Demonstration of Sub-Angstrom Cyclic Nonlinearity using Wavefront-division Sampling with a Common-path Laser Heterodyne Interferometer

Feng Zhao
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA 91109
818-354-3602
Feng.Zhao@jpl.nasa.gov

ABSTRACT

Cyclic ($\lambda/2$ periodicity) nonlinear error due to polarization leakage is a well-known source of error that limits the accuracy of conventional Displacement Measuring Interferometers (DMI). Polarization of the laser beam is used to separate and combine the two interfering beams. With even the state-of-the-art polarizing optics, the linear accuracy of a conventional DMI is limited to about a few nanometers due to polarization leakage.

Several new applications require a linear accuracy better than 0.1nm. A novel common-path heterodyne interferometer was proposed at JPL to address the cyclic error problem. Instead of using polarization and amplitude-division sampling to obtain a reference signal, the proposed interferometer obtains the reference signal by wavefront-division sampling, i.e., the measurement wavefront is sampled symmetrically to get the reference signal.

In the proposed approach, one collimated laser beam at frequency f_o is split into two or more symmetric sections with a reference device such as a truncated corner cube or a retro-mirror with holes. The sections that are reflected from the reference device are then used as the reference signal. Other sections of the f_o wavefront are directed to the measurement targets which use corner cubes or retro-mirrors to reflect the measurement beam back to the interferometer. Both the reference and reference sections are then mixed with a collimated beam at a slightly different frequency, $f_o + \Delta f$, which serves as a local oscillator. The heterodyne fringes are then separated with truncated mirrors and focused into separate photo-detectors.

The phase difference between the reference and measurement signals is then used to calculate the displacement between the measurement target and reference device as in other double-pass DMI's. Since the reference and measurement signals are derived from the same collimated wavefront, any changes in the optical path length due to soak temperature changes in the interferometer optical elements will be common-mode. This feature greatly improves the temperature stability of the interferometer.

Results from a proof-of-concept experiment will be reported in this paper. The measurement indicates that the cyclic error from this setup is as small as 27pm RMS. Long term stability results also indicate that the interferometer has an excellent thermal stability, better than 0.1nm over 1 hour period.