MICROPROBE METROLOGY STUDY: LATEST RESULTS
Raymond H. Yang¹, Stuart T. Smith¹, Borja de la Maza²
¹Center for Precision Metrology
University of North Carolina at Charlotte
Charlotte, NC, USA
²Asociacion Innovalia, Spain

OVERVIEW
This abstract presents continuing work on an evaluation study of recently developed microprobe systems integrated into an ultra-precision, eight-axis motion control stage. As of writing, mechanical mounts and hardware interfacing for four different probes is complete. As a first step in this study, measured contact point deviations in one direction are used as a measure of repeatability. A gage block artifact has been produced and multiple measurements of surface separation are used to determine deviations of dimensional measurement for the simplest possible case. The next step is to extend this to dimensional measurement of the artifact geometry with probes used in 1D mode. A scan algorithm has been developed and first results will be shown. Probes to be studied include: 1D UNCC, Triskellion IBS, PTB ACP and Instituc MicroTouch.

STAGE SYSTEM
A dynamic ultra-precision positioning machine for nanoscale engineering has been developed. The complete system comprises of two orthogonal long range translation stage carrying a 6 DOF short range stage. Each of the long range stage can traverse 50 mm while the short range stage can provide up to 17 micrometers of linear positioning and 160 x 10⁻⁶ radians of angular motion [1]. The main operation of the short range stage is to compensate errors generated by the long range stage during traverses. FIGURE 1 shows the positioning stage and a blow-up view of the one dimensional probe. Currently, positioning of the $x$- and $y$-axis along with angular motion about the $z$-axis is monitored by laser interferometers, while positioning of the $z$-axis and angular motion of $x$- and $y$-axis are monitored by 3 capacitance gages. FIGURE 2 shows the back view of the stage system with the two different measurement systems. The probe system is mounted on the metrology frame and drops vertically down to the working platform. Note that in this configuration, the work piece is moving and the probe is stationary. A full eight axis control of the measuring machine was achieved by combining previous work on controlling a single axis system with recent studies on

FIGURE 1: Stage system comprising of a 2 DOF long range stage carrying a 6 DOF short range flexure-based actuator stage and 1D probe system.Inset shows probe in-situ.

FIGURE 2: Current feedbacks include 3 laser positioning signals and a nest of 3 capacitance gages measuring in the vertical plane.
cascaded controller strategies [2]. As a measure of full 8-axis capability, a 'hold' demand over an extended period was monitored. FIGURE 3 shows a time period of 20 seconds where the controller was switched 'off' after 6 seconds.

**1D PROBE**

As a first step to integrate a probe system with the ultra-precision positioning stage, a 1D capacitance base probe has been developed and has been used to measure a common reference artifact. FIGURE 4 shows a solid model and a photograph of the 1D cap probe. This comprises a cantilever beam that is etched ¾ along its length. Two glass plates with patterned electrodes are clamped either side of this beam so that the ¾ etched length can move freely in the gaps determined by etching depth. The two electrodes on the glass plates form a differential capacitor with the beam as the moving electrode. A sphere attached to the free end of the beam forms the contact probe tip.

The reference artifact used for these measurements is constructed from three steel commercial gage blocks wrung together with the central block offset as shown in FIGURE 5.

A first test measurement of the 1D probe was carried out to determined system measurement repeatability. This test was performed by touching the probe to the inner surface of the two outer gage blocks in the gap created by the offset block. In FIGURE 6, a sinusoidal translation of the artifact is applied so that the probe cyclically comes in contact with gage blocks 1 and 3. The red oval in FIGURE 6 highlights data at one of the contact regions. A closer analysis reveals what is happening as the probe comes in contact with the gage block surface. FIGURE 7 shows a close up view of what is happening in the contact region. For this system, the probe is stationary and the artifact is moving. A number of regions can be identify in this plot, these are; a) Artifact approaching probe, b) Artifact contacts with probe, c) Artifact continues moving in probe direction, probe is being deflected, d) Artifact stops moving, probe has reach maximum deflection point, e) Artifact
moving in opposite direction (retracting), but still in contact f) Position where surface first contacts probe, surface adhesion forces keep the probe in contact, g) Adhesion forces keep probe in contact, deflecting probe in opposite direction, h) Adhesion forces at its maximum, i) Adhesion forces broken, probe returns to null position, j) Artifact continues moving away from probe.

A major issue at this time is defining a contact point based on a continuous stream of data during contact. From FIGURE 7, during the approach of the probe towards the specimen, there are two clear sets of data; one region being the horizontal data set from a to b (probe prior to contact), the second region being b to c (probe in contact). It seems reasonable as one definition of contact to use the point of intersection between two straight line fits of the data in these two regions. Other definition of probe contact point can be considered. FIGURE 8 shows the deviation of these contact measurements for contacts on one of the surfaces. FIGURE 9 shows the deviation of measurements of successive separations between the two inside gage block surfaces from which a standard deviation of 24 nm was found.

TRISKELION PROBE
A second probe that is under evaluation is the Triskelion Probe produced by the combined efforts of IBS Precision Engineering and Lion Precision. FIGURE 10 shows a picture of the Triskelion probe mounted into the measuring machine. This probe has a ruby spherical probe tip of diameter 500 micrometers attached to a tungsten carbide shank of length 8.5 mm. It should be noted that, in contrast to the previous probe, this is a 3D isotropic probe. While the mounting and hardware interfacing has been completed. Repeatability studies and full artifact scan algorithms have been implemented for this and the 1D probe mention in the previous.
section. This study is still ongoing, as an example of the data set corresponding to a full scan of the artifact. FIGURE 11 shows a measured data set obtained from x and y laser interferometer displacement of the stage and the correspond output of one of the capacitance sensors of the Triskelion probe.

CONCLUSIONS
A full 8 axis control of the displacement platform has been demonstrated. Mechanical mounting and hardware interfacing for different probes to be used as part of a probe performance evaluation study is complete. Early measurements using our in-house developed 1D probe have shown repeatability values both of around 20 nanometers for repeated contacts at the same point on a surface as well as measurement deviations of dimension between two surfaces on a gage block artifact. These deviations have many contributing factors and it is not easy to separate individual effects at this level. Significant sources of error are considered to be thermal variations that disturb components of the measurement loop, ambient variations effecting interferometer measurement and contact interactions, ground borne and airborne vibrations, particulate and environmental surface contamination, algorithms for the extraction of contact point location from complex contact interaction signals and contact interaction force variations both from point to point as well as at the same location over time. Efforts to reduce these effects through compensation, reduction and environmental control are ongoing.

In addition to implementation of the machine controls, we have implemented an algorithm to scan multiple points around the artifact obtained measurements using the 1D and Triskelion probe. Currently, we are post processing data and developing algorithms to extract contact point data from signals provided by these different probes.

ACKNOWLEDGEMENTS
The authors would like to thank the center for precision metrology, CPM affiliates for funding the study and IBS precision engineering for loaning the probe and equipments.

REFERENCES

FIGURE 11: Raw data cloud of laser reading of X, Y and probe1 data during three complete cycles around the artifact. The positive and negative probe output represents different contact direction.