

Quality Tools for Technical Requirement Compliance

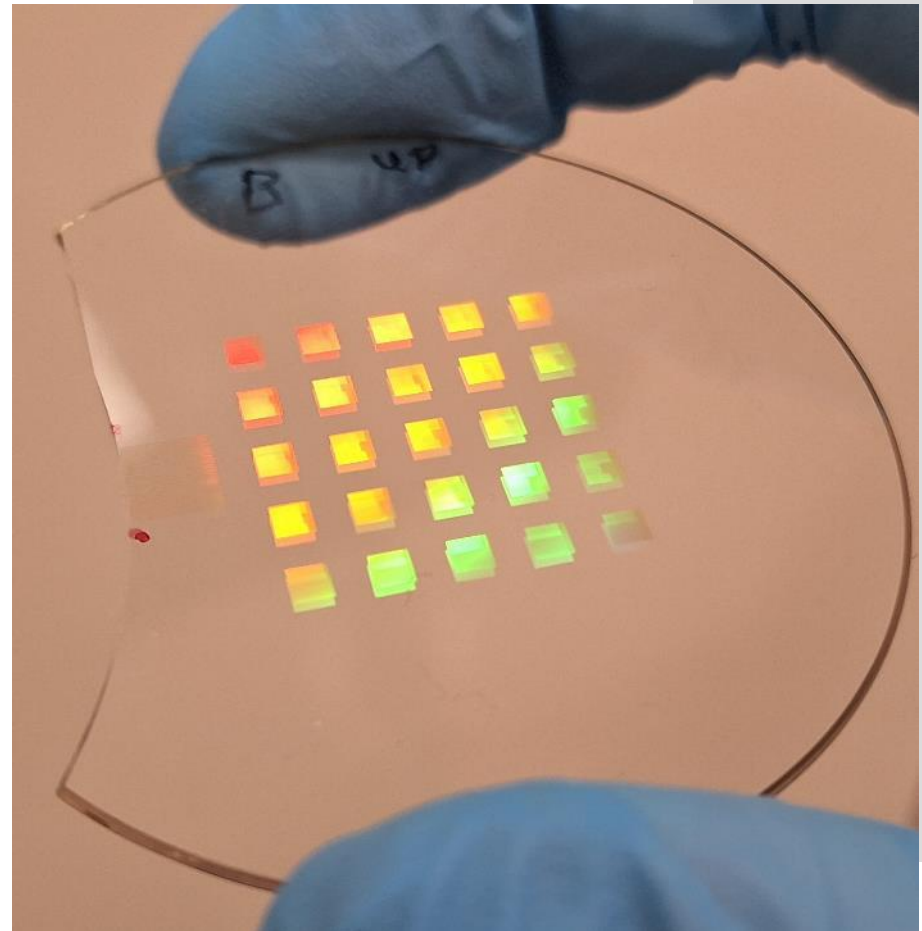
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A. Lassila

VTT MIKES

EPIC Technology Meeting on Photonics for XR: through emerging technologies and challenges at Microsoft, 27-28 May 2024, Espoo, Finland

Inline

- VTT & VTT MIKES
- Technical requirement compliance in XR & Traceability
- XR measurands
- Selected VTT MIKES instruments
 - Diffractometer
 - Angular position measurement
 - Scatterometry
 - Spectral scatterometry
 - Microscopy: AFM & SEM
- Conclusion



VTT is a visionary research and innovation partner for companies and society

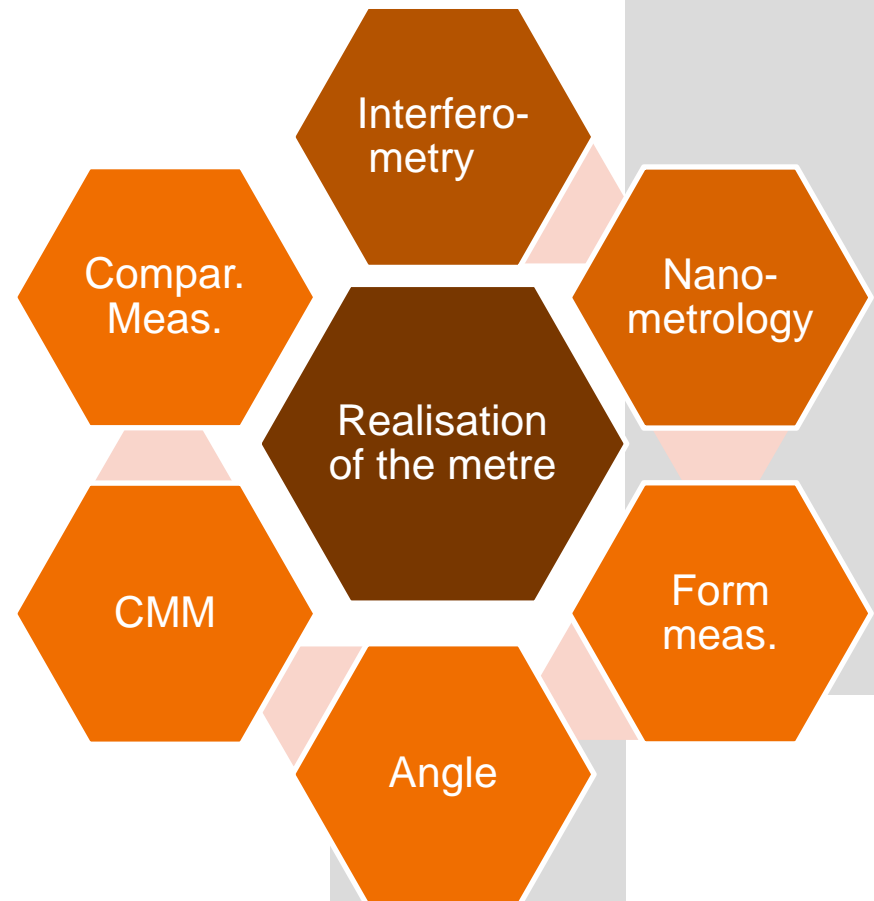
- VTT is one of Europe's leading research institutions. We are owned by the Finnish state. We advance the utilisation and commercialisation of research and technology in commerce and society.



