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Air turbulence effects on measurement stability of the differential interferometer

Introduction
Interferometer systems are used in precision motion control applications for a number of reasons, including the inherently high resolution available from 'wavelength of light' based systems, and the ability to measure directly in the plane of the worksurface - a feature that enables Abbé offset error to be eliminated.

In non-controlled environments, fluctuations in atmospheric conditions affect the laser beam, and therefore, the stability of measurement. These effects can be the dominant performance limiting factor.

To determine the magnitude of air turbulence effects on measurement stability, a series of tests have been undertaken using a Renishaw RLE10 laser interferometer system, comprising an RLU10 laser unit and an RLD10-X3-DI differential interferometer detector head. Tests were conducted over both balanced and differential path lengths using a variety of beam shielding techniques.

The results of these tests are summarised in this application note.

Test conditions
Tests were performed under the following environmental conditions:

Test A: Test rig within a Perspex box, still air tube surrounding the beam path, laboratory air conditioning system switched off

Test B: Test rig within a Perspex box, laboratory air conditioning system switched off

Test C: Test rig within a Perspex box, wedged open, laboratory air conditioning system switched off

Test D: Test rig fully exposed, laboratory air conditioning system switched off

Test E: Test rig fully exposed, laboratory air conditioning system switched on

Test duration was 10 minutes, with each test being repeated a number of times. Average test results are shown in Table 1.

Test results - measurement error ±nm (±ppm)

Test	Balanced path length (both arms at 200 mm)	Differential path length (reference arm at 200 mm, measurement arm at 400 mm)
A	0.36 nm (0.002 ppm)	1.40 nm (0.0035 ppm)
B	0.63 nm (0.003 ppm)	1.68 nm (0.004 ppm)
C	2.05 nm (0.005 ppm)	3.06 nm (0.0075 ppm)
D	14.18 nm (0.0355 ppm)	19.56 nm (0.049 ppm)
E	27.54 nm (0.069 ppm)	38.15 nm (0.0955 ppm)

Table 1: test results

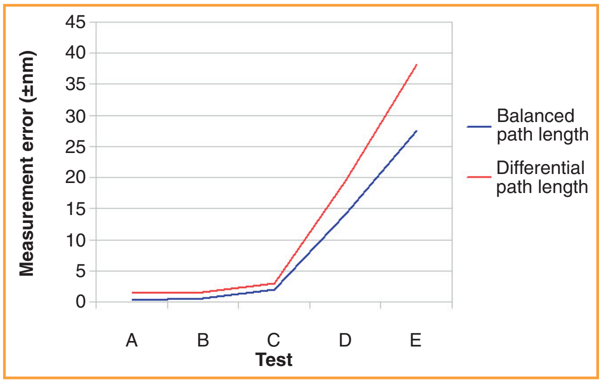

Figure 1: graphical test results

Conclusion
Measurement error is shown to reduce for both balanced and differential path lengths as environmental protection around the beam and test rig increases.

As anticipated, balanced path length tests demonstrate a lower level of measurement error than corresponding differential path length tests.

The lowest levels of measurement error are achieved in Test A, where the rig is placed in a Perspex box and a still air tube surrounds the beam path. For industrial applications, such levels of shielding are impractical, however, results obtained from tests B and C, where the test is located within a box, (similar to applications inside a machine with covers in place), indicate even low level shielding provides a significant improvement in performance.

Further testing
Once balanced and differential path length testing was complete, supplementary testing was carried out using a standard RLD10 0° beam launch plane mirror detector head to allow further comparisons. For this testing, the measurement path length used was 400 mm.

Figure 2 below shows a schematic of the various optical configurations tested.

