52. IWK
Internationales Wissenschaftliches Kolloquium
International Scientific Colloquium

TECHNISCHE UNIVERSITÄT ILMENAU

Image Processing, Image Analysis and Computer Vision

Measuring large areas by white light interferometry at the nanopositioning and nanomeasuring machine (NPMM)

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September 12th, 2007

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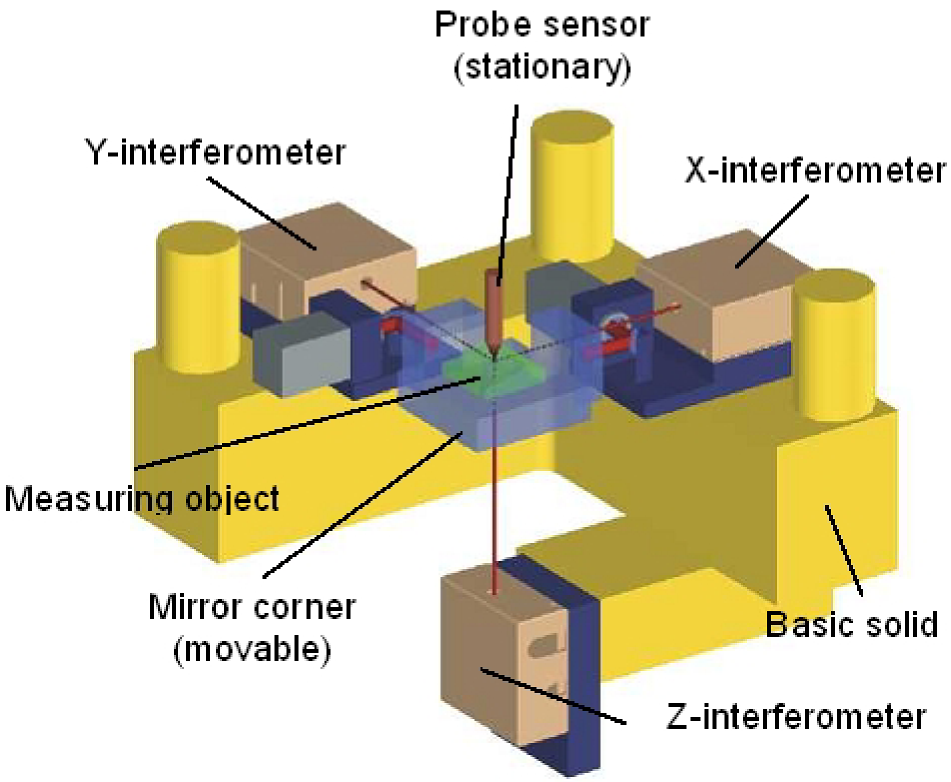
Outline

- Motivation
- Measurement setup
- Principles of scanning white light interferometry
- Interferogram analysis methods
- Measuring large areas
- Determination of sensors orientation and scaling
- Correction of sensors tilt
- Exemplary results
- Software environment
- Conclusion
- Outlook

Motivation



Basic set-up of the NPMM according to the comparator principle of Abbe

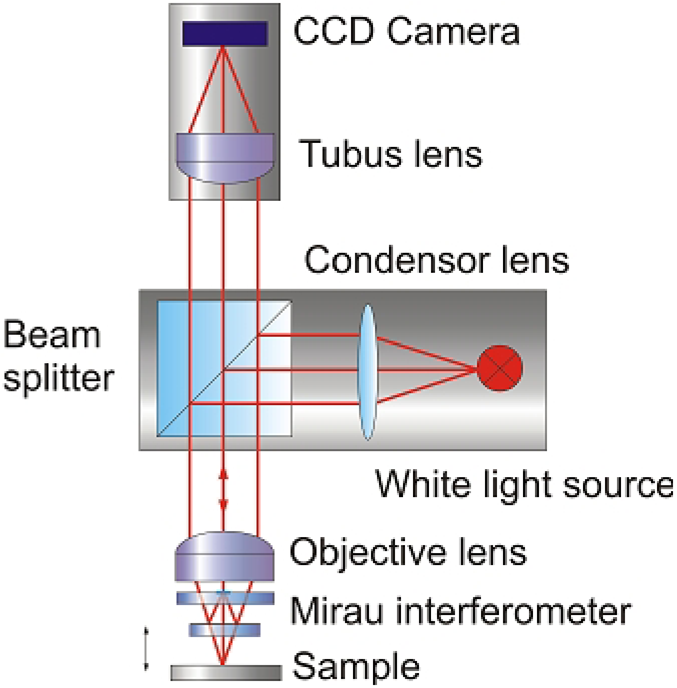
- NPMM features a measuring volume of 25 x 25 x 5 mm³ with a resolution of 0.1 nm

→ Advantages for white light interferometry

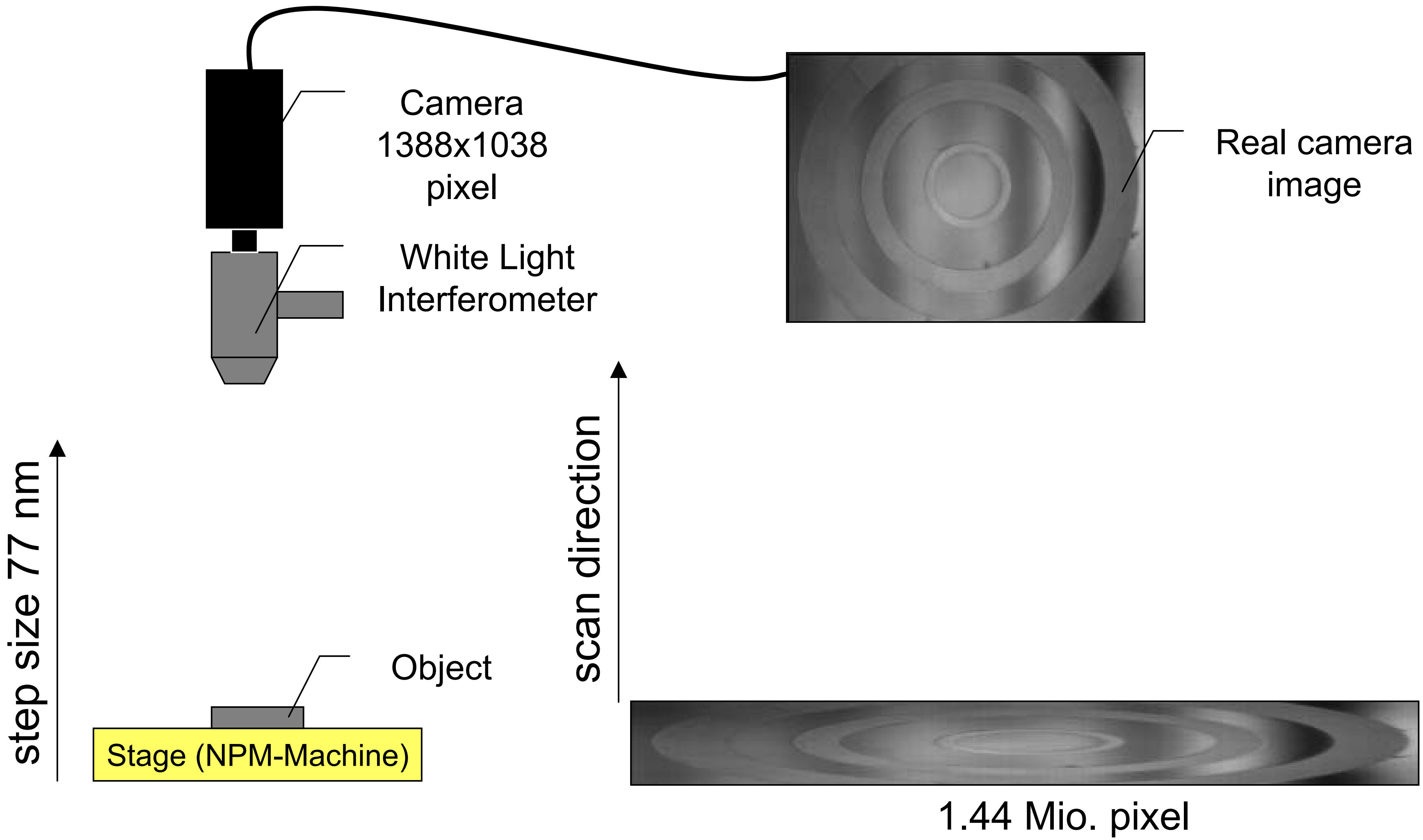
- ✓ Low positioning noise
- ✓ Large perpendicular pass trough range with 5 mm
- ✓ Stitching of adjacent single measuring results to a common large height map