VTT MIKES - Length metrology

- MIKES
National metrology institute of Finland
- Length Team
 - Realization of the metre and radian
 - Scientific research
 - Calibration & measurement service
 - Consultancy service for solving measurement problems of industries

Measurements traceable to SI-unit
=> Can be repeated with same results



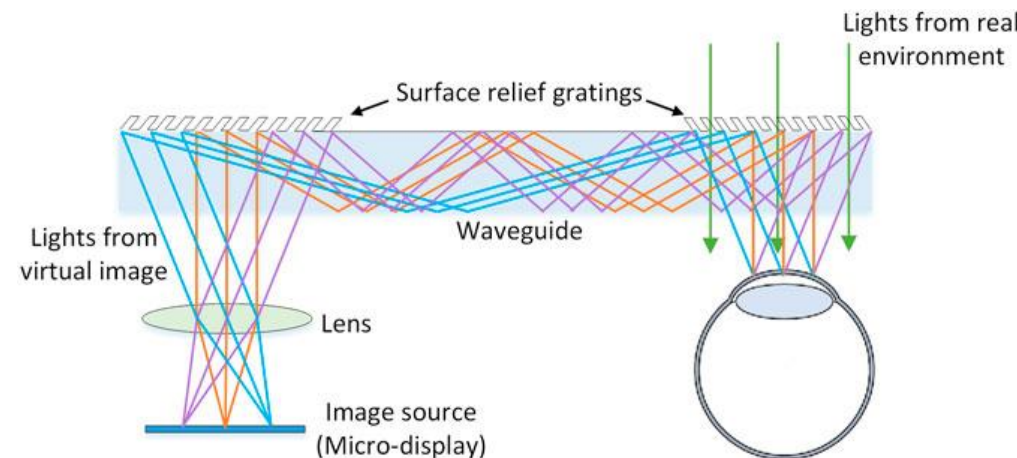
Technical requirement compliance in XR

Complicated high-tech systems

- Several components
- Different suppliers

How to guarantee the correct operation?

- In design
 - Requirements are set for each component
 - Requirements are challenging
 - ~10 pm for pitch
 - ~1 arcsec for angular position
 - Agreement with simulations & measurements?
- Quality control is needed
- Metrological traceability
- ⇒ Measurements in real SI units



Courtesy of Xinxing Xia, Front. Virtual Real., 14 March 2022, <https://doi.org/10.3389/frvir.2022.838237>

Traceability guarantees correct measurements



NMI = National metrology institute

XR optics: Measurands

Waveguides:

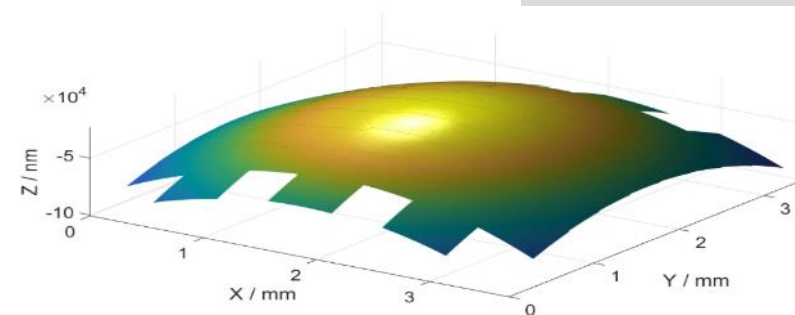
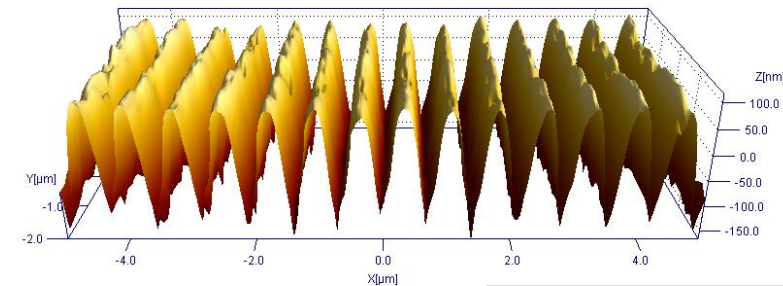
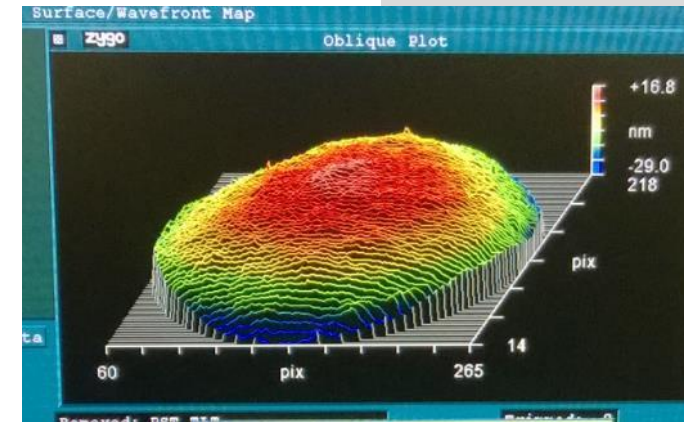
- Thickness, thickness variation
- Flatness
- Parallelism

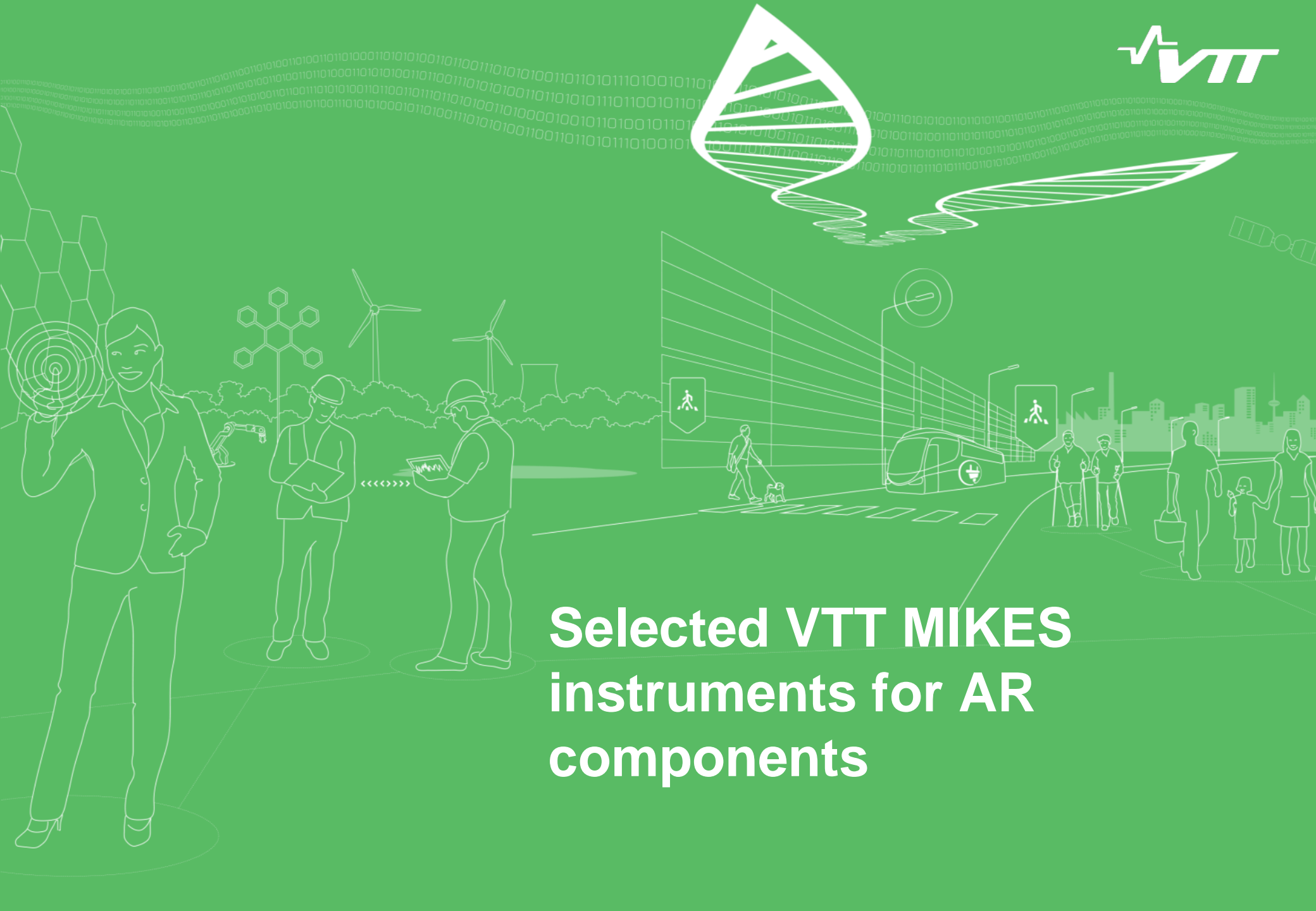
Waveguide couplers, DOEs:

