

# PRÄZISIONSTEAM

## OPTICAL 3D SURFACE METROLOGY FOR INDUSTRY & RESEARCH

Benjamin Oevermann  
Global Account Management 3D Surface

This what we mean by **EXACTLY.**



# MarSurf CM/CP/CL Series – Optical 3D Surface Inspection

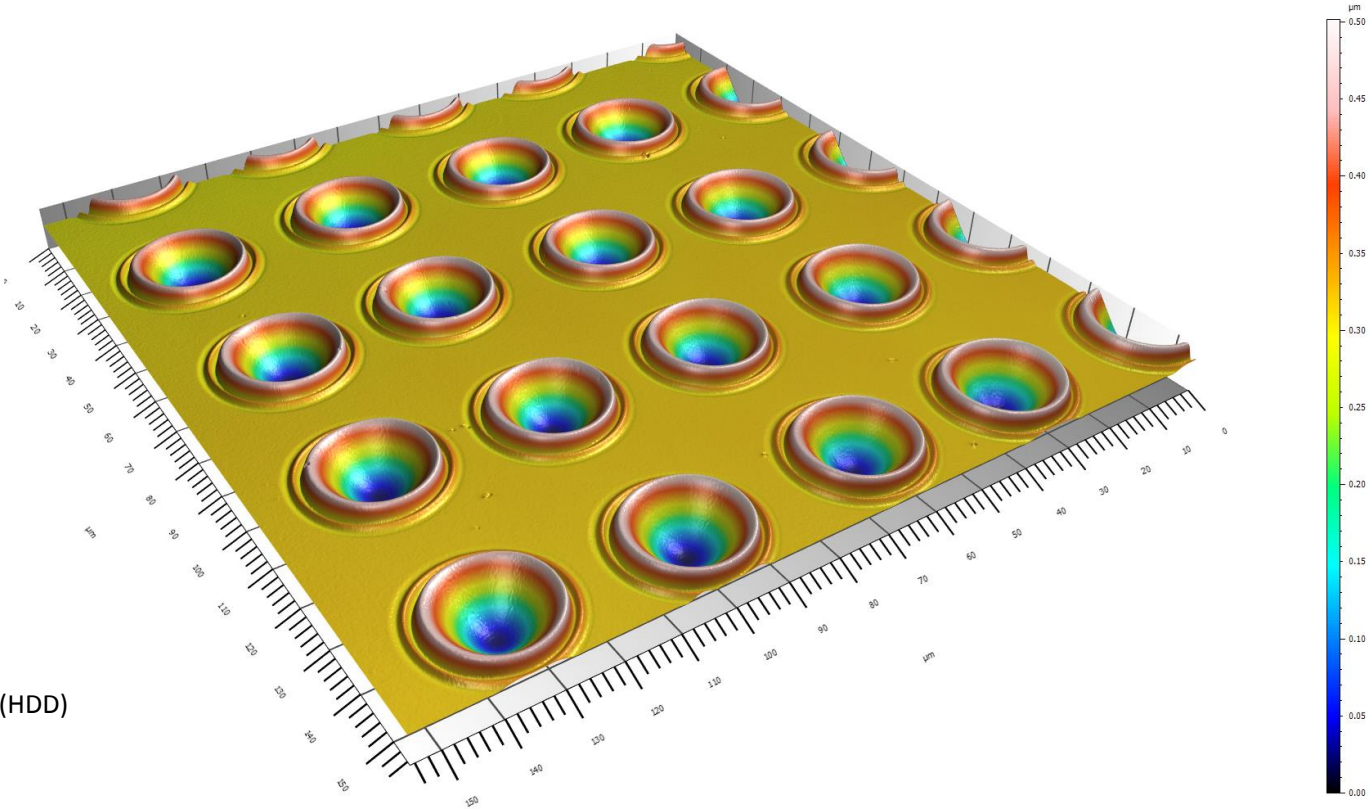


Image:  
Surface of hard disk drive (HDD)

# Company

- Founded in Germany in 1861
- 2.000 employees worldwide
- > 1.000 products for Metrology Applications
- Global Service and Support network



