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Measurement of nanometer scale displacement by using the optical interferometer based on a 3x3 optical fiber coupler

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Abstract

The optical interferometric system based on optical fiber has the disadvantage of poor stability. For the case of acquiring nanometer scale displacement, the sensitivity depends heavily on the initial phase of the system. In a conventional interferometric system based on a 2×2 interferometer, having two input ports and two output ports, the interference signal varies sinusoidally with optical path-length difference (OPD). Thus, for the case of small displacement measurement, the initial phase or the operating point heavily affects the sensitivity of the system. Even in a laboratory condition, unfortunately, the optical fiber-based system easily suffers from the drift of OPD. To mitigate this issue, various studies have explored solutions, such as adding a modulator to the interferometer and keeping the operating point at a constant phase. However, this approach often introduces complexity to the system and needs for additional equipment. In response, we have developed an optical interferometer using a 3×3 optical fiber coupler, creating a system that is impervious to changes in the initial phase drift. With utilizing the inherent phase of the 3×3 interferometer, we could get the IQ (in phase and quadrature phase) information of the interference signal. Therefore, the slow drift of the system can be measured and compensated with ellipse fitting, which means the fast sensing signal can be measured with any initial phase without hurting the sensitivity. We present the optical interferometric system implemented solely with a 3×3 optical fiber coupler. With this, the minute displacement of the surface induced by ultrasound wave could be successfully measured. We expect that the ultrasound wave used for the non-destructive diagnostic of the structure in a harsh environment can be measured remotely in a safe place.

Keywords: Optical interferometer, 3×3 optical fiber coupler, Laser, Ellipse fitting