Measurement setup

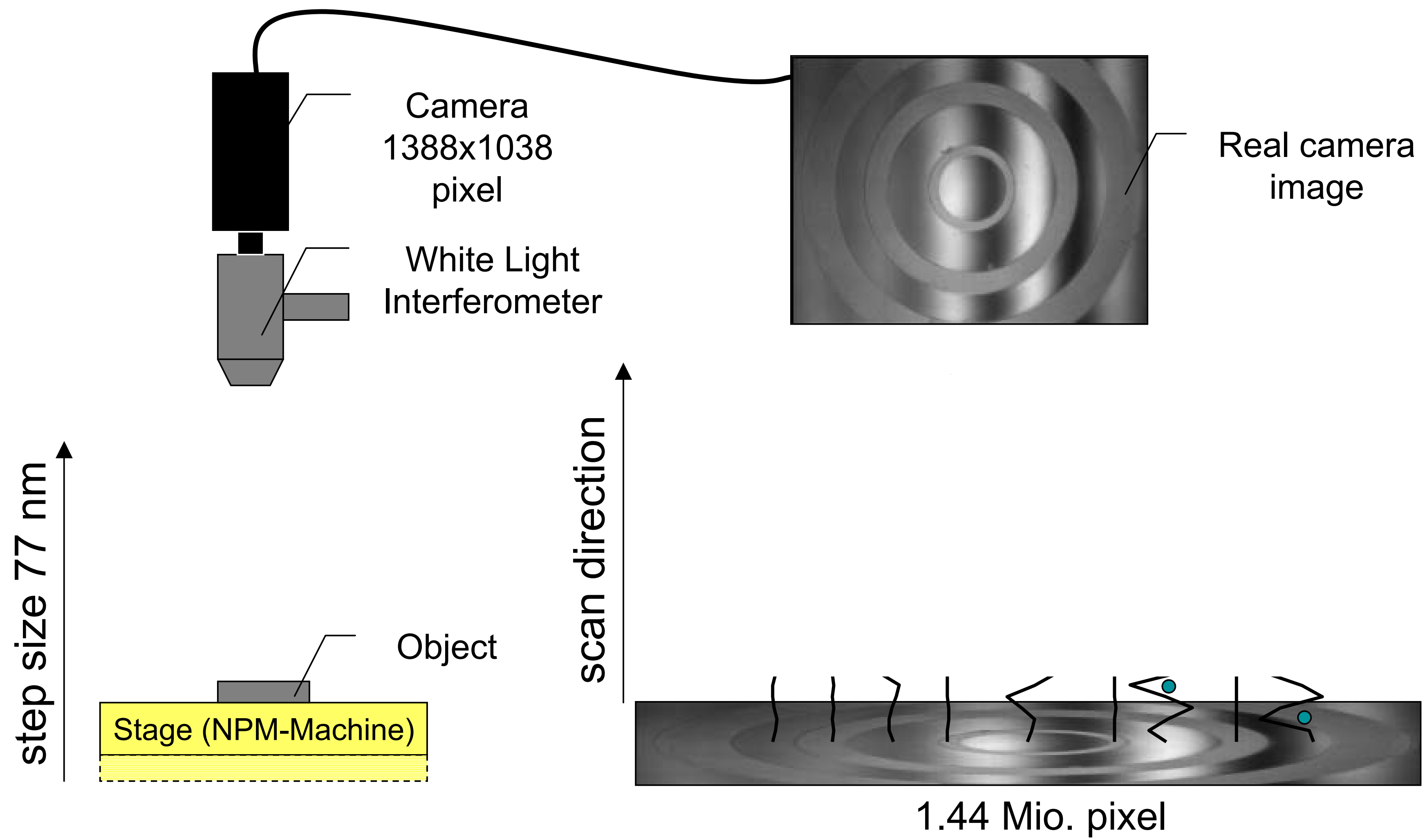
- White light interferometry sensor
  - Tube from a focus sensor coupled with a Mireau-interference objective
  - 14-bit monochromatic CCD camera (FireWire 1394b, up to 30 fps)
  - Halogen light source
- NPMM is placed on an oscillation-damping system
- Acoustic hood



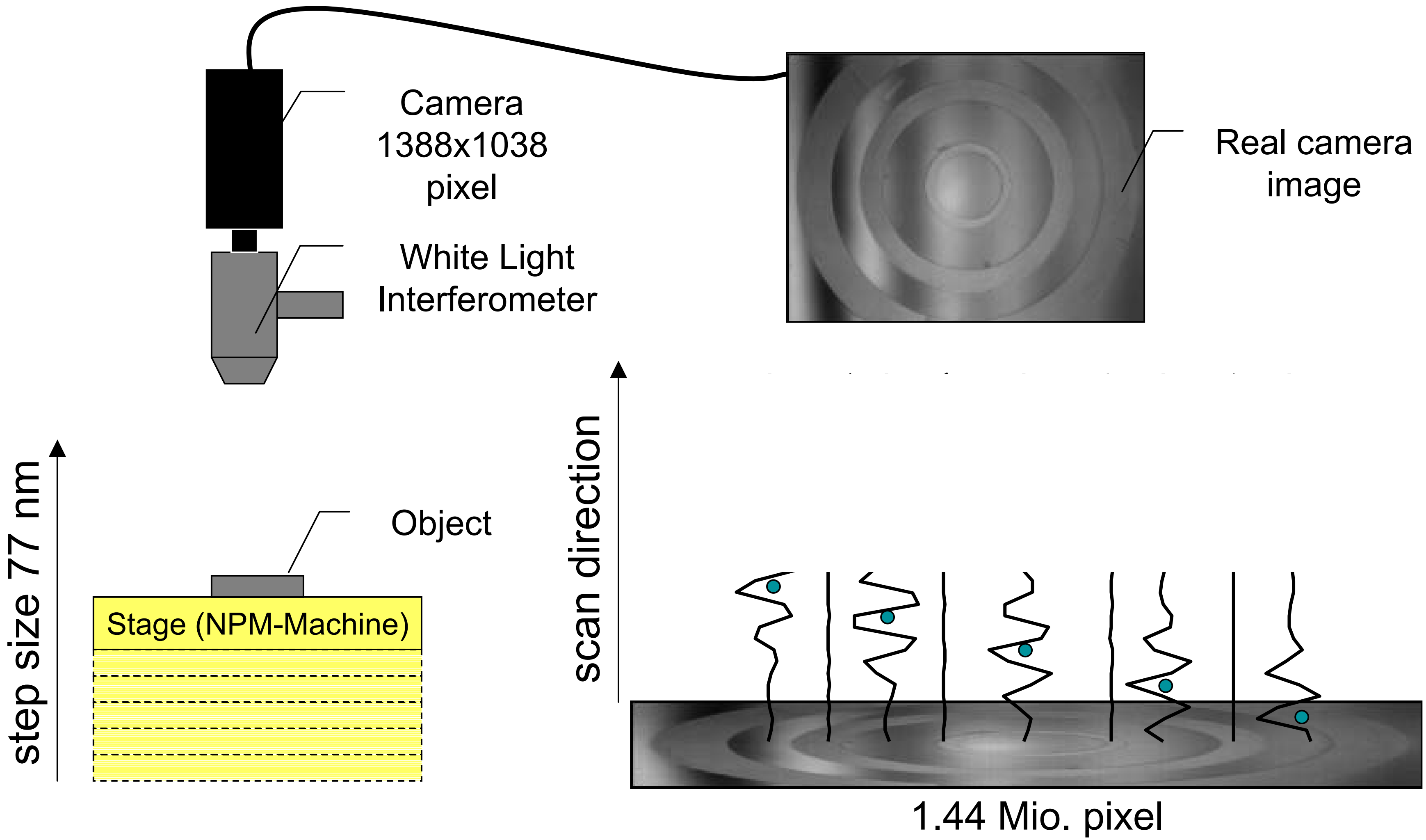
Principles of scanning white light interferometry



