Simulation of Chucked Wafer Flatness

G. Schmöller, R. Johannes

immersive SIM engineering

P. Wagner, H. Gerber

Wacker Siltronic

Content

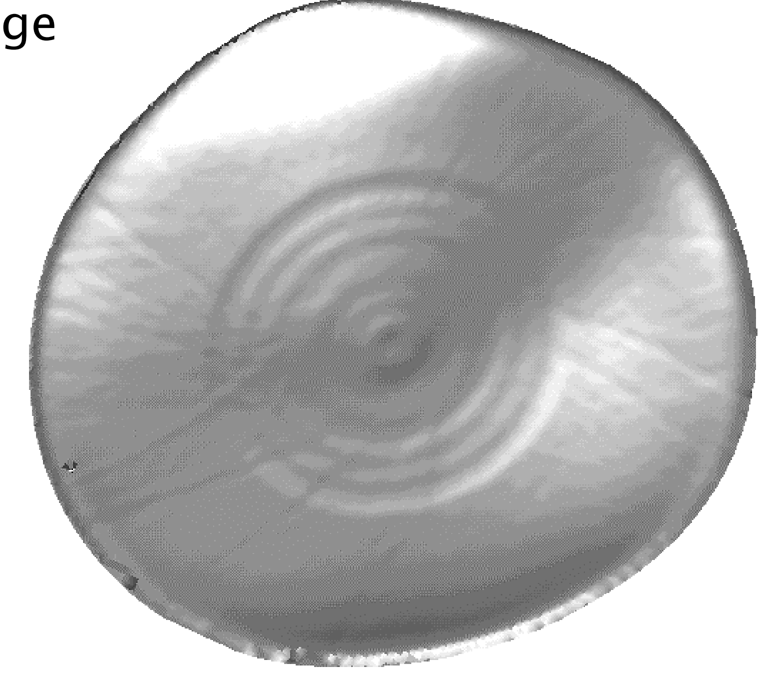
- motivation
- Finite Element Analysis (FEA) with Si wafers
- used FE models
- influence of
  - pin distance
  - backside contour
  - vacuum force
- effects near solid chuck edge
- summary and outlook

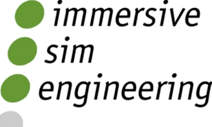
Motivation

- to predict surface flatness of wafers clamped on litho-chucks
- to avoid usage of chucks for flatness measurement in production environments

FEA with Si Wafers

- extreme differences in dimensions
  (Ø 200 mm → 2 nm flatness deviation: factor 10^8)
- required mesh density results in a large number of elements
- expensive contact simulation with many iteration steps
- generates convergence problems with common FEA solvers
- bending of a circular plate
- no simplification possible without neglecting important influences





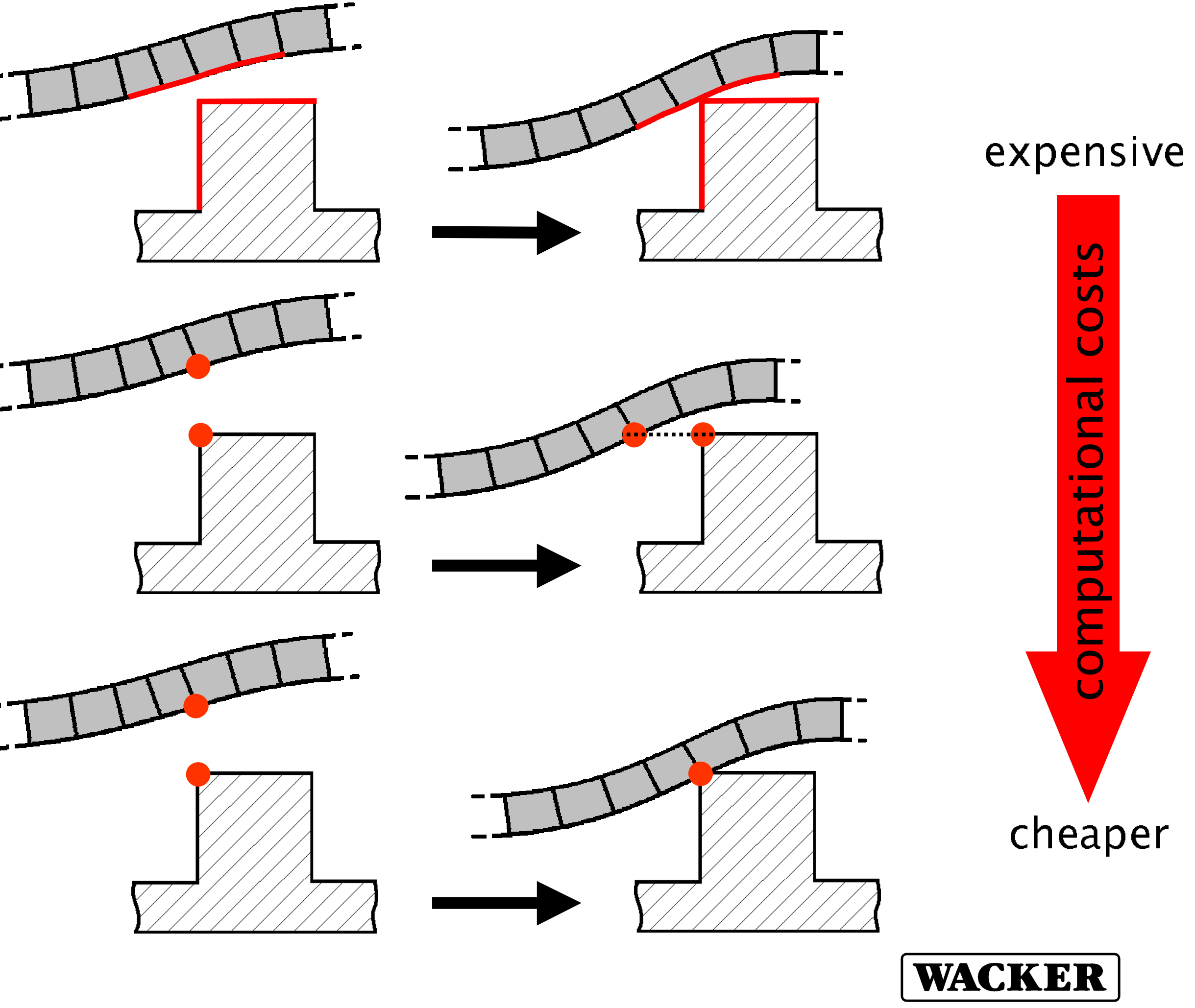
WACKER

Different Levels of Wafer/Chuck Contact

surface to surface contact

gap contact (point to point)

