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Measuring the mechanical and optical losses of coatings by an optomechanical cavity

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One of the most critical parts of gravitational wave interferometers are their mirror test masses as coating thermal noise is one of the main limiting factors of the instrumental sensitivity in the frequency band from 20 to 2000 Hz.

Our research work is driven by the aim to study the thermal noise of the highly reflective mirror coatings, indeed new generation gravitational waves detectors, such as Einstein Telescope (ET), are planned to work at 1550 nm or 2100 nm wavelengths and in non-ambient (cryogenic) conditions. New coatings with extremely low absorption and thermal noise are therefore to be developed and it is of paramount importance to evaluate those properties in realistic conditions.

Yet, characterizing both mechanical and optical losses in these coatings presents challenges, particularly at cryogenic temperatures, where thermo-elastic interactions between the coating and the substrate complicate the analysis.

Our study proposes an innovative experimental setup to measure both optical losses and mechanical dissipations in freestanding coating membranes across a wide temperature range. By suspending the coating as a thin membrane, this approach minimizes thermo-elastic interactions and enables precise measurement of the coating's properties in the whole range between room temperature and few Kelvins.

The experimental apparatus includes a low-vibration cryostat inside of which an optical cavity will be installed, together with a set of piezo actuators to precisely control the membrane position and alignment within the cavity field. The measurement consists in placing the membrane inside the resonator so that it couples with the stationary electromagnetic field circulating inside the cavity. The optical losses can be measured by monitoring the finesse of the Fabry- Perot cavity as a function of the membrane position along the optical axis, while the mechanical dissipations will be measured using the cavity as a sensitive transducer of the membrane vibration spectrum and deriving the mechanical dissipations from a suitable data analysis procedure.

Preliminary data from testing low-stress Silicon Nitride (SiN) membranes confirm the functionality of the setup. Future efforts will focus on optimizing the experimental apparatus and expanding the instrumentation for more comprehensive measurements.

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