Interferometric fringe rejection in tunable diode laser spectroscopy

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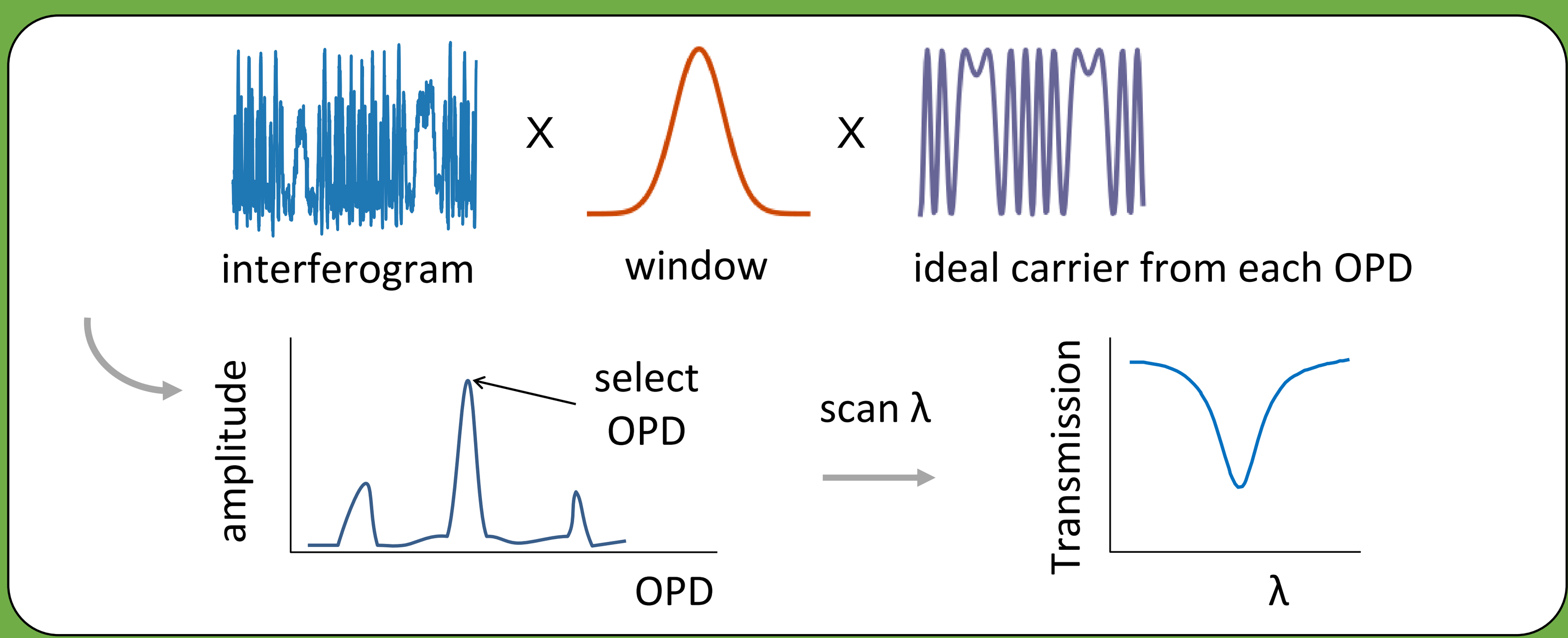
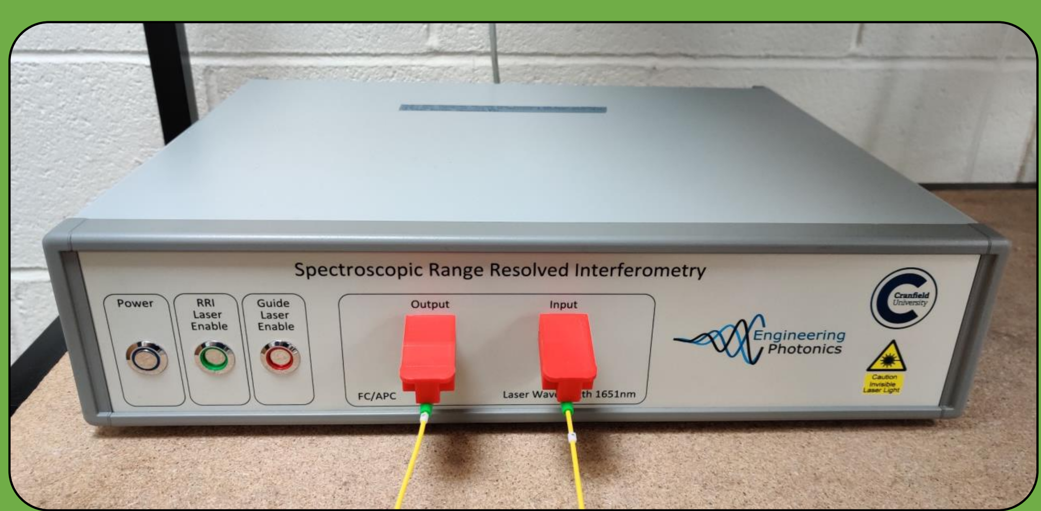
Introduction