- Pitch, homogeneity
- Grating parameters
- Angular position

Lenses, aspheres, freeform optics

- Form errors, surface irregularity
- Focal length, power
- Imaging errors, modular transfer function
- Haze





Selected VTT MIKES instruments for AR components

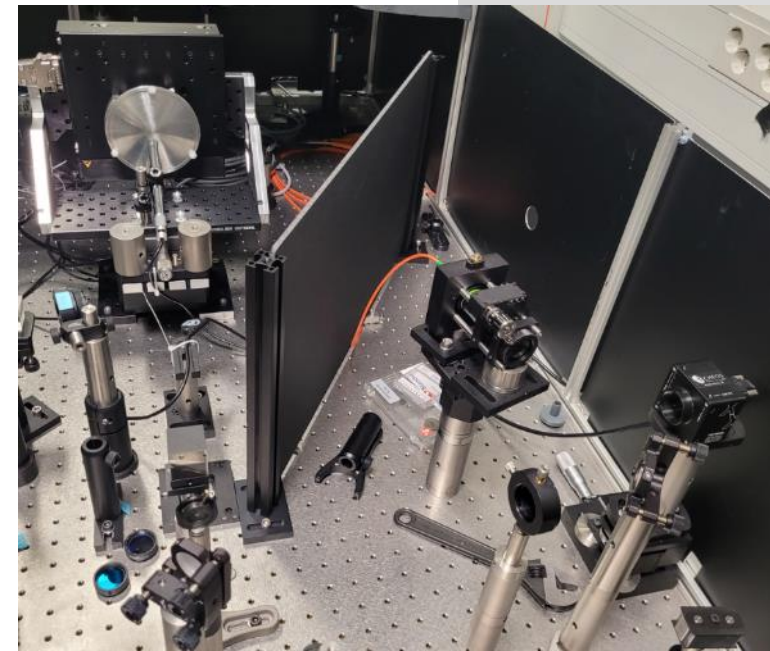
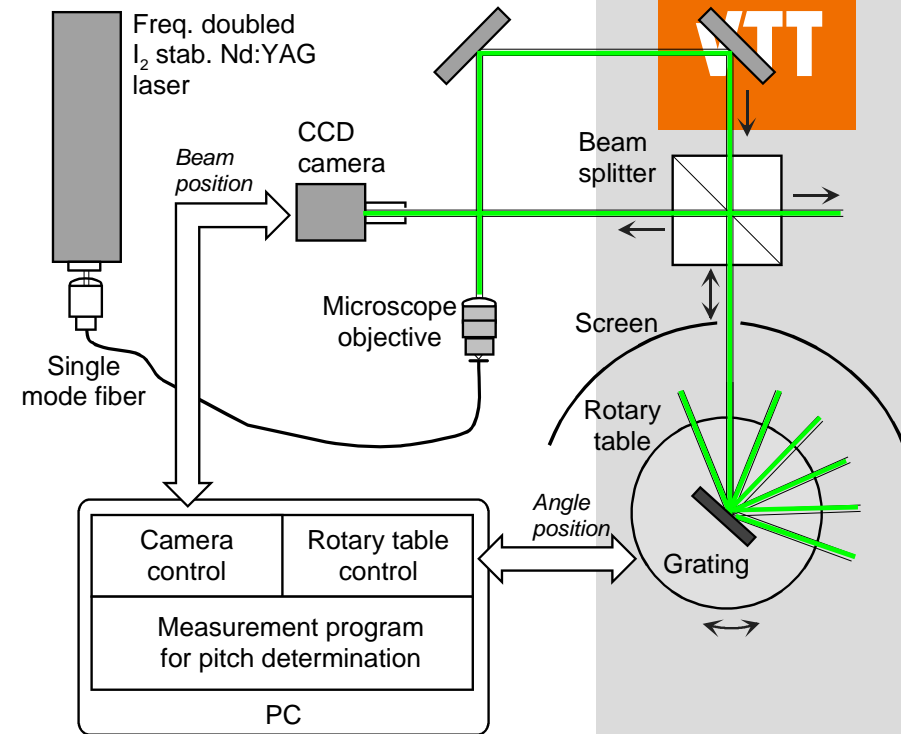
Grating pitch: Traceable high accuracy Diffractometer

