Operation of low threshold cryogenic calorimeters in a dry dilution refrigerator in the COSINUS experiment

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- Operation of cryogenic thermometers
- Vibrational backgrounds
- Vibration decoupling

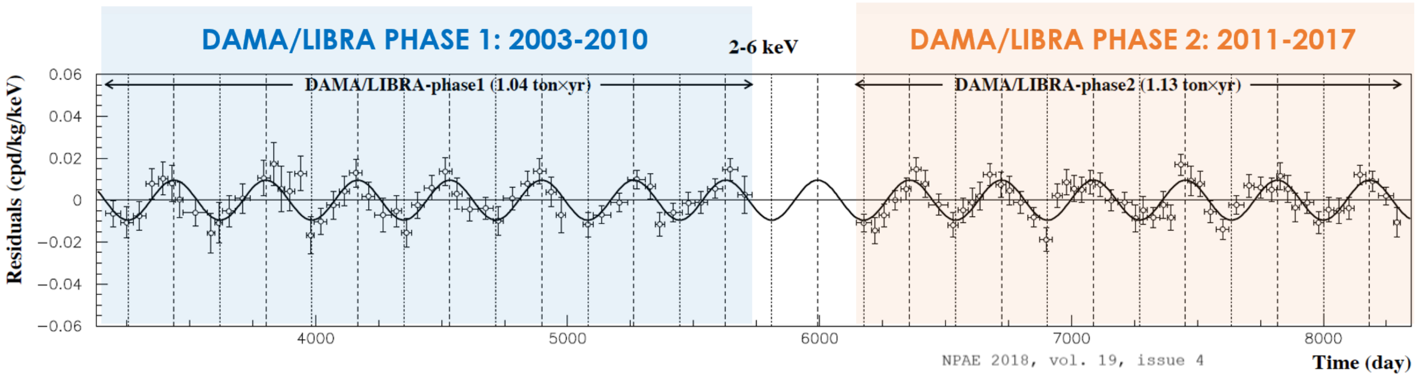
COSINUS

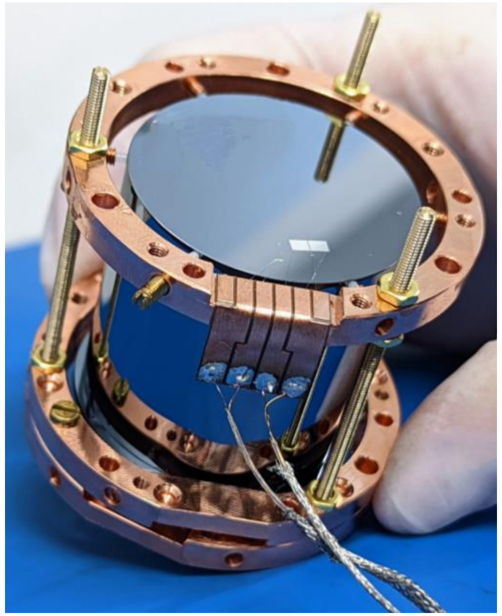
Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

The COSINUS experiment

- Motivation: Cross-check DAMA dark matter results
- Location: Laboratori Nazionali del Gran Sasso
- Operation of NaI as low threshold calorimeter
- Operation inside a dry dilution cryostat at 10 mK
- 2-channel readout for particle discrimination