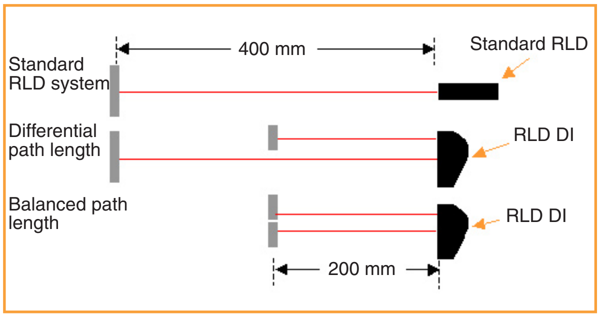

Figure 2: configuration schematic

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The complete set of test results is given in Table 2 and illustrated graphically in Figure 3 below.

Test results - measurement error ±nm (±ppm)

Test	Balanced path length (both arms at 200 mm)	Differential path length (reference arm at 200 mm, measurement arm at 400 mm)	Standard RLD10 (400 mm measurement arm)
A	0.36 nm (0.002 ppm)	1.40 nm (0.0035 ppm)	4.44 nm (0.011 ppm)
B	0.63 nm (0.003 ppm)	1.68 nm (0.004 ppm)	4.64 nm (0.0115 ppm)
C	2.05 nm (0.005 ppm)	3.06 nm (0.0075 ppm)	5.12 nm (0.013 ppm)
D	14.18nm (0.0355 ppm)	19.56 nm (0.049 ppm)	29.75 nm (0.0745 ppm)
E	27.54 nm (0.069 ppm)	38.15 nm (0.0955 ppm)	49.29 nm (0.123 ppm)

Table 2: test results, all configurations

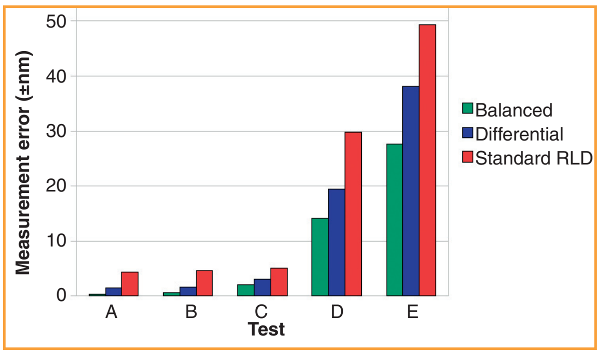

Figure 3: graphical test results, all configurations

Conclusion

Testing clearly shows that the differential interferometer arrangement provided by the RLD DI head can be used to reduce air turbulence induced noise where machine geometry permits. For optimum performance the measurement and reference arms should be of similar lengths.

Methodology

Testing was performed using a purpose built Invar test rig, providing a maximum axis length of 1 metre, using an RLU10 laser unit, an RLD10-X3-DI differential interferometer detector head and plane mirror optics.

Initial testing was performed using optical configurations providing a balanced path length and a differential path length under the varying environmental listed overleaf.

Test duration was 10 minutes, with each test being repeated a number of times. The average measurement error for each test was then calculated and used to populate the results table.

Each of the initial five tests were then repeated, using a plane mirror configured RLD10 0° beam launch detector head in place of the differential interferometer.

Procedure

The test rig was assembled as shown in Figure 4. The detector head was attached to one end of the Invar rig and the plane mirror optic(s) attached to an optical mount whose position could be adjusted to suit the path length required.

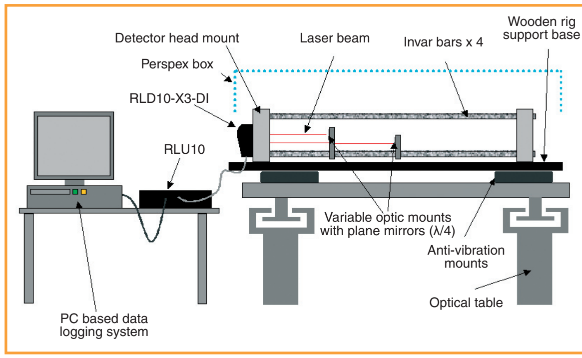

Figure 4: test rig set-up

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