forced contact



immersive
sim
engineering

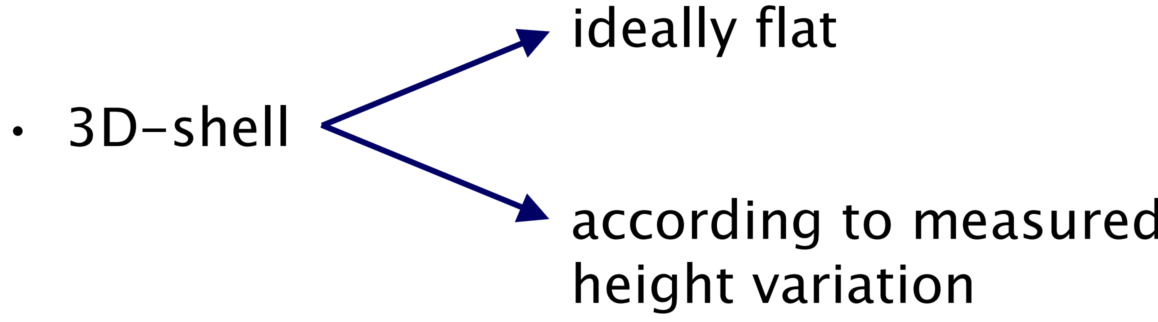
WACKER

Model Data

- Si wafer radius r = 100 mm (8" – wafer)
- constant thickness of 0.725 mm
- chuck is assumed rigid
- pin chuck with 0.2 mm pin diameter and solid edge above r = 97 mm
- vacuum force applied only inside chuck edge
- Si wafer material parameters:
  - elastic modulus E=148000 MPa
  - Poisson's ratio μ = 0.22
  - isotropic

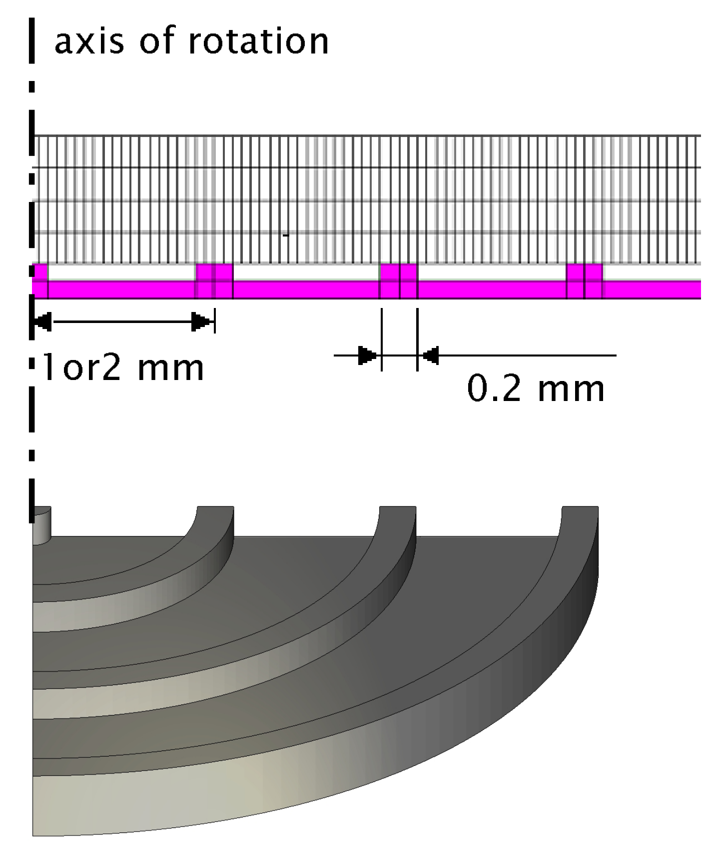
WACKER

FE Models

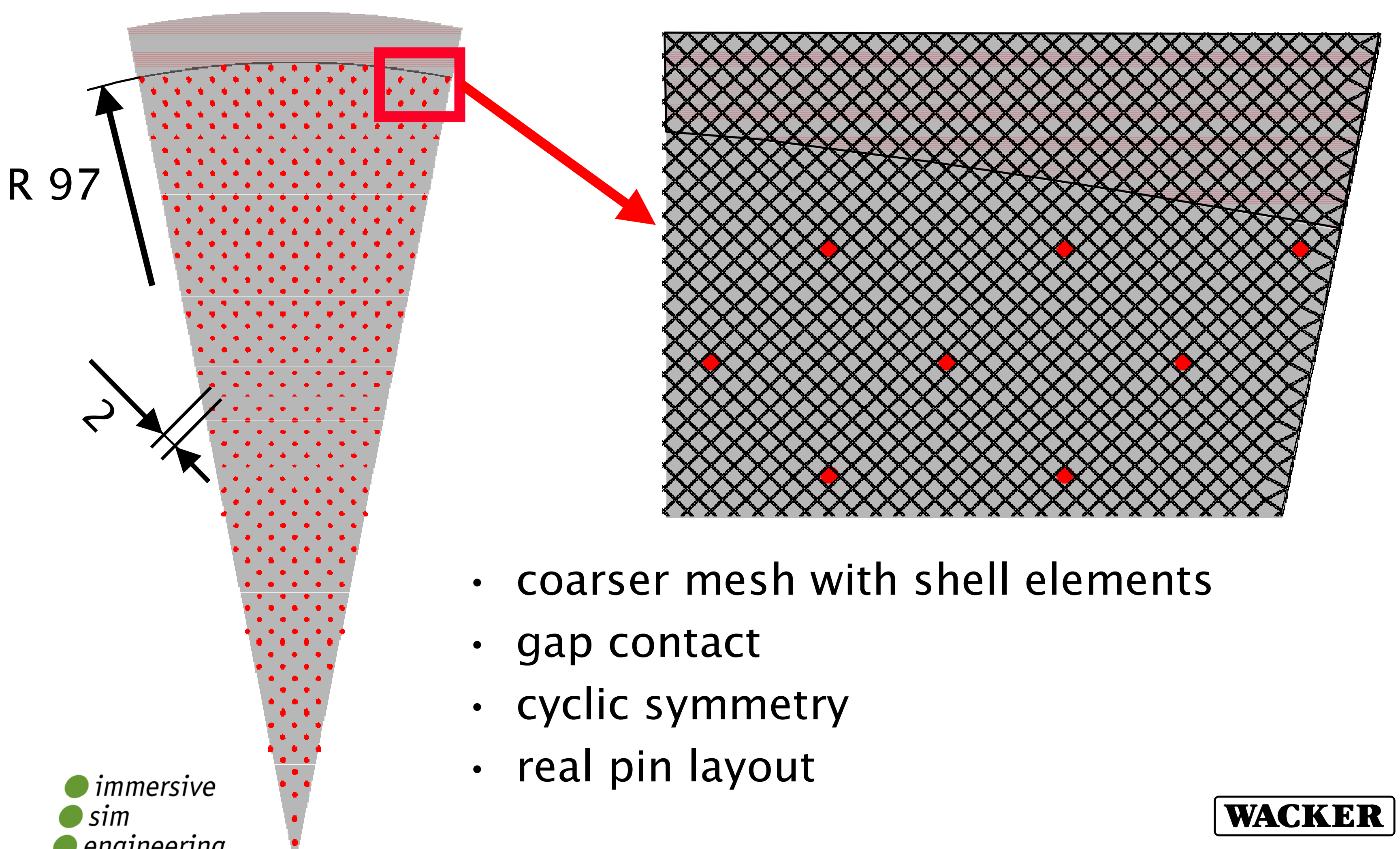


Axisymmetric Model

- fine resolution
- considers behavior of a circular plate
- surface to surface contact
- corresponds with a “ring” chuck
- allows different profiles on front- and backside