- Range-resolved interferometry (RRI) is a technique recently pioneered at Cranfield for measurement of physical parameters such as displacement, shape and strain, in both free space and optical fibre, via measurement of interferometric phase [1].
- We have adapted this technique with the addition of a slow wavelength scan across a gas line and to measure intensity rather than phase, to give spectroscopic range-resolved interferometry (S-RRI) [2]. An advantage is the in-built rejection of unwanted, parasitic interference fringes from anywhere in the system.

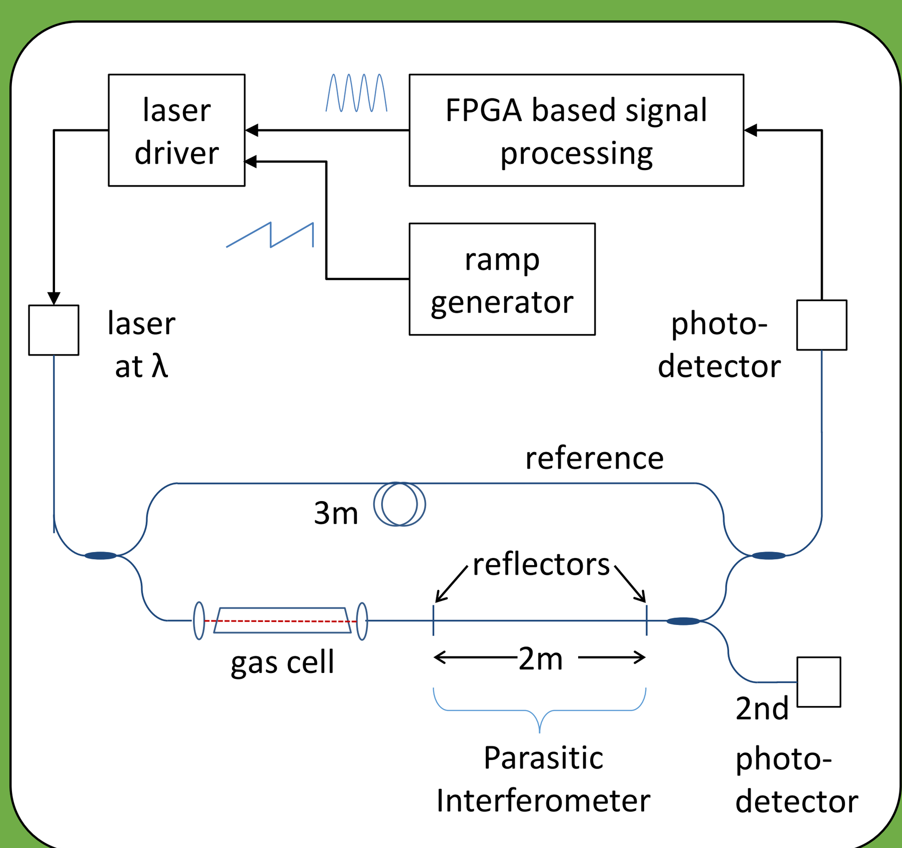
Principle of Operation



- One or more interferometers are deliberately introduced to the system and interrogated using a laser with a sinusoidally modulated injection current to reveal a signal comprising a superposition of interferograms from all possible interferometers in the system.
