Advanced Design, Analysis and Control of the Transverse Dynamic Force Microscope (TDFM) in the Bristol Centre for Nanoscience and Quantum Information (NSQI)

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Introduction

Transverse dynamic force microscopy (TDFM) is a cutting edge form of atomic force microscope that can scan nano-scale specimens such as DNA in a non-contact manner to generate 3D models. However improvement in the robustness of the current design is required. Advance control is required to improve the scan time and accuracy.

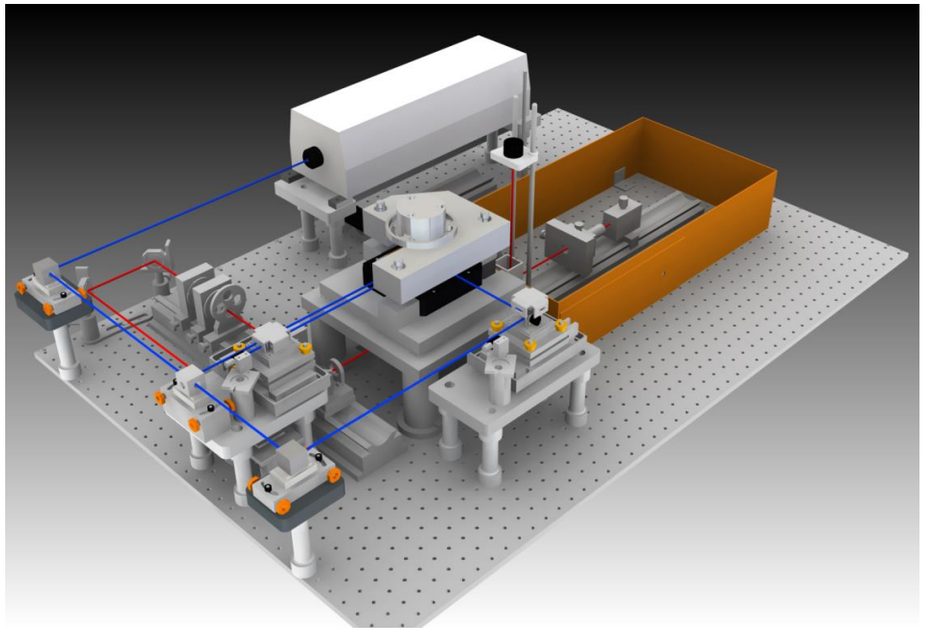

Figure 1: TDFM set up

As a result, the aim of this project is to improve the usability, functionality and performace of the TDFM to enable fast and accurate scans. Two aspects are looked into in this project: **Design and Control.**

Design

Investigation into the implementation of the High Speed Nano-Position Stage (HS-NPS) laser path resulted a new layout plan and various new components. An extensive CAD model and calibration guide have also been documented to improve the understanding of the TDFM and the alignment calibration procedure for the cantilever and laser path.

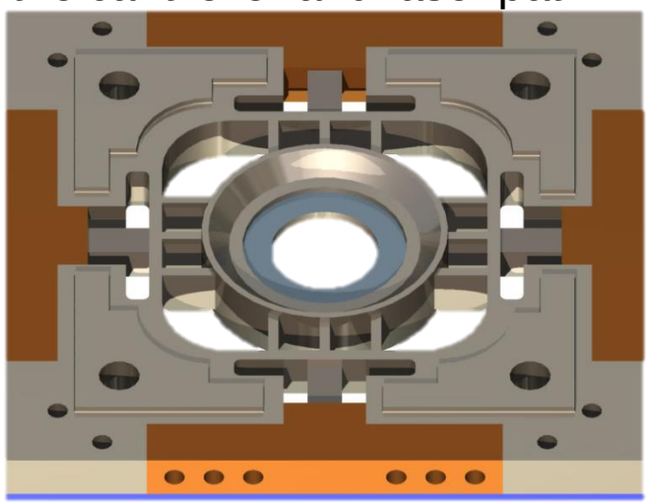

Figure 2: HS-NPS

A new HS-NPS has also been designed in order to minimize the out of plane vibrations, increase measurement accuracy related to undesired stage deformations using Finite Element Analysis.

Control

System identification was carried out to model the HS-NPS. MIMO controller has then been designed with the use of H_∞ control design methodology, aiming to control and actuate the HS-NPS up to bandwidth as high as 1 kHz.

Controllers for the vertical cantilever were successfully constructed using H_∞ and simulated both independently as a dual-stage actuation system with the small piezo as the lead actuator.

For controller implementation, investigations were done to identify the most ideal digital filter that has the least quantization error. A bit shift constant optimization algorithm was developed using particle filter to aid the testing and analysis. It was found the second order section form with integer data type produce the most accurate result.