Novel Signal Processing Module of Fabry-Perot Interferometer

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Abstract

In this investigation based on the self-developed folded Fabry-Perot interferometer, a novel signal processing module is optimized and integrated with others units. In order to acquire refined interferometric signals, the previous piezo transducer (PT) modulation mechanism is modified to improve the signal stability without complex adjustments or arrangements. With the aid of the improved signal processing module, the experimental results have revealed that the maximum standard deviation of the signal gain and its relative zero drift are less than 0.02 V during the linear displacement measurement. Obviously, the testing results performed with the proposed module are more stable and accurate significantly. Finally, interferometer with the improved signal processing module is verified with the commercial interferometer. Experimental results have demonstrated that the difference of the maximum standard deviations between both interferometers is about 0.3 μm.

Key word : Fabry-Perot interferomter, signal processing module, linear displacement measurement

1 Introdution

Due to the demand on high precision measurements or positionings, submicro- or nanometer measurement technology becomes more relevant and necessary. The laser interferometer is a common measurement instrument to realize the calibration of the precision machine tools or the linear positioning of a stage. The signal processing quality is essential for determining the measurement accuracy of the laser interferometer employed for above-mentioned applications.

The usual commercial interferometer based on a non-common optical path structure is sensitive to environmental disturbances and mechanical

vibrations. To eliminate these errors, the proposed Fabry-Perot interferometer system arranged with the common optical path bears the characteristics being more insensitive to such fluctuations. To enhance the measurement stability and accuracy of the developed Fabry-Perot interferometer, its signal processing module has been modified.

In order to verify the feasibility of the optimized system, comparison measurements between the proposed Fabry-Perot interferometer and a commercial interferometers have been conducted. The comparison results analysed according to ISO 230-2 standard have shown that the difference in bidirectional system positioning deviation, repeatability and accuracy are less than 1 μm. It is proved that the proposed system can be employed for high-precision displacement measurements or the calibration for machine tools.

2 Measurement Principle

The structure of the proposed Fabry-Perot interferometer with a common optical path shown in Figure 1, compose of the reference mirror and corner cube retroreflector (CCR). The arrangement of the corner cube retroreflector (CCR) realizes that the incident light and the reflected light parallel each other to improve alignment efficiency.

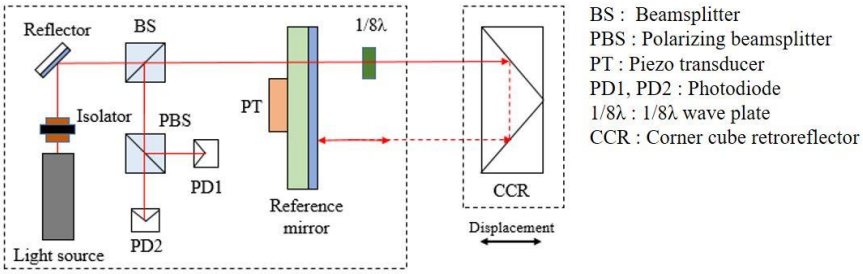


Figure 1: Improved optical structure of Fabry-Perot interferomter

3 Signal Processing Module

The interferometric signals are transmitted to two photodiodes which detect the intensity of the emerging interference beam. The signal amplification processing is shown in Figure 2. After the signal amplification processing, the signals will be processed with the low-pass filter circuit to eliminate the DC offset and avoid the signal leakage due to the DC drift, as shown in Figure 3.

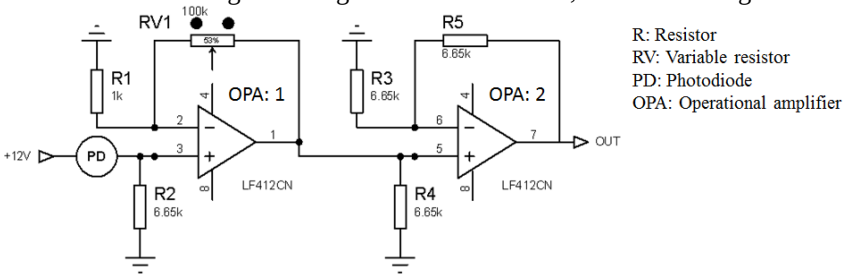
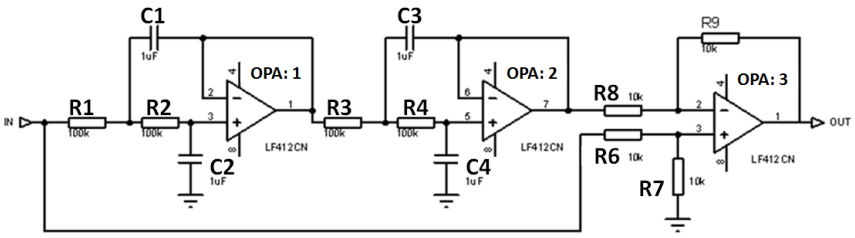


