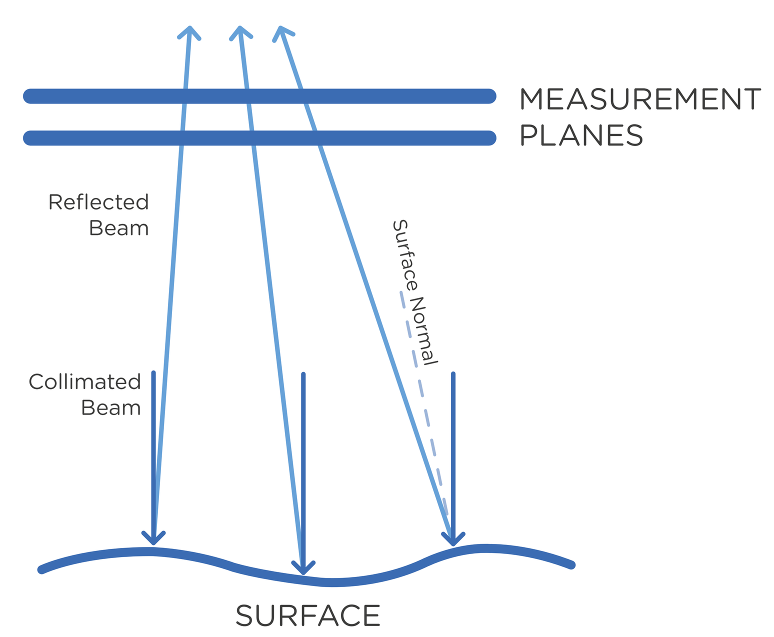
WOOPTIX

WAVE FRONT PHASE IMAGING APPLIED TO WAFER GEOMETRY

Lateral Resolution better than 5µm & Height Resolution of 0.3nm

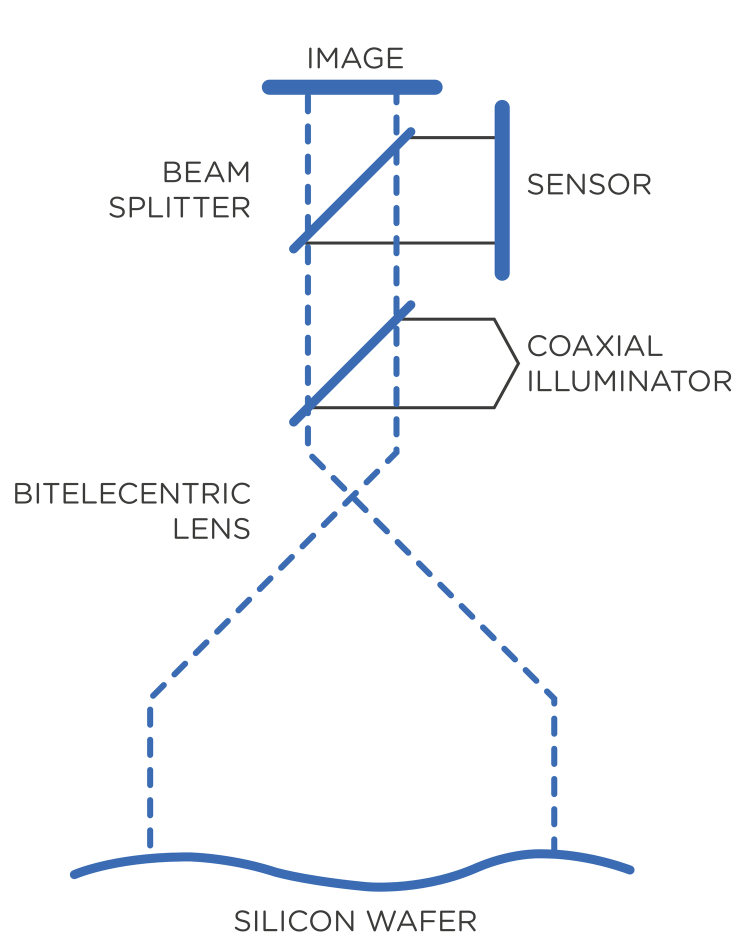
INTRODUCTION

WFPI is based on registering the intensity distribution at two different optical planes using two conventional imaging sensors while acquiring two images with the exact same field of view.