3D Model



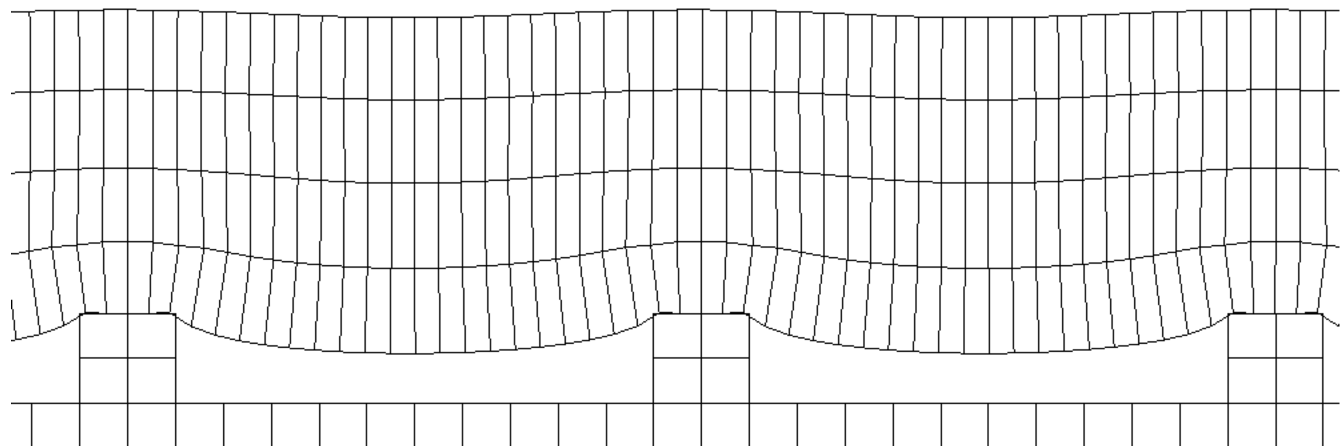
- coarser mesh with shell elements
- gap contact
- cyclic symmetry
- real pin layout

immersive
sim
engineering

WACKER

Influence of Chucked Backside Contour on Frontside

FS = BS + THK ?



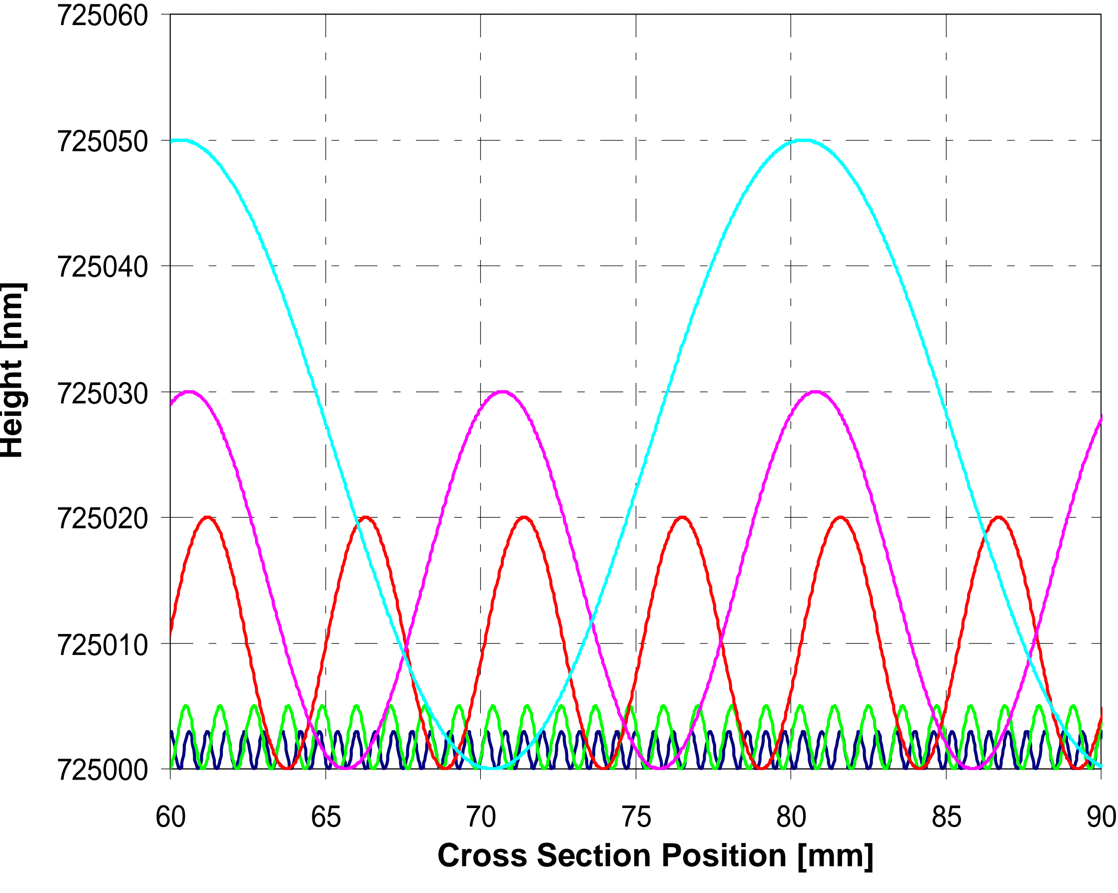
this cannot be resolved with shell elements!