COSINUS



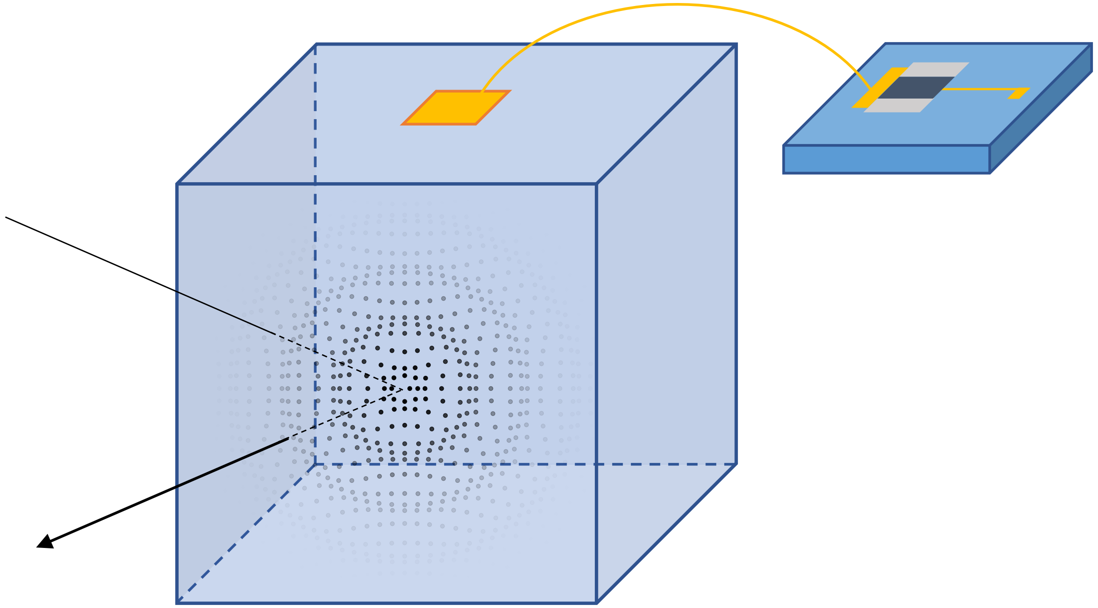


COSINUS at DPG spring meeting 2022

Status of COSINUS

➢ See talk of Martin Stahlberg (T104.1)