Principles of scanning white light interferometry



Principles of scanning white light interferometry



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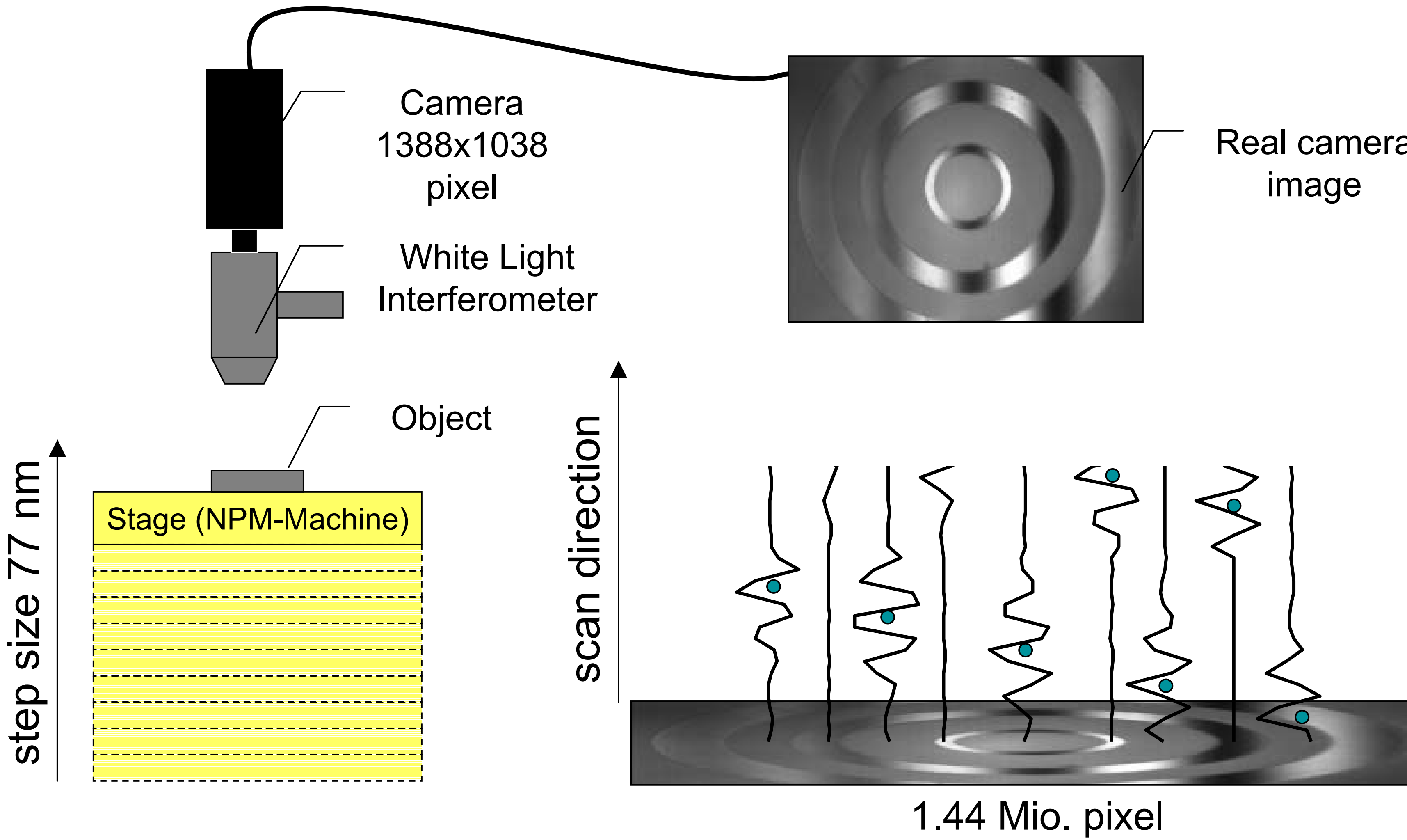
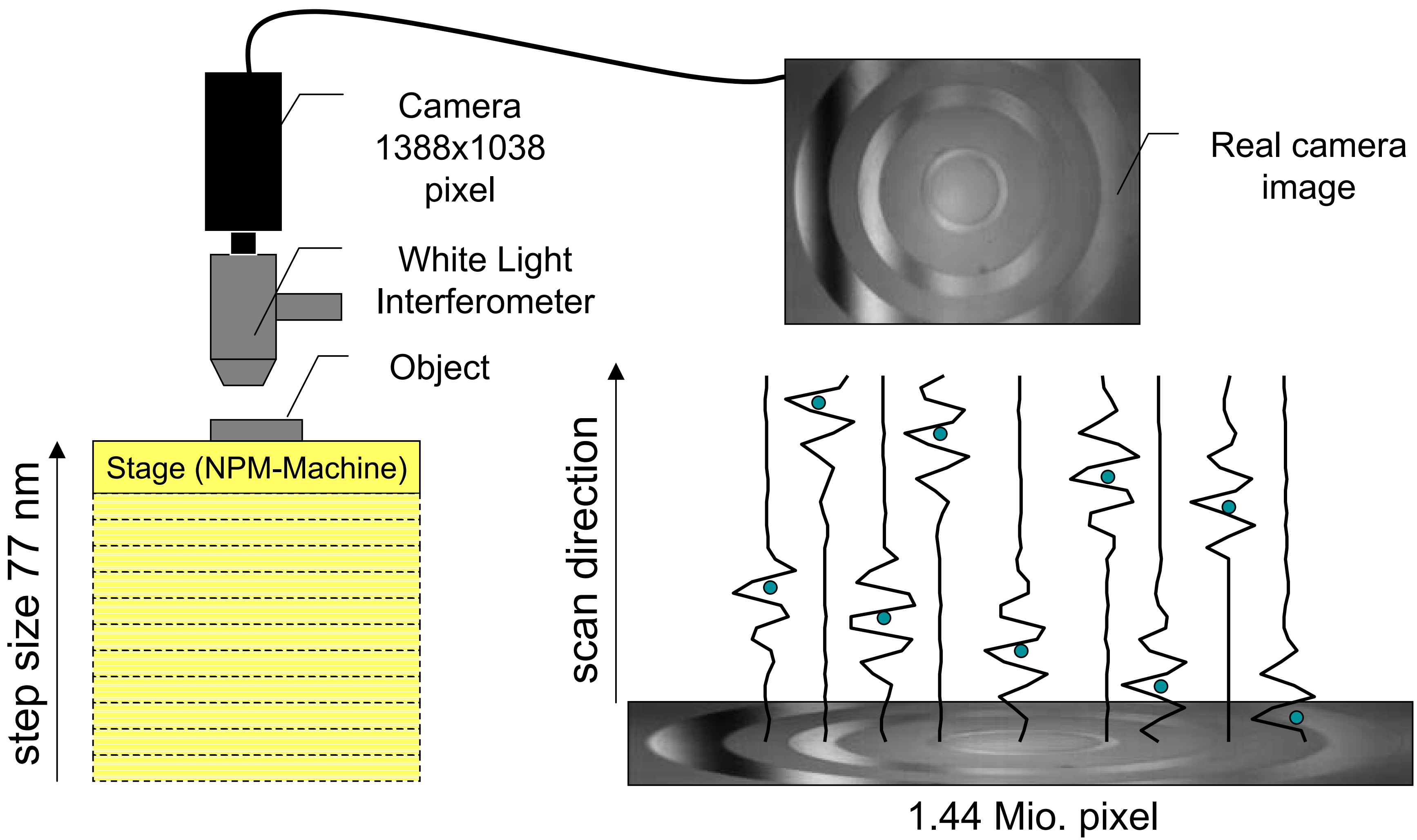
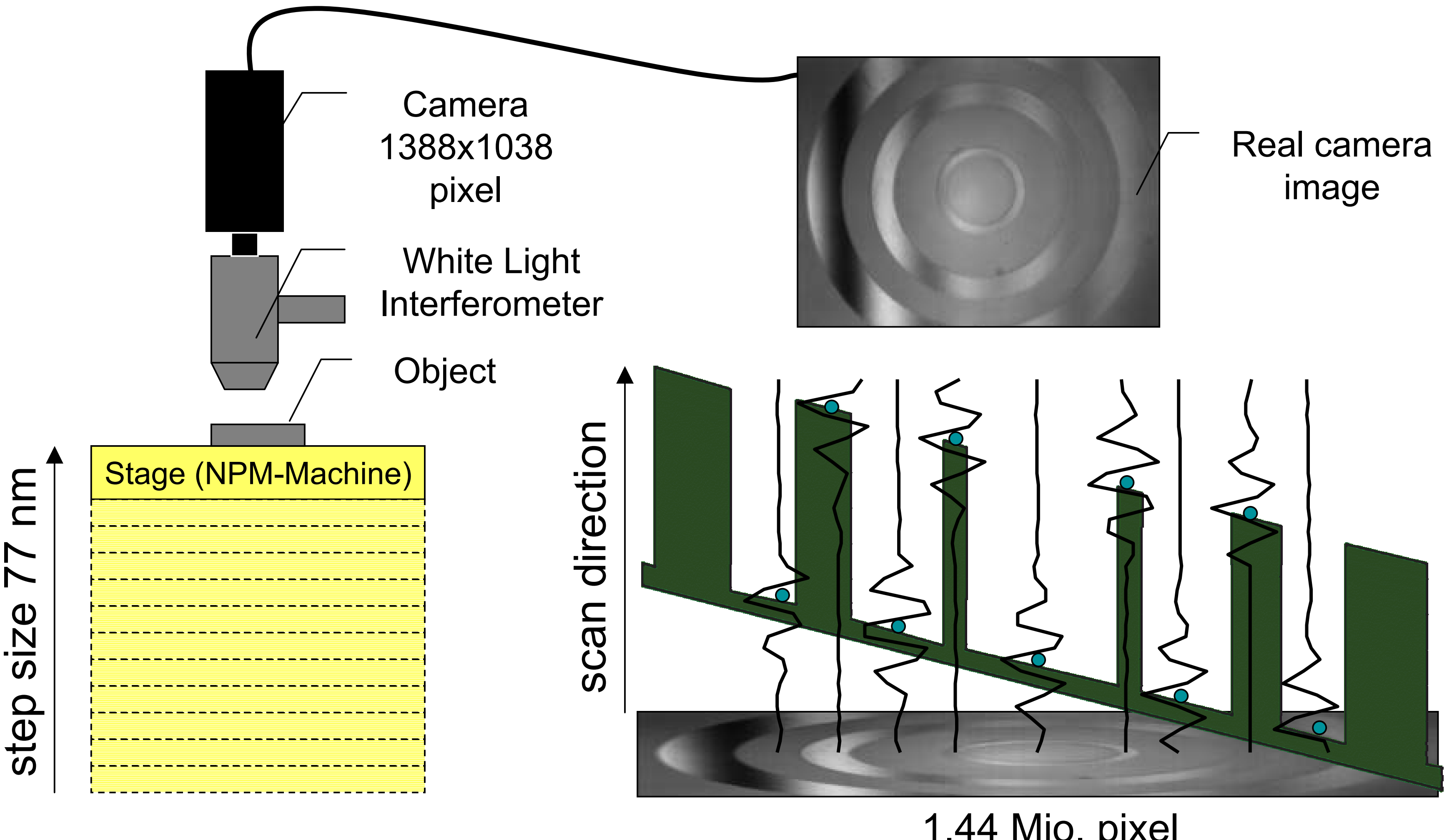
Principles of scanning white light interferometry



