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Development of a metrological atomic force microscope system with improved signal quality

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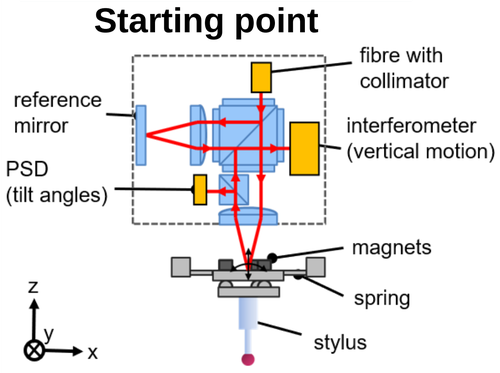
Motivation

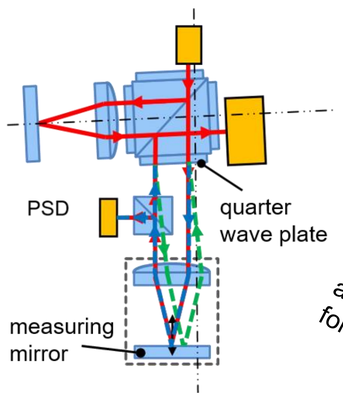
A new metrological atomic force microscope (MAFM) with a homodyne interferometer and a tilt measuring system by a position sensitive device (PSD) has been developed. The combination allows the simultaneous three-dimensional detection of the position, bending and torsion of the cantilever. Based on an existing interferometric detection head of a micro-tactile 3D probe [1], the sensor head was revised and adapted for atomic force microscopy. The new measuring system uses two tiltable plane mirrors and a shiftable focus lens to adjust the direction of the focused laser beam and position of the focus. With this adjustment unit, the focused laser beam can be steered perpendicular to the reflecting backside of the cantilever. Regarding the probe system, the optical design of the measuring head has been reengineered to reduce the disturbing interferences on the PSD and the influence on the bending and torsion signals. The integration of the MAFM head in a nanomeasuring machine (NMM-1) creates the possibility of traceable dimensional measurements over a large range of 25 mm × 25 mm × 5 mm with sub-nanometer resolution.

System design

Starting point



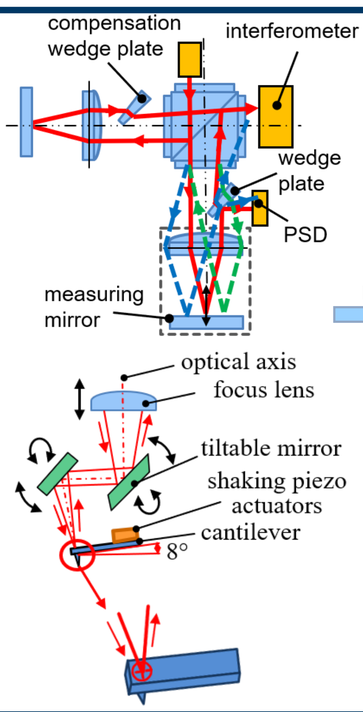
- The original measuring head was used for different probe systems.
- The position and the tilt angles of the reflecting surface were measured simultaneously with one focused beam.



- Disturbing interferences appeared due to multiple reflections on the quarter wave plate.

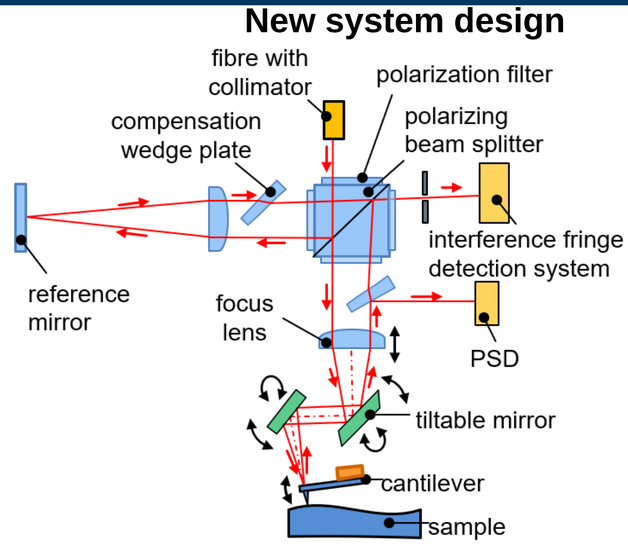
wedge plates
overcome disturbing interferences

