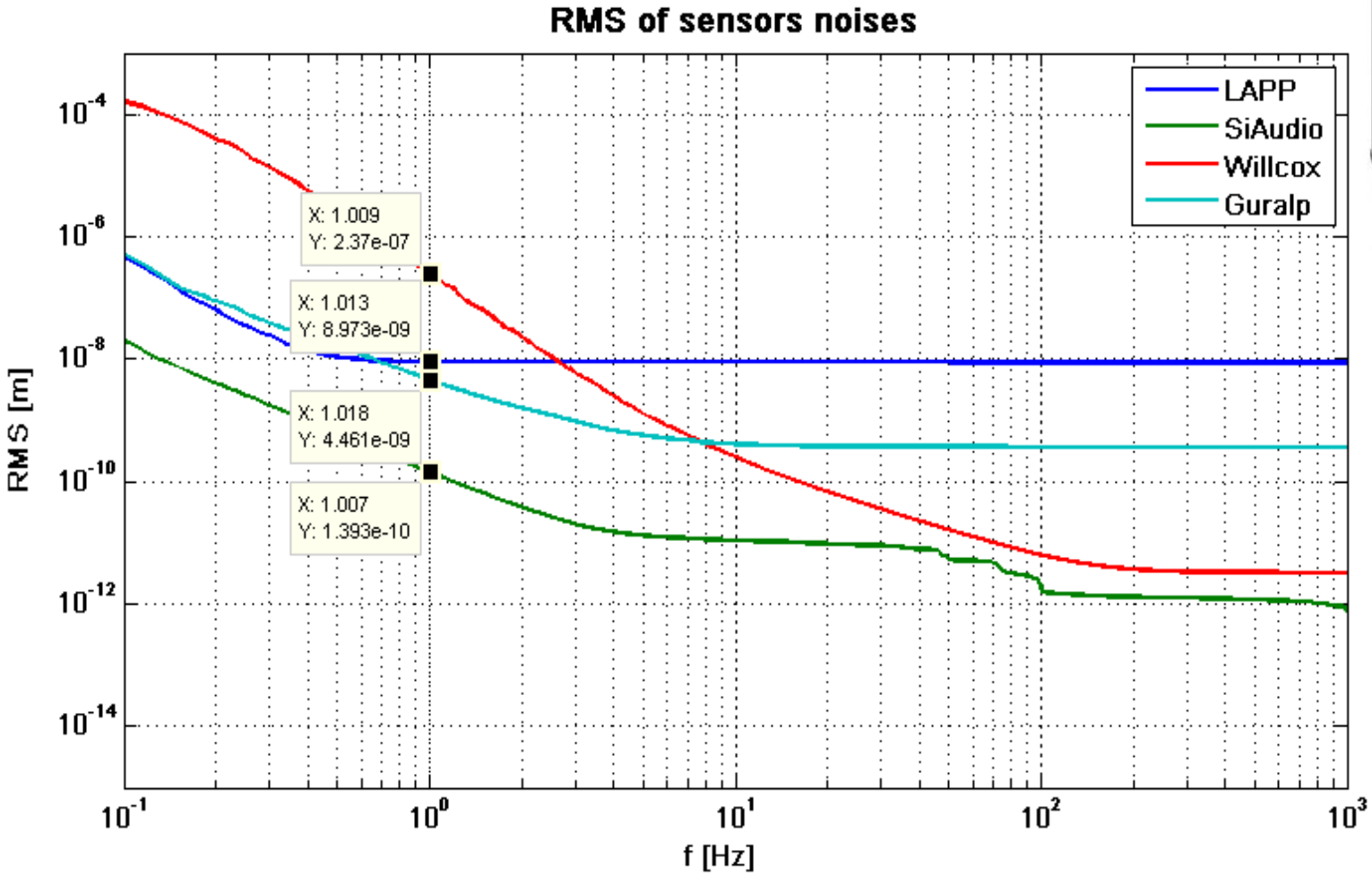


Conclusions

- Seismic sensors will be used to check how ground motion influences BPM characterization.
- Resolution is the main limit for state of the art sensors.
- What we understand under RMS@1HZ resolution and how do we measure it.
- Direct comparison of sub-nm displacement sensors to overcome data ambiguity.
- Increasing the resolution with multi-reflection Michelson interferometer.

Thank you for your attention!

RMS of sensors noises



Self-noise measurement problem

- Mass locking vs. corrected difference??