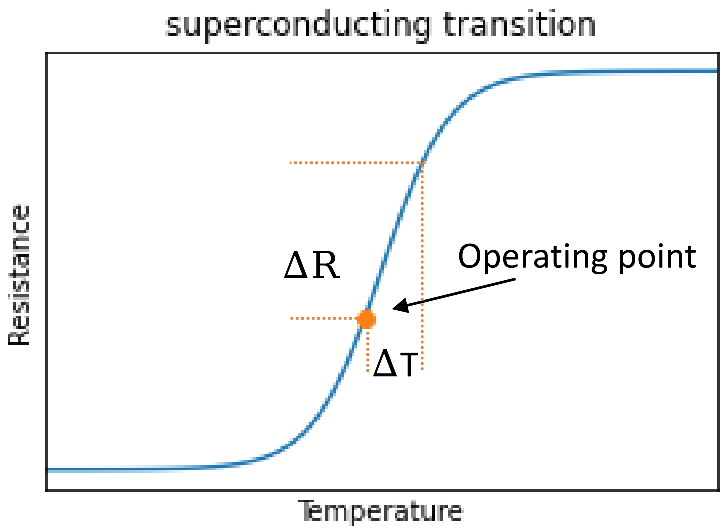
COSINUS detector design

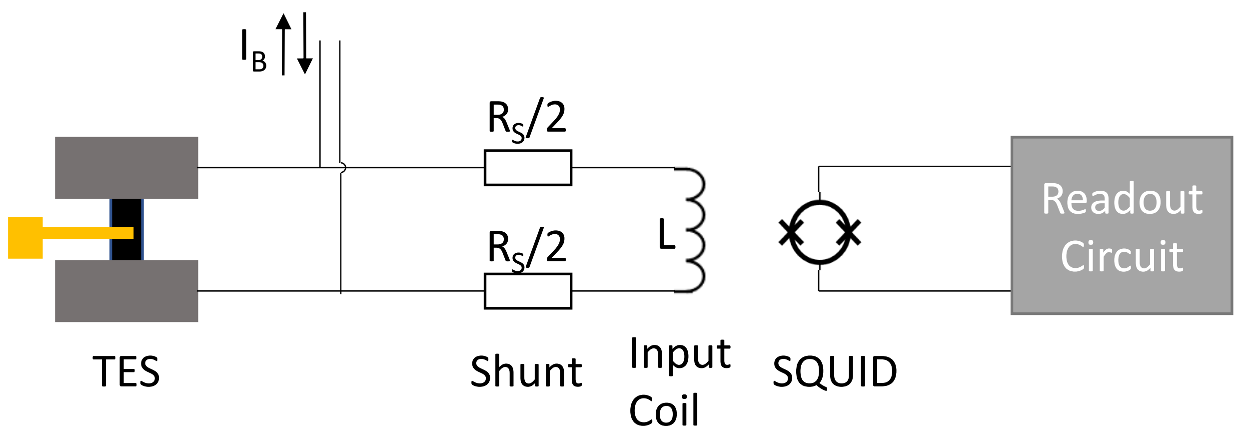


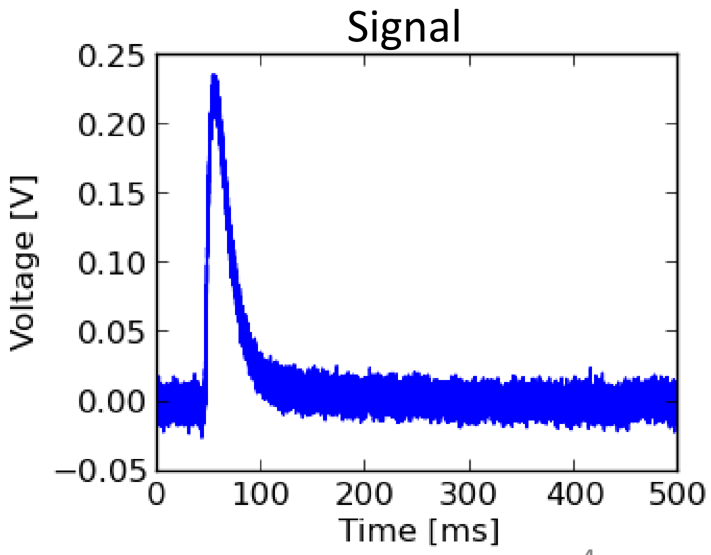
➢ See talk of Mukund Bharadwaj (T104.2)

Operation of cryogenic thermometers

- Measurement of µK-temperature differences with tungsten transition edge sensors (TES)
- Energy deposition leads to change in temperature and film resistance
- Electrical readout using SQUIDs as amplifiers



