Interferometer-based nanopositioning and nanomeasuring technology at the limits of physics and technical feasibility

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Abstract

Nanomeasuring Technology is undisputedly an enabler for the acquisition of new knowledge in the nanoworld and at the same time for the implementation of nanotechnology in real applications. More and more, the limits of physics and technology are being put to the test. In particular, the fabrication of X-ray optics will not make decisive progress without high-precision nano instrumentation.

In recent years, the TU Ilmenau has succeeded in developing nanopositioning and nanomeasuring machines for a measuring range of 200 mm x 200 mm x 20 mm with a resolution of 20 pm. These machines are able to achieve a relative resolution of 10 decades. The enormous performance is only made possible by the consistent application of error-minimum measurement principles, highly accurate interferometric measurement technology in combination with highly developed measurement signal processing and comprehensive error correction algorithms.

A remarkable result was achieved in length measurements of precision gauge blocks in the millimetre range: a short-term repeatability of 20 pm in combination with a reproducibility over a period of 5 years of less than 150 pm. The achieved relative resolution of 10^{-10} exceeds the potential of current conventional frequency stabilization of He-Ne lasers. Here, the first time an approach of direct coupling and stabilization of a He-Ne laser to a phase-stabilized optical frequency comb controlled by a GPS atomic clock disciplined oscillator. This enables a frequency stability of the vacuum wavelength of the He-Ne laser of 2×10^{-12} and for the first time a permanent traceability of the laser frequency to the SI unit second. Further, the coupling of the thus stabilized He-Ne laser via optical fibers with the laser interferometers of the NPM machine was demonstrated. A further remarkable advance was achieved by controlling the refractive index of the NPM machine within a climate chamber to ppb levels.

The talk concludes with a presentation of future developments towards 1000-mm nanomeasuring machines based on an inverse kinematic approach.

Keywords: nanopositioning and nanomeasuring machine, laser stabilization, frequency comb, control of the refractive index of air