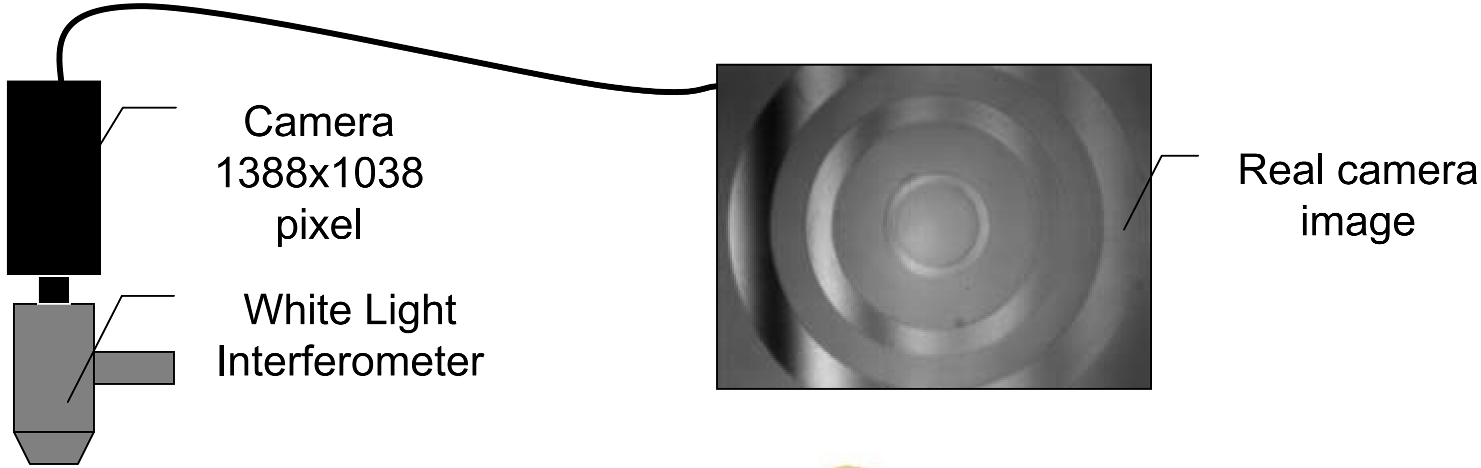
Principles of scanning white light interferometry



