A femtometre-resolved all-fibre speckle wavemeter

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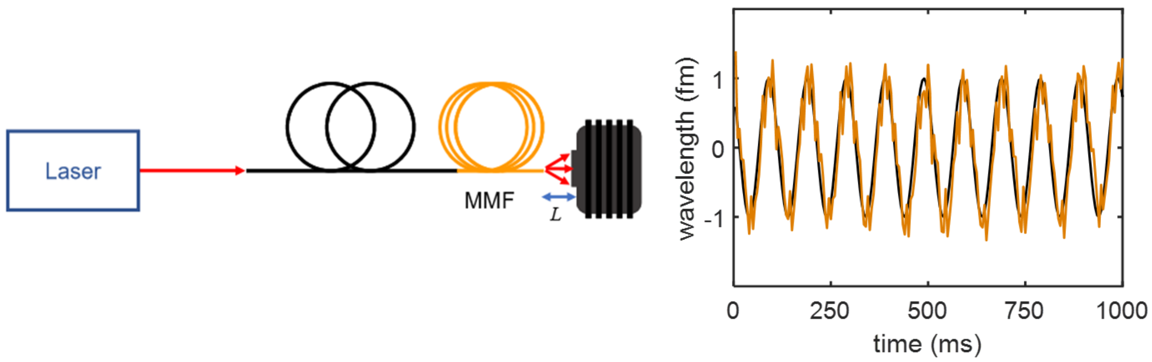
The speckle pattern produced when a laser illuminates a random medium can, with appropriate analysis, be used to uniquely identify the wavelength of the illuminating source. We have demonstrated that principal component analysis can be used as a very sensitive probe of the speckle pattern produced by random prisms [1] and integrating spheres [2]. However, to date, the state-of-the-art realisations of speckle spectrometers have been based on the use of multi-mode fibres as the scattering medium [3] and on transmission matrix analysis approaches, achieving a compact and stable device with picometre resolution.

Here, we show that the speckle pattern produced by propagation through a metre-long step-index multi-mode optical fibre can be analysed with principal component analysis to achieve a femtometre-precision wavemeter, and present progress in the measurement of complete spectra, which demonstrates the applicability of our approach to many existing experiments.

Moreover, we demonstrate that the speckle wavemeter can be used as part of a feedback loop to stabilise lasers to a fractional stability of 10^{-9}. With the freedom to lock the laser at any user-desired frequency and a robust, compact setup, the method holds promise for the new generation of portable cold atom experiments currently being developed for quantum technology applications.



(left) The all-fibre speckle wavemeter
(right) Meaurement (orange) of a 1fm-amplitude sinusoidal wavelength modulation (control signal shown in black for reference

References:

[1] M Mazilu, et al. Opt Lett **39,** 96 (2014)

[2] N K Metzger, et al. Nat. Commun. **8**, 15610 (2017)

[3] H Cao, J. Opt. **19**, 060402 (2017)