Investigated Wafer Profiles

- different global forms:
  - without bow
  - negative bow (15 µm)
  - positive bow (15 µm)

- mathematical surface contour (sinusoidal waves with different wavelengths and amplitudes)

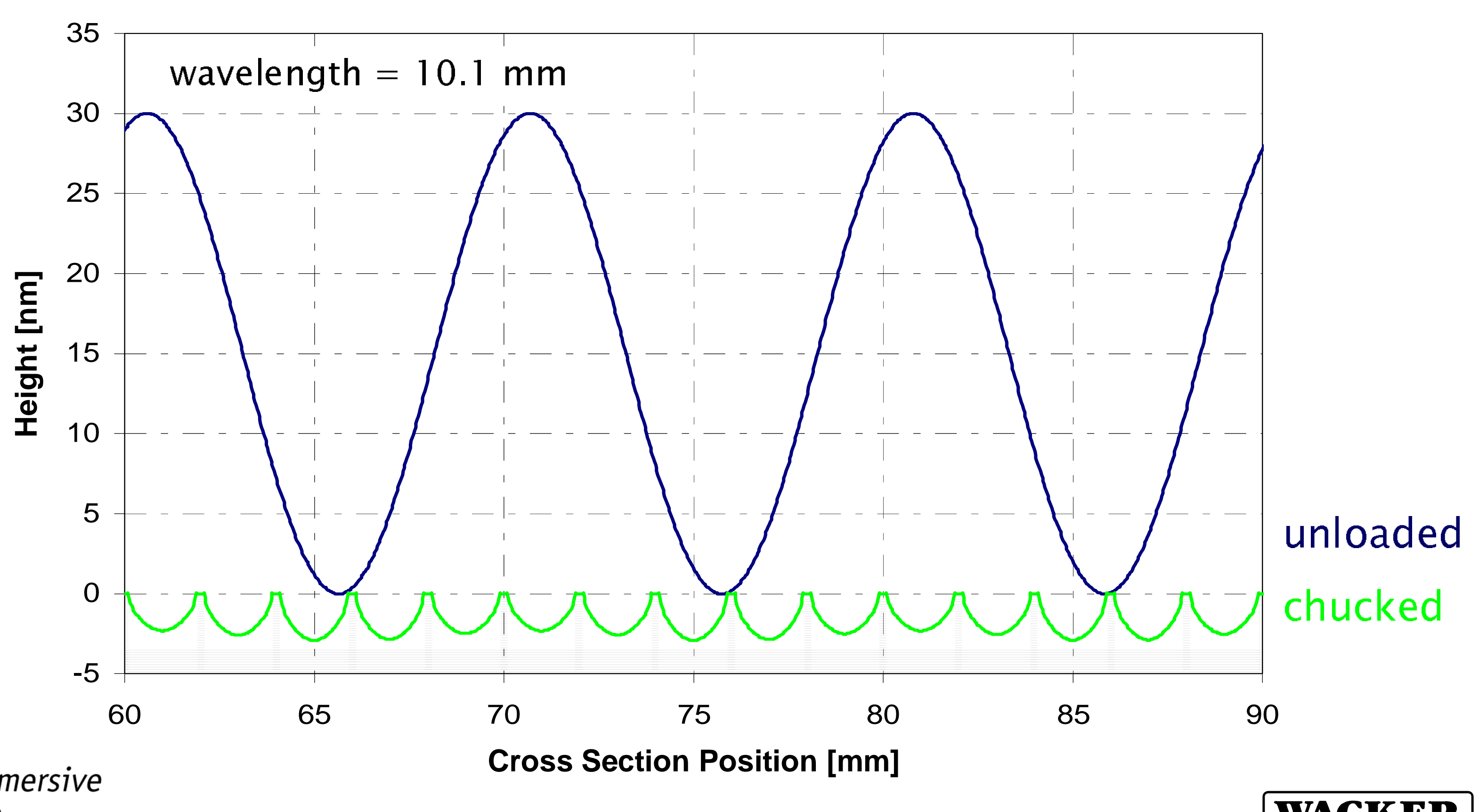
wavelength [mm]	PV [nm]
0,6	3
1,1	5
5,1	20
10,1	30
20,1	50



WACKER

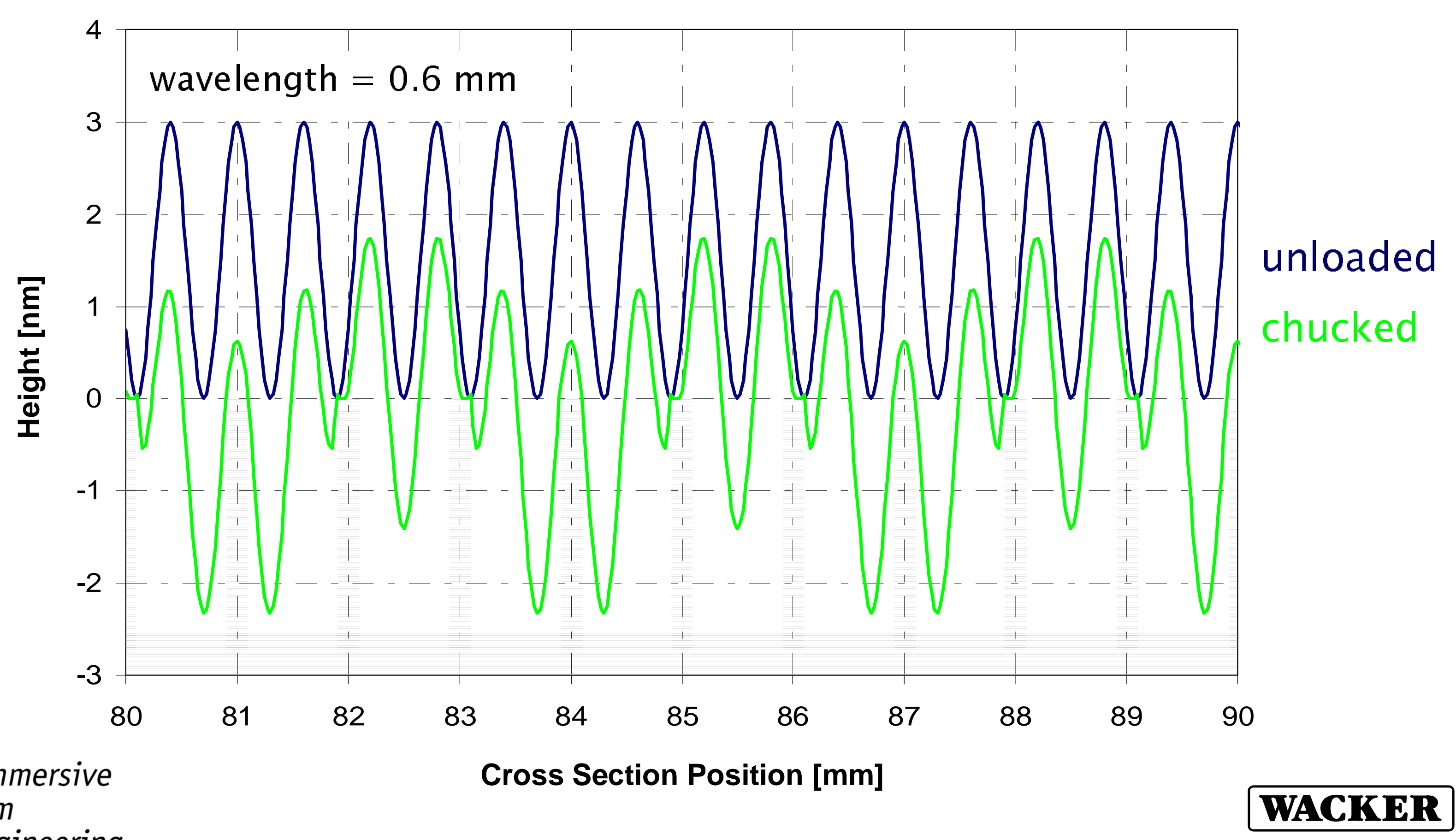
Low Frequency Profiles ...