The wave front phase is translating into measuring the slope of the surface which allows for a geometric reconstruction of the silicon wafer.

WFPI system can be achieved by using a powerful LED to illuminate the silicon wafer through a bitelecentric lens and measuring the reflected intensity using 2 industrial cameras at different locations along the optical path.



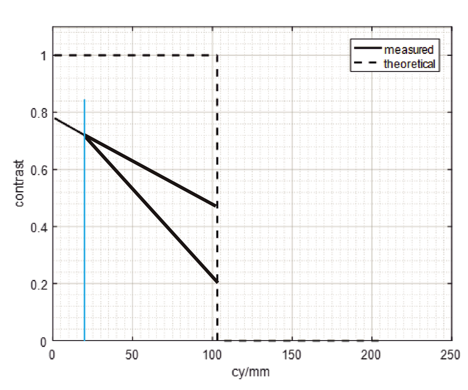
An entire silicon wafer can be imaged in a single snap shot providing depth information in every pixel acquired.

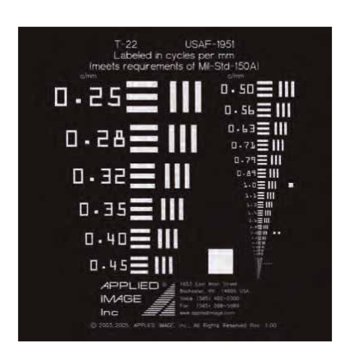
LATERAL XY RESOLUTION

To measure XY resolution, the WFP map must first be calculated, then one can measure different contrast values for resolution values using a known target. Optical resolution limit is set by F# = 7.5 and λ = 650nm = **4.875**µm

System Limitation: $cy/mm = \frac{1mm}{2\times 24\mu m} \approx 20$

Optical Limitation: $cy/mm = \frac{1mm}{2\times 4.875\mu m} \approx 103$

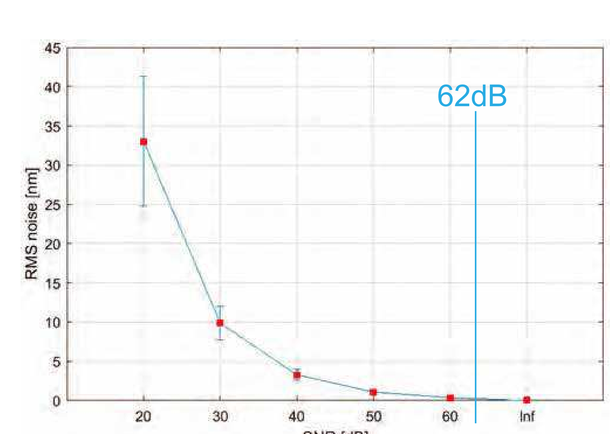




If extrapolated, the contrast vs lateral frequency response in the WFPI system is expected to detect a signal up to the optical resolution limit of 4.875µm.

AMPLITUDE Z-HEIGHT RESOLUTION

Noise limitation in WFPI is given by the image sensors used. Signal-to-noise-ratio (SNR) levels ranging from 20dB to infinite (equivalent to ∞ exposure time were plotted. The two noisy images were analyzed using the WFPI algorithm to generate Z-height distances with noise.