Mahr Headquarters Göttingen, Germany

# Technology - Dimensional surface metrology

## Dimensional surface metrology

Tactile systems

AFM

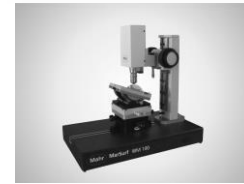
REM

Optical systems

Confocal

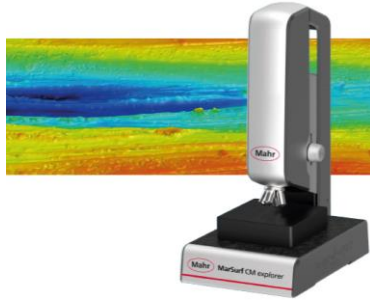
Inter-ferometer

Vision systems



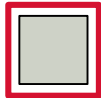
# Technology - Platforms

## MarSurf CM

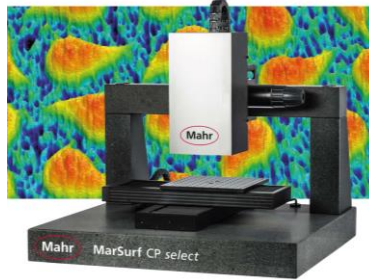


### 3D microscopy

- 3D roughness
- 3D structure
- Wear & tribology



## MarSurf CP



### 2D/3D profilometry

- 2D/3D form
- Defect detection
- Roughness



## MarSurf CL

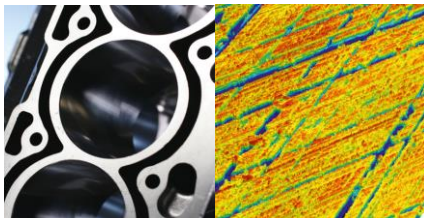


### 3D profilometry

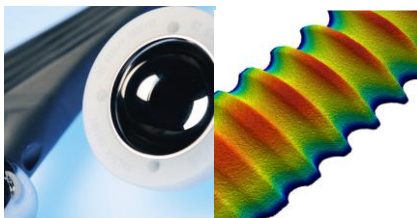
- 3D form
- Defect detection
- Production control



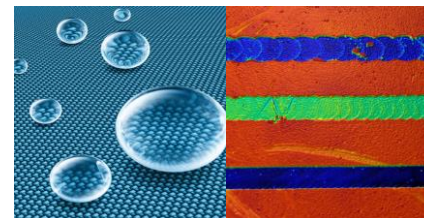
# Applications - Industries



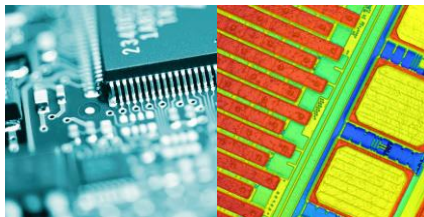
Automotive



Medical technology



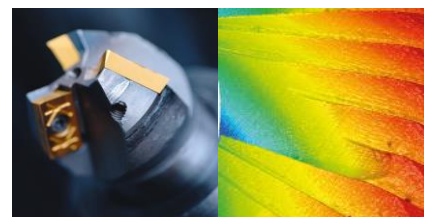
Materials science



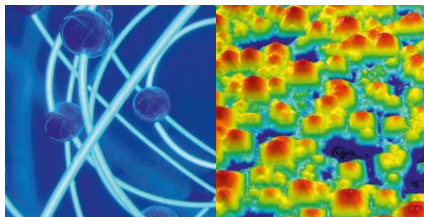
Electronics & semiconductor



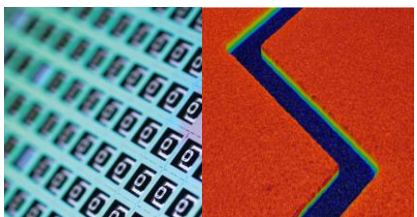
Printing and security



Tools



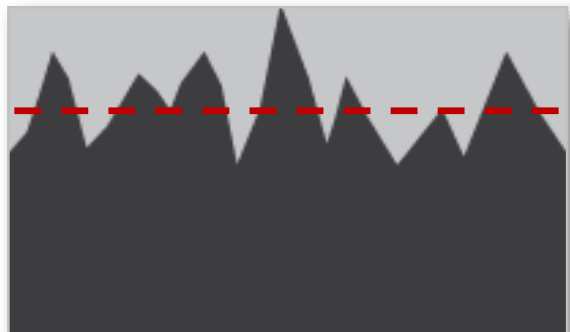
Energy



Microsystems

# Applications – Measurement Tasks

Roughness (Ra,Rz,Sa,Sz)



