Design of a sample holder for a metrological atomic force microscope

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Abstract

This paper describes the design of a sample holder for a metrological atomic force microscope. Most attention goes to the measures taken to improve its mechanical and thermal stability. Dynamic simulations show a high natural frequency of the sample holder, which reduces the influence of floor vibrations on the measurement. A sample placement mechanism gives the user the possibility to easily reach and place the sample.

1 Introduction

In a metrological AFM, interferometers perform a three dimensional measurement of the relative positions of probe and sample [1]. These machines provide the link in the traceability chain between non-metrological AFMs and the length standard. Therefore, they can be used to improve the accuracy of non-metrological AFMs.

Figure 1 shows a two dimensional view of the metrological AFMs principle. The system consists of three orthogonally placed interferometers, a positioning stage and an AFM probe with deflection sensor. The positioning stage moves the sample holder in a scanning motion, while the probe tip remains fixed in space. At the same time, the interferometers accurately measure the displacement of the sample with respect to the AFM probe. The right hand side of the figure shows the design of the machine frames, as presented in a previous paper [2].

The scanning sample principle of the metrological AFM imposes a number of important restrictions on the sample holder design. One of these restrictions is due to the limited statical stiffness of the positioning stage. In order to reduce the dynamical compliance of the stage, the mass of the sample holder should be limited. At the same time, the stiffness of the sample holder itself should be sufficiently high.

Besides the mechanical requirements, it is also necessary to take the thermal aspects into account. The following paragraphs explain the sample holder design in more detail.

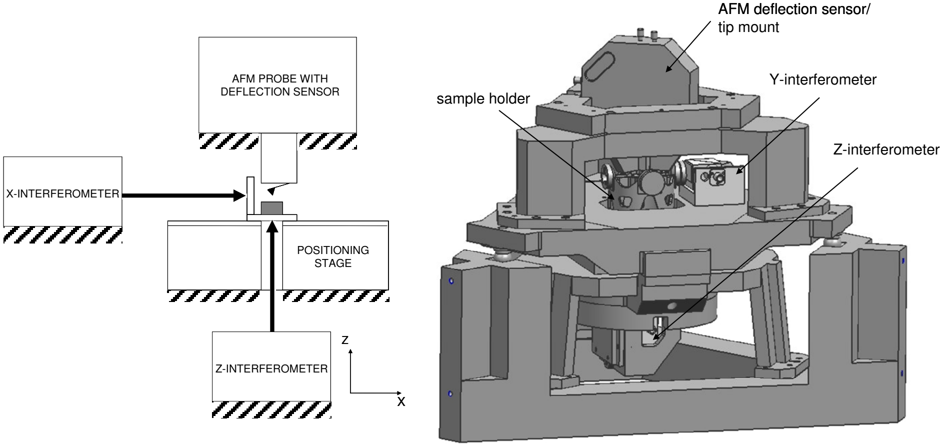

Figure 1: Metrological AFM principle and design (X-interferometer not shown)

2 Sample holder

2.1 Design

Figure 2 shows a one dimensional scheme of the sample holder. The design consists of an Invar mirror support and an Invar coarse positioning table. The mirror support holds the target mirrors of the laser interferometer. The coarse positioning table allows for planar motion of the sample with a stroke of 4 mm x 4 mm. In a first approach, the actuation can be done manually. After coarse positioning, an electromagnetic locking system fixes the coarse positioning table to the mirror support. To allow for thermal expansion, the complete structure is kinematically mounted on the

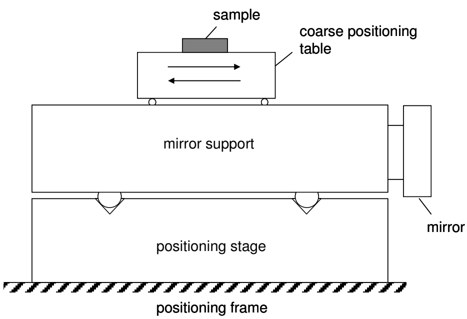

Figure 2: Scheme of the sample holder

aluminium positioning stage. A major advantage of the proposed configuration is that coarse positioning has no influence on the alignment of the target mirrors.

Figure 3 shows the design of a sample holder with low weight and high stiffness. The total mass is limited to 0.65 kg. The figure also shows the impulse response of the positioning stage, when loaded with this mass. For this experiment, an accelerometer was mounted on the applied load. The results indicate a natural frequency in the range of 170 Hz to 220 Hz. Since measured floor vibrations are under 20 Hz, the dynamic stiffness of the positioning stage is sufficiently high.