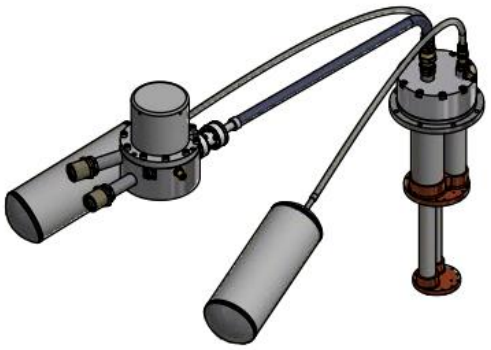


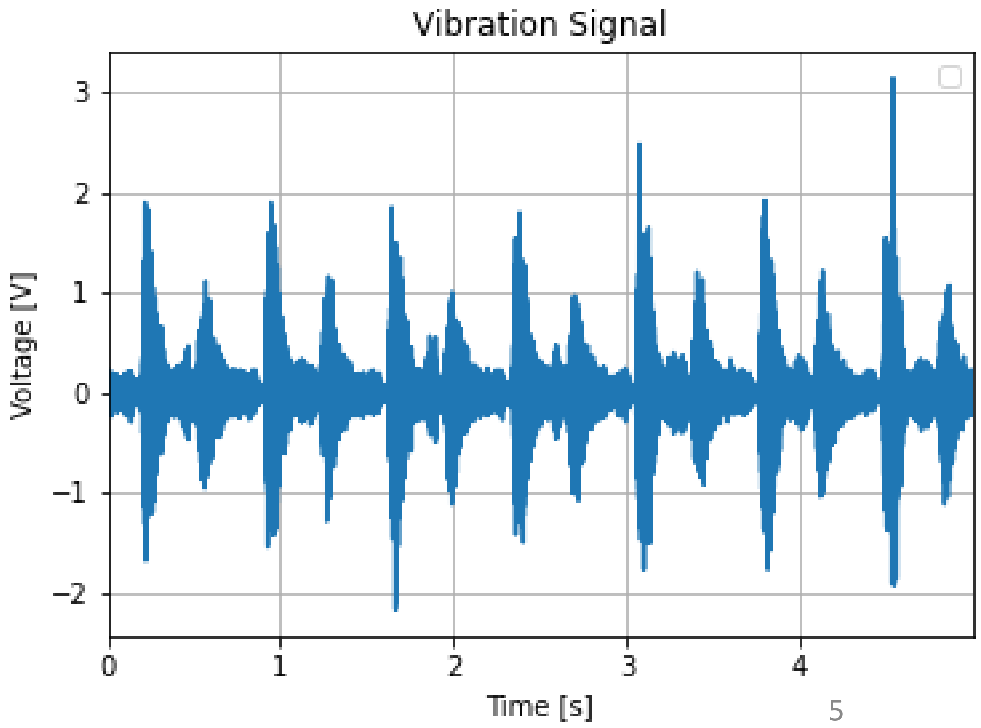


Dry dilution refrigerators

- Usual (wet) cooldown procedure:
    1. Liquid Nitrogen to 77 K
    2. Liquid Helium to 4 K
    3. He-evaporation to 1 K
    4. $^3He/^4He$ dilution to 10 mK
- Dry cooldown procedure:
    1. Pulse Tube compression to 2 K
    2. $^3He/^4He$ dilution to 10 mK

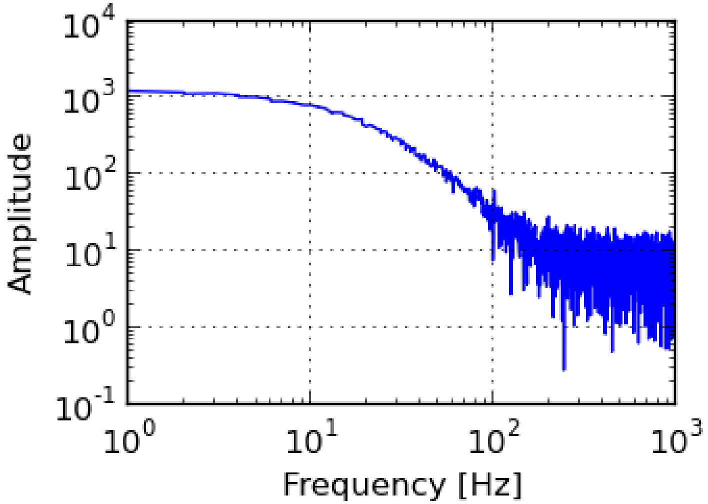
➢ Lower cost + easier handling, but increased vibration level

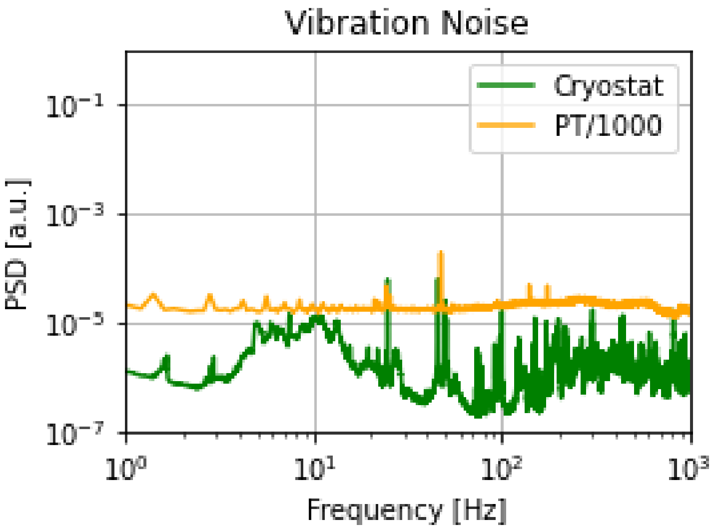




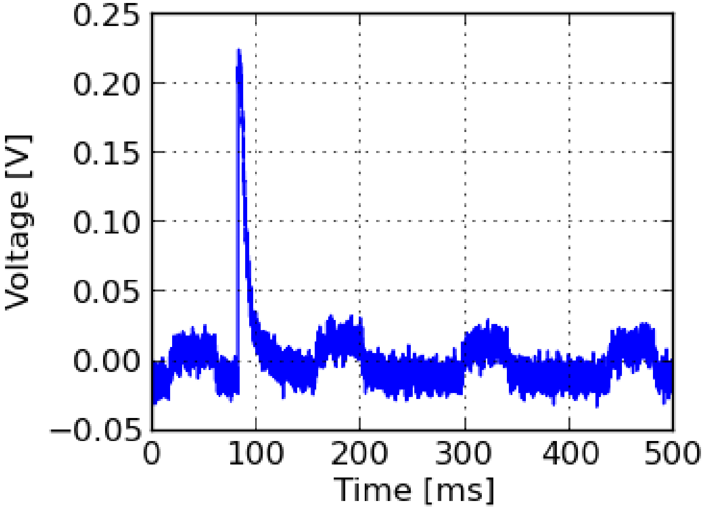
Vibrations in a dry dilution refrigerator