Camera Noise 62dB

RMS Noise 0.3nm

σ = 0.1nm

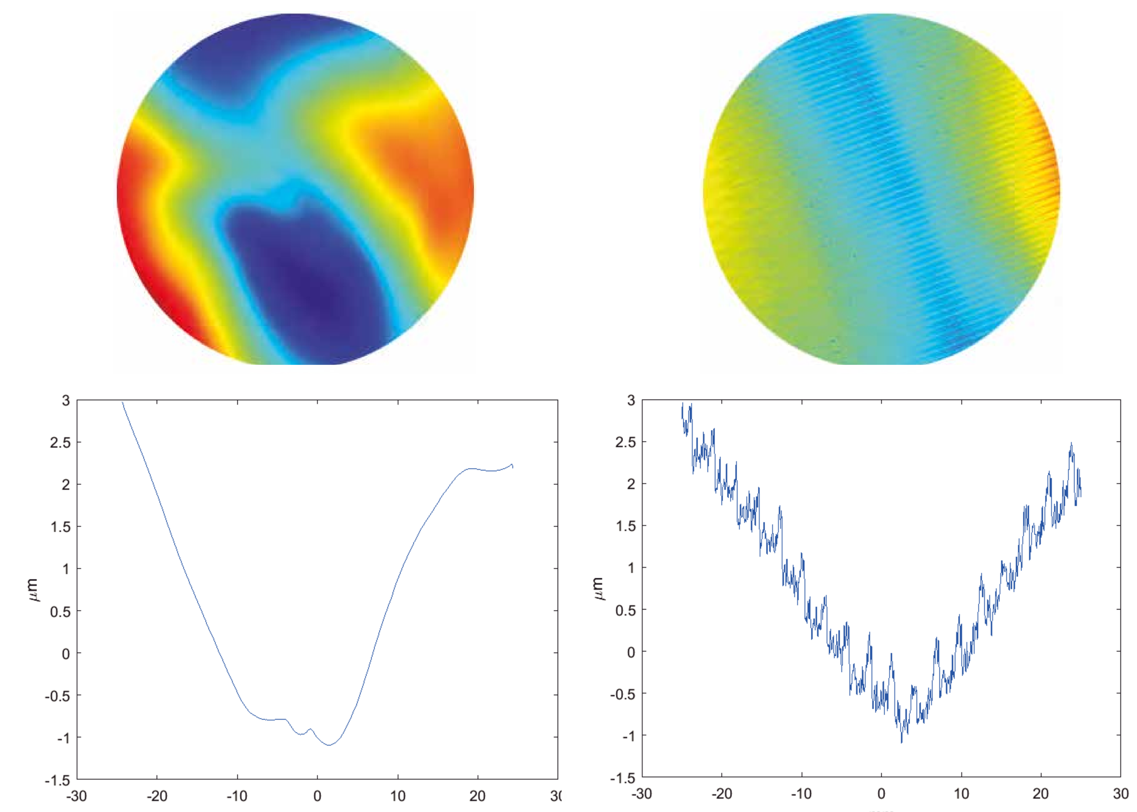
The noise level for AFM is about 0.1 nm and the noise level for an optical profiler is on the order of 0.4 nm.