... (wavelength >> pin distance) are pulled down to the chuck



High Frequency Profiles...

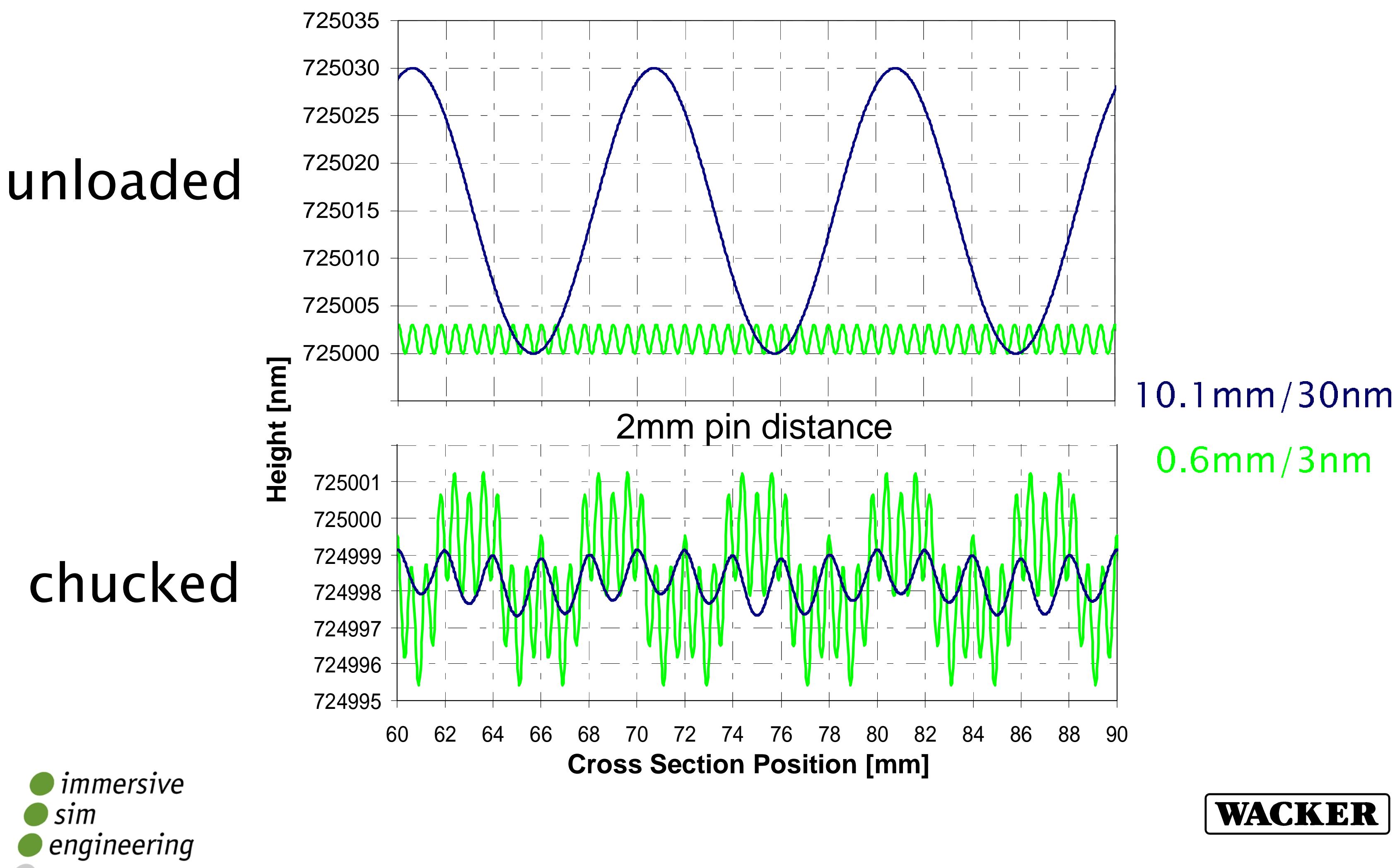
... (wavelength < pin distance) persist



immersive
sim
engineering

WACKER