Signal content





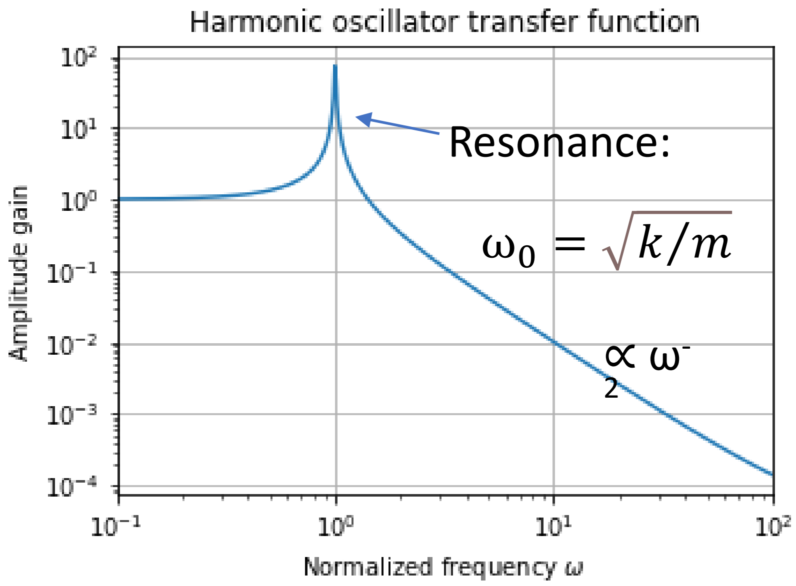
Signal with microphonics

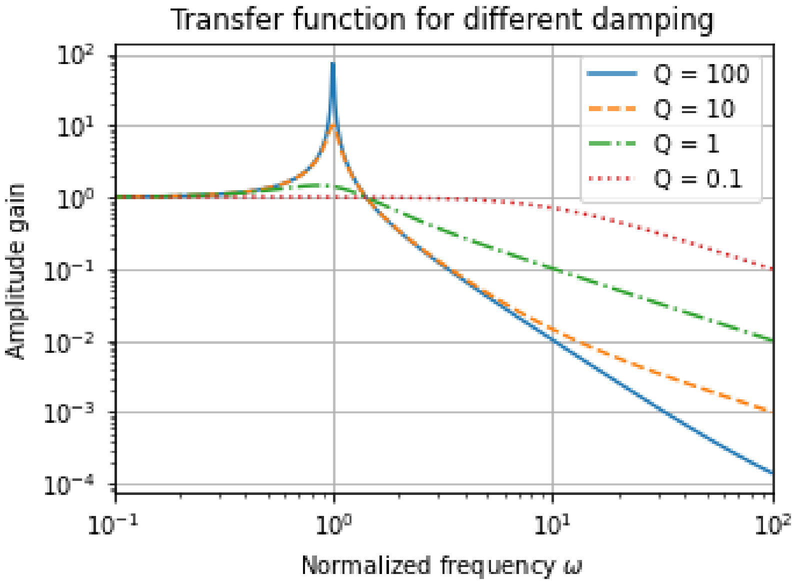


- Vibration induced microphonics are a dominating noise source
  - ➢ Decoupling necessary for stable operation

