Measuring fundamental thermal phase fluctuations in a passive fibre resonator

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Optical fibre sensors provide a robust platform to perform strain measurements down to the sub-picostrain level. This makes them ideal for sensing in harsh environments such as smelting furnaces or the seafloor. The sensitivity of all these devices is ultimately limited by unavoidable length fluctuations of the optical fibre, which are associated with fundamental thermal fluctuations. Until now, the leading edge for ultra-precise fibre sensing has made use of sensors based on distributed-feedback fibre lasers, due to the benefits of having an autonomous sensor that produces its own output. However, theory suggests that this approach suffers from higher levels of thermal noise than could be achieved by using external optical interrogation of a "passive" fibre resonator [1].

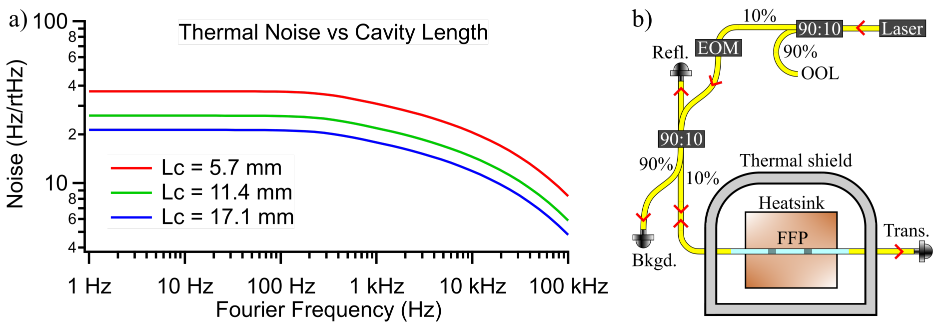

Figure 1: a) Theoretical noise floors for the fundamental thermal phase fluctuations, for different cavity lengths. b) Diagram of experimental set-up (OOL = out of loop measurement, EOM = electro-optic modulator, FFP = fibre Fabry-Perot, Refl. = reflected signal, Bkgd. = background signal, Trans. = transmitted signal).

This theoretical hypothesis has yet to be experimentally verified [2], but if the improvement in sensitivity can be realised it might allow for the design of next-generation fibre sensors as well as providing much needed experimental insight into the fundamental limits of optical fibre measurement. Motivated by this, here we present our latest results measuring the thermal noise floor of our custom passive fibre resonators, which are designed to measure these fundamental thermal fluctuations (Fig. 1a). The sensitivity of these measurements also required the use of a thermally- and acoustically-isolated environment (Fig. 1b).

[1] S. Foster, *Phys. Rev. A*, **86** 4, 043801 (2012).

[2] G.A. Cranch and S. Foster, *Science*, **335** 6066, 286 (2012).