Design and Control of a High-Speed Nano-positioning Stage for the Transverse Dynamic Force Microscope

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Introduction

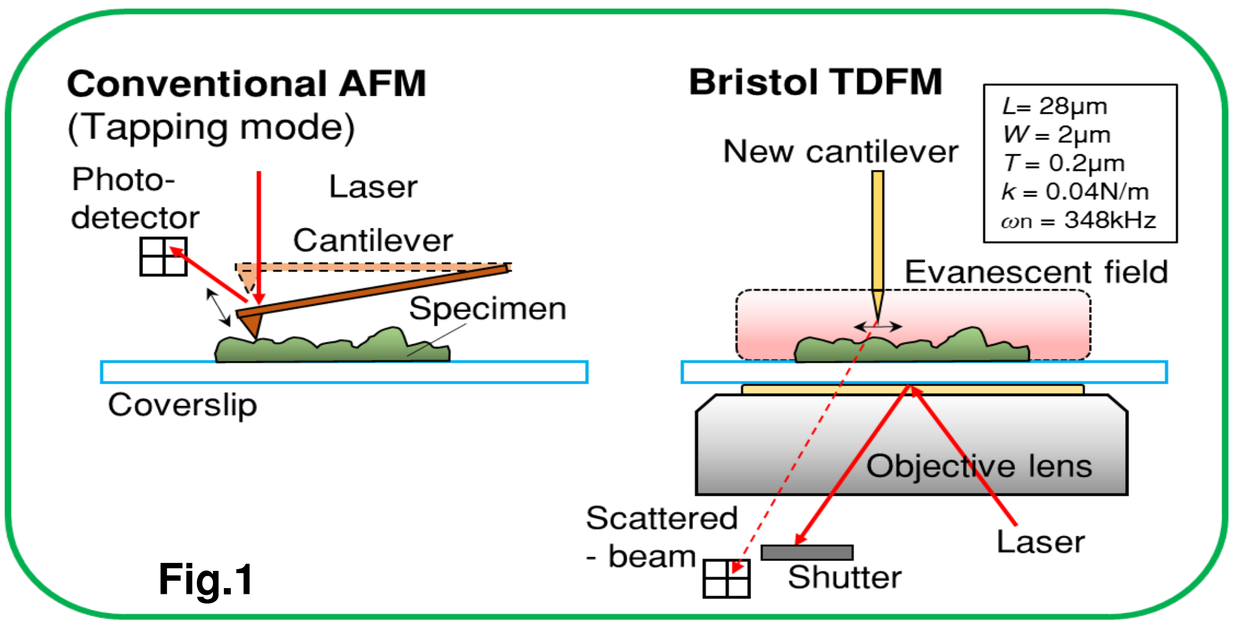


Fig.1

The high-speed transverse dynamic force microscope (HS-TDFM) is a novel non-contact scanning probe microscope with high precision X-Y-Z positioning in the order of nanometres. This microscope can generate 3D topographical models of nano-scale specimens such as DNA polymerases using a vertically oriented cantilever and an evanescent field based detection mechanism (Fig.1). The scanned information is used to investigate biological interactions and the dynamic behaviour of single molecules under physiological conditions. The main part of the HS-TDFM consists of two components: a cantilever scanning a specimen along the Z-axis and a high-speed stage positioning the specimen along the X- and Y-axes.

Aims of this work

- Improve the performance and functionality of the existing TDFM.
- Design a high-speed XY nano-positioning stage (HS-NPS) to enhance the bandwidth (speed) and minimise unwanted out-of-plane (Z-axis) vibrations.
- Develop and implement a robust closed-loop controller for the new stage.

