Universität Stuttgart

Characterization of Near- to Far-Field Transformers by Interferometric Fourier-Scatterometry

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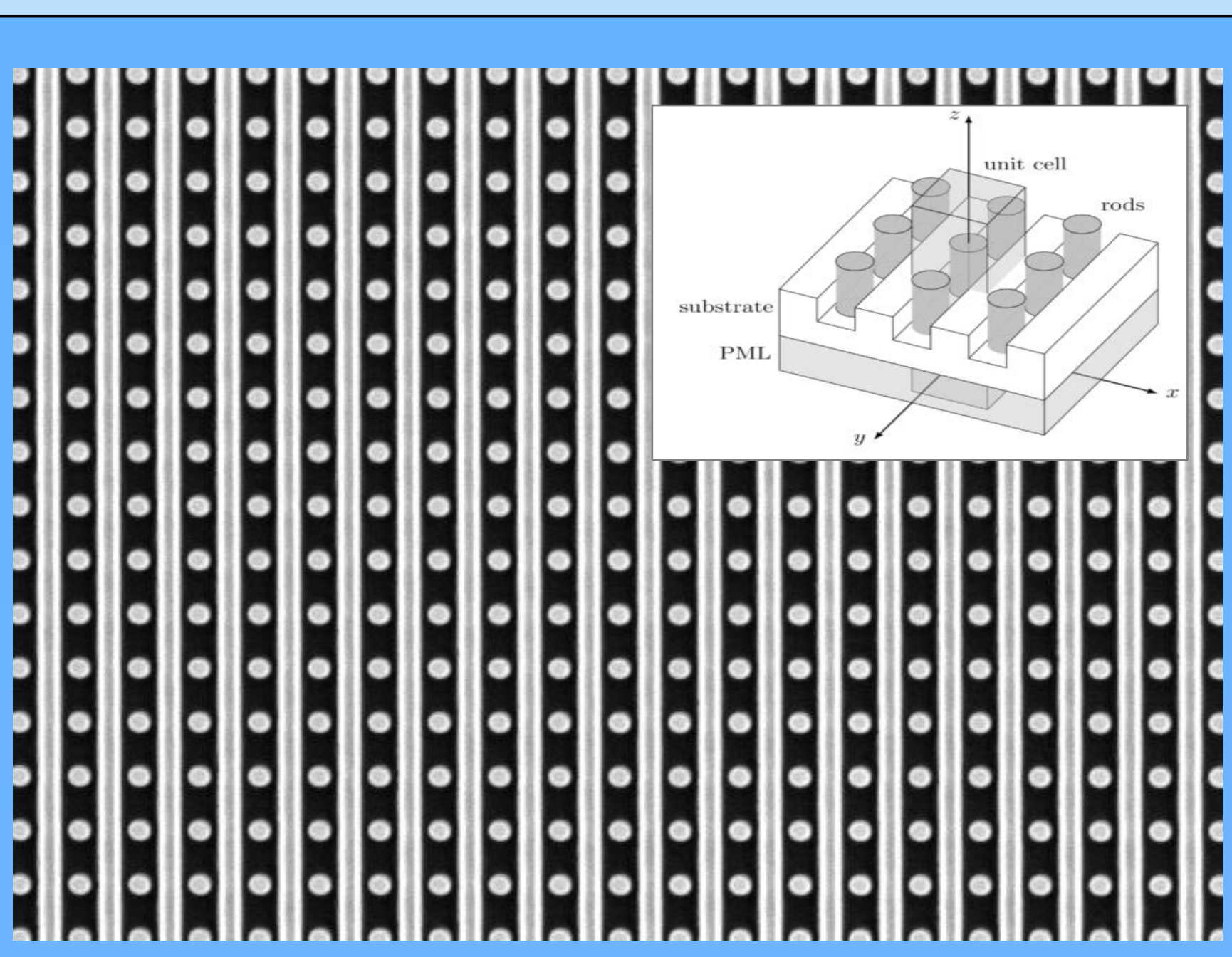
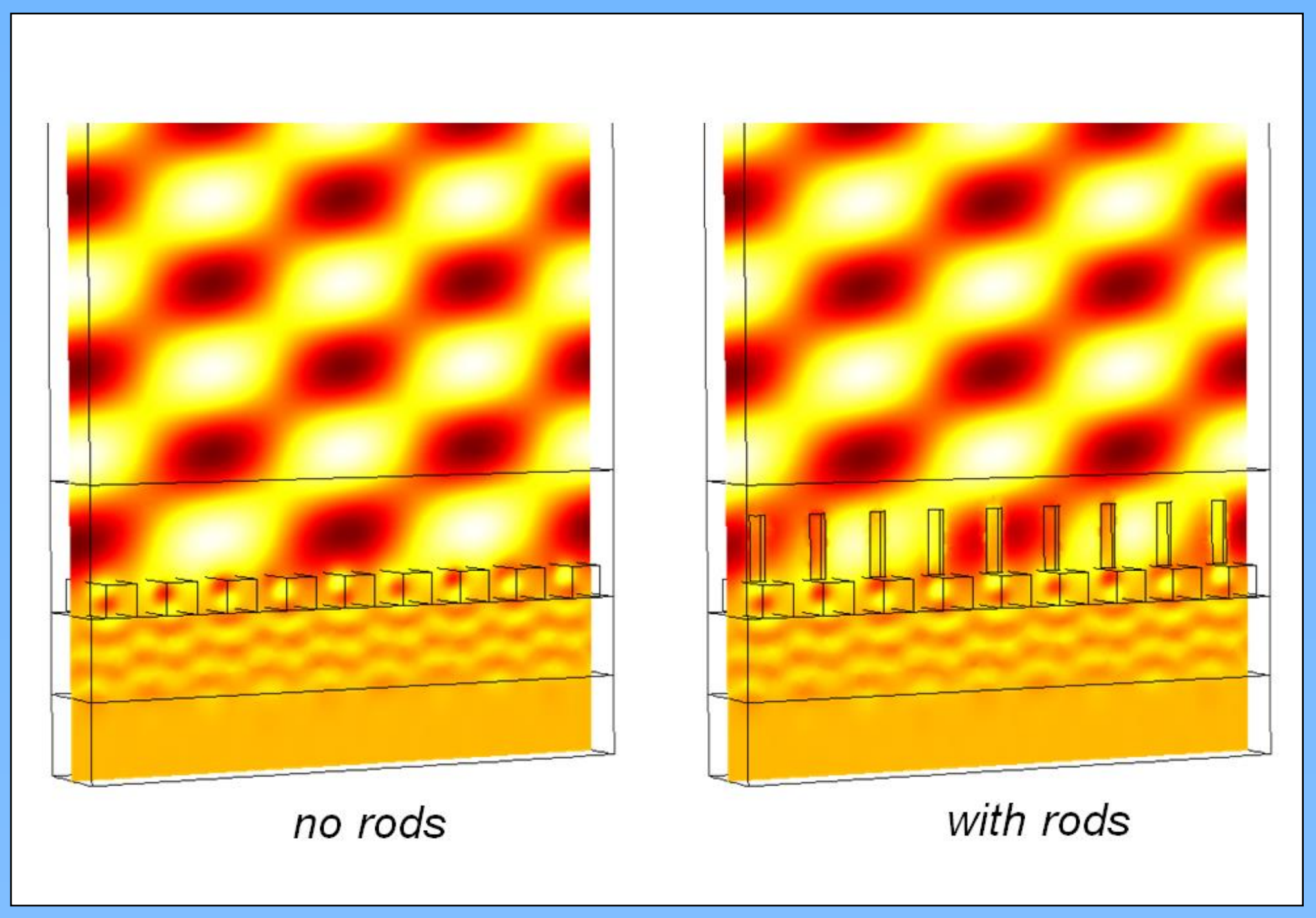
Objectives