Decoupling concept

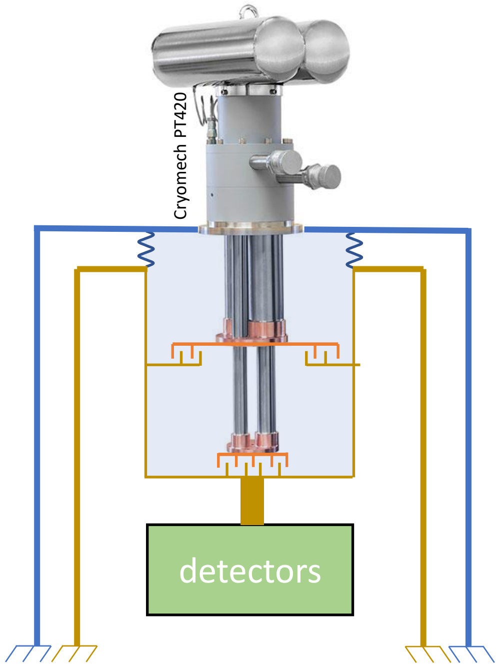
- 1st level: Cryoconcept technology
- 2nd level: spring-based decoupling
- Harmonic Oscillator: decoupling for $\omega \gg \omega_r$
  - ➢ Use spring-based decoupling and chose low resonance frequencies
  - ➢ Damping is necessary to reduce resonance amplitude
  - ➢ Fine tune damping factor to suppress resonance to an acceptable niveau



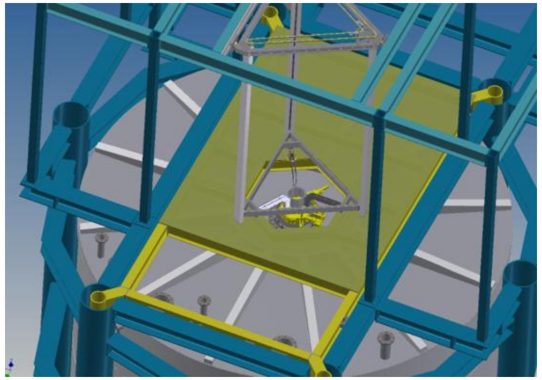


Decoupling outside the refrigerator

- Cryoconcept „ultra quiet technology" allows for decoupling from environmental noise
  - Use separate frames for noisy machines (e.g. pumps) and cryostat
  - No physical contact between both frames
  - Exchange gas for thermalization
  - @LNGS: build separate building structures instead

