Design of an interferometrically traceable AFM at MIKES

Antti Lassila and Virpi Korpelainen

Centre for Metrology and Accreditation, P.O. Box 239, 00181 Helsinki, Finland
antti.lassila@mikes.fi, virpi.korpelainen@mikes.fi

www.mikes.fi

Introduction

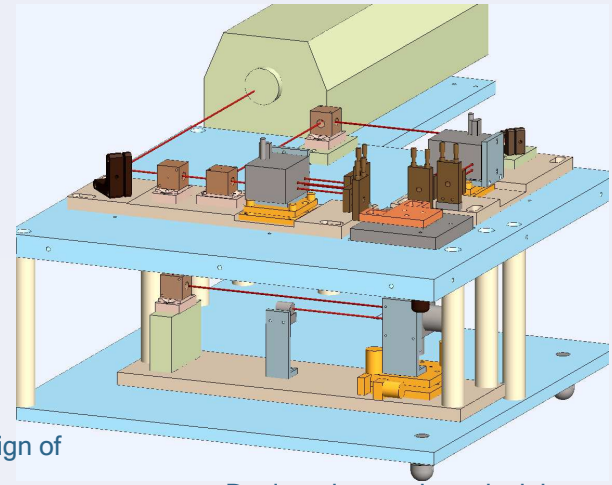
- During last years large investments have been directed to development and research of micromechanical and nanotechnological products
- All quantitative measurements at micro- and nanometre scale
  - in research (accuracy and reliability of results)
  - in production industry (checking critical dimensions against tolerance limits)

should be traceable to the definition of the metre

↗ Guarantees accurate and commensurate results and high quality

- MIKES has started a project to establish a metrological AFM in order to realise traceable length scale in the nanometre region and to offer related calibration and measurement services
  - Target uncertainty level ~1 nm with sub-nanometer resolution

➔ Straightforward source of traceability for Finnish economy and science community



Traceability chain for SPM measurements

Definition of SI-unit metre
↓
Realisation of metre
↓
Laser f calibration
↓
Interferometrically traceable AFM
↓
Calibration of physical transfer standards
- 1-D, 2-D pitch standards
- step height standards

↓
Calibration of SPM
↓
Traceable SPM measurements

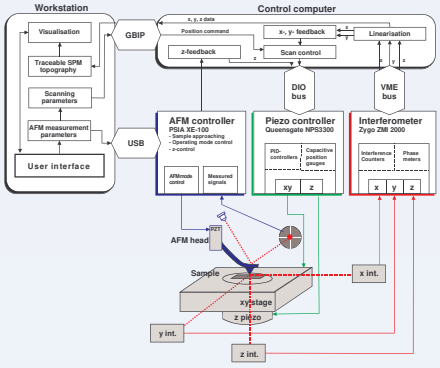
Main principles of the design of the MIKES' AFM

- Elimination of scanner errors
  - Non-linearity, hysteresis and creep of the piezo movements
    ⌦ direct 3-D interferometric measurement of the movements
  - Angular errors and cross-talk
    ⌦ separate xy- and z- flexure-guided piezo actuators
- Design of interferometers
  - Abbé error
    ⌦ measurement axes of interferometers cross at AFM tip location
  - Cosine errors ⌦ adjustment with quadrant detectors
  - Dead path error ⌦ differential optics & software correction
  - Non-linearity of the laser interferometers
    ⌦ developed self-calibration method with online correction
- Minimising of other errors
  - Thermal effects ⌦ Invar and SuperInvar alloys & isolation of heat sources
  - Vibrations ⌦ firm structure & installation on a damped table
  - Acoustic effects ⌦ sealed acoustic enclosure

Designed operation principle

- AFM measurement parameters are set at the user interface:
  - AFM mode (contact, non-contact, tapping...)
  - Scanning parameters
- Control computer regulates the scanning
  - Piezo controller drives the xy-piezos to correct positions
  - Linearised feedback from the xy-interferometers for accurate positioning
- AFM controller
  - Operation mode control
  - Feedback for the z-piezo to keep the tip deflection at the set point
- 3-D interferometric measurement
  - Linearisation of xyz-position data of the heterodyne interferometers by an online non-linearity correction

➔ Traceable SPM topography



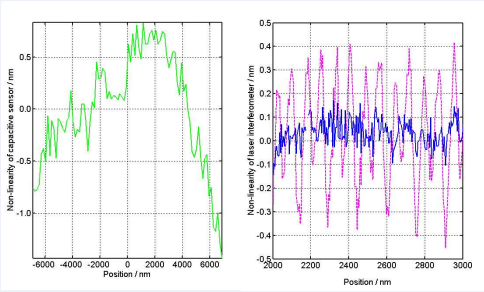
Self-calibration method

- In interferometric measurements at nanometre scale, one of the main uncertainty components is the periodical non-linearity of the laser interferometer
- Different natures of non-linearities the interferometer and capacitive sensors is used to eliminate both non-linearities

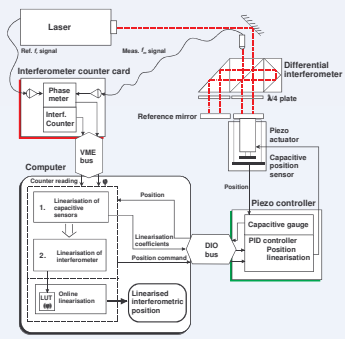
1. Non-linearity of a capacitive sensor is measured by a laser interferometer with step length of one count of the interferometer i.e. λ/4 and corrected
2. Non-linearity of the laser interferometer is measured with sub-periodic stepping using the linearised capasitive sensor as a reference

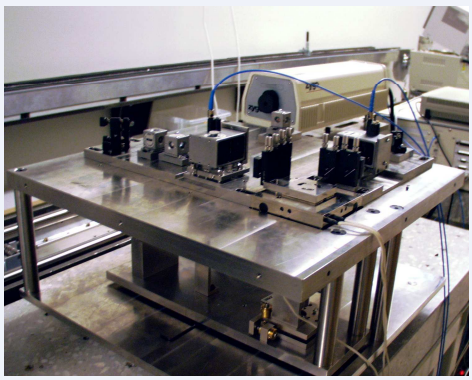
➔ Phase dependent non-linearity correction vector

↗ Non-linearity of a laser interferometer can be corrected online with sub-nanometre accuracy



Non-linearity of the capacitive sensor, measured non-linearity and residual non-linearity - after applied correction - of the interferometer





Current status

- Designed and constructed
  - Interferometer set-up
  - Metrological frame
  - Elimination of errors
- Non-linearity of the interferometers
  - Determined
  - Self-calibration method developed
- AFM head
  - Specified
  - Ordered

➔ This year

- Combine of AFM head with other set-up
- Control electronics
- Software

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