Performance verification of a dual sensor stage

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Abstract
The current trend for nanopositioning with increased speed has led to the development by Queensgate of a dual sensor system for servo control of single axis displacement stages. The stage and control system is currently being evaluated using optical interferometry developed at the National Physical Laboratory. Preliminary results show the performance of the optical interferometer and the stage.

1 introduction/Stage development
Queensgate Instruments and NPL have joined forces to develop and characterise the next generation of displacement stages. A Queensgate NPS X-15A single axis displacement piezo driven flexure stage \cite{1} has been fitted with a second sensor in addition to the usual capacitance sensor feedback. This offers the advantages of a 60\% reduction in settling time and a 50\% reduction of the load dependency of the stage which in turn increases the versatility of the stage.

2 Interferometer development
In order to meet the metrology requirements for stage characterization, the NPL plane mirror differential optical interferometer \cite{2} has been upgraded with new fringe counting electronics and is being re-characterized against the x-ray interferometer \cite{3}. This homodyne optical interferometer which uses thin metallic coatings to achieve quadrature phase separation \cite{4} between the two output signals is now fibre fed. A new versatile fringe counting system based on a National Instruments Platform has been developed. Signal collection from the interferometer is achieved using 1.0 MHz 16 bit analogue to digital converters fitted to a National Instruments Single Board Real Time Input/Output (NIsbRIO) card with an integrated field programmable Gate
array (FPGA) and microprocessor running LabVIEW real-time software. A block diagram of the complete system is shown in figure 1.

Figure 1: Block diagram of fringe counting system

Figure 2 shows the tasks performed by the software that now include a real time fringe Heydemann correction [5] to compensate for interferometer non-linearity.

Figure 2: Block diagram showing tasks performed by the software

The x-ray interferometer is an ideal tool for characterising optical interferometers [3] and can be regarded as a ruler or translation stage whose length scale is based on the lattice spacing of silicon. Figure 3 shows the stability of the upgraded optical interferometer when referenced against an x-ray interferometer. Over sixteen hours the drift was ~ 150 pm.

Figure 3: Drift in the optical interferometer
A power spectrum of the interferometer noise is shown in figure (4); it shows noise to be at the $1 \times 10^{-6}$ (nm$_{\text{RMS}}$)$^2$ level.

![Power spectrum of interferometer noise](image)

Figure 4: Power spectrum of interferometer noise

The non-linearity of the modified interferometer is currently being assessed, but previous measurements of the original interferometer show it is of the order of ±20 pm. We expect a significant improvement due to the improved coatings, new electronics and better input optics, all of which make the interferometer suitable for stage characterization.

3 Stage verification

Figure 5 shows the position noise of the stage measured using the optical interferometer at a sampling rate of 10 kHz; the RMS noise is 0.14 nm.

![Noise measurement of stage](image)

Figure 5: Noise measurement of stage
Figure 6 shows the response of the stage to a 100 nm step captured by the interferometer. The blue (solid line) shows the interferometer signal and the red (dotted) shows the response of the second sensor (Pos Mon) in the stage. The response time of the stage to reach a steady state with second sensor is ~4.85 ms compared to ~14 ms without.

Figure 5a and 5b: Step response of stage with second sensor and without second sensor measured using optical interferometry

Future work will complete the characterization of the stage and interferometer.

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References: