Precision Quality Factor Measurement & Noise Characterisation: E-TEST Cryogenic Prototype

Singh H.[1], Winand F.[2,1] , Zeoli M.[3,1], Amorosi A.[1,2], Odeau S.[1], Collette C.[1,2]

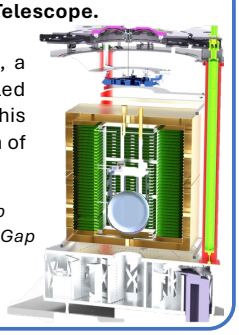
[1] Precision Mechatronics Laboratory, A&M department, Université de Liège, Belgium
[2] BEAMs department, Université Libre de Bruxelles, Belgium
[3] IRMP, Université Catholique de Louvain-la-Neuve, Belgium

hsgahlot@uliege.be

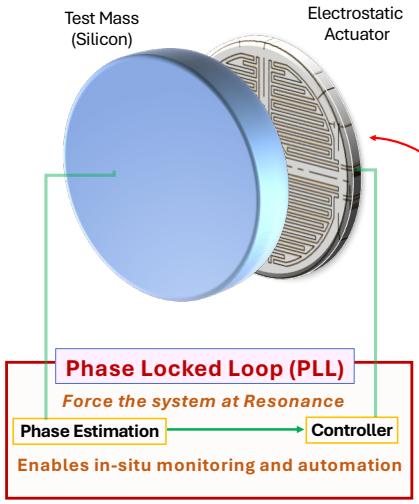
Context

- **E-TEST**[1], a cryogenic seismic isolation prototype for the **Einstein Telescope.**
- To meet the demands of next-gen gravitational-wave detectors, a 100 kg monocrystalline silicon test mass is suspended and cooled to 20 K for low thermal noise and <10 Hz vibration isolation. This poster highlights **three key advancements** toward characterisation of Thermal Noise-

1. *Precision Mechanical Q Factor Measurement using Phase-Locked Loop*
2. *Analysis of Potential Squeezed-Film Damping in the Electrostatic Drive Gap*
3. *Non-Contact Temperature Measurement of Cryogenic Silicon Surfaces*

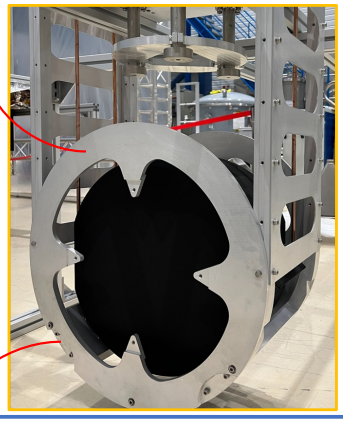


Quality Factor

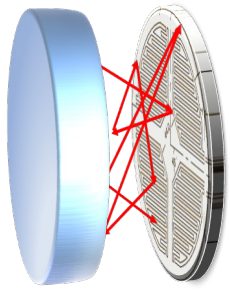


Why PLL?

- **Ring-down too slow** for **Silicon**
- Faster, **Real-time tracking of Resonance**,
- **Continuous measurement**, No waiting for decay[2].



Squeezed Film Damping



Trapped Air
(Squeezed Film Damping)

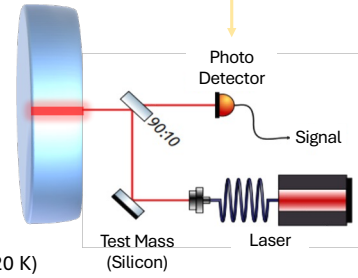
Energy loss (Thermal noise)
(Relevant even at low pressure)

Same Approach ↕ Noise Evaluation

Residual Gas Damping
In Cryostat Gap

Temperature Measurement (Non-Contact)

- Thermal Contraction* (room → 20 K) → Surface deformation → Blur fringes
- Thermo-optic variation affected by impurities[3]
- Free Carrier Absorption
- Laser Alignment Issues in Cryo



Why it matters?

- **Q changes** with temperature (room → 20 K)
- Accurate temp tracking helps correlate **Q vs T**

References

[1] Sider, A., et al. "E-TEST Design Report." arXiv:2212.10083 (2022).
[2] Lu, Marie, et al. Measuring the Quality Factor of Cryogenic Silicon. LIGO-T1400668, LIGO Laboratory, 2014.
[3] Adhikari, Rana X., et al. "A Cryogenic Silicon Interferometer for Gravitational-Wave Detection." *Classical and Quantum Gravity*, vol. 37, no. 16, 2020, p. 165003, IOP Publishing.

Use the QR code to view Full References, Acknowledgement, and More Information.