REDUCING LOW-FREQUENCY VIBRATIONS FOR THE CRYOGENIC EINSTEIN TELESCOPE

The Einstein Telescope is envisioned to achieve amplitude-spectral-density strain sensitivities on the order of $10^{-24}\ 1/\sqrt{\mathrm{Hz}}$ [1]. This corresponds to approximately to $10^{-20}\ \mathrm{m}/\sqrt{\mathrm{Hz}}$ for the displacement of the mirrors along the beam direction. This is similar to ligo/Virgo but with the added complexity Leiden Institute of Physics (LION) hosts several research groups specializing in ultra-low temperature experiments, requiring ultra-low vibration levels. Ongoing experiments in our group have demonstrated in a cryogenfree dilution refrigerator at $30 \cdot 10^{-15}\ \mathrm{m}/\sqrt{\mathrm{Hz}}$ at 100 mK [2]. Once we reduce vibrations sufficiently, we aim to investigate strategies that add a thermal link with good thermal conductance, that doesn't add vibrations.

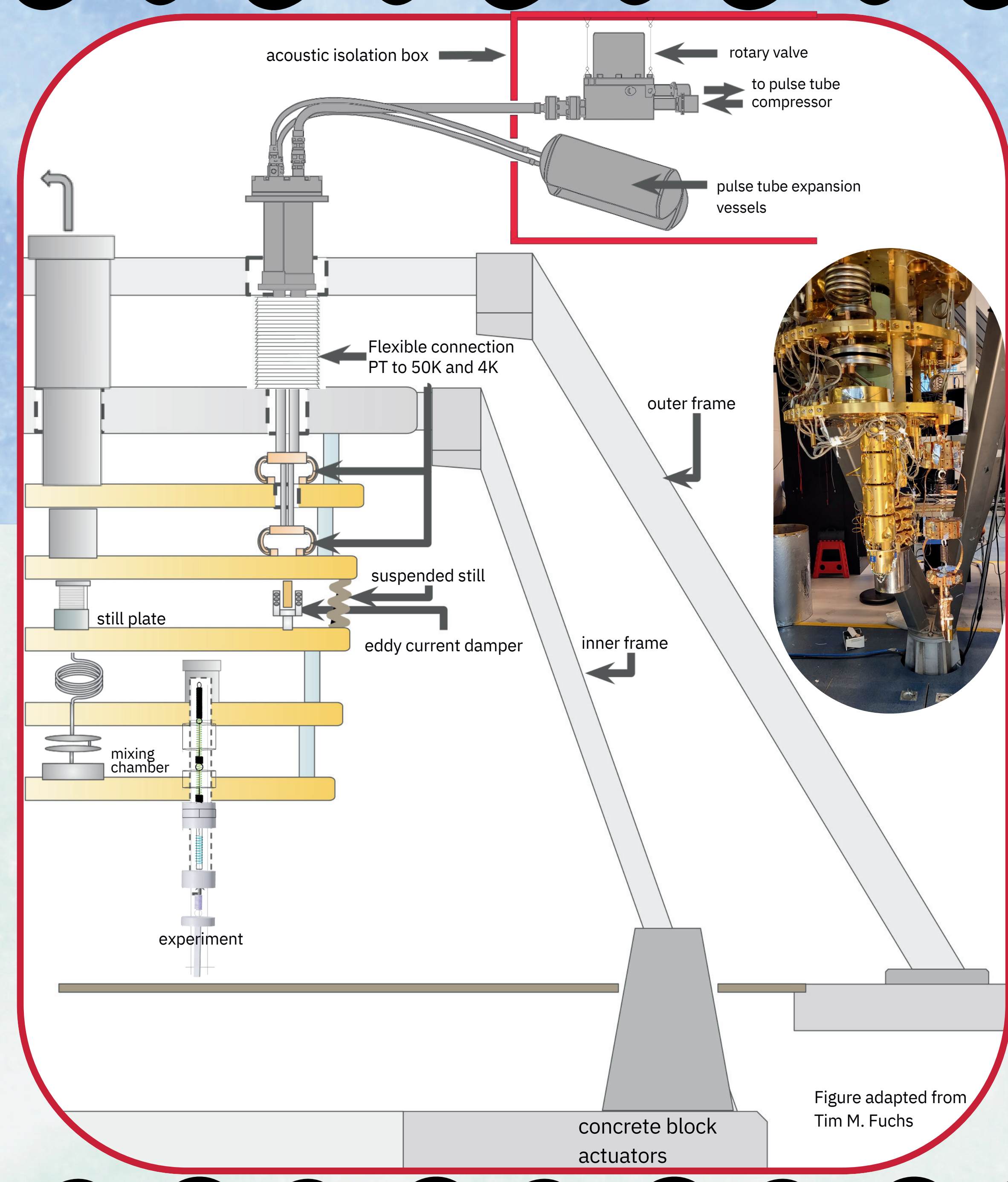
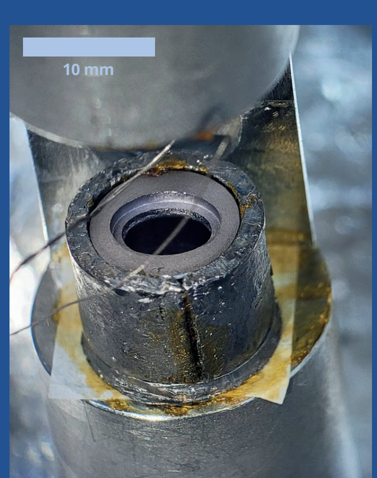
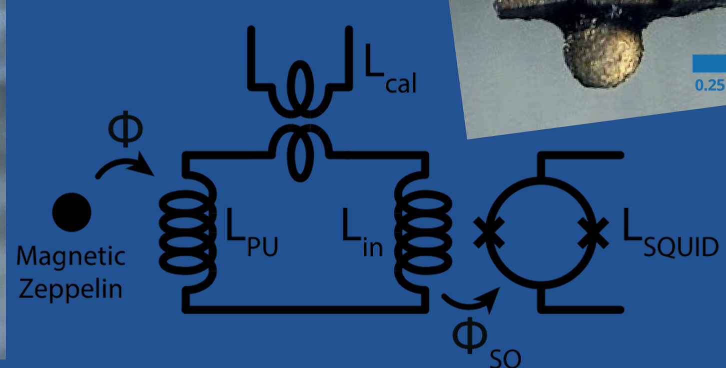