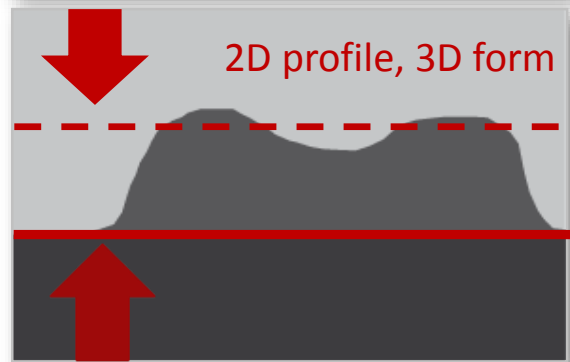
Wear



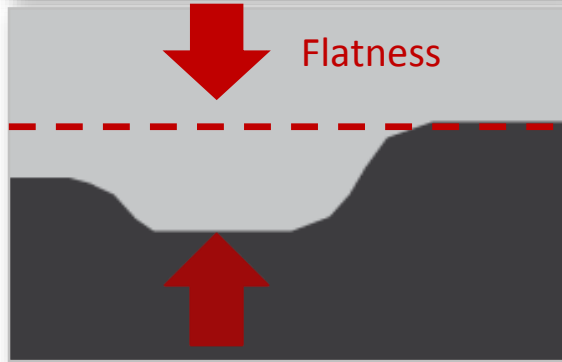
Coplanarity



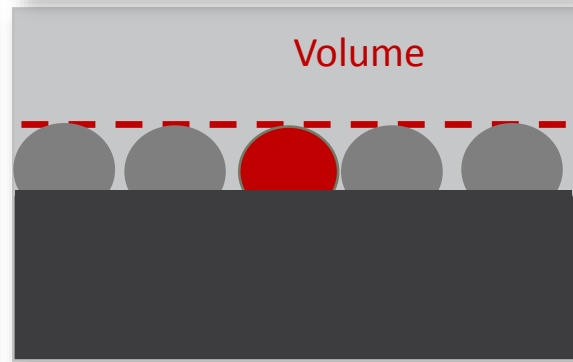
2D profile, 3D form



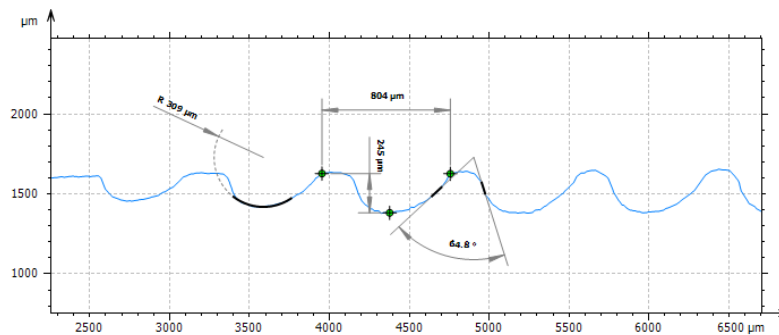
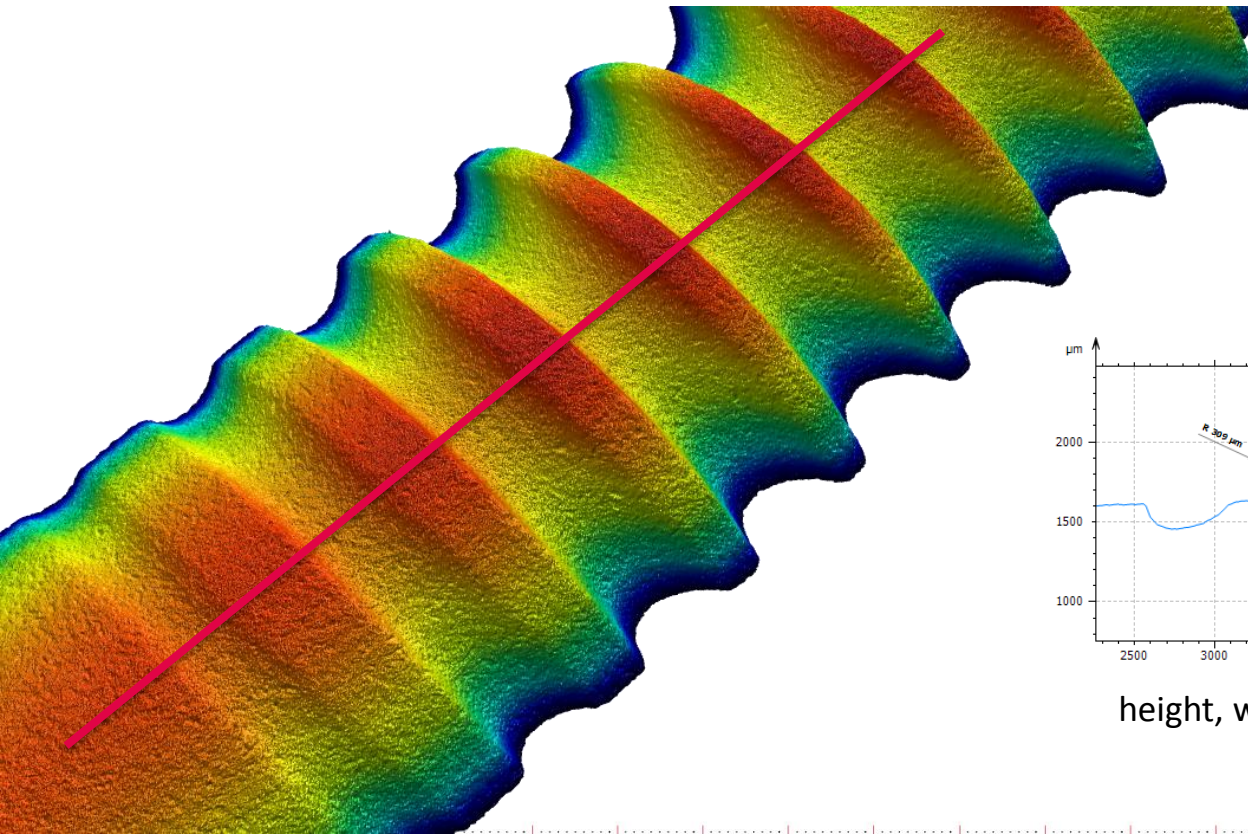
Flatness



