Application Notes
AP1115 A

multiple-pass optical adapter for high resolution in turbulent environment

I. What is the problem?

For high resolution and high accuracy measurement in a shop environment, the measurement is effected by air turbulence. For a laser interferometer type measurement, typical resolution 0.00001 mm. However, because of the air circulation, or turbulence, the effective laser beam path length (OPD) is fluctuating. This fluctuation limited the accuracy of the laser measurement. Long time-average has been used to minimize the effect of air turbulence. However, too much averaging may cause a time-lag and inconvenience in the measurement. Another method is to control the environment to minimize the air circulation and temperature gradient or to cover the laser beam path completely. However, in a shop environment, both of these are difficult to achieve.

II. What is the multiple-pass optical arrangement?

For a typical laser interferometer, the laser beam is reflected by a retroreflector target, and the displacement of the target is determined by measuring the change in the optical path length. A multiple-pass is an optical arrangement, with the laser beam reflected back and forth between the retroreflector target and some mirrors or prisms mounted stationary with the laser head. It has been shown in Ref [1] and [2] that multiple-pass optical arrangement can increase the resolution, and reduce the effect of air turbulence.

III. How the multiple-pass optical adapter work?

Conventional multiple-pass optical arrangements using mirrors and prisms are rather complex and difficult to align. The multiple-pass optical arrangement developed by Optodyne (patent pending) can easily be achieved by attaching an optical adapter (an accessory) to the single aperture laser head (MCV-500 laser calibration system) and using a 25mm diameter retroreflector as target as shown in Fig. 1. The number of passes between the optical adapter and the retroreflector is increased by a factor of 6. That is, a one mm displacement of the retroreflector will become an 6 mm increment of the effective optical path length. Hence the resolution is increased by a factor of 6 and the air turbulence is averaged over the 6 parallel paths. For a MCV-500 laser system, the standard range is more than 10m. Hence the range becomes 10m with the 6-pass optical adapter or 1,6m. Since the maximum velocity is 5m/sec, the maximum velocity with the 6-pass optical adapter becomes 0,8m/sec.

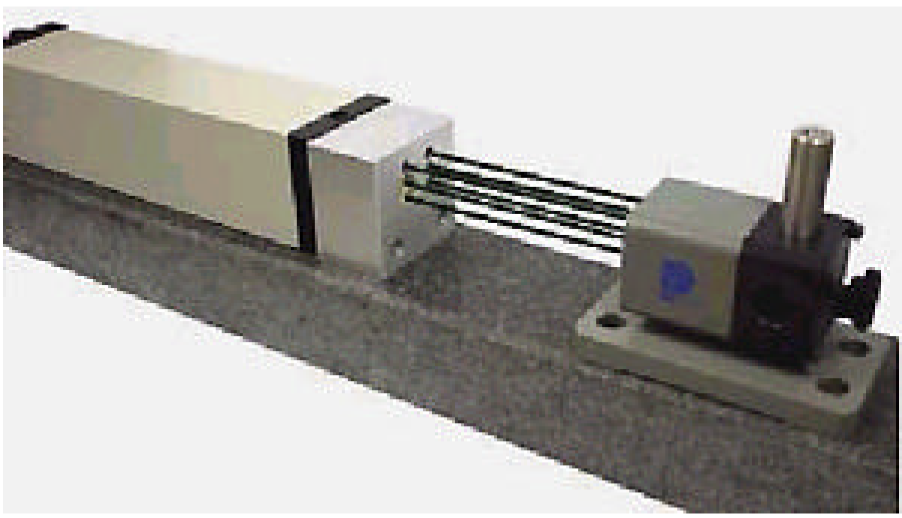

Fig. 1 A 6-pass optical arrangement achieved by an optical adapter and a 25mm diameter retroreflector

IV. Test results

To verify that the multiple-pass optical arrangement can reduce the effect of refractive index change of air, two laser systems were set up co-axially with both retroreflectors mounted together and with equal distances from the laser heads. A typical result is shown in Fig. 2. The heavy line is the fluctuation in the 6-pass optical arrangement and the light line is the fluctuation in a single-pass optical arrangement. The effect of air circulation or the refractive index change, is reduced considerably in the 6-pass optical arrangement.

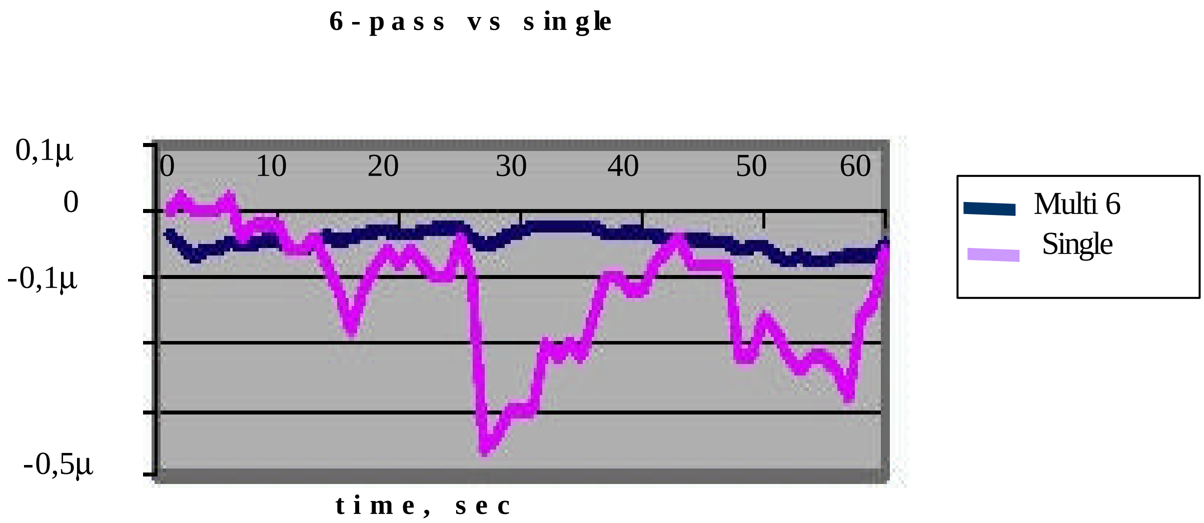

Fig. 2 Effect of air circulation on a 6-pass optical arrangement and on a single pass optical arrangement.

V. References

1. D. Shu, E. E. Alp, J. Barraza, T. M. Kuzay, and T. Moooney, "Optical design for laser Doppler angular encoder with sub-nrad sensitivity", J. Synchrotron Rad. Vol. 5, pp826-828, (1998).
2. 2. Y. Tanimura, "A new differential laser interferometer with a multiplied optical path difference", Annals of the CIRP Vol. 32, No. 1, pp449-453 (1983).

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