- Optical metrology of sub-wavelength structures
- Increased sensitivity by plasmonic nanostructures



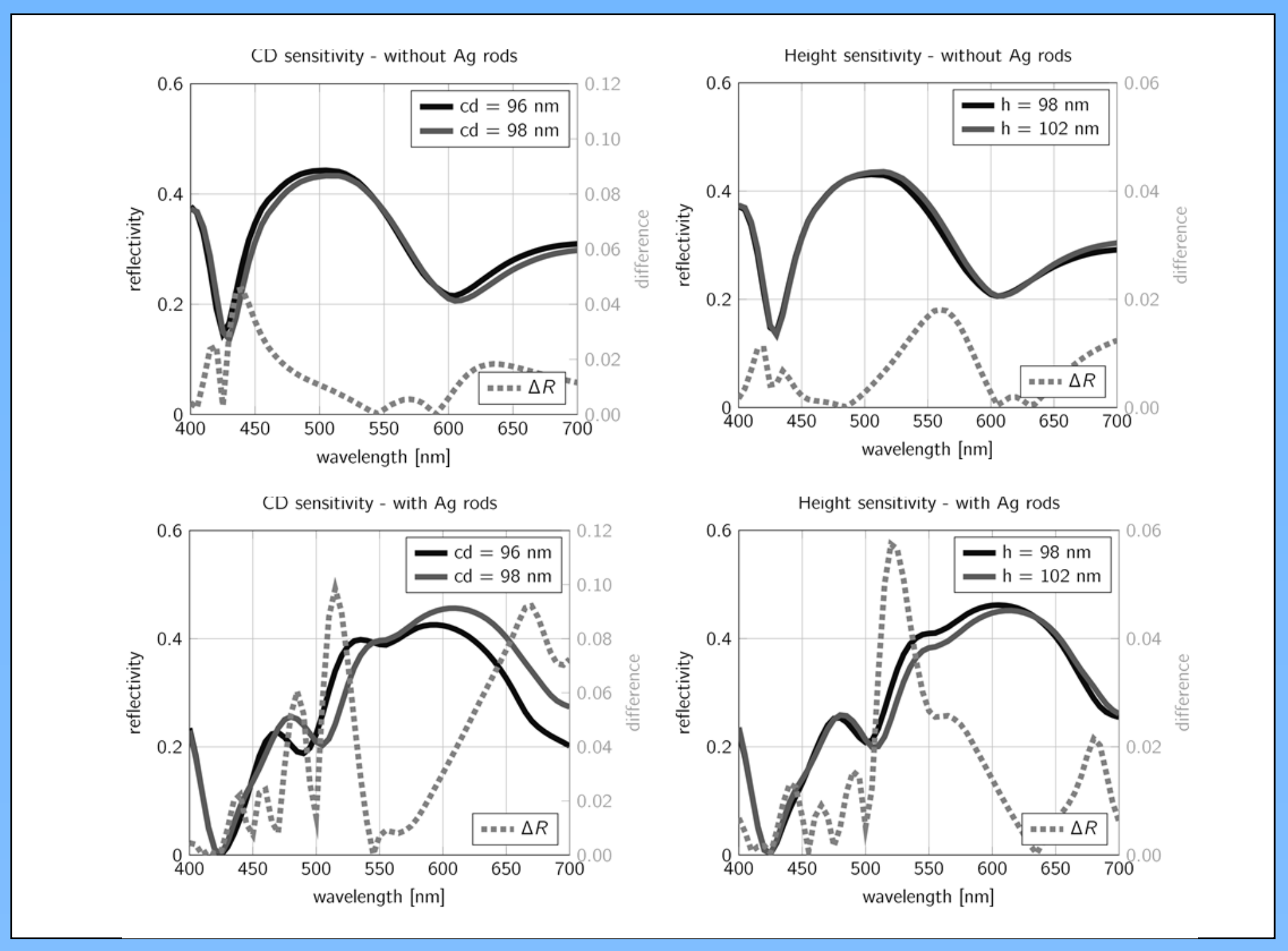
Near- to far-field transformers



FEM-simulation

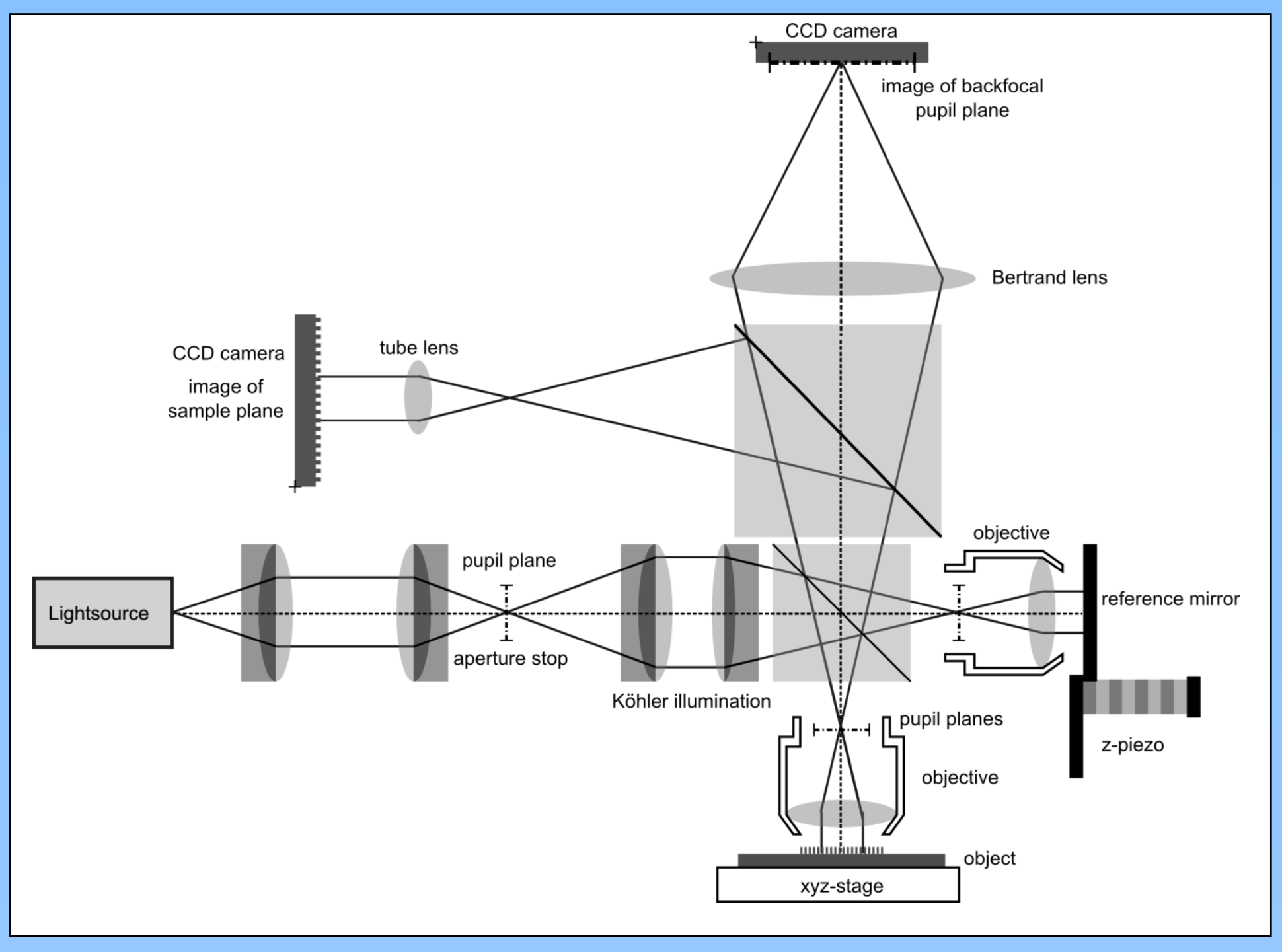
It is generally known that information about interesting features of small structures can not propagate because this information is connected to evanescent waves. Our idea is to convert these evanescent waves through plasmonic nanostructures into propagating waves. Structures which make such a conversion with a high efficiency are called “near- to far-field transformers”. In our experiments we have chosen nanorods as near field structures because it is well known that these structures can show surface plasmon resonances which can be excited by an electromagnetic field in the visible wavelength range. These resonances are dependent on sub-wavelength spatial variations of the geometry of the nanorods and should be influenced by the surrounding electromagnetic field of the grating structure we want to analyze.

There have been various approaches to improve scatterometric sensitivity, mainly by increasing the used illumination wavelength range, variation of the incidence angle or a high numerical aperture illumination as well as combinations with other measurement methods as for example white light interferometry. While all these methods increase the sensitivity of the measurements by increasing the information content of the measurement itself, the approach presented in this work comes from a different direction. The simulation branch needed for all scatterometric measurements can be exploited itself to design an optimized scatterometric sensitivity inherent to the structure. While this may not be generally applicable due to practical constraints, it is conceivable for alignment, testing or calibration targets.