Figure 2: The signal amplification circuit



R: Resistor
C: Capacitor
OPA: Operational amplifier

Figure 3: low-pass filter circuit

In this study the piezo transducer actuator is used to generate a micro-displacement of ±λ/4 in the optical cavity for the signal modulation. Its characteristics include fast response, low energy consumption, small size, and immunity to magnetic field interference.

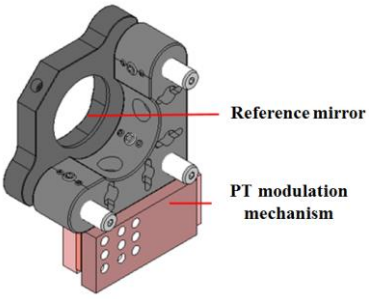


Figure 4: PT modulation mechanism

4 Experimental results

Figure 5 has revealed that the maximum voltage deviation of the signal gain and its relative zero drift are less than 0.02 V. It means that the amplitude of the orthogonal signal was stable from start point (the distance from reference mirror to CCR is about 120 mm) to end point (the distance from reference mirror to CCR is about 220 mm). Consequently, the signal offset in initial point and end points are almost overlapped together.

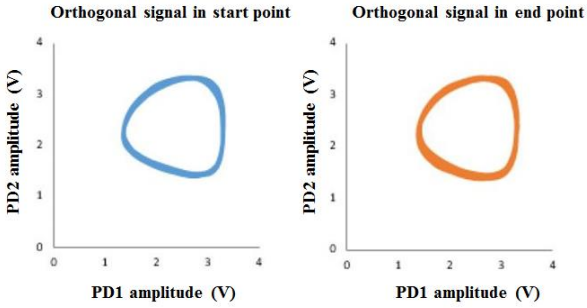


Figure 5: Orthogonal signal comparison between start and end point

In this experiment, the displacement of movement stage are measured by Fabry-Perot interferometer (FPI) and commercial interferometer (CI) in the same time. The results demonstrated that the positioning deviation of the comparison measurement between FPI and CI are less than 0.3 μm, as shown in Figure 6.

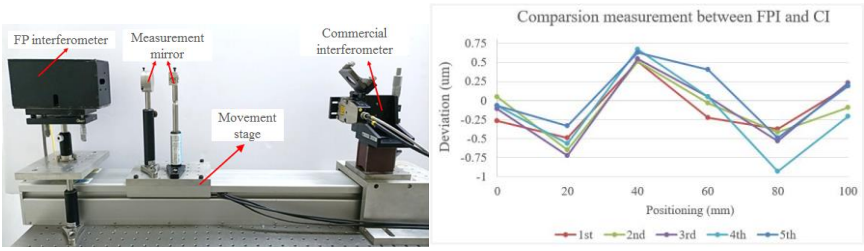


Figure 6: Comparison measurement between FPI and CI

5 Conclusion

This investigation based on the self-developed folded Fabry-Perot interferometer aims to the optimization and improvement of the corresponding interferometric signals. Results from the testings of the modified signal module and the comparison measurements demonstrated that the measuring performances have been distinctly improved. The Fabry-Perot interferometer integrated with this module can achieve the measurement demand of the submicron order.

References

[1] C.P. Chang, P.C. Tung, L.H. Shyu, Y.C. Wang, and E. Manske, “Modified Fabry-Perot interferometer for displacement measurement in ultra large measuring range”, Review of Scientific Instruments, Vol. 84, pp.053105, 2013.

[2] Anthony Chukwujekwu Okafor, Yalcin M. Ertekin, “Vertical machining center accuracy characterization using laser interferometer, Journal of Materials Processing Technology, Vol.105, 2000.

[3] International Standard: ISO230-1, “Test code for machine tools -- Part 1: Geometric accuracy of machines operating under no-load or quasi-static conditions”, Third edition, 2012.

[4] International Standard: ISO230-2, “Test code for Machine Tools-Part 2: Determination of Accuracy and Repeatability of Positioning Numerically Controlled Axes”, Third edition, 2014.

[5] Texas Instruments, “LF412-N Low Offset, Low Drift Dual JFET Input Operational Amplifier”, 2014.