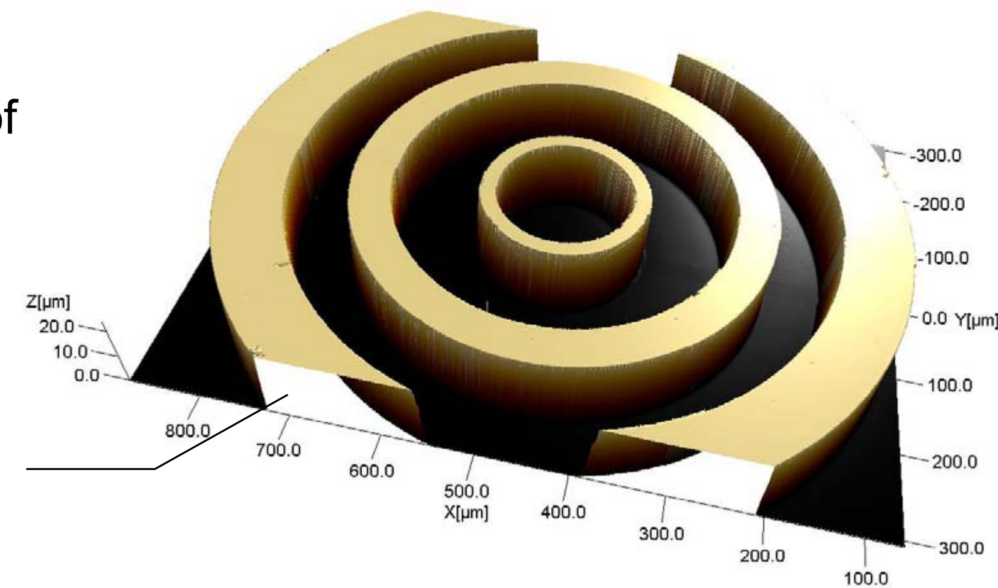
Principles of scanning white light interferometry



Principles of scanning white light interferometry



- Z-scan with determination of zero optical path difference per pixel
- Parallel measurement of 1.44 million data points (pixel)

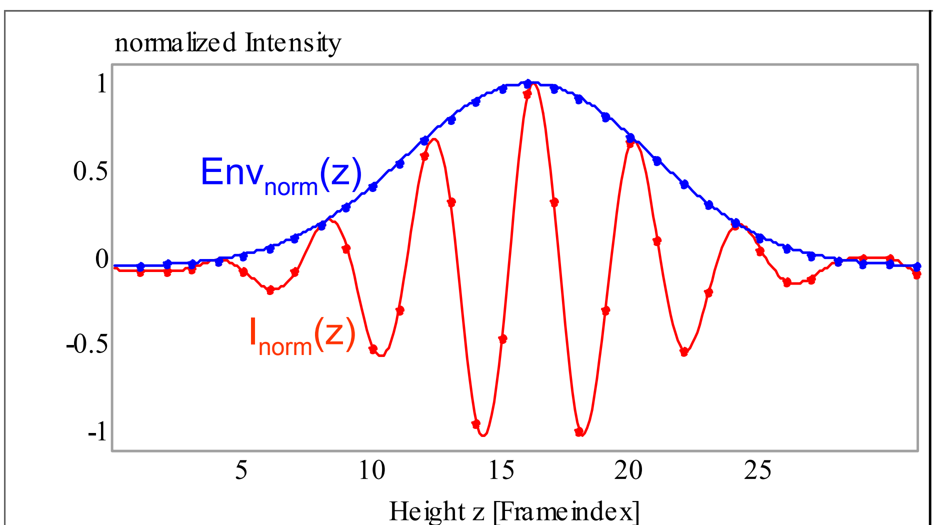


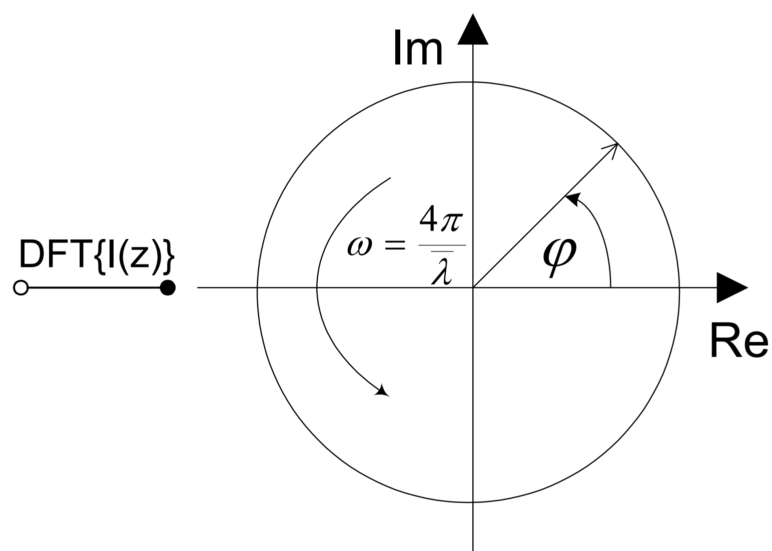
3d estimation of the ring structure

Interferogram analysis methods

- Envelope evaluation
  - Suitable for rough and smooth surfaces
  - Envelope extraction by Matched Filters, Hilbert-Transformation, fast Bucket methods, et al
  - Approximation of the envelopes peak position by Gaussian or parabola fit, iterative gradient-based peak search, et al

- Phase evaluation
  - Suitable for smooth surfaces
  - Phase shift determination by fast Bucket methods (such as Carré) or more precise Fourier analysis
  - Allocation of fringe order by envelope evaluation or spatial phase unwrapping





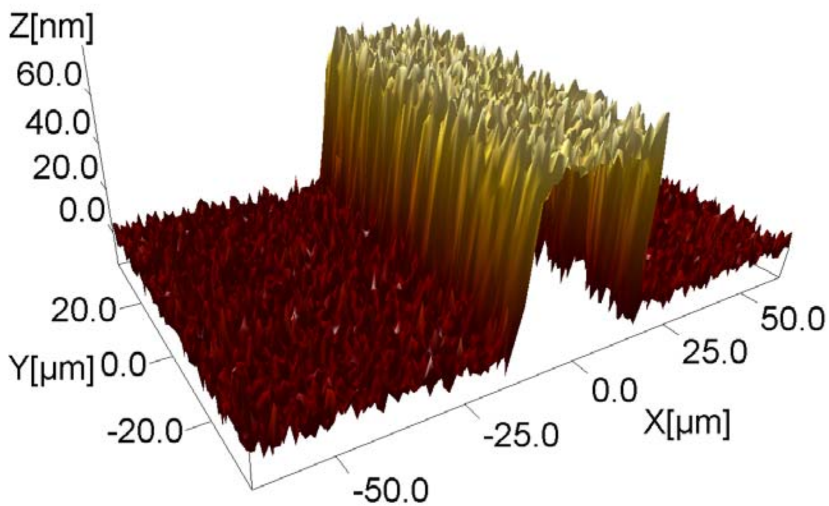
Comparison of the results of measuring a PTB layer thickness standard:

- Sampling step width in perpendicular direction: ***dz = 77 nm***
- Given step height (ISO 5436-1) of section *R1*: $\boldsymbol{H_{R1} = 69.1\ nm \pm 1.2\ nm}$

Envelope evaluation:

$H_{R1,N=30} = 69.11\ nm \pm 0.19\ nm$

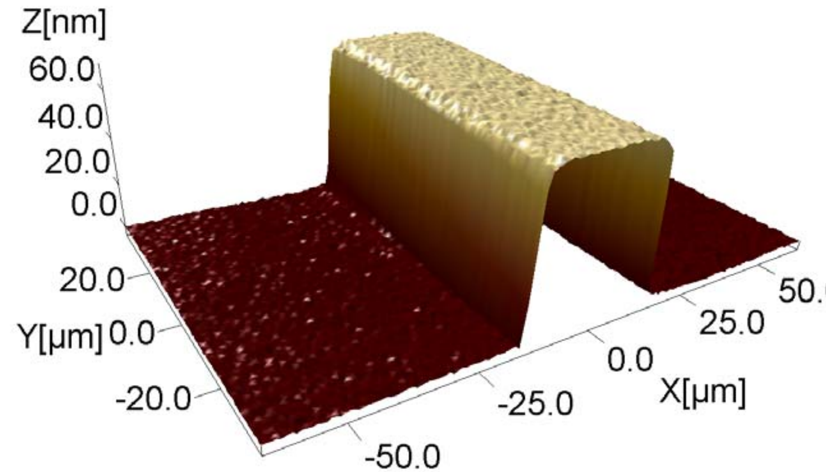
$\sigma(H_{R1,N=30}) = 0.51\ nm$



Phase evaluation:

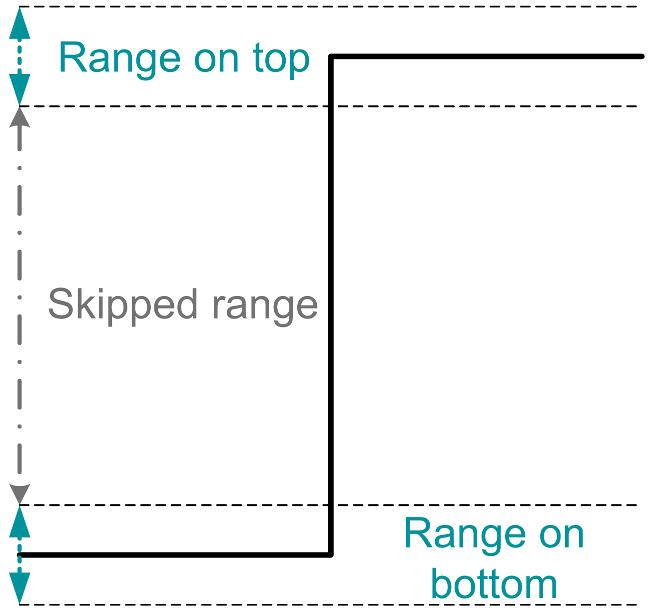
$H_{R1,N=30} = 69.26\ nm \pm 0.04\ nm$

$\sigma(H_{R1,N=30}) = 0.11\ nm$

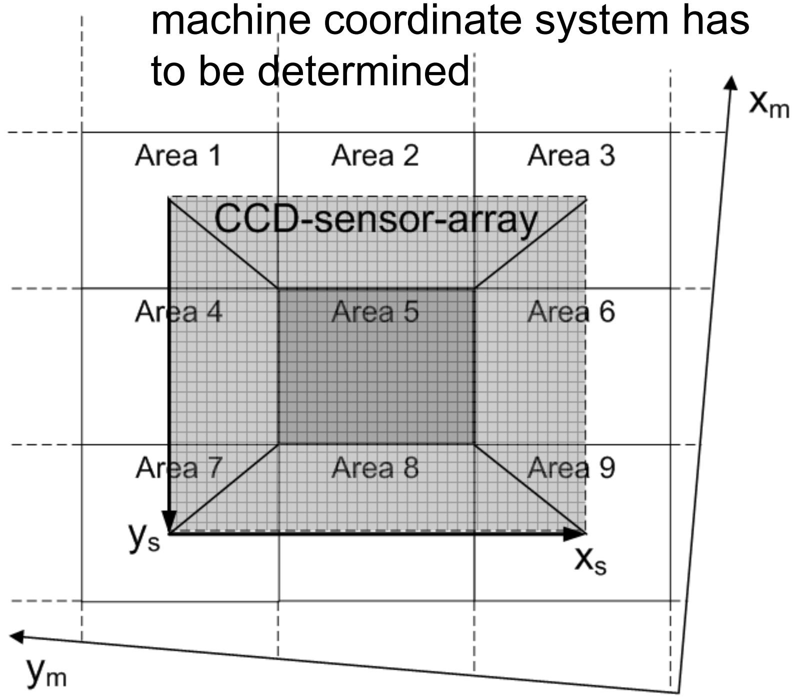


Measuring large areas

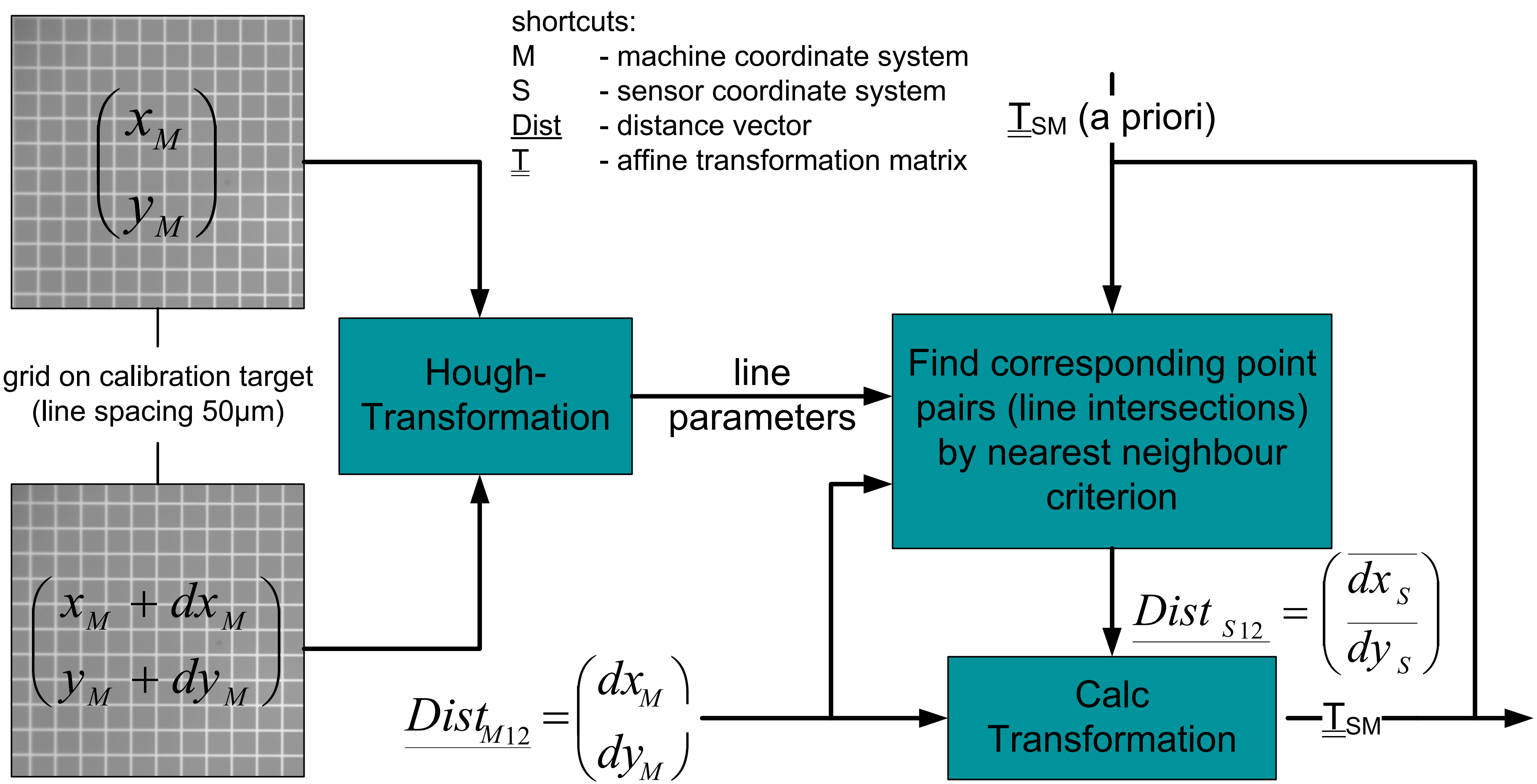
- Perpendicular orientation
  - Skipping of height-steps with high speed, where no fringes occurring
  - Definition of multiple pass-through ranges per measuring area