Increased sensitivity: CD, Height

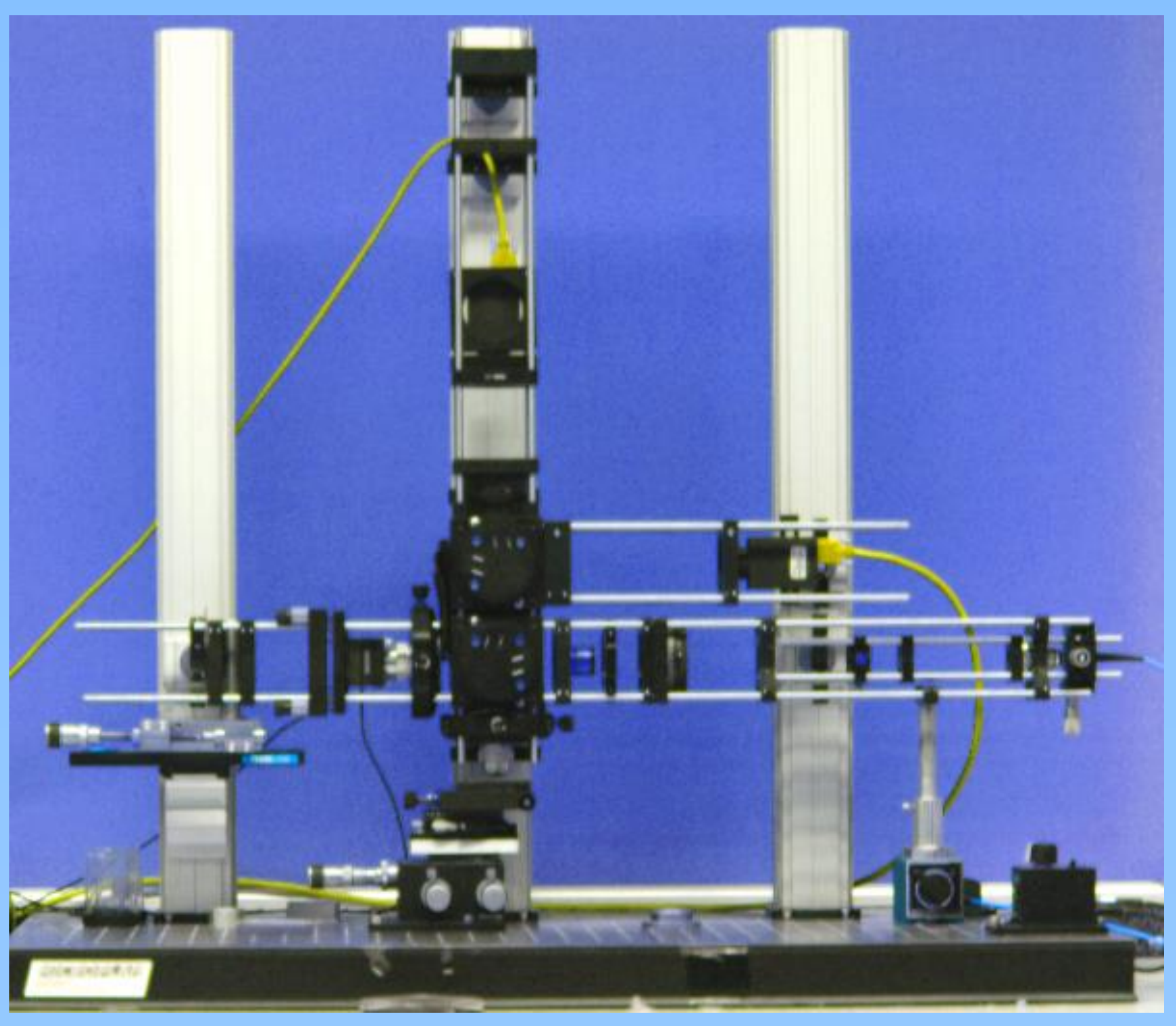
Interferometric Fourier-scatterometry



Linnik-Fourier-Scatterometry

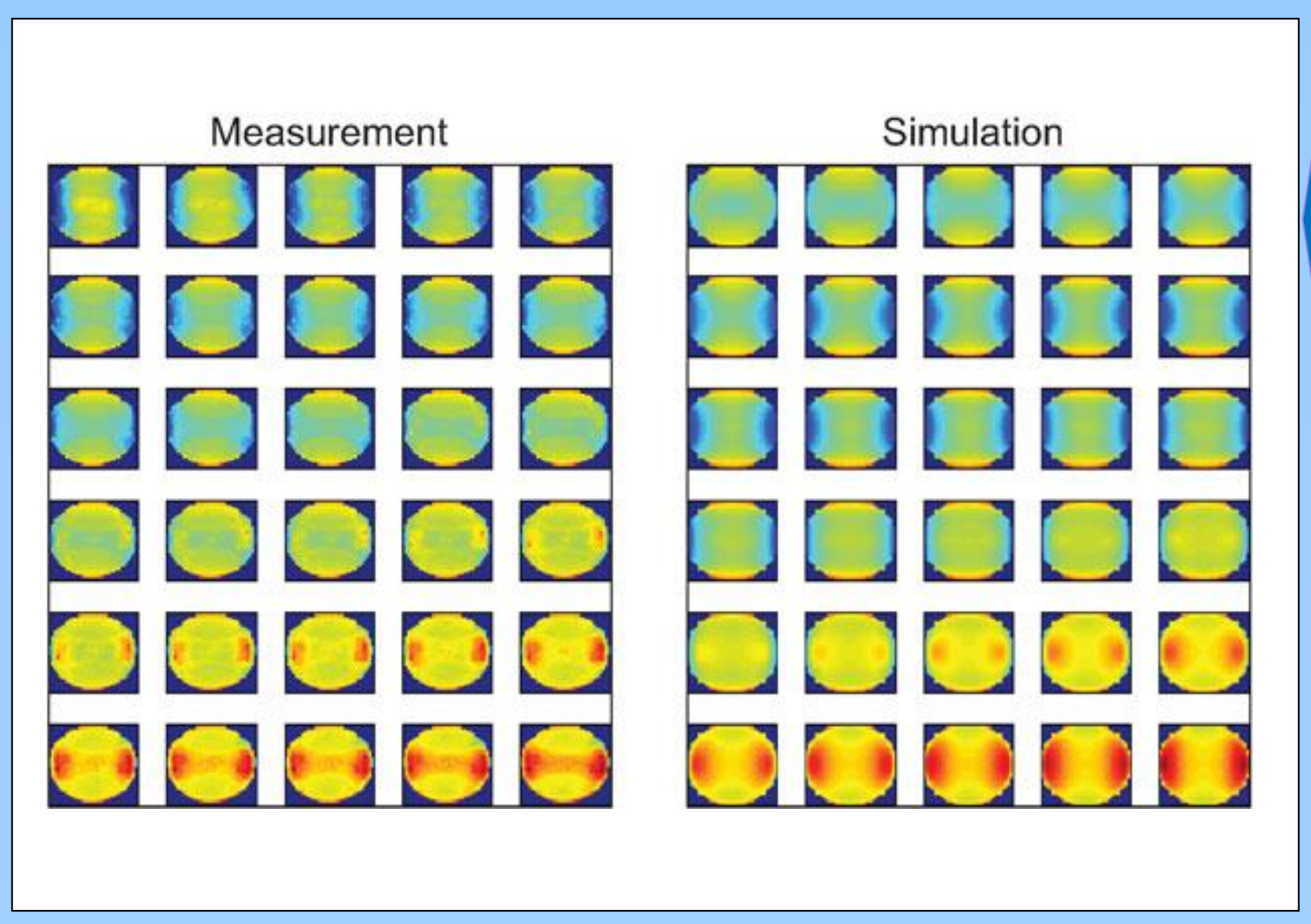
Scatterometry is a well-established, fast and precise optical metrology method used for the characterization of sub-lambda periodic features. The Fourier scatterometry method, by analyzing the Fourier plane, makes it possible to collect the angle-resolved diffraction spectrum without any mechanical scanning. Because additional depth sensitivity for nanostructures is often required, a combination of profile-sensitive Fourier scatterometry with white light interferometry, which takes advantage of the superior subnanometer resolution for topographic measurements, has been studied. In addition to an angle-dependent angular response, performing a Fourier analysis of the white light signal even facilitates wavelength-dependent measurements without spectrometer.

