Characterization of laser offset phase locking for a Newtonian noise sensor

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Newtonian noise, caused by gravitational fluctuations from changes in local mass density, will be a low-frequency sensitivity-limiting noise source for future ground-based interferometric gravitational-wave detectors [1]. A sensor for measuring Newtonian noise is being commissioned, called the Torsion Pendulum Dual Oscillator (TorPeDO) [2, 3]. This sensor consists of two freely-suspended perpendicular torsion bars that will differentially rotate from Newtonian fluctuations. The differential readout will be made using the Pound-Drever-Hall (PDH) technique on four Fabry-Perot cavities at the ends of the bars, as shown in Figure 1(a).

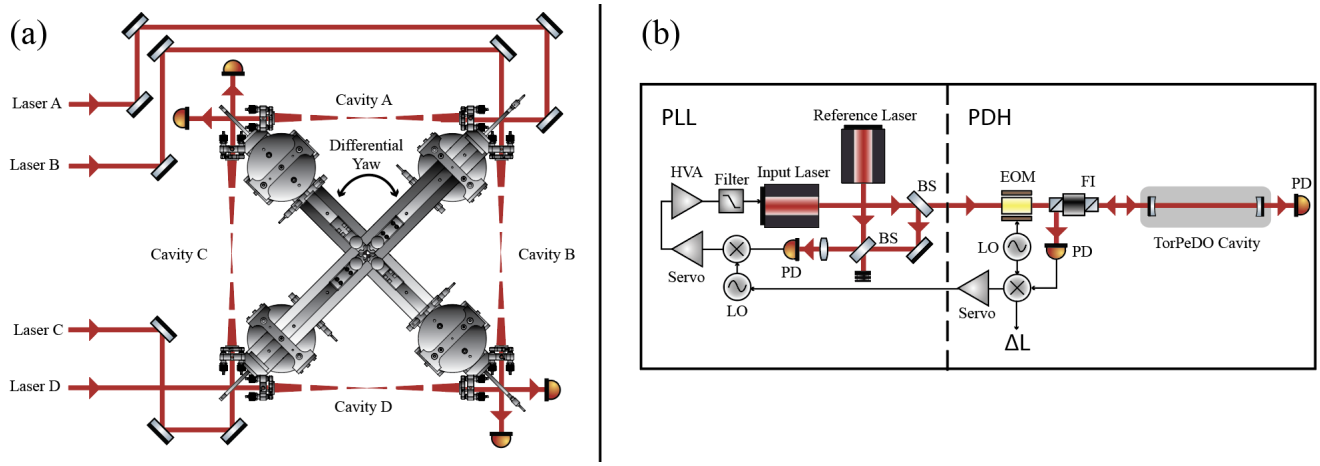

Figure 1: (a) Schematic of the TorPeDO system torsion bars and optical readout [3]. (b) Simplified measurement laser path, showing offset PLL and PDH components. BS: beamsplitter, EOM: electro-optic modulator, FI: faraday isolator, PD: photodetectors, LO: local oscillator, HVA: high voltage amplifier.

Relative laser frequency noise between the four lasers is a limitation for the TorPeDO readout, as it will not be suppressed in the common-mode differential measurement. For this, in addition to the PDH readout, each of the four readout lasers are controlled to a common reference laser with an offset-optical phase-locked loop (PLL), as shown in Figure 1(b). We will present the characterization of the simultaneous four offset-optical phase-locked loop set up of the TorPeDO scientific readout, and discuss their performance and limits with respect to the scientific readout requirements for the experiment.

[1] J. Harms, *Living Rev. Relativ.*, **18**, 3 (2015)

[2] D. J. McManus et al. *J. Phys.: Conf. Ser.* **716**, 012027 (2016).

[3] P. W. Forsyth, *Doctoral Thesis*, Australian National University (2022).