Automated laser diffraction setup

- Littrow configuration
- For calibration of grating **pitch**
- **Homogeneity** of grating pitch by scanning
 - Measurement area 50 mm × 50 mm
 - Thousands of measurement points

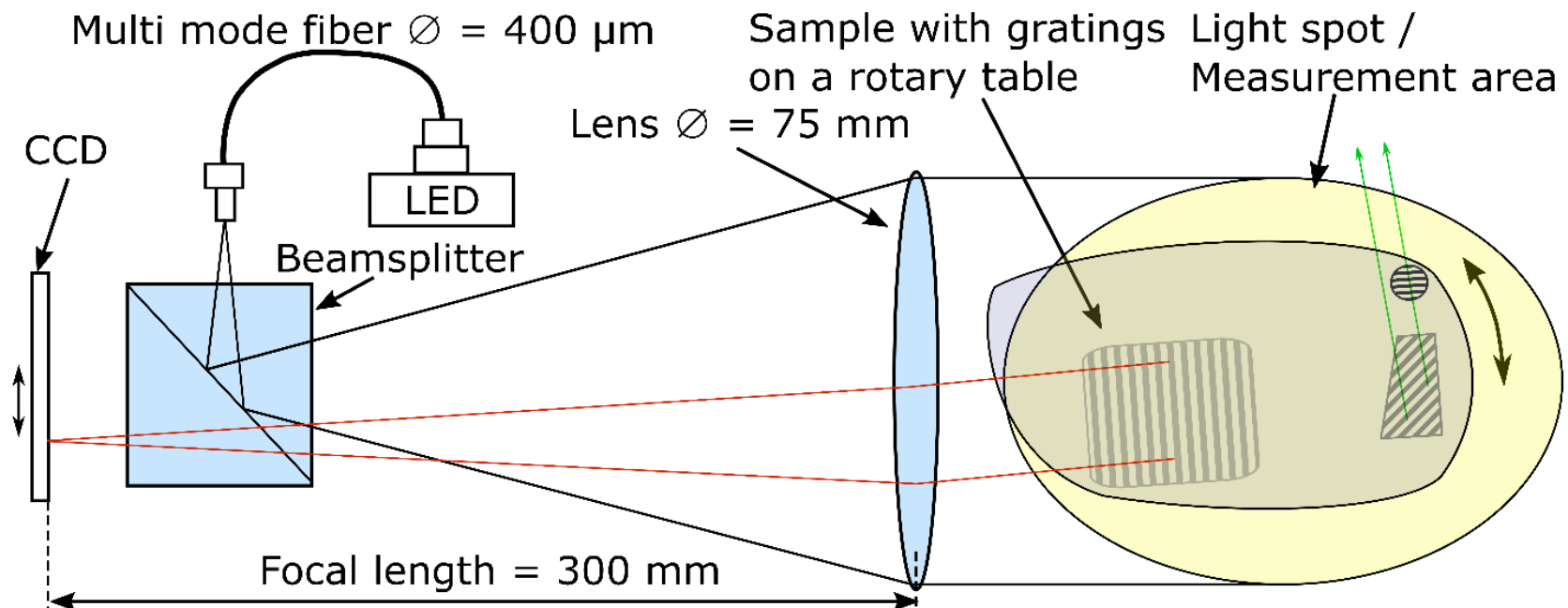
Traceability & Uncertainty

- Accurate calibrated laser wavelength
- Error compensated rotary table, uc < 1 arcsec
- High accuracy period measurement
 - ~3 pm for 300 nm pitch,
 - ~10 pm for 700 nm pitch
 - ~20 pm for 2 μm pitch