RESULTS

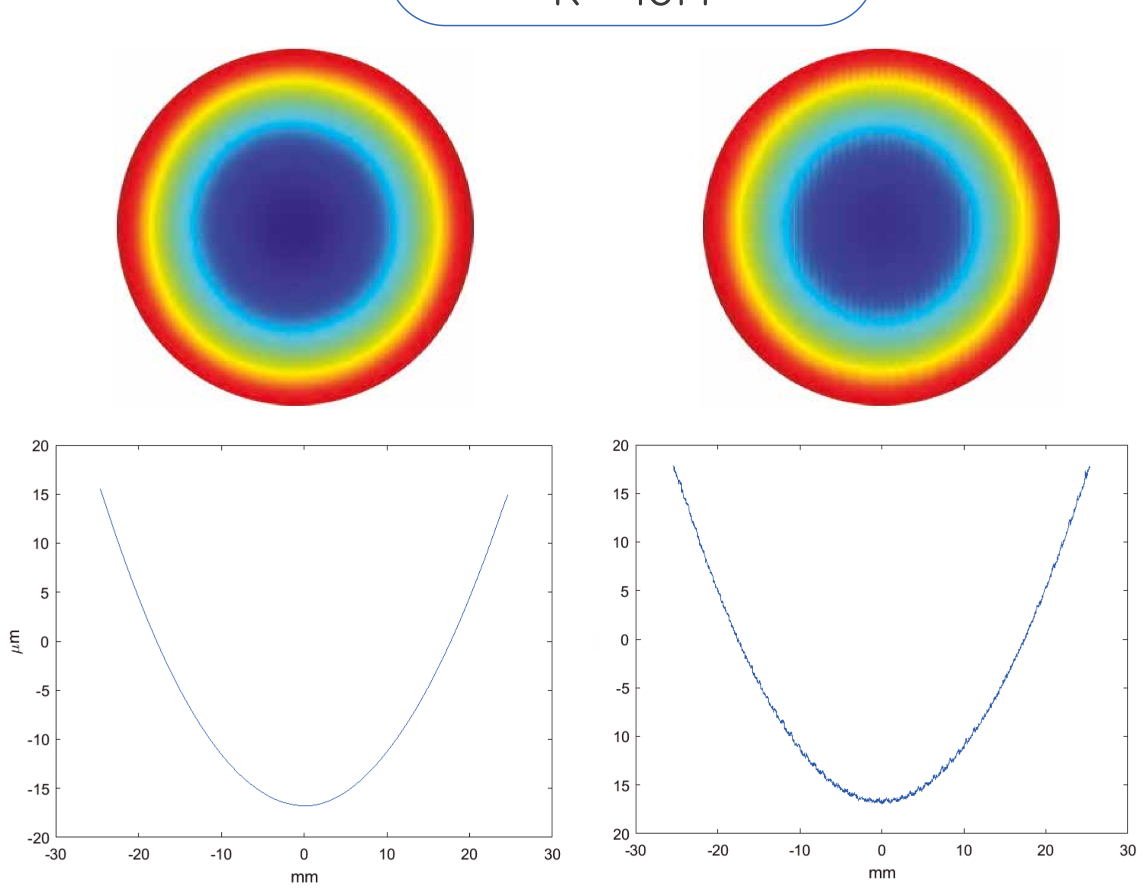
WFPI VS WHITE LIGHT INTERFEROMETRY

- 50 mm mirror
- 5 million data points in both data sets
- 0.1 seconds for WFPI
- 150 seconds for white light interferometry
- Extremely los noise in WFPI

FLAT MIRROR



CONCAVE MIRROR R = 10M



CONCLUSIONS

WFPI can acquire millions of wafer topographic data points with µm level lateral, and sub nm Z-height resolution, on a silicon wafer in a single image snapshot.

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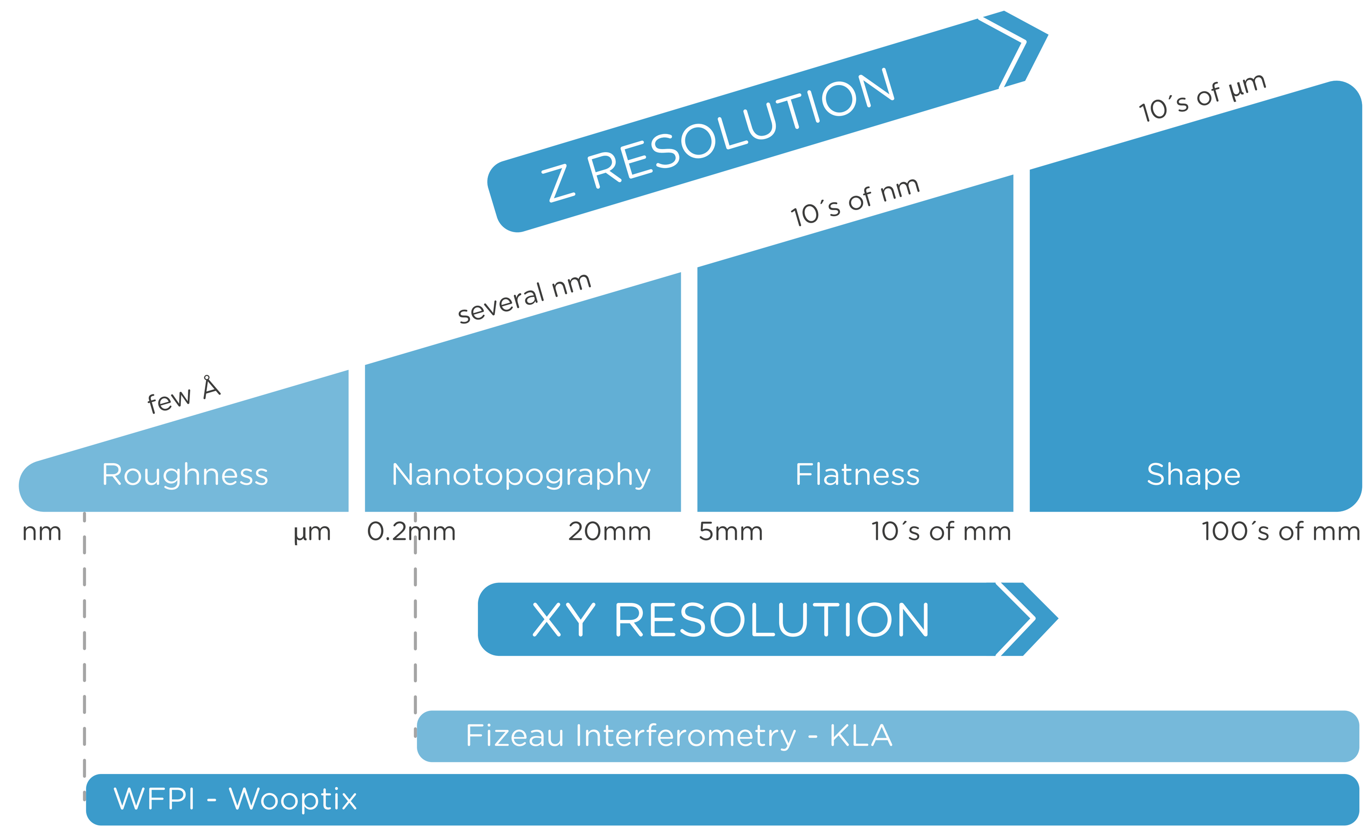
WFPI measurers the silicon wafer geometry of the entire wafer in just a single snapshot taking only 0.1 seconds collecting millions of data points with higher lateral resolution and better height resolution than any current semiconductor fab metrology systems.