tiltable mirrors
adapt beam direction for AFM



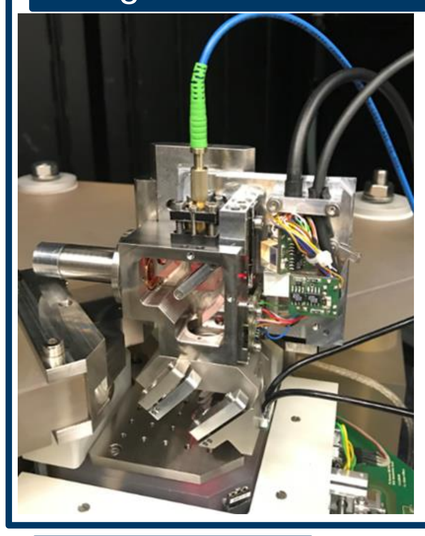
reengineered

New system design



- ✚ Wedge plates with a wedge angle of 0.5° have been integrated to reduce the disturbing interferences.
- ✚ Two tiltable plane mirrors are used to adjust direction of the focused laser beam and position of the focus.

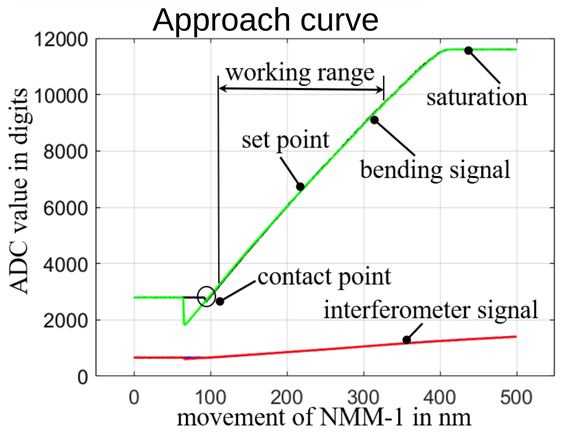
Integration in NMM-1



- The scanning motion is carried out by the NMM-1.
- In contact mode the interferometer signals can be determined by the DSP unit of the NMM-1. Dead path and environmental influences can be corrected directly.
- Ellipse correction can be carried out using the recorded quadrature signals (sin/cos).

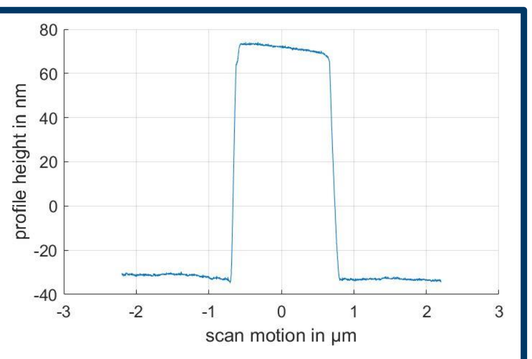
Results

Approach curve



Working range and set point can be determined.

TGZ2 from NT-MDT
(nominal step height: 108 nm ±2 nm)



- Profile height: the difference between the calibrated AFM bending signal and the z-axis position data of the NMM-1.
- Calculated step height (according to DIN EN ISO 5436-1): 107.01 nm with standard deviation of 3.1 nm

Conclusion

- This new metrological atomic force microscope (MAFM) allows simultaneous measurements of position, bending and torsion of the cantilever.
- The use of the wedge plate reduces significantly the disturbing interferences on the PSD and the influence on the bending and torsion signals.
- An angle adjustment range of ±3° and a displacement adjustment range of 250 µm ~ 290 µm (adjust only one mirror while the other one is fixed) are realized.
- The combination of the MAFM head and the NMM-1 allows measurements over a range of 25 mm × 25 mm × 5 mm with sub-nanometer resolution.

References

[1] F. G. Balzer, T. Hausotte, N. Dorozhovets, E. Manske, G. Jäger. Tactile 3D microprobe system with exchangeable styli, Measurement Science and Technology, 094018 (2011); doi:10.1088/0957-0233/22/9/094018
[2] T. Hausotte, F.-G. Balzer, N. Vorbringer-Dorozhovets, E. Manske. Surface and coordinate measurements with nanomeasuring machines. International Journal of Nanomanufacturing, 2012, 467–483

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