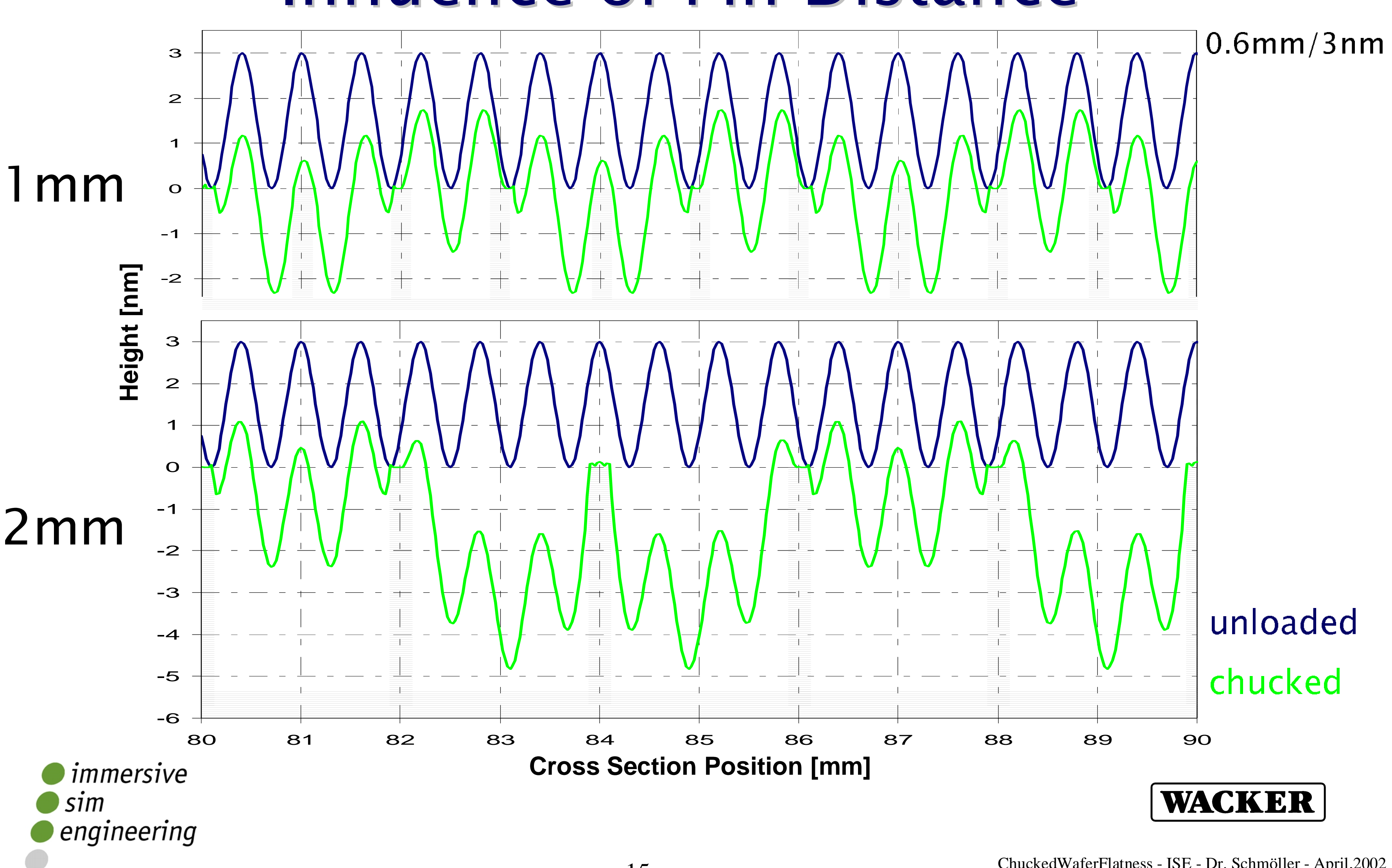
Influence on Frontside



immersive
sim
engineering

WACKER

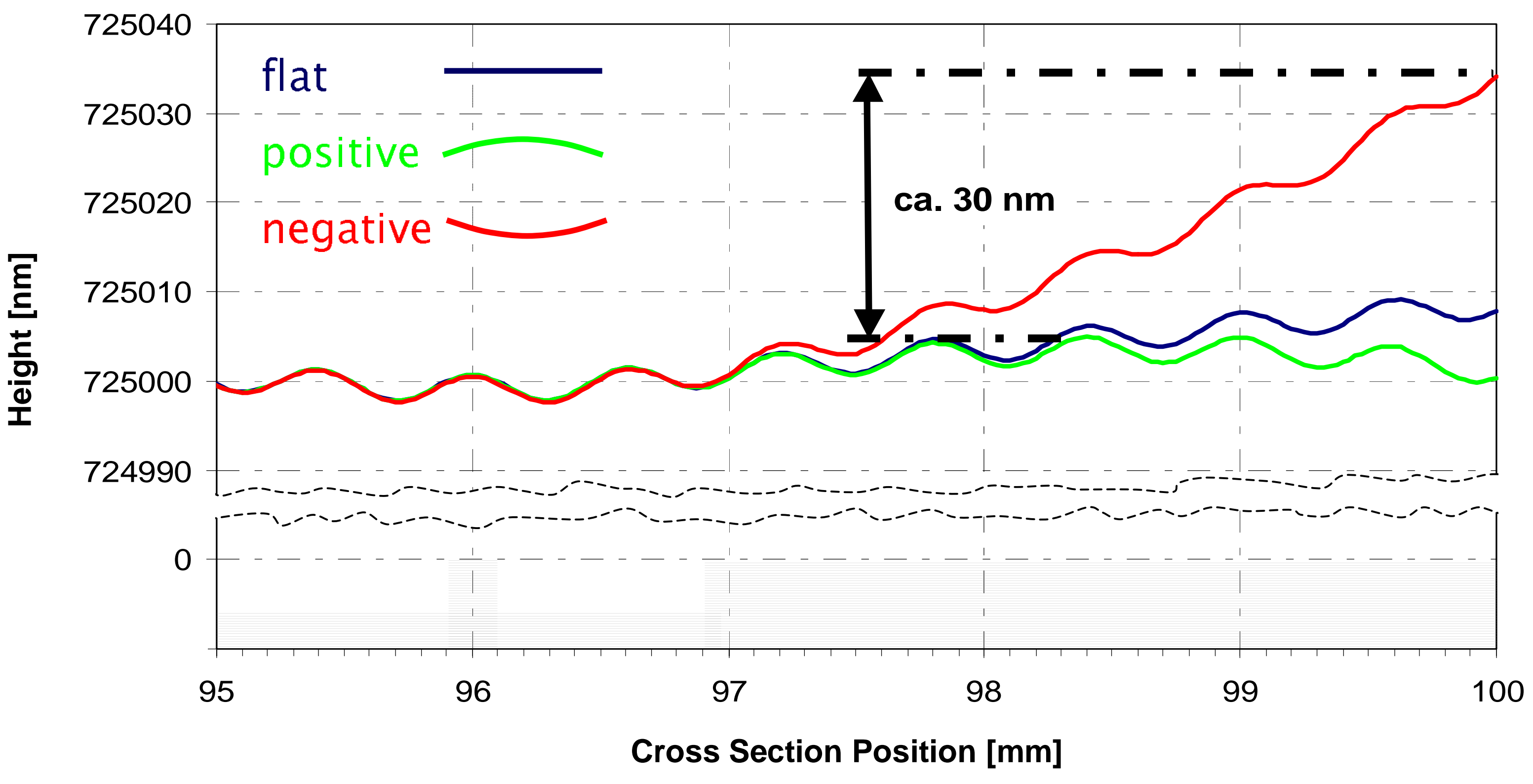
Influence of Pin Distance



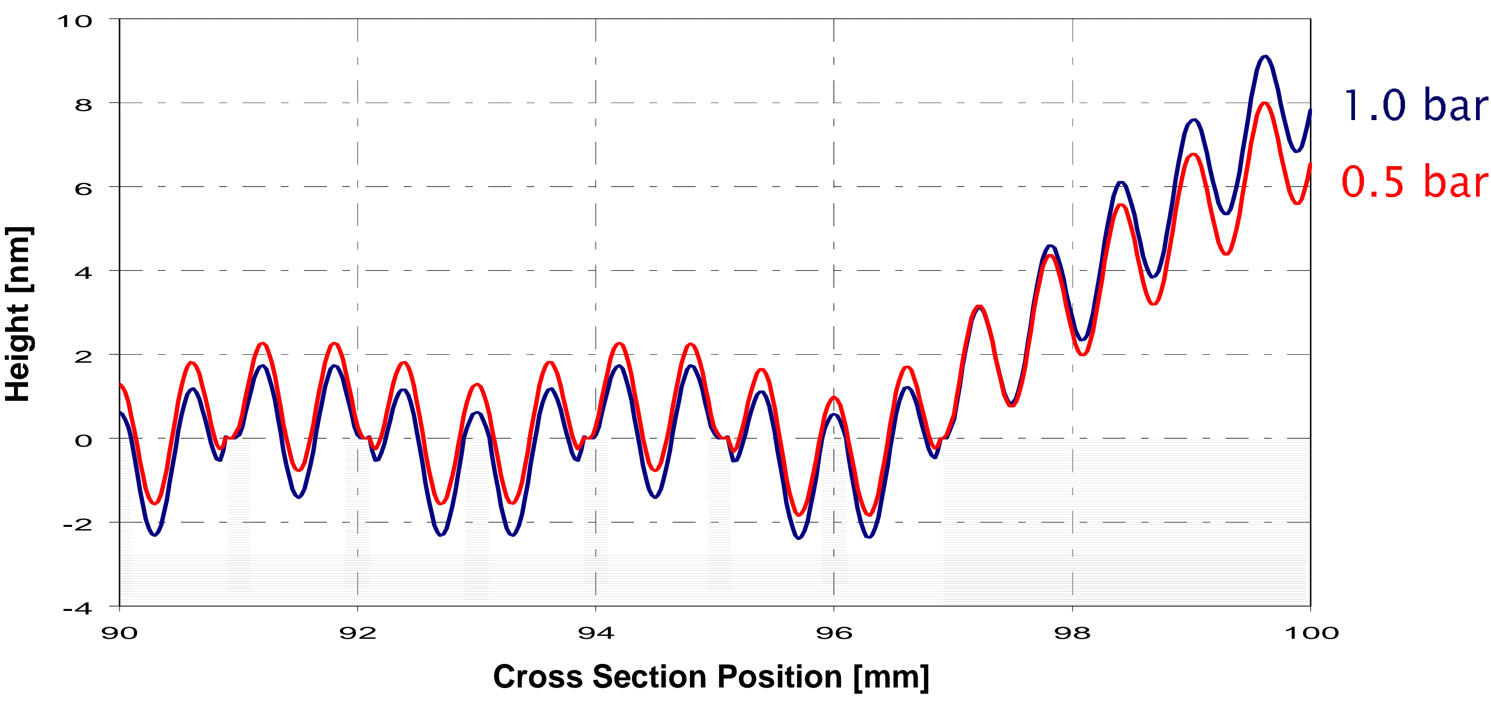
immersive