We use a Linnik-type interferometer which enables us to use a large numerical aperture of NA=0.95 to collect the diffraction spectrum for higher angles in the pupil plane. The trade-offs of this approach include higher calibration demands and a less compact design that is also more sensitive to environmental influences such as vibrations. A polarizer allows to select s or p polarized illumination. The backfocal plane of the objectives is imaged with the help of a Bertrand lens on a CCD Camera, while the image plane is imaged with help of a matched tubelens. Both lenses are especially designed and aberration corrected for the used microscope objective.



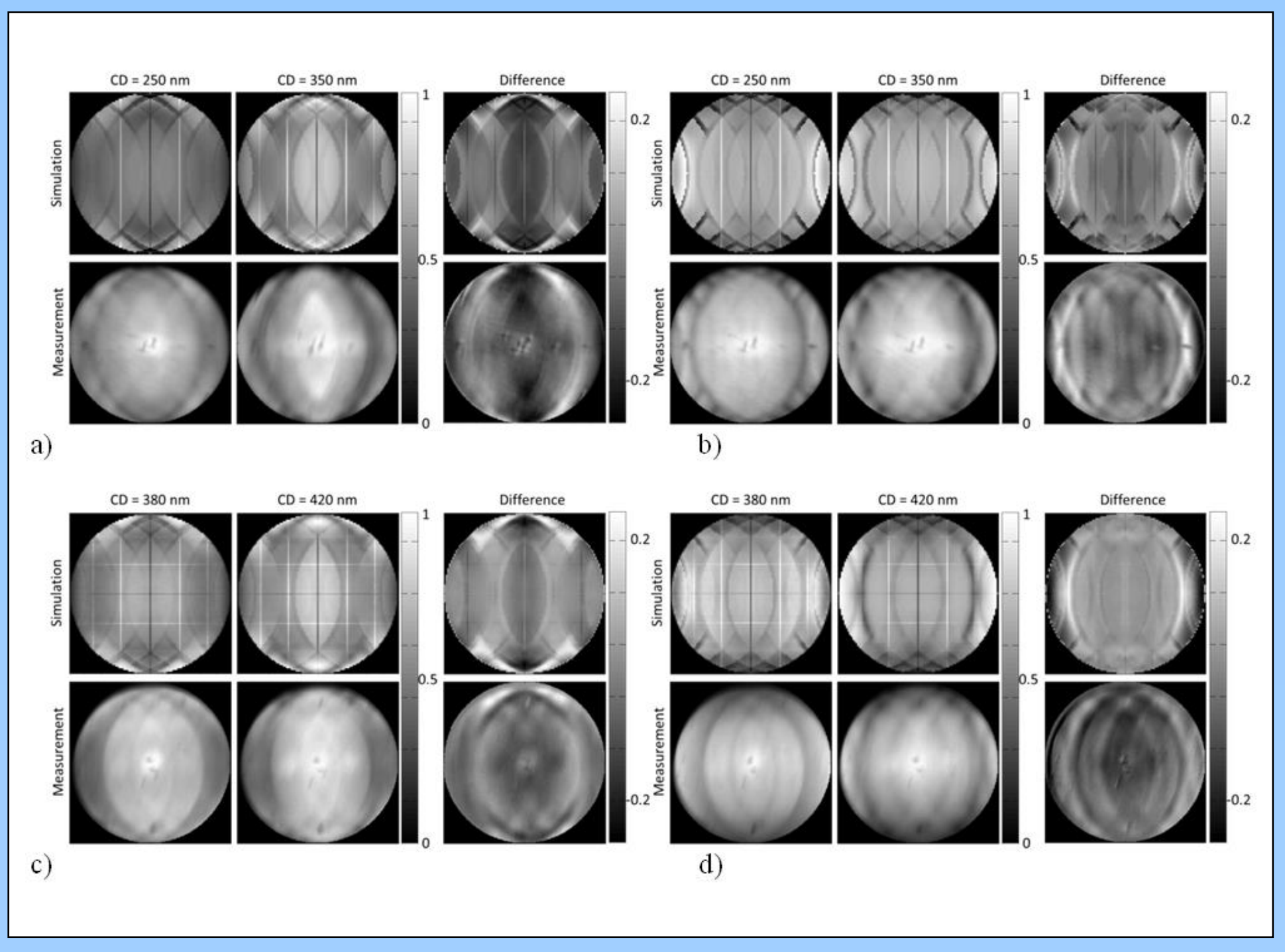
Experimental Setup

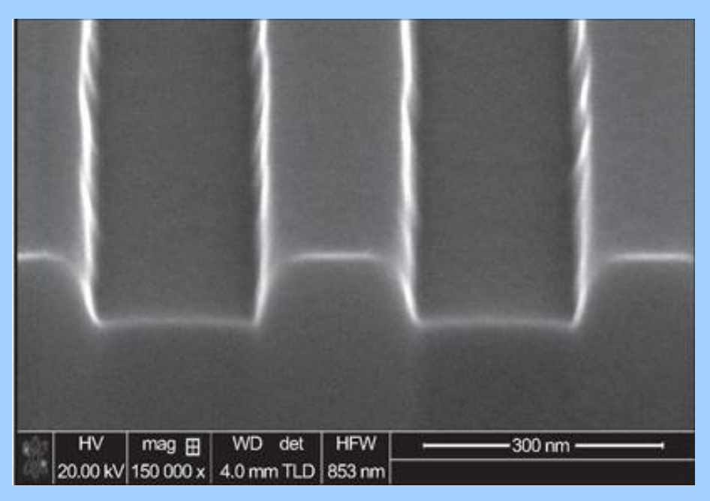
Results



To compare the simulation results for the white light interference Fourier scatterometry, we have chosen an etched silicon line grating. It has a nominal CD of 200 nm and a period of 400 nm. Because we are illuminating with white light from 400 to 800 nm, this structure is in the sub-lambda regime. For the reconstruction, we computed a library including the variations of the parameters around the values obtained from AFM and SEM measurements. The library was computed for mid-CD values from 160–200 nm in 1 nm steps, the height was varied from 65 to 95 nm in 1 nm steps, and the SWA was varied from 74 to 85° in 0.5° steps. Rounding was also taken into account. However, the sensitivity was significantly lower compared with the other parameters, so rounding did not have an impact on the reconstruction results.

