PROCEEDINGS

53. IWK

Internationales Wissenschaftliches Kolloquium
International Scientific Colloquium

Faculty of
Mechanical Engineering

PROSPECTS IN MECHANICAL ENGINEERING

8 - 12 September 2008

www.tu-ilmenau.de

TECHNISCHE UNIVERSITÄT
ILMENAU

Home / Index:
http://www.db-thueringen.de/servlets/DocumentServlet?id=17534

Published by
Impressum

Publisher Herausgeber	Der Rektor der Technischen Universität Ilmenau Univ.-Prof. Dr. rer. nat. habil. Dr. h. c. Prof. h. c. Peter Scharff
Editor Redaktion	Referat Marketing und Studentische Angelegenheiten Andrea Schneider
	Fakultät für Maschinenbau Univ.-Prof. Dr.-Ing. habil. Peter Kurz, Univ.-Prof. Dr.-Ing. habil. Rainer Grünwald, Univ.-Prof. Dr.-Ing. habil. Prof. h. c. Dr. h. c. mult. Gerd Jäger, Dr.-Ing Beate Schlütter, Dipl.-Ing. Silke Stauche
Editorial Deadline Redaktionsschluss	17. August 2008
Publishing House Verlag	Verlag ISLE, Betriebsstätte des ISLE e.V. Werner-von-Siemens-Str. 16, 98693 Ilmenau

CD-ROM-Version:

Implementation Realisierung	Technische Universität Ilmenau Christian Weigel, Helge Drumm
Production Herstellung	CDA Datenträger Albrechts GmbH, 98529 Suhl/Albrechts

ISBN: 978-3-938843-40-6 (CD-ROM-Version)

Online-Version:

Implementation Realisierung	Universitätsbibliothek Ilmenau ilmedia Postfach 10 05 65 98684 Ilmenau

Home / Index:
http://www.db-thueringen.de/servlets/DocumentServlet?id=17534

53rd Internationales Wissenschaftliches Kolloquium
Technische Universität Ilmenau
08 – 12 September 2008

W. Gao

Nanomeasuring and Nanopositioning Technologies for Precision Nanomanufacturing

Introduction

This talk presents state-of-the-art nanomeasuring and nanopositioning technologies for precision nanomanufacturing, which is defined here as the manufacturing of precision parts with nanometric tolerances. The talk first makes clear the importance of nanomeasuring and nanopositioning technologies for assurance of the manufacturing accuracies. A number of nano-sensors, including laser interferometers, linear encoders, angle sensors and surface encoders are then be presented. The features of the sensors are compared in terms of measuring principles and specifications. Some multi-degree-of-freedom stages employing the nano-sensors are also provided as the examples of state-of-the-art nanopositioning systems.

Nanomeasuring and Nanopositioning Technologies

The most representative nanomeasuring technology is the length measuring system based on laser interferometry. Laser interferometers are not only used in national standard institutes for establishing the metric but also widely used in industries for precision nanomanufacturing. In a laser interferometer, the laser wavelength is employed as the reference.
Figure 1 shows the principle of a heterodyne laser interferometer [1)]. Laser beams with slightly different frequencies (f_1 and f_2) from a two frequency laser source are projected onto the moving mirror and the reference mirror. λ_1 and λ_2 are the wavelengths of the two beams from the laser source. E_1 and E_2 in the figure are the wavefront functions of the beams. The reflected beams from the mirrors interference with each other at Receiver 2, resulting an interference signal I_S. The signal I_r is received by Receiver 1, which is generated by the direct interfering of the beams from the laser source. The displacement x can be obtained from Ir and I_S by a phase measuring device.