Overview of HS-TDFM

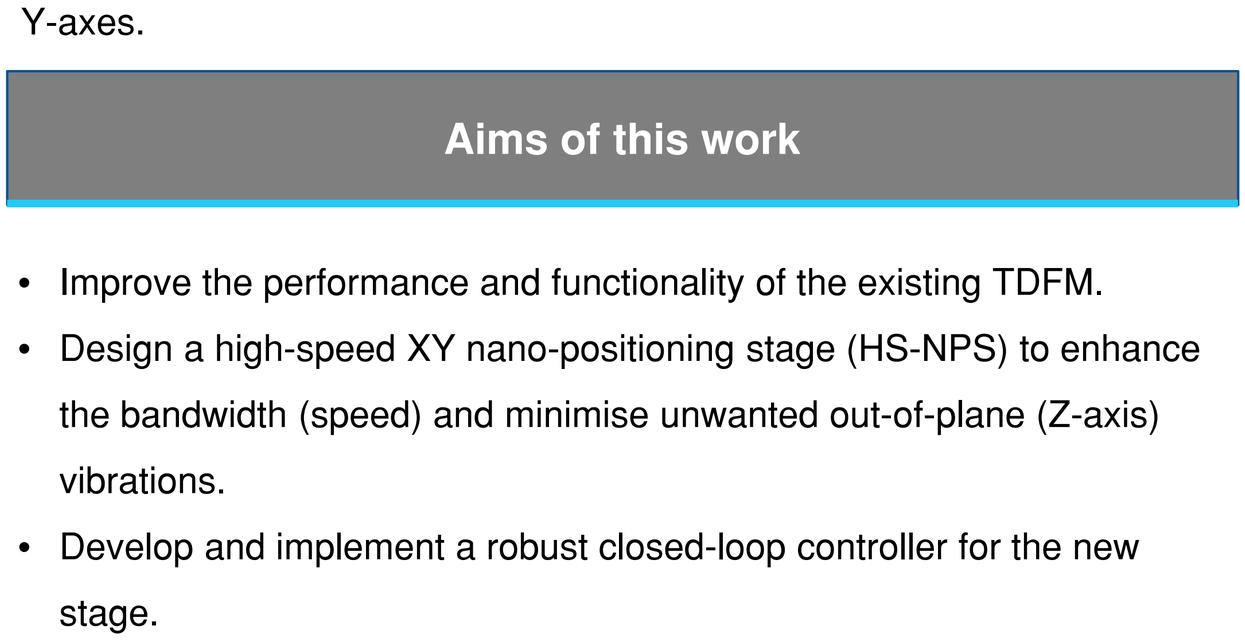
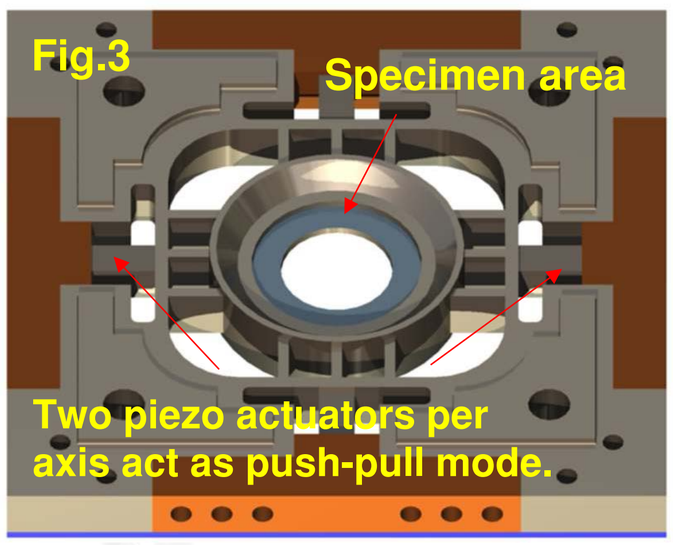
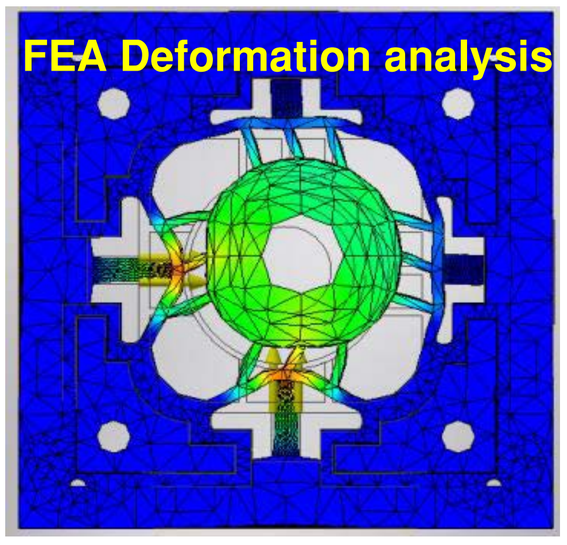


Fig.2

Development of a High-speed Nano-positioning stage





A new HS-NPS was designed and analysed to reduce the vertical vibrations and obtain the first mode of resonance frequency at 7.3kHz using a CAD model and finite element analysis (FEA). This resulted in an increase of the controllable bandwidth of the stage, i.e. speeding up the scan process and the accuracy.