sim
engineering

WACKER

Influence of Bow on Frontside



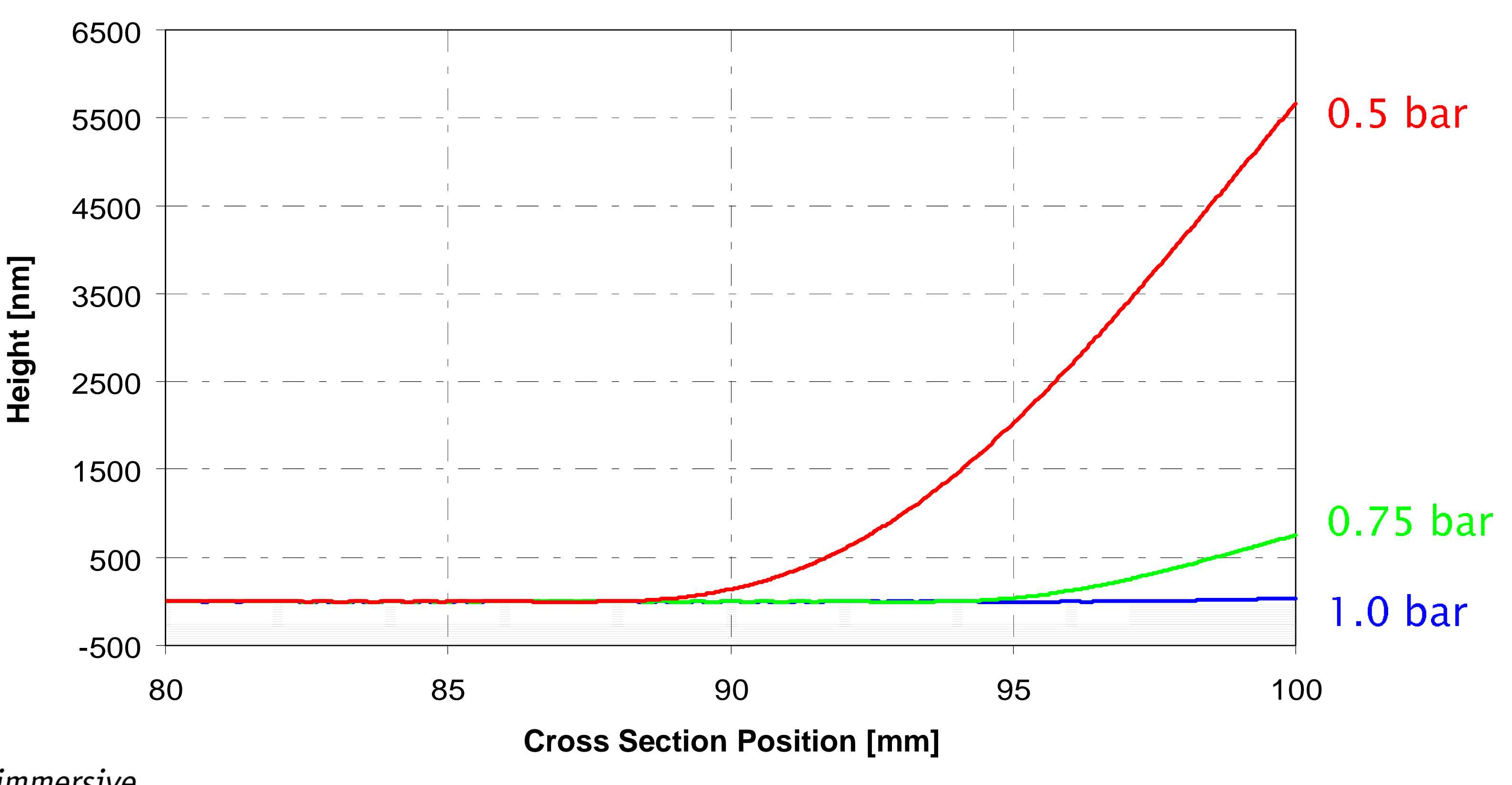
Influence of Applied Vacuum Force



reducing applied vacuum force may minimize wafer deformation and edge effects ...

