Thermally-Insensitive Hollow-Core Fibre Fabry-Perot Interferometer for Laser Stabilisation

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Fibre-based Fabry-Perot interferometers (FPI) can provide long delays in a compact package and are alignment-free after fabrication. This delay is however sensitive to environmental temperature variations due to the fibre thermal sensitivity. This sensitivity is reduced by about 20 times when using hollow core fibre (HCF) rather than standard single-mode fibre (SMF)[1]. HCF-FPIs have been demonstrated with finesse of over 100 and lengths of tens of metres[2]. As the thermal sensitivity of HCF is dominated by thermal expansion[1], it can be further reduced by winding the HCF onto a drum made of a material with zero or slightly negative coefficient of thermal expansion (CTE)[3]. When the temperature increases, the tension under which the HCF is wound on the drum is reduced, but its length follows the size of the drum. We present a HCF-FPI[2] that achieves zero thermal sensitivity for the first time by winding it on a Neoceram spool, a commercially available glass ceramic with slightly negative CTE.

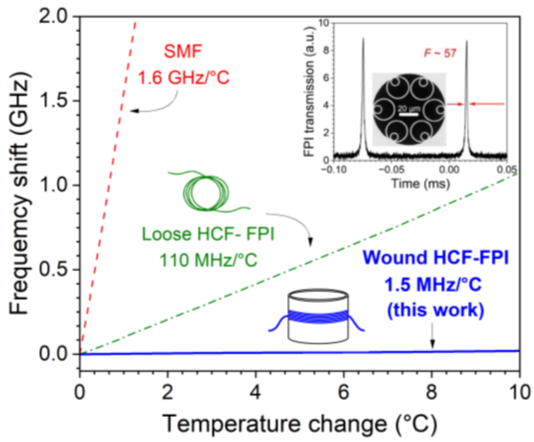

Fig. 1: FPI resonance peak position shift with temperature.

The HCF-FPI was interrogated by a narrow linewidth laser locked to a carrier-envelope offset stabilised optical frequency comb. The interferometer was placed inside a thermal chamber to characterise its thermal sensitivity. The photodetected signal enabled the monitoring of the HCF-FPI resonant transmission peaks. The frequency shift of the HCF-FPI transmission was calculated from the number of observed resonances. Fig. 1 shows the calculated frequency shift of the HCF-FPI when operating close to the zero-expansion point (achieved in the range of 50-60°C) together with the frequency shift of the loose HCF-FPI[2] and loose SMF-FPI[2].

For the Neoceram-coiled HCF-FPI, we achieved a thermal sensitivity as low as 1.5 MHz/°C, corresponding to over 70 times improvement compared to loose HCF-FPI and three orders of magnitude improvement over SMF-FPI This low value was achieved at a temperature where the Neoceram has a negative CTE of -0.22 to -0.25 ppm/°C. The extremely low thermal sensitivity achieved paves the way to implementations in laser stabilisation for frequency metrology, sensing and a range of applications requiring ultra-stable interferometres.

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[1] E. Numkam Fokoua *et al.*, "How to make the propagation time through an optical fiber fully insensitive to temperature variations," Optica 4, p. 659-668 (2017).

[2] M Ding *et al.*, "Long-length and thermally stable high-finesse Fabry-Perot interferometers made of hollow core optical fiber." Journal of Lightwave Technology 38, no. 8 (2020) p.2423-2427 (2020).

[3] I. Barbeito Edreira *et al.*, Thermal properties of a hollow-core optical fiber spooled onto a drum with negative coefficient of thermal expansion, in IEEE Photonics Conference, Orlando, Florida, USA, Nov 12-16, 2023.