Figure adapted from Tim M. Fuchs

THE ZEPPELIN EXPERIMENT

Test mass/Magnetic Zeppelin is 450 µg size 0.75 mm × 0.25 mm $Nd_2Fe_{14}B$





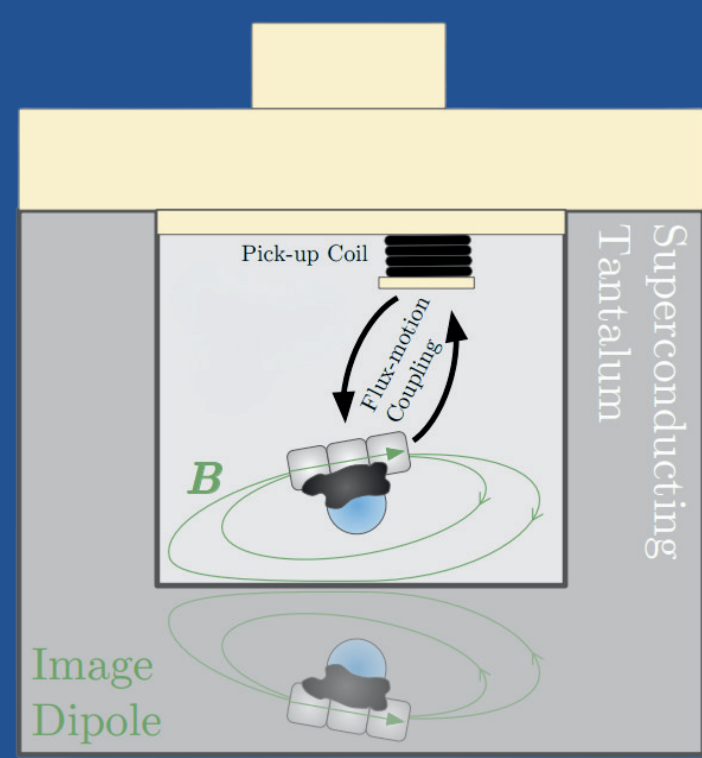


Image adapted from Denis Uitenbroek

VIBRATION ISOLATION NOW

Currently, our experiment is suspended on series of passive vibration isolation, mainly via the cryostat itself and the mass-spring system of the experiment, see figure above.

