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Future Gravitational Wave Detectors: Phase Noise Investigation and Magnetic Noise Mitigation Strategies

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The sensitivity of gravitational wave (GW) detectors is constrained by various sources of noise. Quantum noise pervades the entire frequency band of the current detectors (10 Hz - 10 kHz), while magnetic noise will significantly constrain the sensitivity of future GW detectors, such as the Einstein Telescope (ET), especially at low frequencies (a few Hz to around 100 Hz).
This poster highlights strategies to mitigate magnetic noise, including emission reduction from critical sources and shielding sensitive coupling locations. Additionally, it presents a thorough examination of phase noise causes, employing software simulations to identify methods for addressing these issues in future detectors such as the ET.
In particular, quantum noise manifests in fluctuations in phase (shot-noise) and in amplitude (radiation-pressure noise), in accordance with Heisenberg's Uncertainty Principle. One approach to reduce quantum noise is injecting squeezed light states into the dark port of the interferometer, although degradation can occur due to losses and phase noise. Phase noise can be generated by both the squeezing system and the interferometer itself.
Magnetic noise results from coupling of environmental fields with magnetized elements, such as magnet-coil actuators and Faraday isolators. Sources of environmental fields include the natural background associated with Schumann Resonances, on the order of pT/sqrt(Hz), and "self-inflicted"noise. The latter involves any device carrying an electric current, such as power grid cables, motors, pumps or conductive materials, which are part of the detector infrastructure. Ambient magnetic fields exert forces on permanent magnets or ferromagnetic materials, creating field gradients and induced currents in sensitive electronics and within conductive objects, thereby amplifying the field gradients. Leveraging experience from Virgo and KAGRA, efforts have been made to identify the contributors to magnetic noise, aiming to optimize them in the future ET infrastructure.

Collaboration

Role of Submitter

I am the presenter

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