THE SYSTEM

300 mm system currently in progress of being built.

System for 50mm wafers have been built with 24µm lateral resolution and 4.34 million data points acquired in 0.1 seconds.

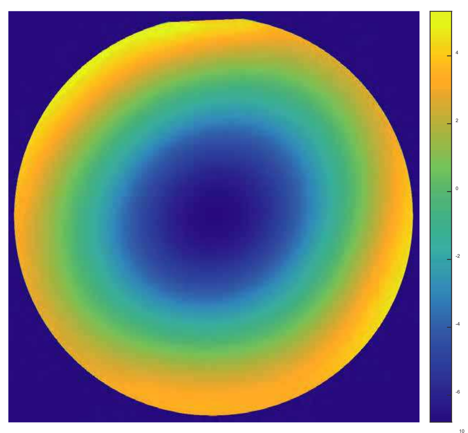
COMPETITION

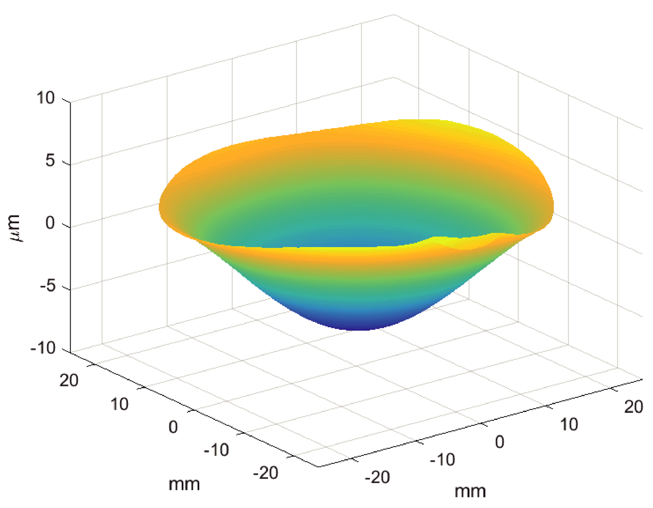


Fizeau interferometry – state of the art and most advanced fab wafer geometry system – collects 700 thousand data points in 60 seconds with resolution above 300µm per data point