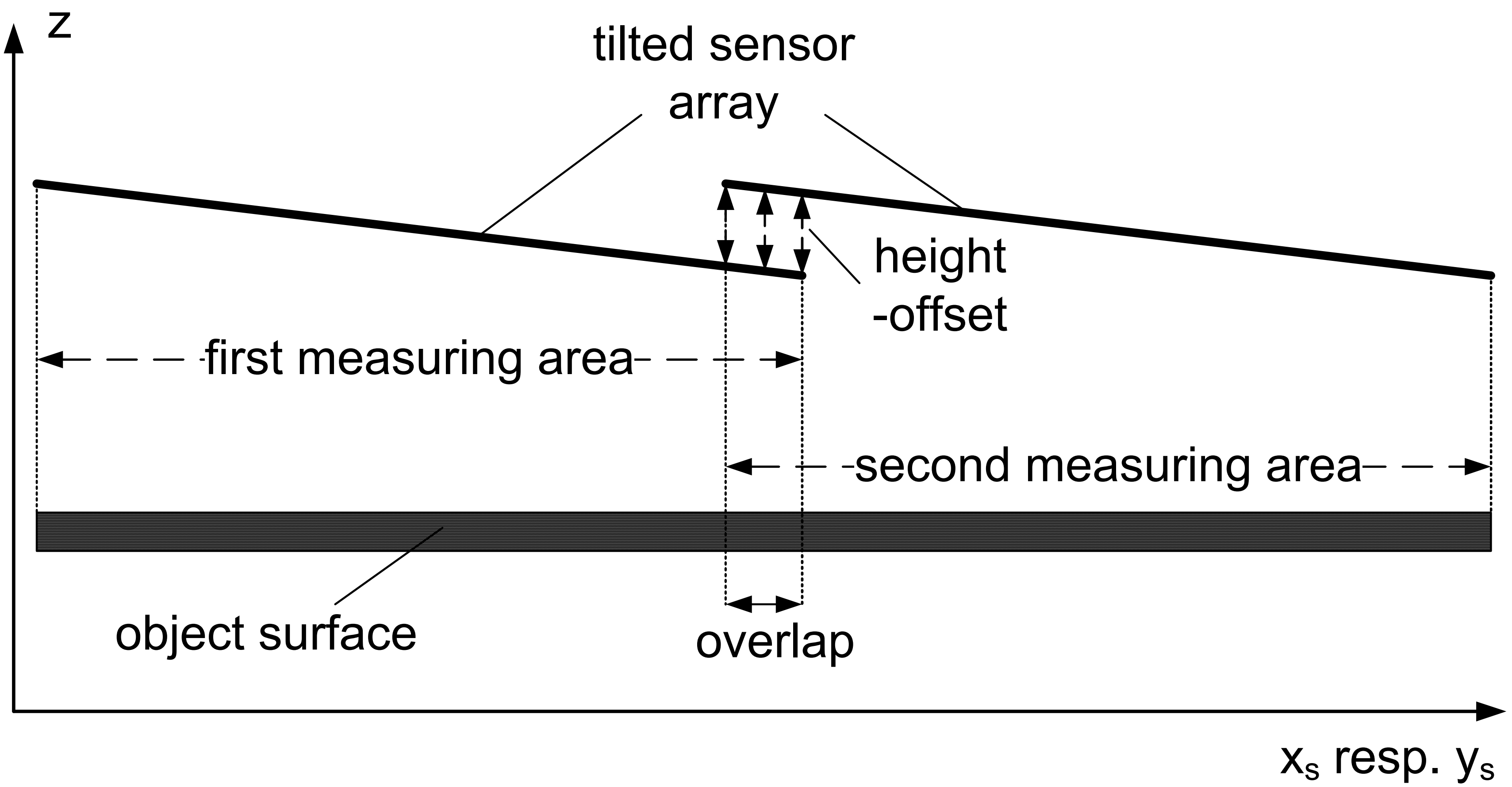
- Lateral orientation
  - topography independent stitching of adjacent measuring areas
  - orientation and pixel scaling of the camera according to the machine coordinate system has to be determined



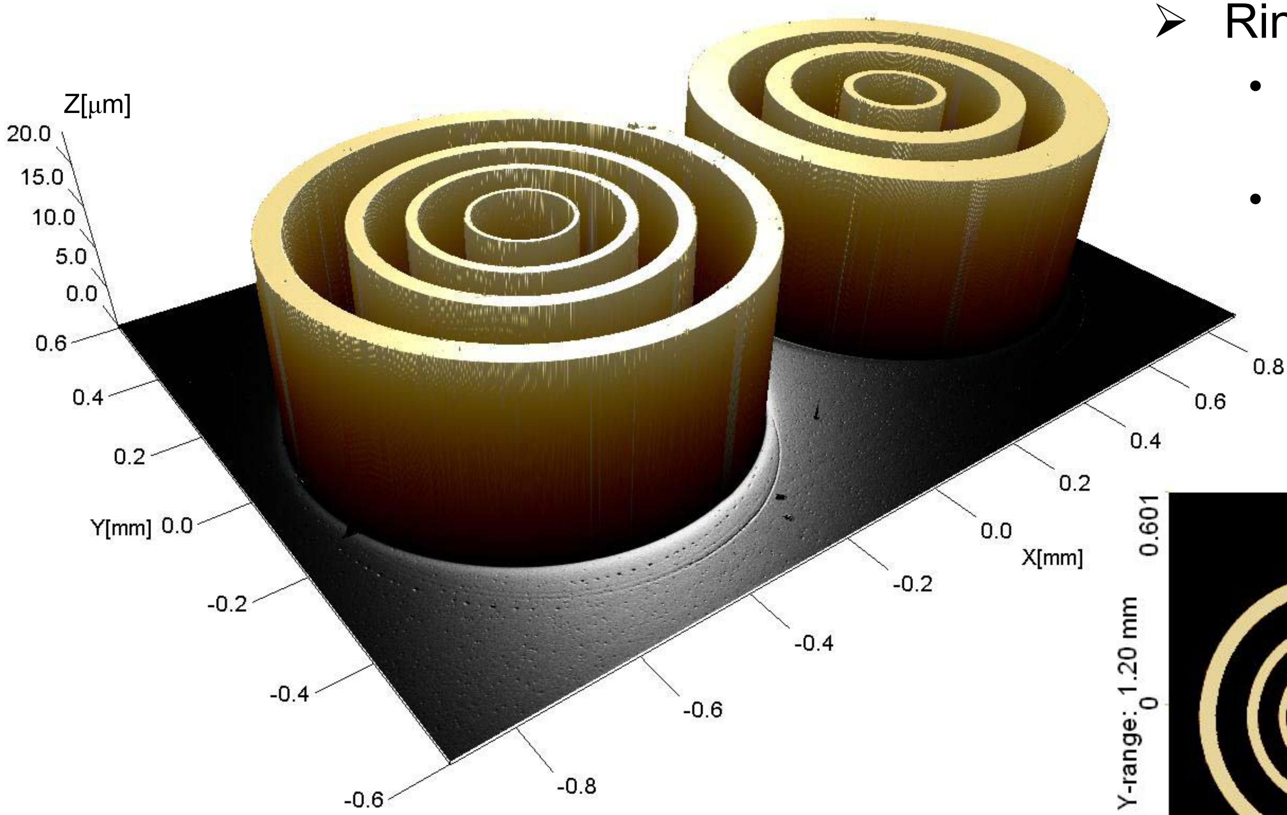
Determination of sensors orientation and scaling



