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Design and manufacturing of superconducting coils for cryogenic (inertial) sensing and actuation for Einstein Telescope and the Lunar Gravitational-wave Antenna

Future gravitational-wave (GW) detectors such as Einstein Telescope (ET) will be cryogenic to decrease thermal noise to be sensitive to low-frequency GWs. In addition to this thermal noise reduction, there is an opportunity for superconductive technology introduction. We can just make our current interferometric sensing and coil-magnet actuation cryo-compatible, but superconductivity solutions thrive –instead of survive –in the cold.

Using the Meissner effect, these devices enable extremely precise actuation and (inertial) sensing that can be deployed near the suspended mirrors of ET. There, they can monitor or actively mitigate tiny, unwanted vibrations. For instance, the heat links from cryocoolers to the bottom of ET's suspensions can transfer such vibrations, and we aim to develop the world's first sensors that have sufficient sensitivity - $\text{sub-fm}/\sqrt{\text{Hz}}$ from 1 Hz onwards - to deploy so near to the mirror. Additional to vibration monitoring, an array of superconducting inertial sensors can be deployed in a permanently shadowed lunar crater with stable cryogenic temperatures. Ultra-sensitive inertial sensors can detect gravitational-wave-induced lunar deformations, using the Moon itself as part of the Lunar Gravitational-wave Antenna (LGWA).

Here we present the sensing and actuation concepts, our approach to designing and manufacturing the geometry of the coils and the first milestone in manufacturing: a thin-film niobium nitride coil in the superconducting state.

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