Volume



# Applications – Dental implants - Microgeometry

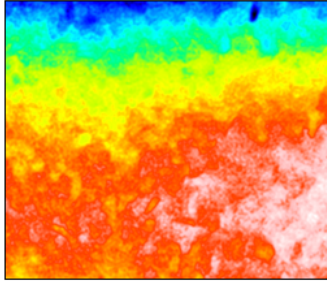


height, width, radius, angle, etc.



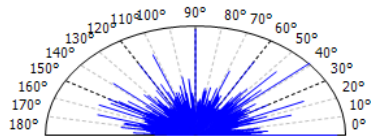
# Applications – Dental implants – Surface Roughness

## Surface Roughness ISO 25178

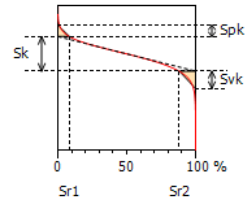
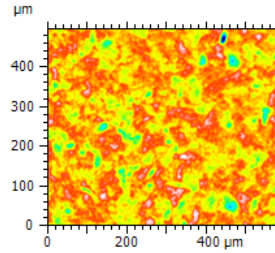


Form removed (Polynomial of degree 2)

$$-32.419 - 0.011174*x + 7.4071e-05*x^2 - 0.34682*y - 5.6...$$



Parameters	Value	Unit
Isotropy	82.198	%
First Direction	40.771	°



Information		
Filter settings	Unfiltered.	
Parameters	Value	Unit
Sk	5.1605	µm
Sa1	0.071167	µm³/µm²
Sa2	0.15479	µm³/µm²

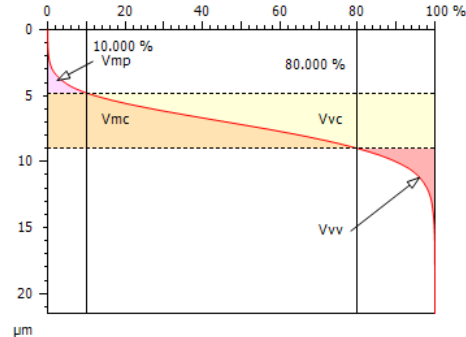
## ISO 25178

### Height Parameters

Sa	1.6475	µm	Arithmetic mean height
Sp	7.3204	µm	Maximum peak height
Sv	14.189	µm	Maximum pit height
Sz	21.510	µm	Maximum height