Influence of Applied Vacuum Force

... but wafer still has to be safely chucked in the whole area



3D Model Ideally Flat

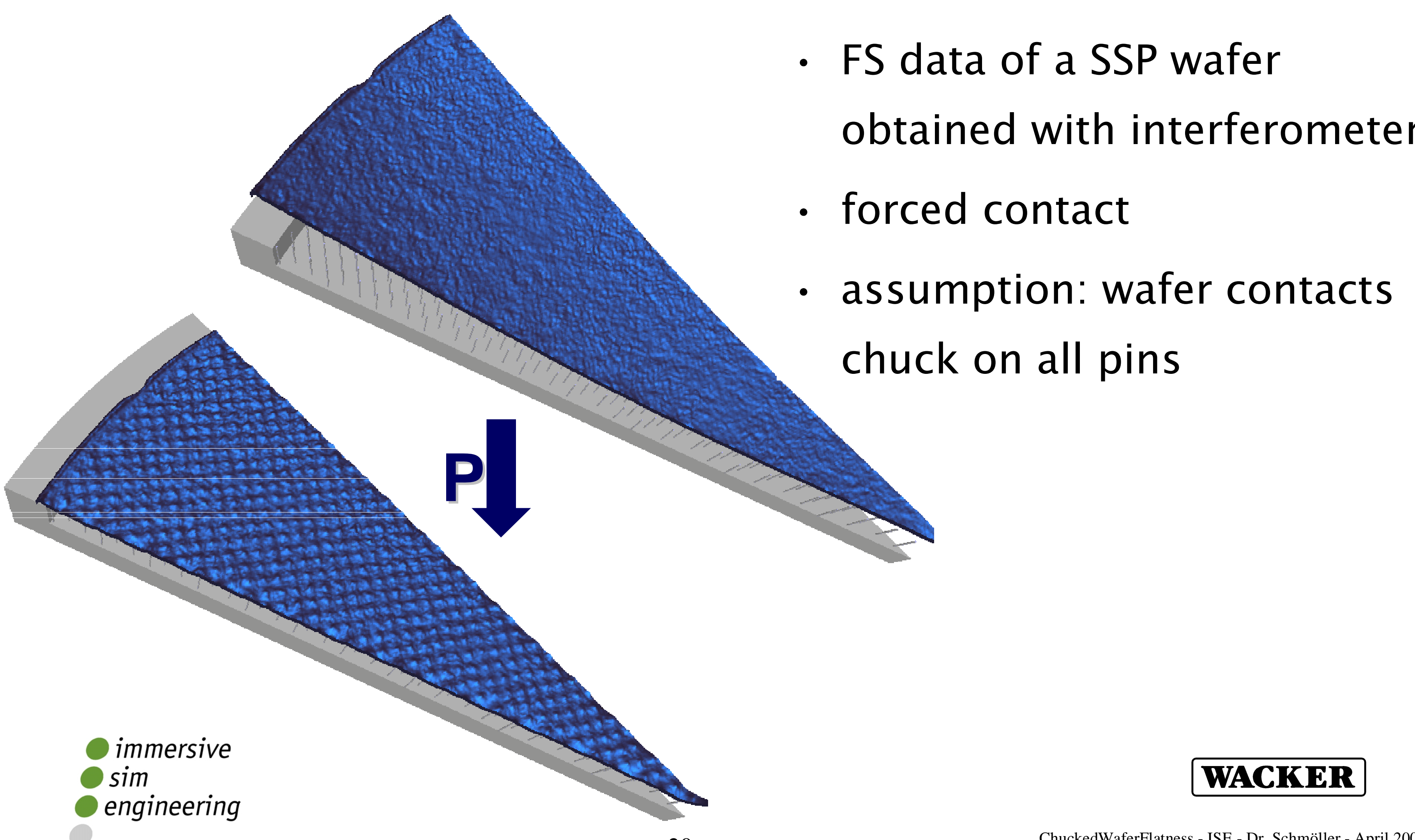
To be learned:

- boundary effects decay over short distance
- deformation independent from radial position

- Contact on all pins !

WACKER

3D Model with Measured Profile



- FS data of a SSP wafer obtained with interferometer
- forced contact
- assumption: wafer contacts chuck on all pins

WACKER

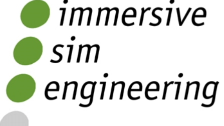
Summary

FE simulations were performed to study various influences on wafer surface topology when clamping the wafer on a stepper pin chuck

- bow and warp are drawn flat with exception of the outer margin, where the wafer profile highly depends on bow
- so do low frequency profiles
- “bad” wafers are getting better whereas “good” wafers are getting worse
- separation of true wafer topology and effects caused by clamping is not possible
- no optimal pin layout which fits for all wafers

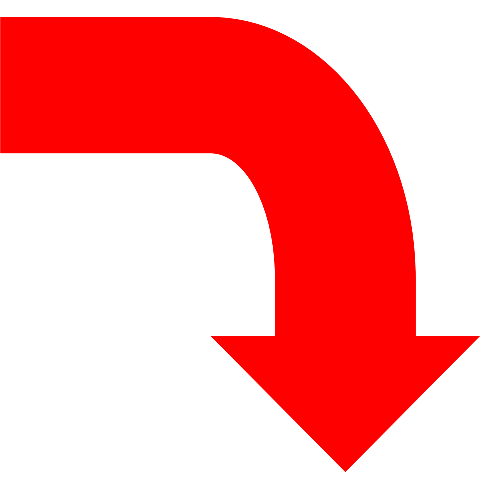
Outlook

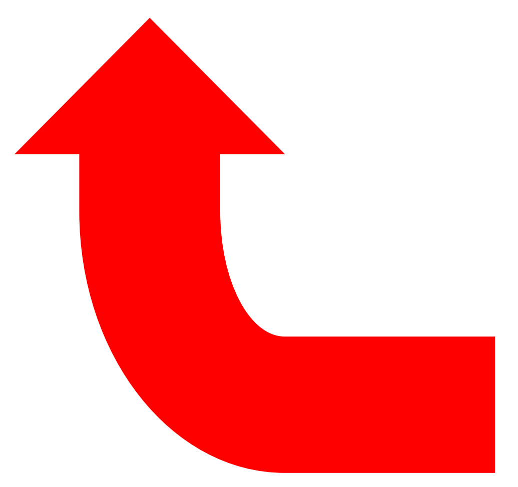
- further improvement of FEA models
- experimental verification of simulation results
- ...
- ...
- online simulation



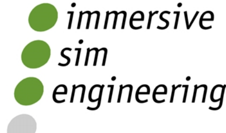
Afterthought

simulation helps
building better wafers
and processors





better processors help
to improve simulation



WACKER