Micro and Nano Measurement Instruments

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Abstract

This paper presents micro and nano measurement instruments for ultra-precision machining. Optical sensors for measurement of angle and displacement are first described. Technologies for improvement of the sensor sensitivity and bandwidth, reduction of the sensor size as well as development of new multi-axis sensing methods are presented. The second half of the paper presents a number of scanning-type instruments for surface profile measurement. Technologies for reduction of scanning errors, automatic alignment of measuring positions, fast scanning mechanisms are addressed.

1 Optical sensors for multi-axis motion measurement

Figure 1 shows a two-degree-of-freedom (two-DOF) linear encoder which can measure the position along the moving axis (X-axis) and the straightness along the axis vertical to the moving axis (Z-axis) of a precision linear stage simultaneously [1]. It is composed of a reflective-type scale grating and an optical sensor head. A

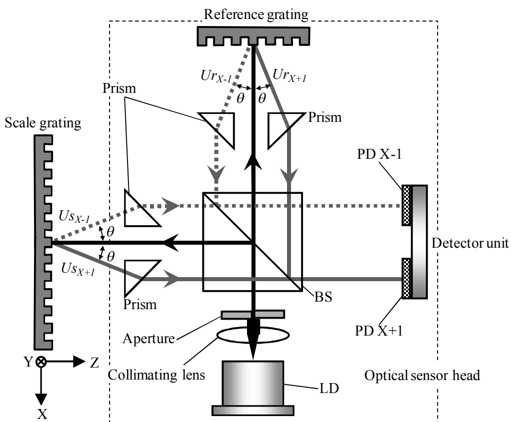

Figure 1: A two-degree-of-freedom (two-DOF) linear encoder

reference grating, which is identical to the scale grating except the scale length, is employed in the optical sensor head. Positive and negative first-order diffracted beams from the two gratings are superposed with each other in the optical sensor head to generate interference signals. The prototype two-DOF linear encoder has sub-nanometer resolutions in both the X- and Z-axes. The concept has also been extended to measurement of three-axis displacement [2]

Figure 2 shows the schematic of a three-axis angle sensor for angular error motion measurement of a linear stage [3]. The sensor consists of a laser diode as the light source, and quadrant photodiodes (QPDs) as the optical position-sensing device. Differing from a conventional 2-axis autocollimator, the sensor uses a diffractive grating as the target mirror. It is confirmed that the resolution of θx is about 0.2 arc-seconds, and those of θy and θz are about 0.02 arc-seconds.

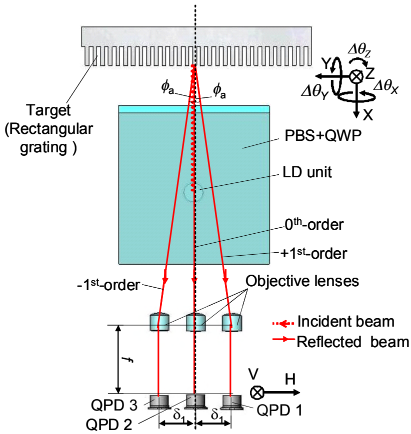

Figure 2: A three-axis angle sensor

2 Scanning-type measurement instruments of surface profile measurement

Figure 3 shows a scanning measurement system aspheric microlenses and microlens moulds [4]. A contact-stylus sensor, which is mounted on an air-bearing linear slide, is employed to spirally scan the surface of the aspheric microlens mounted on an air-bearing spindle. To remove the influence of the scanning error motions of the spindle and the slide, a ring artifact is attached around the lens and two capacitance-type displacement sensors are set on the two sides of the contact-stylus sensor to scan the surface of the ring artifact.. The micro-stylus is composed of a glass shaft and a glass micro-ball. A PZT actuator is integrated into the glass tube micro-ball stylus to construct a tapping mode micro-ball stylus.

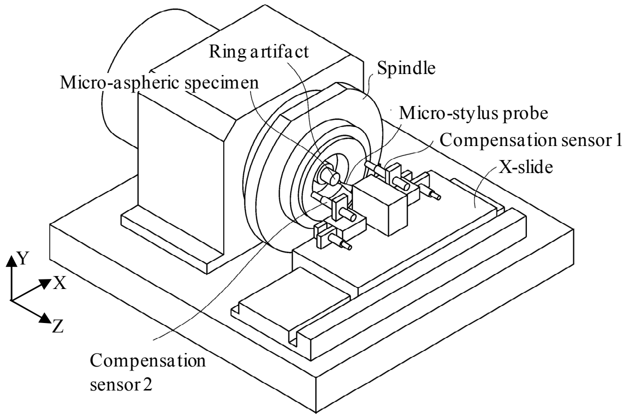

Figure 3: A scanning micro-stylus instrument for micro-aspherics

Figure 4 shows an atomic force microscope (AFM) based instrument for nanometer edge profile measurement of diamond cutting tools [5]. The instrument is combined with an AFM unit and an optical sensor for alignment of the AFM probe tip with the top of the diamond cutting tool edge in the submicrometer range. The tool edge top is first brought to the center of the beam waist in the XZ-plane through monitoring the variation of the photodiode output. The tool edge is pulled back after recording the position of the tool edge top at the beam center. Then, the AFM tip is similarly positioned to the beam center to aligned with the tool top.

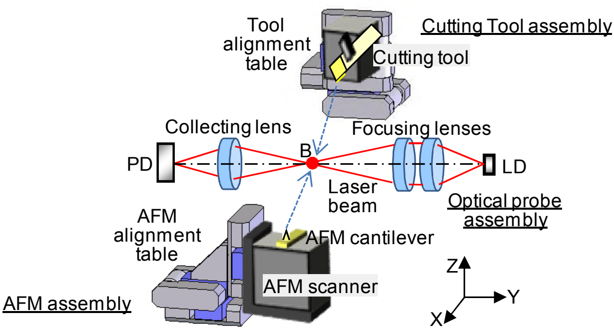

Figure 4: An automatic alignment AFM for cutting edge measurement

Figure 5 presents spiral scanning-type AFM for large area mico-textured surfaces. The instrument consists of a compact and precision AFM probe-unit, a linear stage and a spindle [6]. The sample is mounted on the spindle and the AFM probe-unit is mounted on the linear stage. In this measurement system, the specimen is measured rapidly in a spiral scanning pattern, which is made by rotating the spindle and moving the linear stage in radial direction.

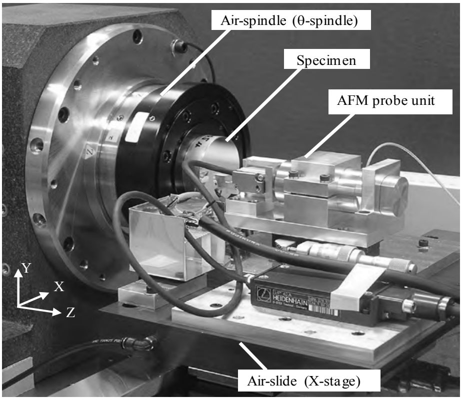

Figure 5: A spiral scanning-type AFM for large area measurement

3 Summary

A number of micro and nano measurement instruments developed in the Research Center for Precision Nanosystems, Tohoku University for surface profiles and motion errors have been presented. Efforts have been made in various aspects of measuring technolgies such as sensors, alignment of measurement positions, scanning mechanisms, data processing, and error separation.

References:

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