HS-NPS Control Results

The HS-NPS was manufactured and controlled by a $H\infty$ controller. The displacements of X and Y axes were measured by laser interferometers. All controllers and filters were implemented on a FPGA board. Fig.4 shows the results without/with $H\infty$ control. The demand signal tracking performance was significantly improved by the $H\infty$ control.

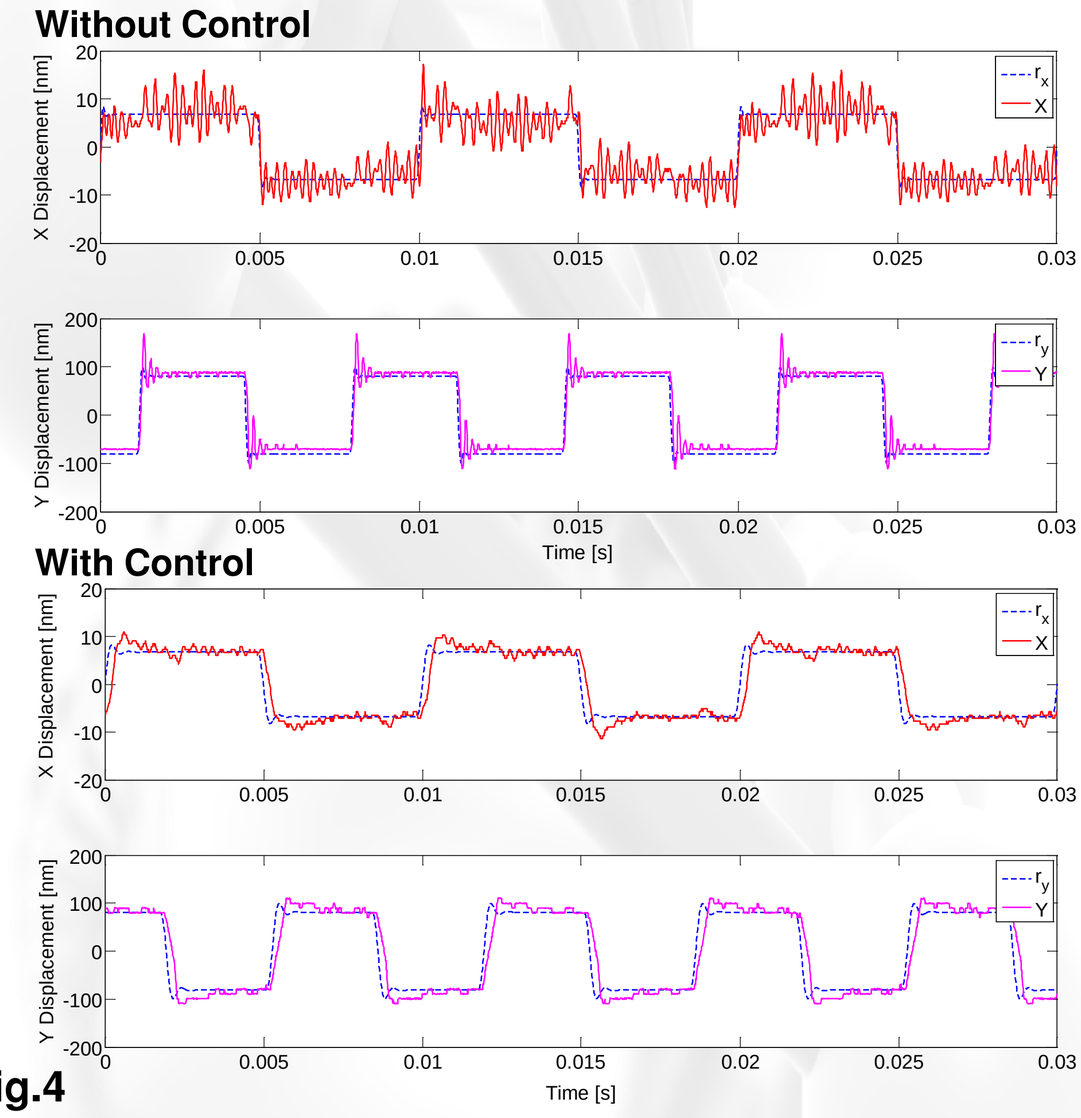


Fig.4

Acknowledgements

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