In this case the analyzed structures are polymer line gratings fabricated by two-photon-polymerization. The period of the lines is 1800 nm while the height is 500 nm. There are gratings with different line widths (250 and 350 nm). The complete grating is covered with a 20 nm layer of gold. Pupil images for these structures were taken for both s and p polarization. The resulting images and the difference in pupil plane intensity are shown together with the results of the same measurements and simulations with added nanorods between the lines. For the case with rods the linewidths are 380 nm and 420 nm, meaning that the difference is smaller than for the lines without the rods (250 nm to 350 nm). The rod itself has a radius of approx. 175 nm and a height of 500 nm. The results show a good agreement between simulation and measurement.



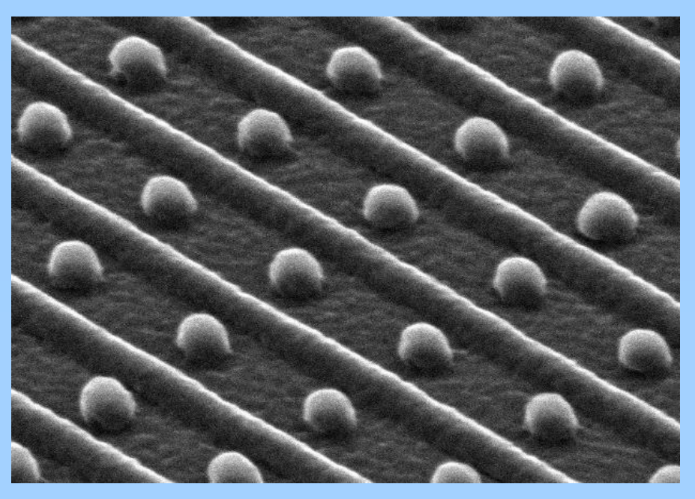


Interferometric Fourier-Scatterometry:

CD=200 nm, p-pol,

z-scan: −150 to 150 nm, stepsize 10 nm

Silicon grating from Qimonda AG, Dresden



Fourier-Scatterometry

a) line grating p-pol b) line grating s-pol
c) lines+rods p-pol d) lines+rods s-pol

2PP-structures from C. Reinhardt, Laser Zentrum Hannover

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