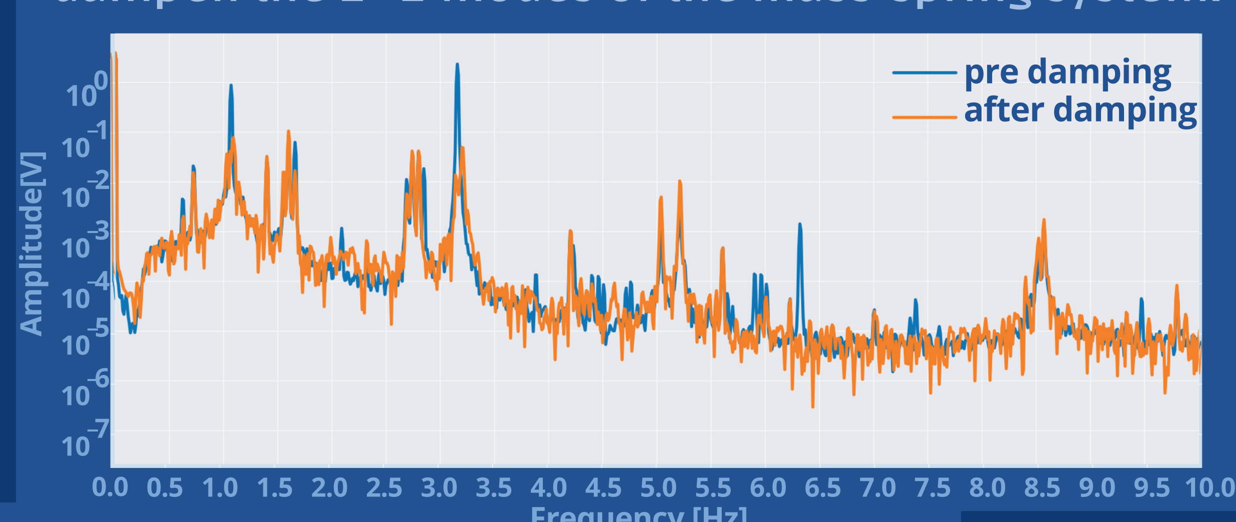
Shown here are simulations of the first and second z-mode of the mass-spring system.