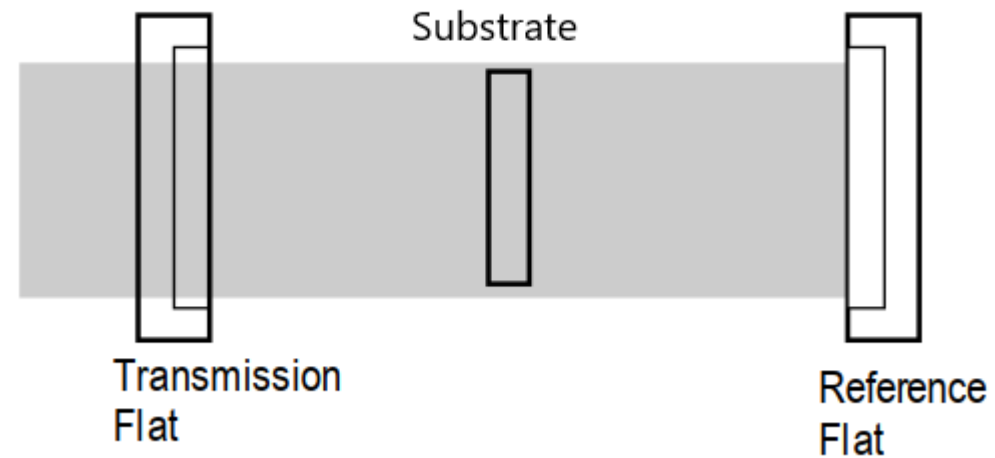
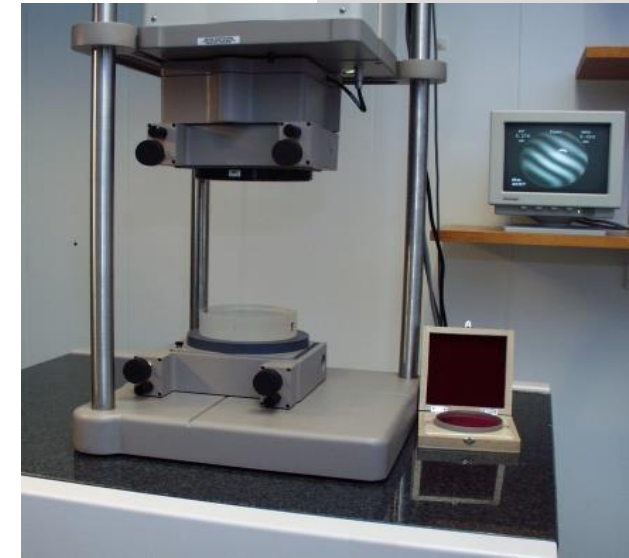
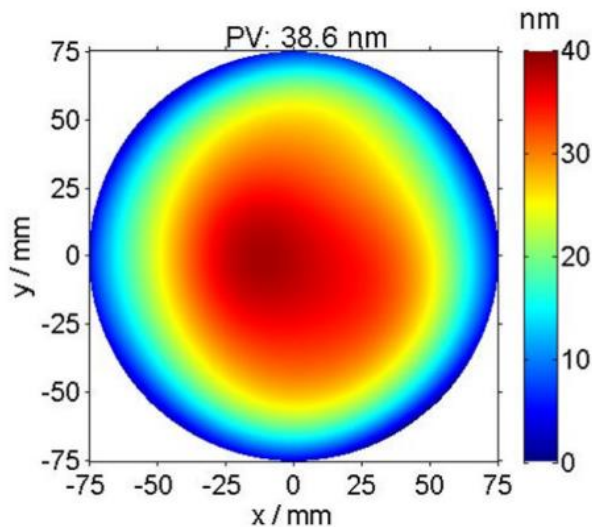
Grating orientation measurement

- Grating orientation is important in AR applications
- VTT developed detector for $pitch = 280 \text{ nm} \dots 500 \text{ nm}$
- High accuracy rotary table
- Uncertainty of the measurement is $\sim 1.5^\circ$



Flatness & thickness variation: Interferometric methods

- Substrate properties are often relevant for function of DOE e.g. when substrate is used as a waveguide
- Fizeau interferometer and white light interference microscope can be used to measure **flatness** and **parallelism** of substrate
- Localised **thickness variation** is seen
- Uncertainty $\sim \lambda/40$



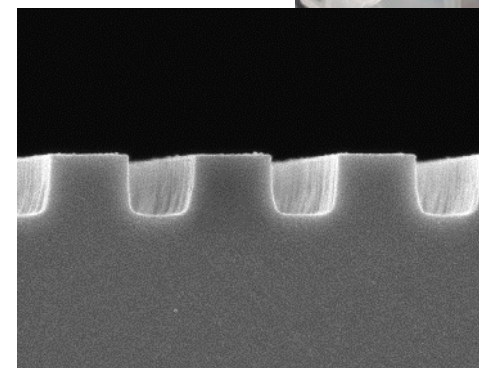
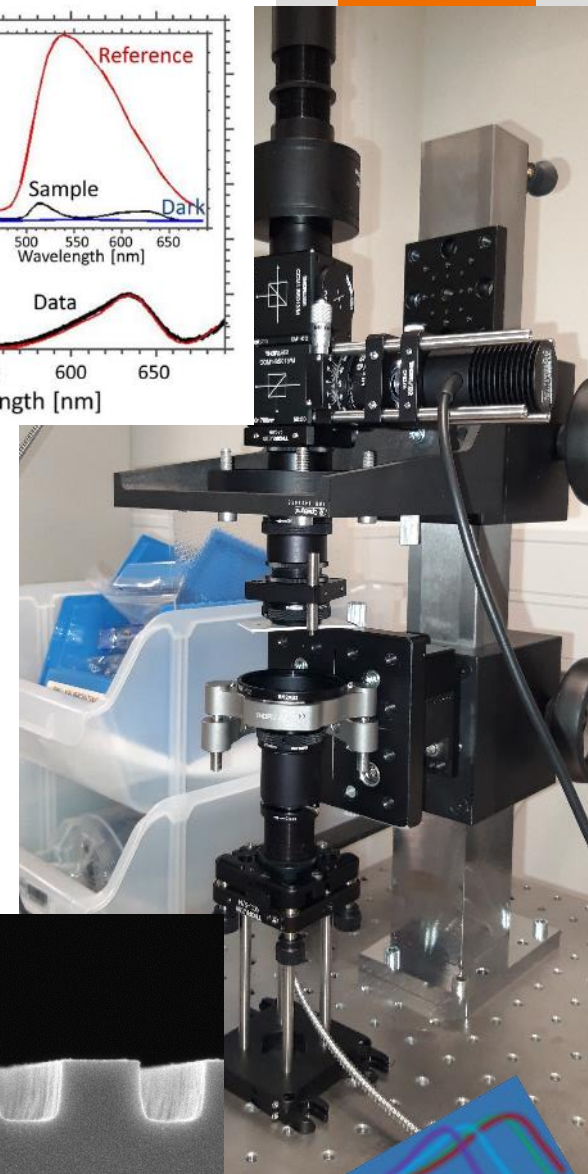
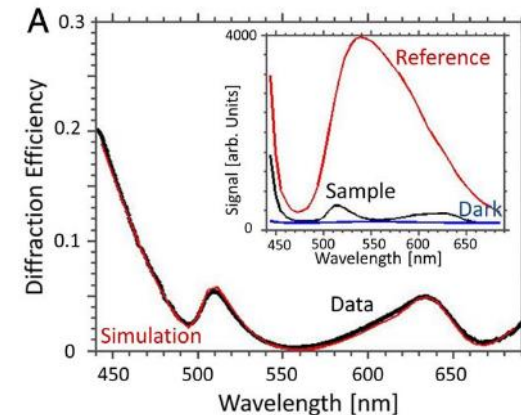
Quabis, A., Lassila A., et al.(2017), Intercomparison of flatness measurements of an optical flat at apertures of up to 150 mm in diameter. *Metrologia*, 54(1), 85-93. <https://doi.org/10.1088/1681-7575/aa535c>