- Signals that correspond to a chosen optical pathlength difference (OPD) are demodulated using its ideal carrier in the manner of a lock-in amplifier.
- The fringe rejection properties were tested using a fibre-coupled gas cell of length 1m in a simple Mach-Zehnder interferometer set-up.

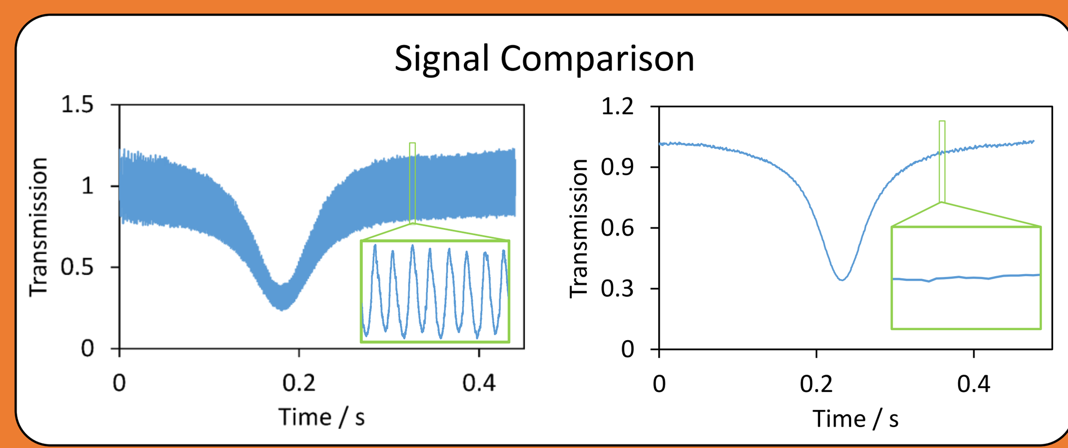


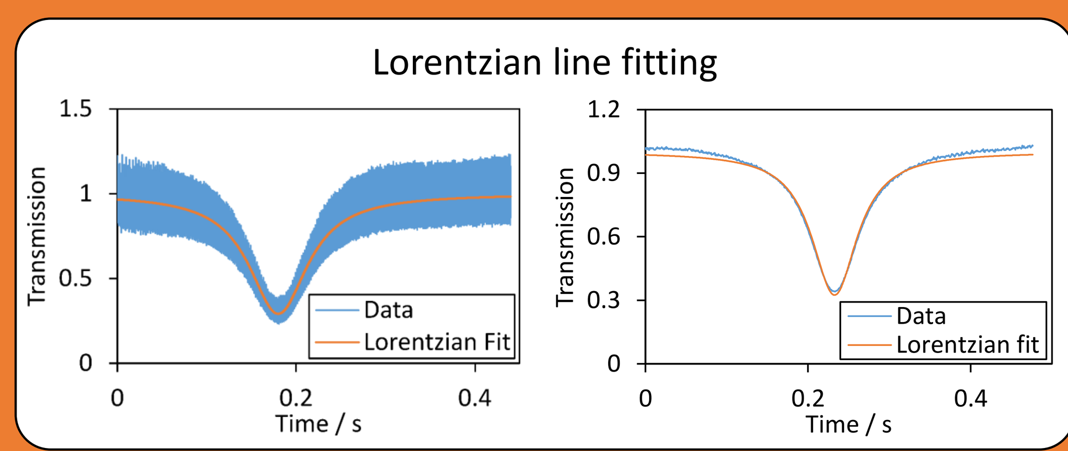
- A 1654nm DFB laser was modulated sinusoidally at 49kHz with an amplitude of 8pm (p-p).
- A parasitic interferometer was introduced to test fringe rejection.
- Interferograms were extracted via digital signal processing running on an FPGA processor.
- An additional wavelength scan (2Hz, 0.5nm) facilitated the measurement of gas spectra.