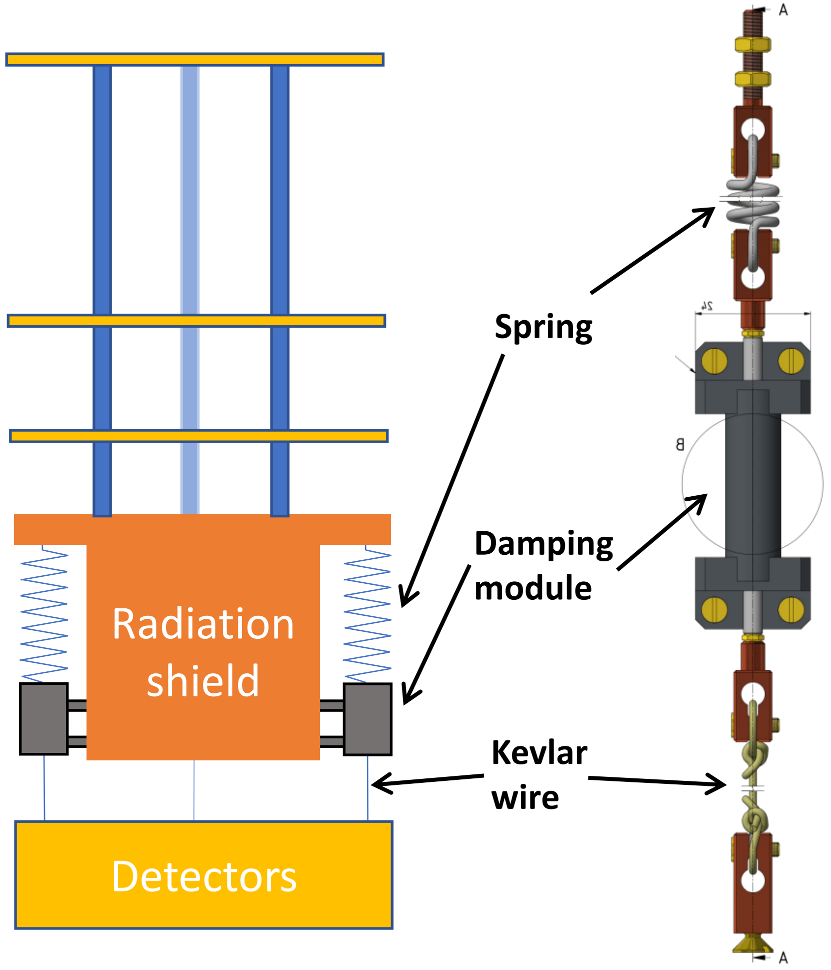


https://cryoconcept.com/product/the-ultra-quiet-technology/



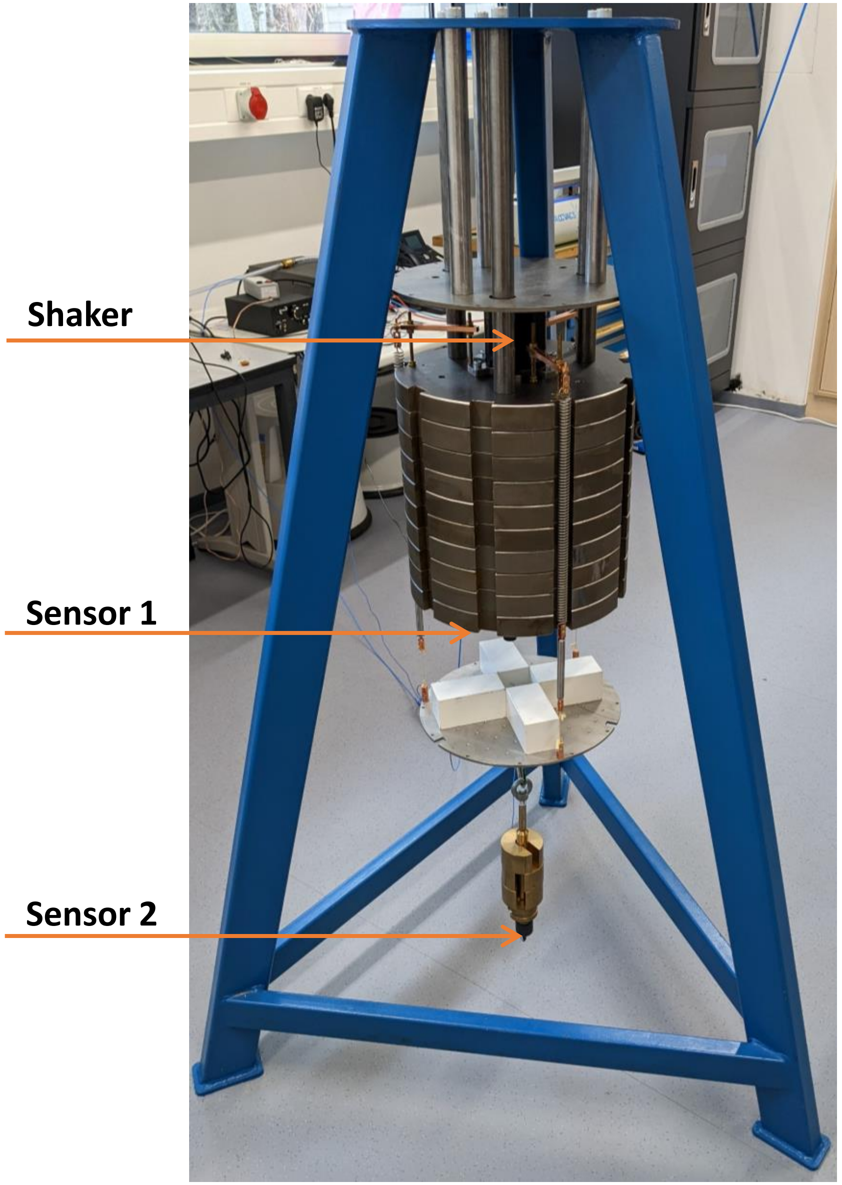
Decoupling inside the refrigerator

- Use the radiation shield for fixation:
  - ➢High mass allows for a quiet starting point
  - ➢Cooling power for the Cu-shield is high
- Decoupling system consists of 3 parts:
  1. Springs to decouple vertical motions
  2. ~10 cm for damping modules
  3. Kevlar to decouple horizontal motions and for thermal decoupling from the detectors