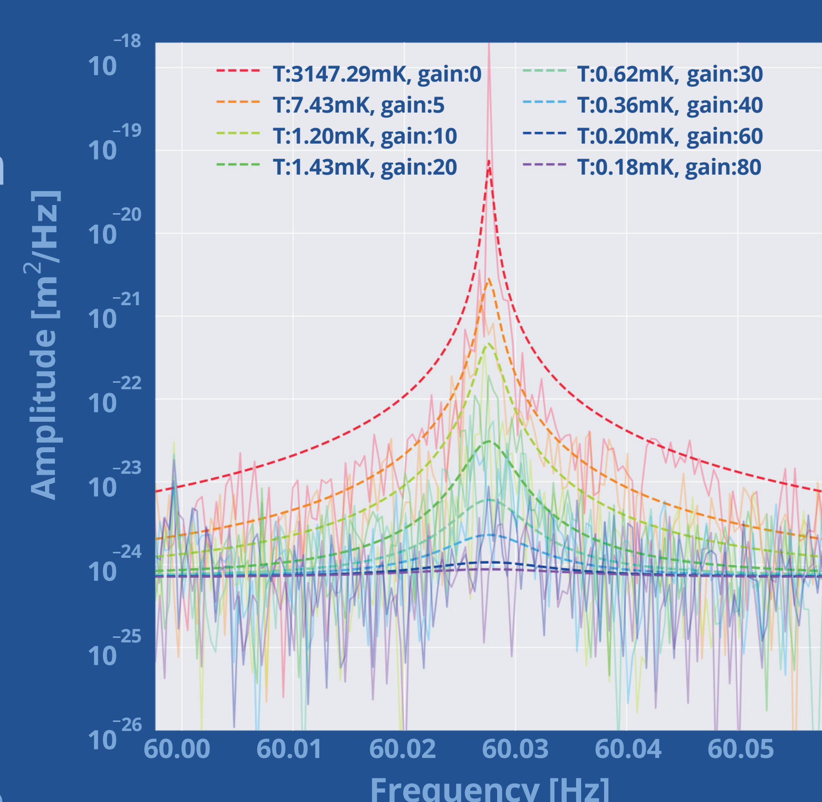
GOALS

- Actively do feedback damping on more than two vibrational modes of the mass-spring system
- Monitor and identify vibrational sources, including from the vibration isolation system itself.

PRELIMINARY RESULTS

We can actively do feedback cooling on multiple resonant modes of the levitated magnet, resulting in cooling the mode temperature. Furthermore, we dampen the 1st z-modes of the mass-spring system.





OUTLOOK

- Deploying mini-GAS system, similar in design as for ETpathfinder
  - characterizing crackling in the system at low temperatures
- Because of the low temperature environment of the telescope, we will be testing a superconducting inertial sensor [3].

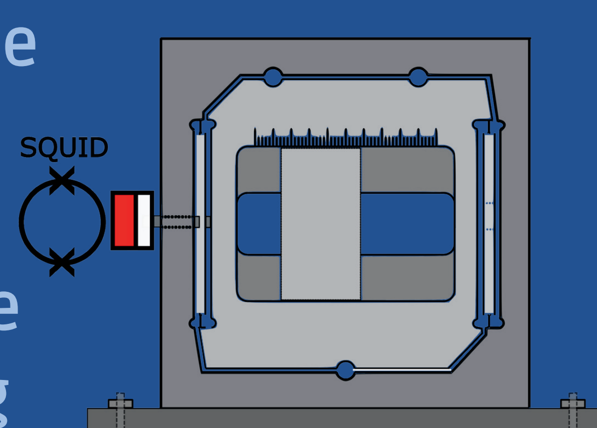
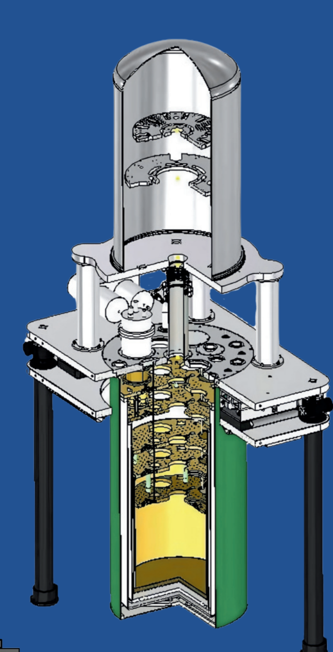


Image adaped from Joris van Heiningen


rendering made by Hugo van Bohemen

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1. M. Punturo et al., The einstein telescope: a third-generation gravitational wave observatory, Classical and Quantum Gravity 27 (2010) 194002.
2. T. M. Fuchs, D. G. Uitenbroek, J. Plugge, N. van Halteren, J.-P. van Soest, A. Vinante, H. Ulbricht, and T. H. Oosterkamp, Measuring gravity with milligram levitated masses, Science Advances 10, eadk2949 (2024).
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JURRIAAN LANGENDORFF[1], DENNIS UITENBROEK[1], BAS HENSEN[1], JORIS VAN HEIJNINGEN[2,3], TJERK OOSTERKAMP[1]

[1] LEIDEN INSTITUTE OF PHYSICS, LEIDEN UNIVERSITY, P.O. BOX 9504, 2300 RA LEIDEN, THE NETHERLANDS

[2] NIKHEF, SCIENCE PARK 105, 1098XG, AMSTERDAM, THE NETHERLANDS

[3] DEPARTMENT OF PHYSICS AND ASTRONOMY, VU AMSTERDAM, DE BOELELAAN 1081, 1081 HV AMSTERDAM, THE NETHERLANDS

Universiteit Leiden The Netherlands

LIOF LION Leiden Institute of Physics Nikhef