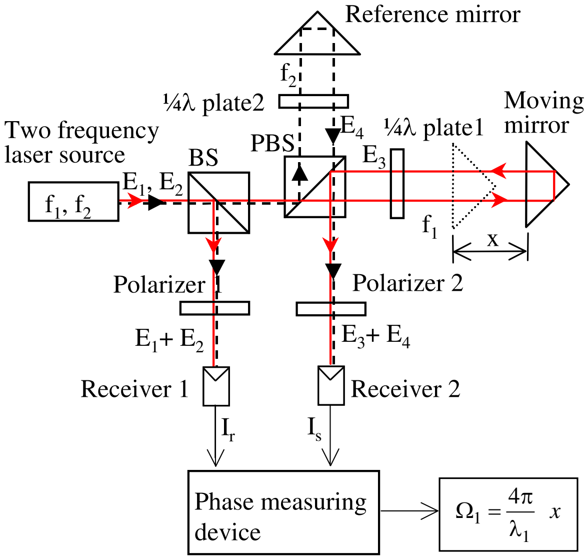

Figure 1 The principle of a heterodyne laser interferometer

Figure 2 shows an advanced length scale laser interferometer [2)]. The interferometer is developed for calibration of the fine linear encoders with nano-scales up to a length of 1600 mm. A stabilized He-Ne laser is used as the laser source. The resolution of the interferometer is approximately 0.8 nm and maximum traveling measurement speed is 20mm/s. The accuracy (uncertainty of measurement) is better than 40 nm over a length of 1 m. Figure 3 shows a nano-scale measurement result by the laser interferometer.

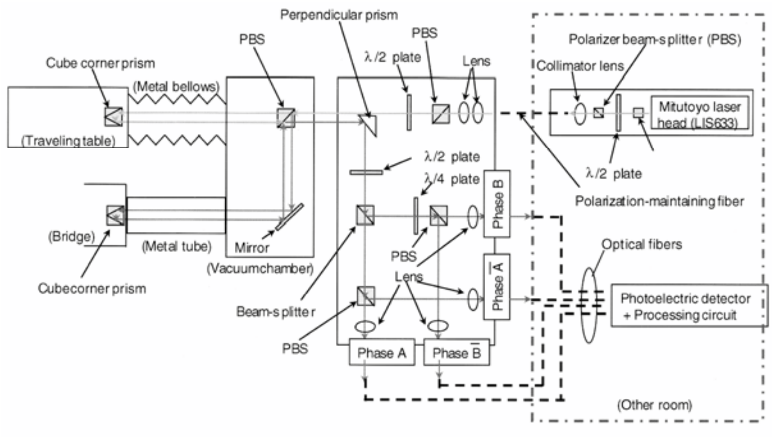

Figure 2 The schematic of a laser interferometer

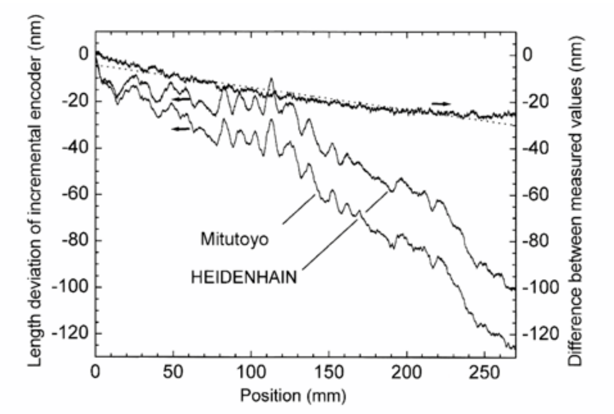

Figure 3 Nano-scale measurement result by the interferometer

Linear displacement can also be measured by linear/planar encoders. Figure 4 shows the principle of a surface encoder for measurement of the X-, Y- and Z positions/displacements [3]. The three-axis surface encoder employs two XY-grid mirrors with identical pitches and amplitudes of X- and Y-directional grids as the stationary reference mirror and the moving scale mirror, respectively. The positive and negative first-order diffraction light beams from the two XY-grids superimposing with each other to generate interference signals, from which the displacements of the scale grid along the X-, Y-, and Z-axes can be simultaneously obtained with nanometric resolutions. Figure 5 shows the photograph of a prototype surface encoder (three-axis displacement sensor). Figure 6 shows the results of resolution test of the surface encoder. Three conventional capacitive sensors are used for comparison. It can be seen that the surface encoder (three-axis displacement sensor) has the ability to detect three-axis displacements with nanometric resolutions.