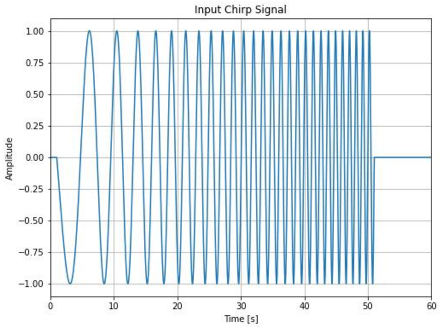
Mockup system

- Mockup system for test of decoupling systems consists of:
  - model of lower part of cryostat
  - 1 shaker to induce arbitrary signals
  - Up to 5 mobile piezo-based accelerometers
- Allows for transfer function analysis

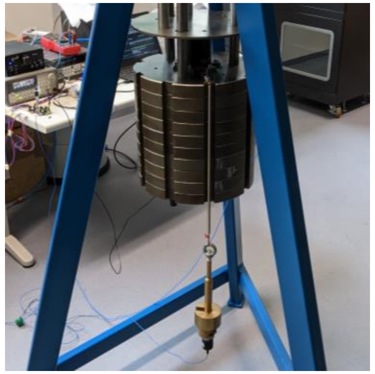


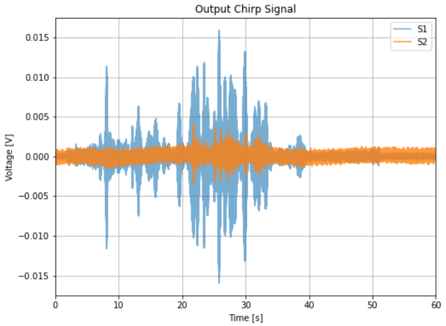
Transfer function analysis

Signal → Emitter → Environment → Sensor → Measurement



(Sine Sweep over bandwidth)

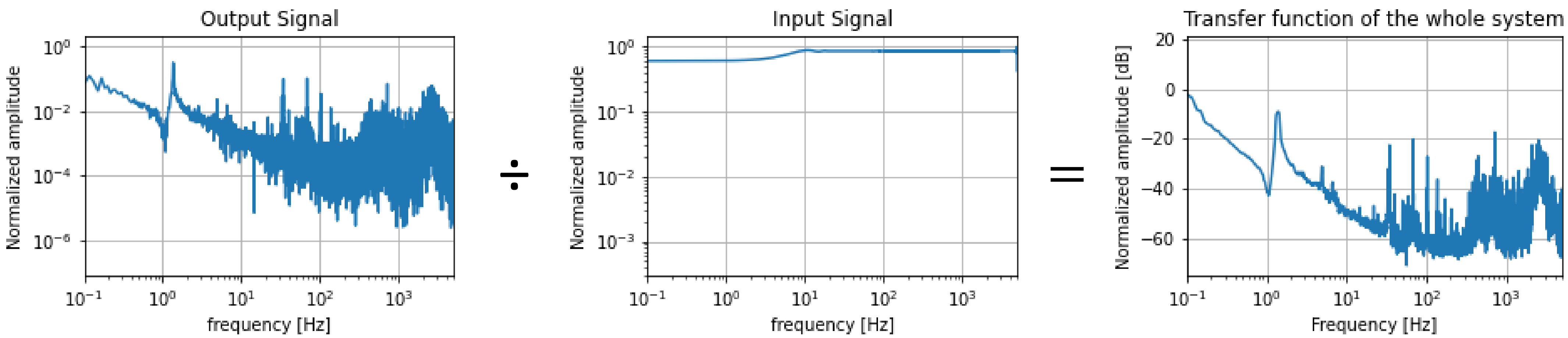




Linear Time-invariant System

Transfer function analysis

- Output signal is the convolution of the input signal with all blocks of the system
- A convolution in time domain is the same as a product in frequency domain
  - ➢The transfer function of the system can be calculated by $\mathrm{TF} = \frac{fft(output)}{fft(input)}$



Summary

- Vibrations need to be under control to operate detectors in a dry cryostat
- A mockup system helps to understand the dynamics of decoupling systems
- The planned system for COSINUS shows promising results
- A lot of open questions are left. E.g.:
  - Behaviour of springs in cold?
  - Damping mechanisms?
  - Effect of other parts of the setup (e.g. cabling)?
- Testing in a real cryostat will be started in summer