Industrial QC applications: Spectral scatterometry

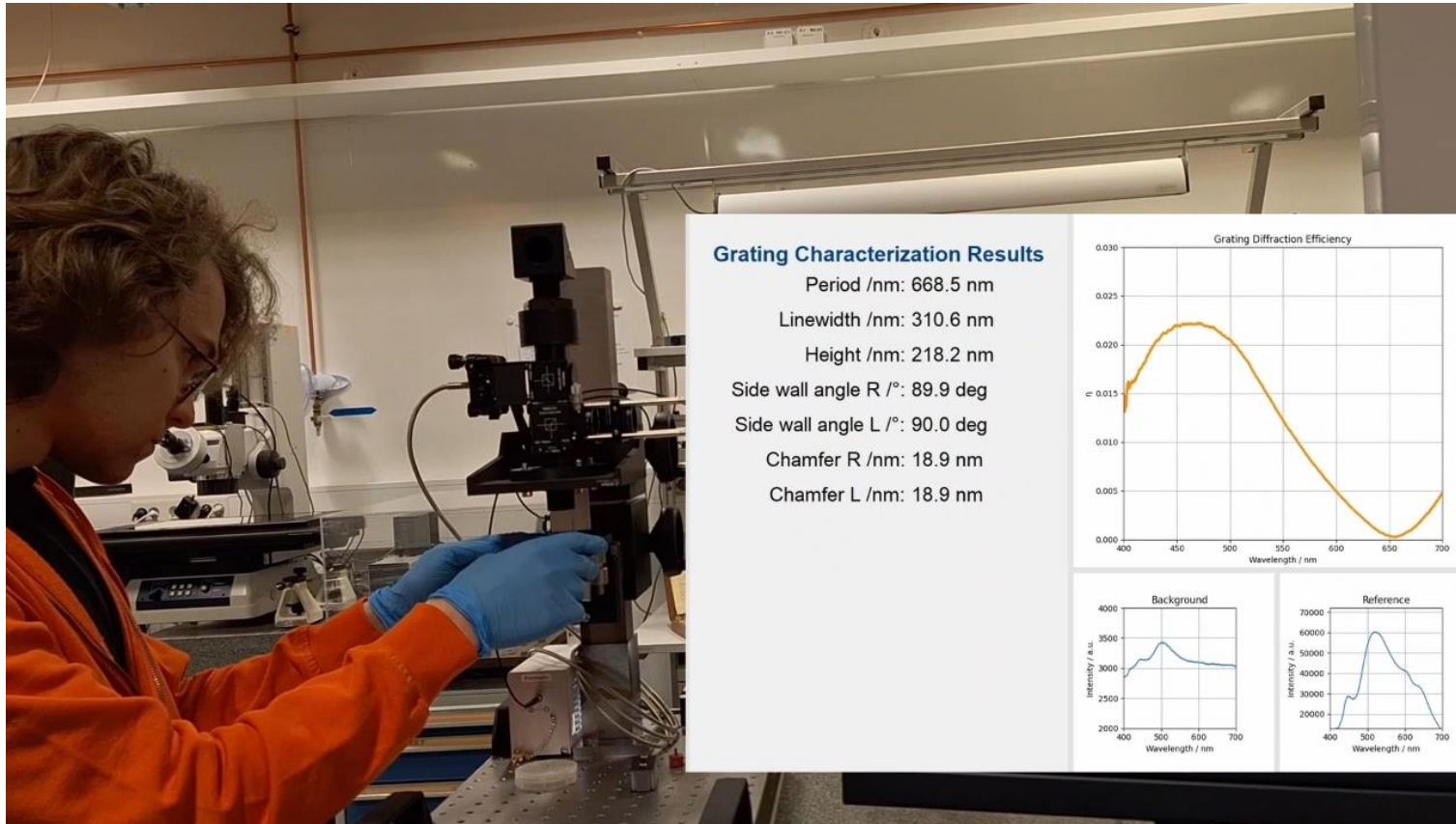
- Self developed reflectance spectral scatterometer
 - White light source
 - Spectrometer
 - Artificial Neural Network data analysis
 - Reference samples from UEF