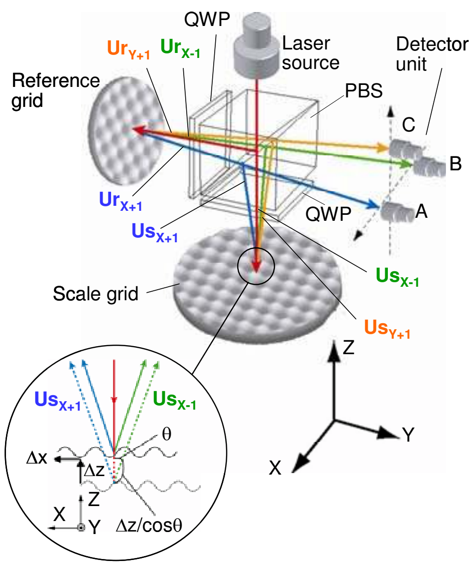

Figure 4 Principle of a three-axis surface encoder

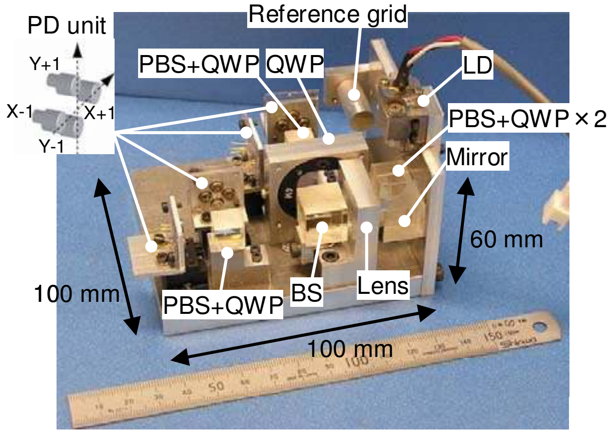

Figure 5 Photograph of the sensor head of a prototype three-axis surface encoder

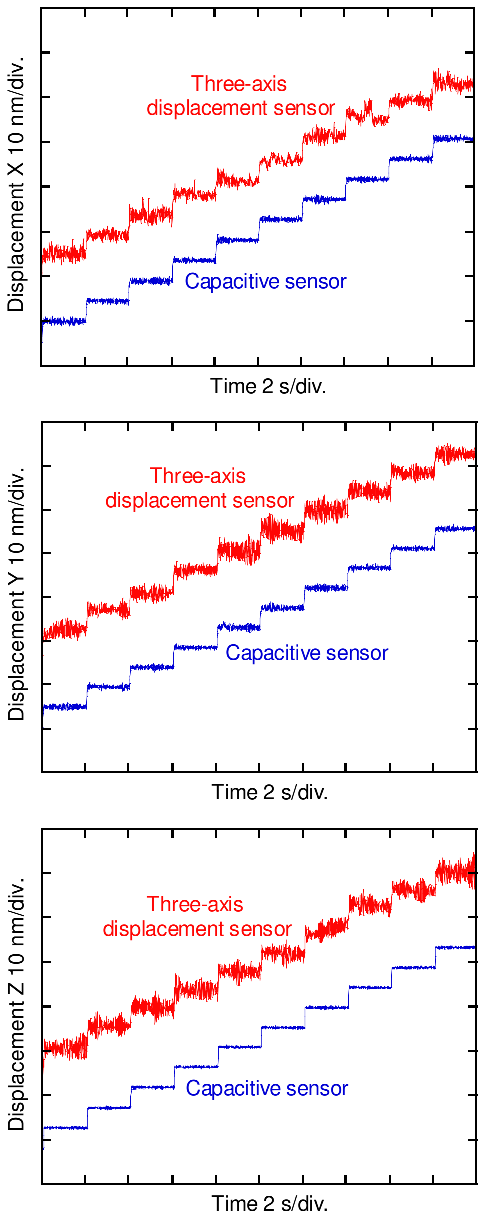

Figure 6 Outputs of the three-axis surface encoder (displacement sensor)

Figure 7 shows a nanopositioning and nanomeasuring machine used for the three-dimensional coordinate measurement in a range of 25 mm x 25 mm x 5 mm with a resolution of 0.1 nm [4]. The interferometers for nanopositioning of the stages are arranged in such a way that Abbe error free measurements are carried out on all three coordinate axes.

Figure 7 The Nano Positioning and Nano Measuring Machine

Conclusion

Nanomeasuring and nanopositioning technologies are playing an increasingly important role in precision manufacturing. Improvement of the reliability of such technologies is of high priority for applications in wider areas of nanotechnology.

References:

[1] http://www.home.agilent.com/
[2] M. Sawabe, et al, A new vacuum interferometric com-parator for calibrating the fine linear encoders and scales, Precision Engineering, 28, (2004), 320-328.
[3] W. Gao, A. Kimura, Three-axis Displacement Sensor with Nanometric Resolution, Annals of the CIRP 56-1, (2007), 529-532.
[4] http://www.sios.de

Author:

Wei Gao, Tohoku University, Aramaki Aza Aoba 6-6-01, Sendai 980-8579, Japan
Phone and Fax: +81-22-795-6951
E-mail:gaowei@cc.mech.tohoku.ac.jp