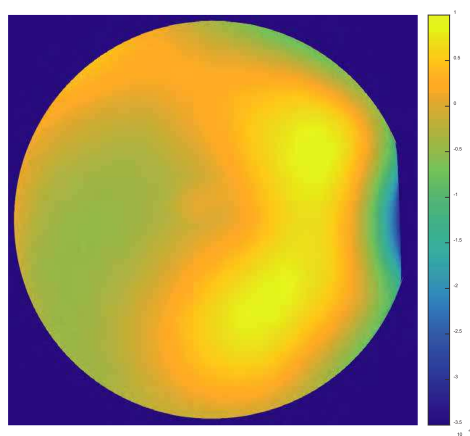
DATA

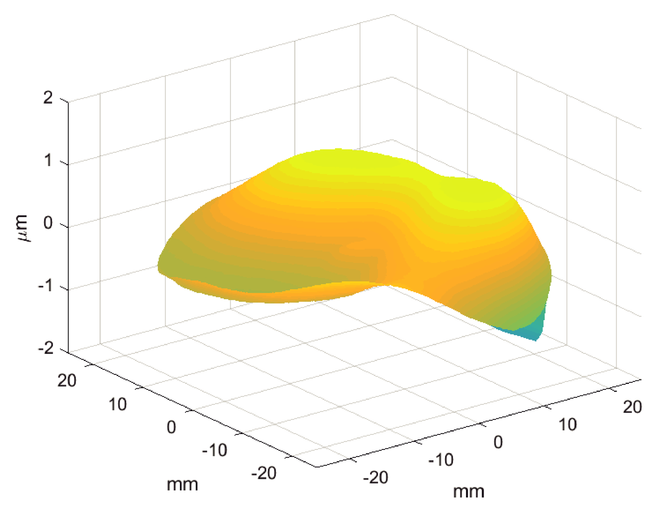
BOW



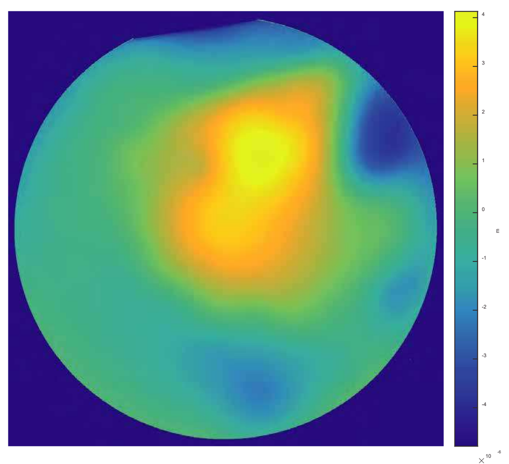


WARP

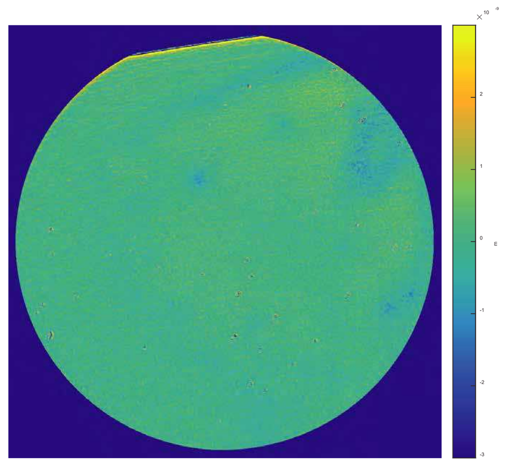




NANOTOPOGRAPHY ROUGHNESS

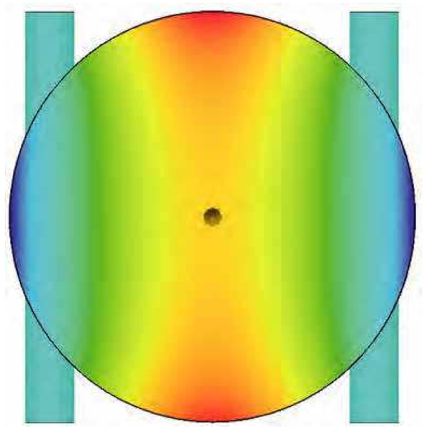


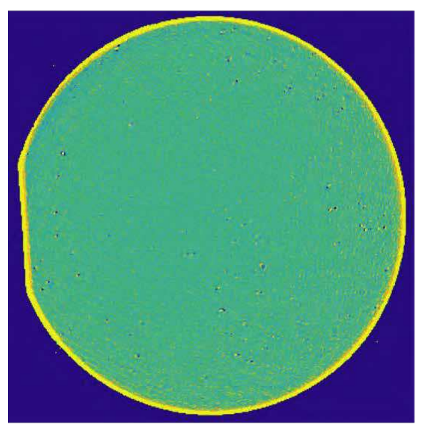
Double Gaussian filtering



NANOTOPOGRAPHY ROUGHNESS

Wafer on the Robotic handler arm using filtering





PATTERNED WAFER GEOMETRY