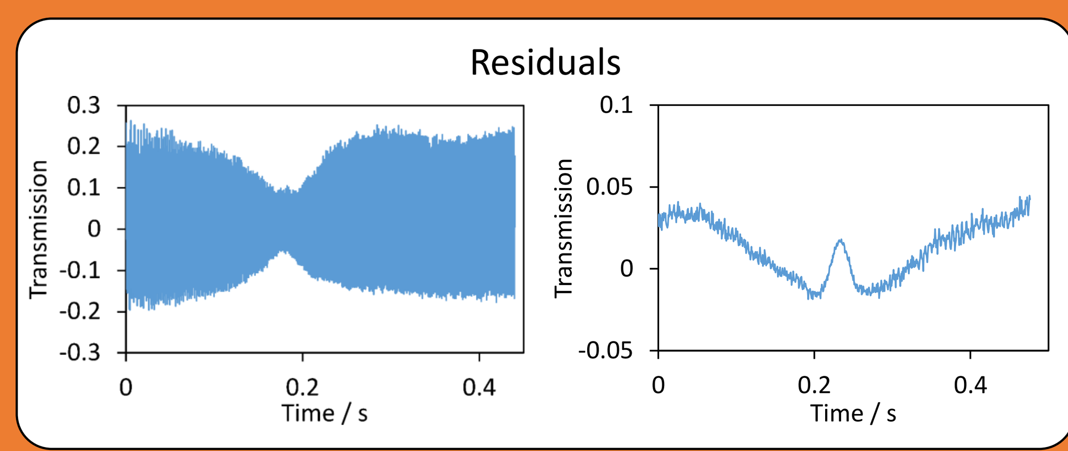


Experimental Results

- A parasitic Fabry-Perot interferometer was introduced in series with the gas cell, created using in-fibre partial reflectors (90%) separated by a distance of 2m. The transmission of methane at 2.5%vol was recorded for the Mach-Zehnder arrangement with S-RRI demodulation.
- As a comparison with a conventional measurement, a second photodetector measured the transmission outside the Mach-Zehnder interferometer and without any sinusoidal modulation of the laser.







- A significant reduction in unwanted fringes can be observed.
- By undertaking a Lorentzian line fit and comparing standard deviations of the residuals, an improvement of approximately 39x was calculated.
- This could potentially be even greater as the fringes could be below the noise floor of the detector.
- Distortion of the Lorentzian lineshape can be seen - caused by use of a finite sinusoidal carrier.

Conclusions

- S-RRI offers a number of potential advantages over other fringe rejection techniques. One can always create a deliberate, wanted interferometer at an OPD that is sufficiently different from that of a parasitic interferometer, therefore the fringe rejection is independent of the free spectral range of the parasitic interference fringe.
- The method uses no moving parts, simple laser modulation and the addition of an FPGA processor only (required for precise synchronisation during demodulation).

References

[1] T Kissinger, TOH Charrett, RP Tatam, "Range-resolved interferometric signal processing using sinusoidal optical frequency modulation," Opt. Express vol. 23, no. 7, pp. 9415-9431, 2015.

[2] JAA Bremner, T Kissinger, J Hodgkinson, RP Tatam, "Fibre-coupled, multiplexed methane detection using range-resolved interferometry," J. Phys. Photonics vol. 3, no. 2, 02LT01, 2021.

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