- Measurement of diffraction efficiency over visible spectrum
 - Spectral diffraction efficiency depends on the grating properties
 - ⇒ grating parameters
 - **period, fill ratio, height, sidewall angles, corner rounding (chamfer), defects**

- Fast and reliable metrology tool
 - Applications in industrial quality control
 - Industrial manufacturing of Diffractive Optical Elements (DOEs)



Industrial QC applications: Spectral scatterometry

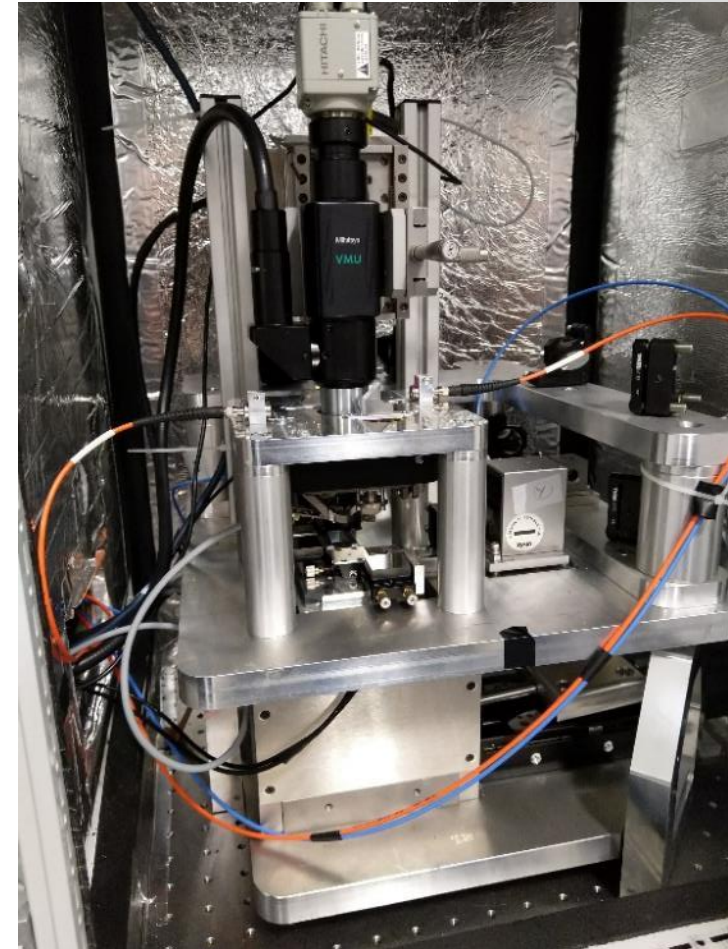


Microscopic methods

- Common methods for offline inspection of DOE
- To measure directly the nanostructure of the DOE

- Atomic Force microscope (AFM)
 - Metrological AFM, 2nd generation
 - Jupiter XR AFM including interferometric position measurement for sample stage
 - For best accuracy interferometric 3D scales needed
 - ⇒ Usable for measurands: **period, homogeneity, lateral & vertical dimensions**

- Scanning Electron Microscope (SEM)
 - High resolution
 - Height measurement requires cutting of the sample
 - ⇒ Usable for measurands: **period, homogeneity, lateral dimensions**



For reliable results traceable calibration needed

Conclusion

- **Calibrated instruments** ⇒ **Reliable technical requirement compliance testing**
- Several instruments & methods developed or available at VTT MIKES for characterisation of AR components were presented
 - Laser diffractometer for grating pitch & homogeneity
 - Measurement of angular position
 - Scatterometry for online quality control
 - Microscopy methods
 - Other methods available
 - Custom solutions
- Instrument development for customers
- Metrology for Photonics industry is one of the focus areas at VTT MIKES
 - New customers welcome
 - R&D partnerships are welcome



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TracOptic



Thank you for your attention

Questions?



bey⁰nd

the obvious

Virpi Korpelainen