## Comparison of single-beam and dual-beam differential interferometry for motion measurements in noisy environments

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**Abstract**

Differential interferometers are widely used in precision motion measurements to minimise the effects of air refractive index fluctuations and to provide locally referenced vibration measurements. A conventional system of the plane mirror differential interferometer [1] uses a symmetrical setup in which a laser beam is split into two beams which then travel parallel in the same direction to a measuring unit with a reference and a target mirror, and the returning beams interfere to form a differential signal. The disadvantage of this configuration is that the reference beam is not co-located with the measurement axis and that therefore any vibrations or disturbances causing angular deviations will lead to an error, the size of which depends on the lateral distance between the reference and the measurement beam, the position of the pivot point and the angle itself.

To overcome this problem, range-resolved interferometry [2] can be used, which allows the simultaneous phase measurement of several interferometers within the same beam. Thus a single-beam differential interferometer [3] can be constructed by placing a semi-transparent reference in front of the target to be measured and the differential movement between the window and the target can be determined. To prove the effectiveness of this method and compare it with regular differential interferometry, a simple test setup, as shown in Fig. 1, using two fiber-coupled collimators and a measuring configuration consisting of a reference window and a target window placed on a piezo element was built.

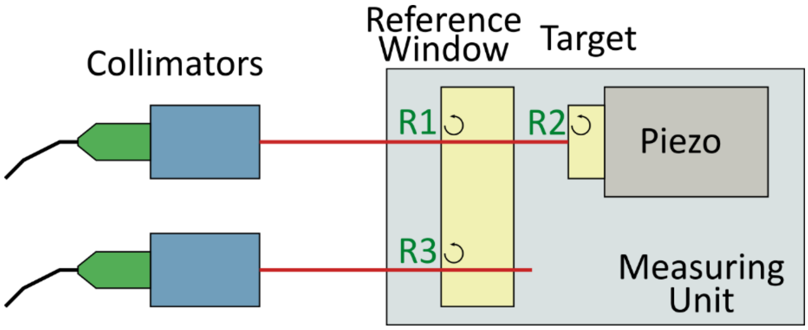


Figure 1: Measurement configuration with single-beam differential interferometer at the top and an additional interferometer used to simulate a regular differential configuration at the bottom.

Fig. 2 shows a comparison of a single beam (signal R1-R2) and a dual-beam (signal R3-R2) differential signals when artificially inducing angular deviations of the measuring unit by tipping it with a finger. Results shows that the single beam signal is significantly less sensitive to the induced disturbances. This principle could be very useful to provide novel measurement capabilities to improve, for example, vibration isolation and active damping systems that would benefit from improved vibration measurements through referencing to a local window.

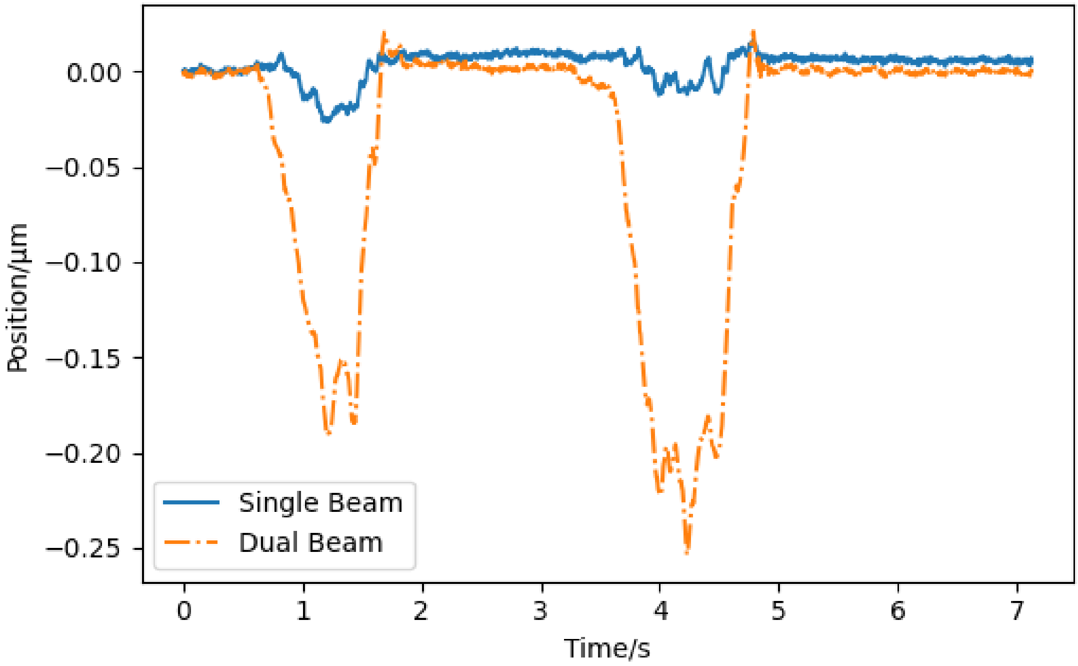


Figure 2: Target position measurement using single-beam and dual-beam approach. The distortions shown are caused by the intentional tipping of the measuring unit.


[1] Hosoe S 1995 Highly precise and stable displacement-measuring laser interferometer with differential optical paths *Precis. Eng.* 17(4) pp 258-265

[2] Kissinger T, Charrett T and Tatam R 2015 Range-resolved interferometric signal processing using sinusoidal optical frequency modulation *Opt. Express* 23(7) pp 9415–9431

[3] Kissinger T, Charrett T, James S, Adams A, Twin A and Tatam R 2015 Simultaneous laser vibrometry on multiple surfaces with a single beam system using range-resolved interferometry *SPIE Optical Metrology 2015, Munich, Germany, Proc. SPIE* 9525:20 (2015)