Optical cavity acceleration sensitivity reduction via feedforward correction

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Laser frequency stabilization to high finesse optical cavities is a key enabling technology for optical frequency standards, ultra-low-noise microwave synthesis, and exploring fundamental physics. NPL's cubic cavity[1] has demonstrated world-leading passive acceleration sensitivities, a crucial characteristic required for ultra-stable optical cavities to succeed beyond a laboratory setting. A recently developed technique to further improve the performance of optical cavities in real-world environments is the real-time feedforward correction of perturbations to the cavity[2]. Such a technique requires: (i) characterizing the response of a cavity to inertial forces; (ii) actively sensing the acceleration experienced by the cavity, then calculating the induced change in cavity length and correcting for it.

We report on the real-time cancellation of acceleration-induced frequency perturbations of a laser locked to a shaken cubic cavity. The feedforward-correction system is based around an array of accelerometers centered on the high-finesse optical cavity and a FPGA for rapid calculation of the frequency correction, which is applied via an AOM. A 32 dB reduction in the acceleration-induced laser frequency noise power spectral density is achieved.

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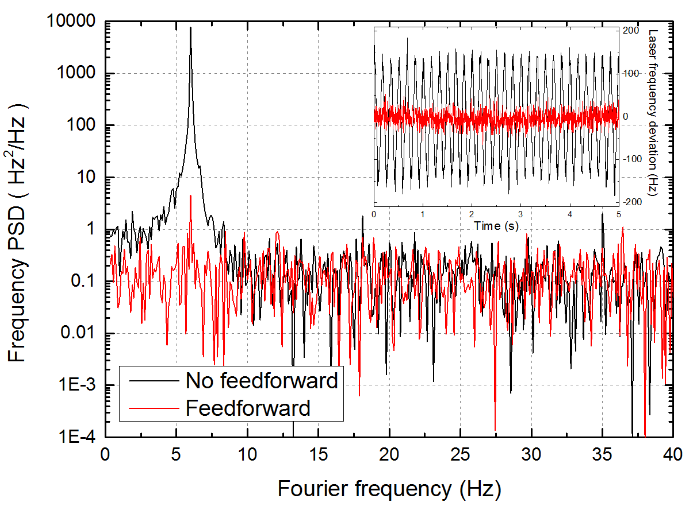

Fig. 1: Power spectral density of the laser frequency, with and without the real-time feedforward correction engaged. A 32 dB reduction in the PSD at the shaking frequency (6 Hz) is observed. Inset: the time-series data showing the cancellation of the driven low-frequency oscillation in the laser frequency.

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[1] S. Webster and P. Gill, "Force-insensitive optical cavity", Optics Letters, vol. 36, p. 3572-3574, 2011.

[2] D. R. Leibrandt *et al*, "Cavity-stabilized laser with acceleration sensitivity below 10^{-12} g^{-1}", Phys. Rev. A, vol. 87, p. 023829, 2013.