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Femtometer-precision displacement sensing with heterodyne cavity-tracking

Precise displacement sensing with femtometer or sub-femtometer readout noise at frequencies below 10 Hz is extremely beneficial for the ET active isolation systems. Here, we present a laser interferometric sensor, named heterodyne cavity-tracking, designed for high-precision relative displacement readout. The scheme utilizes a heterodyne-stabilized optical cavity, incorporating the proof mass, and retrieves displacement via heterodyne interferometry. The combination of the optical cavity and frequency readout pushes the achievable sensitivity into the sub-femtometer regime. The frequency readout and laser frequency control are accomplished using an ultra-high bandwidth phase-locked loop (PLL) phasemeter, which can directly track signals up to 2 GHz, allowing for a fringe-scale operating range in displacement sensing.

Initial experiments have demonstrated an overall displacement readout noise floor of less than $20\,\mathrm{fm}/\sqrt{\mathrm{Hz}}$ for frequencies above 5 Hz and a maximum motion of about $0.15\,\mu\mathrm{m}$, achieving a dynamic range of six orders of magnitude in displacement sensing.

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