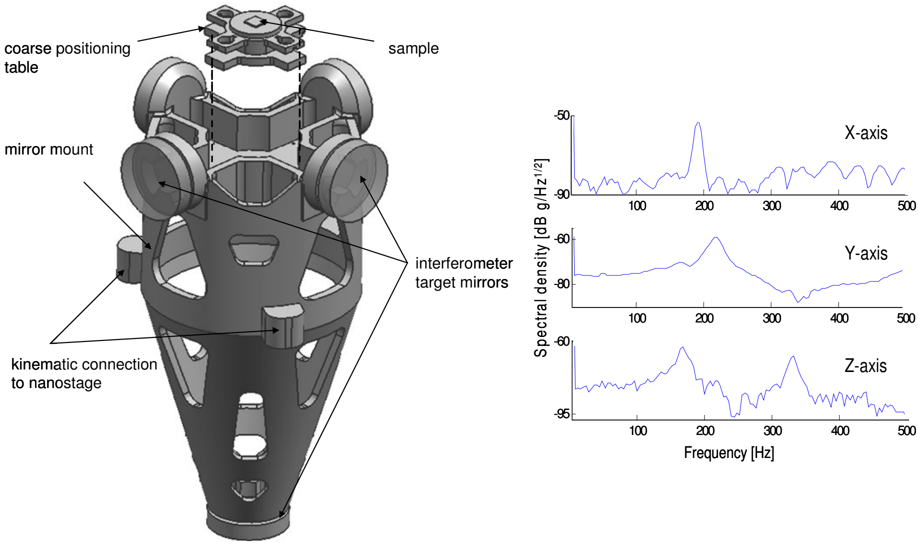

Figure 3: Design of the sample holder (left). Stage impulse response (right).

2.2 Simulation

Figure 4 shows the displacement field of the first eigenmode. In this simulation, the kinematic connection to the positioning stage determines the boundary conditions. The natural frequency is 1750 Hz, making it sufficiently stiff for use in the metrological AFM. In a next step, the kinematic mount itself should be taken into account.

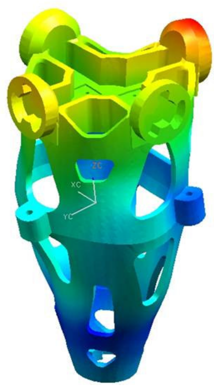

Figure 4: First eigenmode at 1750 Hz

3 Sample placement

Due to the compact design of the whole system, it is difficult for the user to reach the sample. The user, however, can easily replace the AFM probe holder/deflection sensor with a retracting mechanism (figure 5). The four keys of this mechanism allow retraction of the coarse positioning table. One important advantage of this method is that the interferometer target mirrors are not removed from their original position.

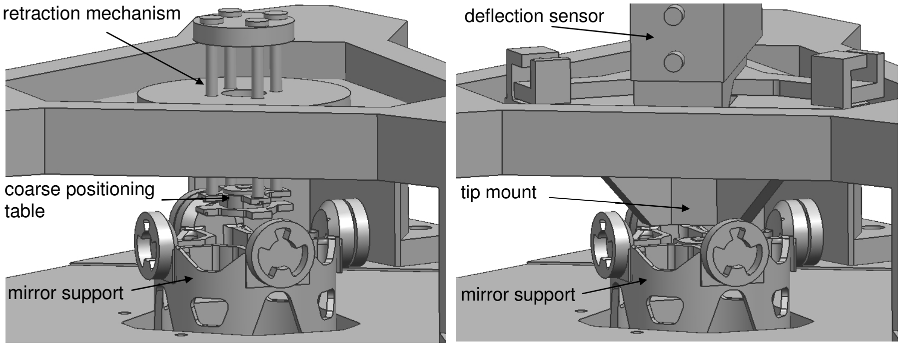

Figure 5: Sample placement mode (left) and sample scanning mode (right).

4 Conclusion

This paper described the design of the sample holder for a metrological AFM. The low mass results in a natural frequency for the positioning stage in the range of 170 Hz to 220 Hz. The structure of the sample holder itself has a first eigenmode at 1750 Hz. The high natural frequencies are necessary to achieve high mechanical stability. Finally, a mechanism for easy sample placement was proposed.

5 Acknowledgement

This research is funded by a Ph.D. grant of the Institute for the Promotion of Innovation through Science and Technology in Flanders. Commercial components were provided by FPS Economy – SMD Metrology, Belgium.

References:

[1] H.-U. Danzebrink et al., Advances in Scanning Force Microscopy for Dimensional Metrology, Annals of the CIRP, 55(2), 2006
[2] J. Piot et al., Design of a thermally and mechanically stable metrological atomic force microscope at KULeuven, Proc. Euspen conference, San Sebastian, 2009