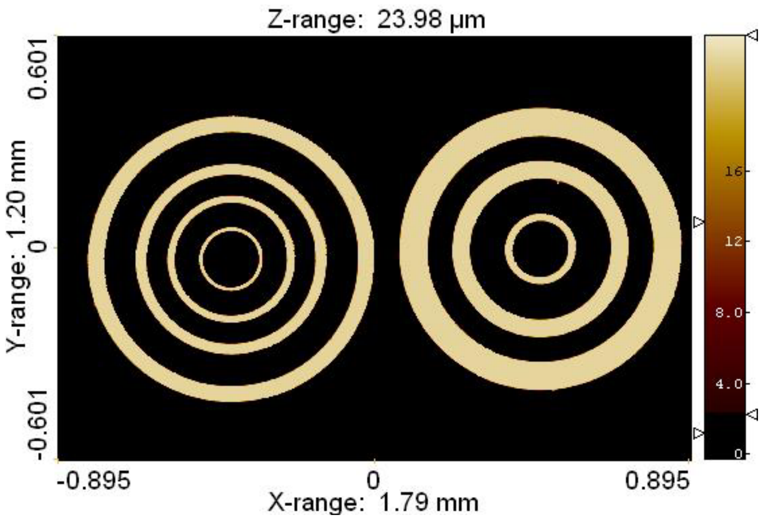
Correction of sensors tilt



Exemplary results

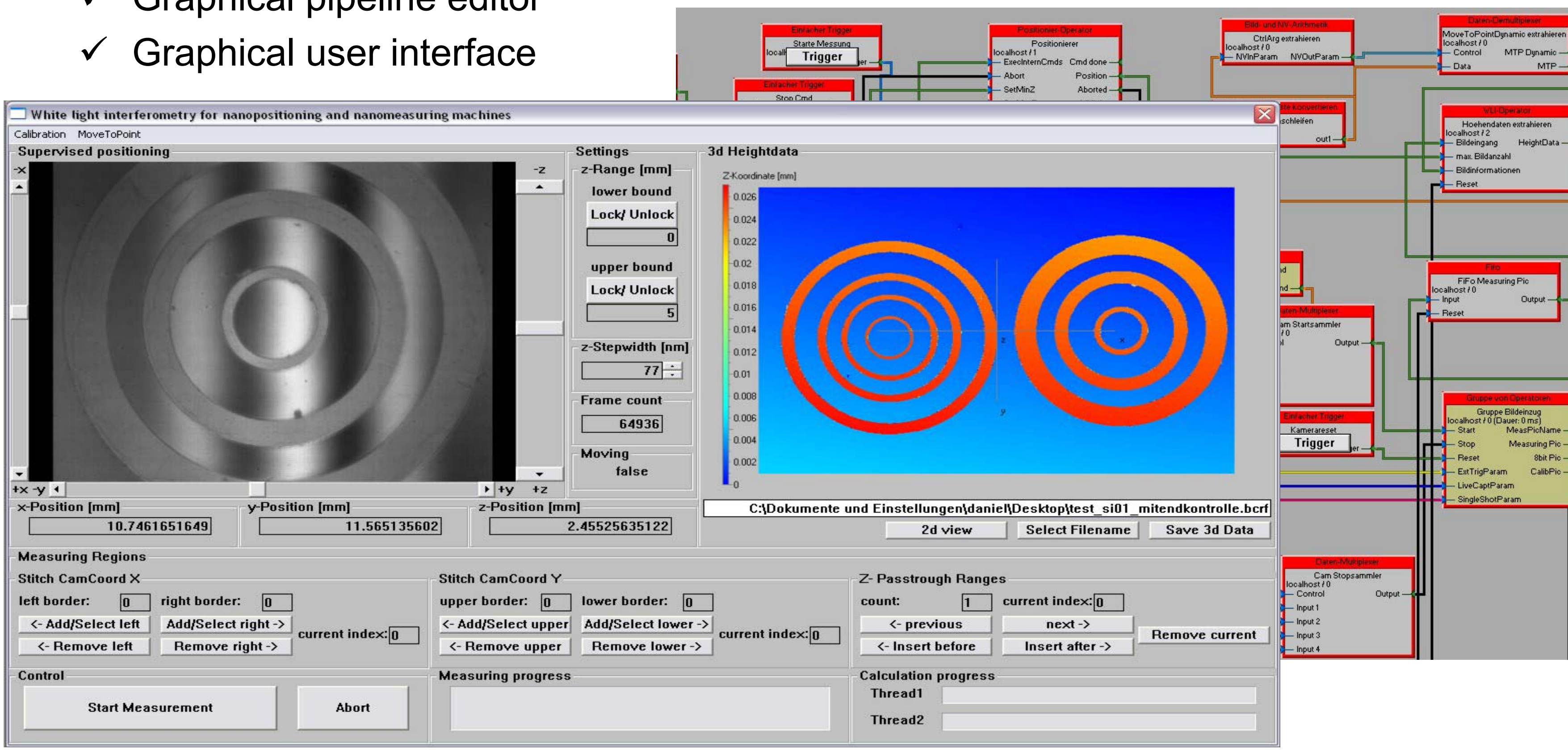


- Ring structures
  - Stitching of 3 x 2 regions (1.79 mm x 1.20 mm)
  - two pass-through ranges at each single region



Software environment

- Software package VIP (Visual Image Processing) –Toolkit from
  - ✓ Rapid prototyping of image processing solutions
  - ✓ Includes large and extensible algorithm libraries
  - ✓ Graphical pipeline editor
  - ✓ Graphical user interface



Conclusion

- ➤ Development of a white light interferometry application for the NPMM
  - ✓ Based on a focus sensor measurement setup
  - ✓ Precise height extraction by envelope or phase evaluation
  - ✓ Skipping of large height differences by jumping to multiple defined pass-through ranges
  - ✓ Stitching of adjacent measuring regions independent of topography
    - Determination of sensors orientation and scaling in advance by a measuring procedure
    - Correction of sensors tilt needs only a small overlap

Outlook

- Redesign of the measurement head
  - ✓ Zerodur base plate with sensor insertion apparatus
  - ✓ Sensor set-up made of Invar for inserting into the base plate
  - ✓ More high-grade compact microscope tube with higher magnification
  - ✓ Set-up for manual sensor aligning

- This project is sponsored by the ministry of education and arts of the Free State of Thuringia (Germany) under the sign B 514-06 007
- Thanks all those colleagues at the Technische Universität Ilmenau and the ZBS Ilmenau e. V., who have contributed to these developments

Thank you very much for your attention!