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W. Hou / Y. Zhang /W. Cui

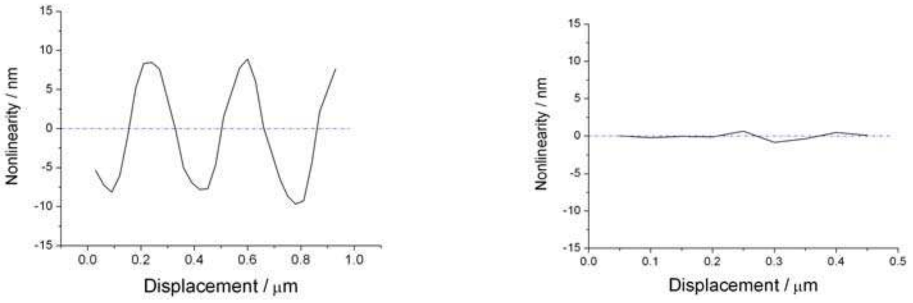
Compensation, Reduction and Elimination of the Nonlinearity of Heterodyne Interferometer Nonlinearity

The heterodyne laser interferometer can achieve a sub-nanometer resolution on the basis of a stable subdivision of the light wavelength using phase measurement and becomes an important instrument with widespread use in scientific research and precise engineering. However, due to inevitable imperfectness in optical system, a phase error occurs in the measurement signal and results in a nonlinear relation between the measured phase difference and the respective displacement, and it often limits the effective resolution of laser interferometer. Finding the most effective approach to the solution is always one of the most important research subjects in current precision measurement. [2-6]

In the past, a simple and easy-to-implement method to compensate for the nonlinearity of heterodyne interferometers has been developed which can be used in most science researches and industry precision measurement.[2] However, this compensation method can only be effective for the first-order error.

Recently, a significant finding was obtained that, like the subdivision of wavelength, the nonlinearity of the heterodyne interferometers, in term of length, can be subdivided by the multiple of the optical path. [6] This gives us a simple and efficient approach to decrease the nonlinearity of the heterodyne interferometers. But it can not be unconditionally reduced, because simply multiple optical paths could bring more optical impairments into interferometer and therefore cause extra nonlinearity.

A new approach is found to eliminate the nonlinearity of heterodyne interferometer. Since the nonlinearity error changes periodically with optical phase shift, it reveals that the nonlinearity could be got rid of if a phase shift is produced with the same size as optical phase shift but in the negative sign. This is achieved with phase detection by rotating a polarizer being located between a $\lambda/4$-waveplate and the optical detector. We compare the phases of both output signals at "constant position" (or at zero position), that is, we keep their phase difference always be constant (or zero) by rotating the polarizer. The rotating angle of polarizer can be exactly measured by optical grating. Therefore, the phase shift is obtained without nonlinearity error, thus the measured displacement is also free of nonlinearity error.



(a) (b)

Figure 1 Nonlinear error detected without phase compensation by rotating polarizer (a) and with phase compensation by rotating polarizer (b).

In Fig. 1 there were no replacements of optical parts during the two measurement processes at all. This means that the frequency mixing in laser interferometer system was in the same level for both measurements, so that the nonlinearity in both measurements should also be in the same level. But the measurement results show a clear contrast that the nonlinearity in Fig.1a is about 15 nm, while in Fig.1b it is obviously eliminated, apart from some arbitrary noise.

This method can be used in most science researches and industry precision measurement, and it is valid for all nonlinearity errors whether it is a first-order or a higher-order error, or caused by any reasons.

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