### Feature Parameters

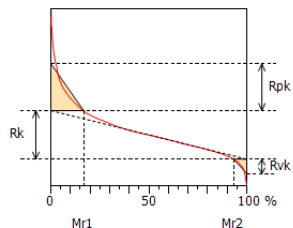
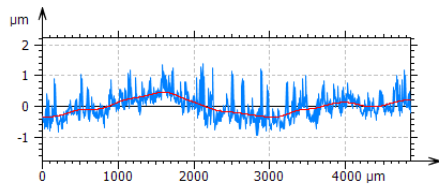
S10z	15.496	µm	Ten point height
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Parameters	Value	Unit
Vmp	0.086228	ml/m2
Vmc	1.8612	ml/m2
Vvc	2.3478	ml/m2
Vvv	0.27781	ml/m2

# Applications – Line Roughness ISO 4287

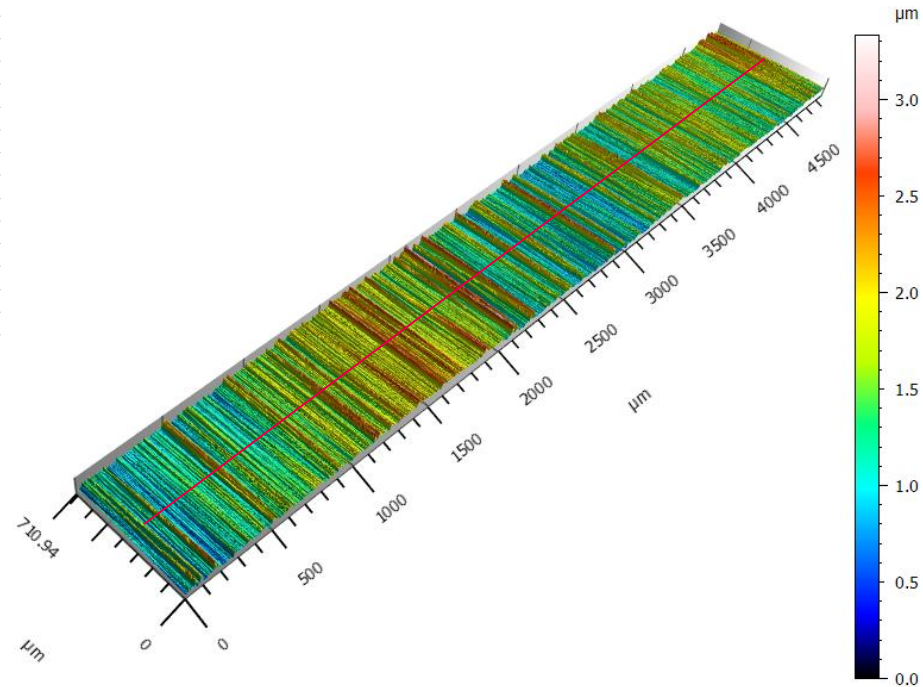
## Line roughness ISO 4287



Information	
Profile	Waviness profile
Filter settings	Gaussian filter, cut-off 800.00 $\mu\text{m}$ , End effects managed

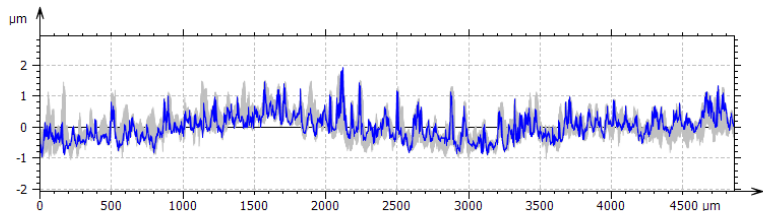
ISO 4287		
Amplitude parameters - Roughness profile		
Ra	0.23221 $\mu\text{m}$	Gaussian filter, 0.8 mm, End effects managed
Rz	1.8008 $\mu\text{m}$	Gaussian filter, 0.8 mm, End effects managed
Rp	1.1889 $\mu\text{m}$	Gaussian filter, 0.8 mm, End effects managed
Rv	0.61183 $\mu\text{m}$	Gaussian filter, 0.8 mm, End effects managed
Rt	2.2182 $\mu\text{m}$	Gaussian filter, 0.8 mm, End effects managed
Rq	0.31173 $\mu\text{m}$	Gaussian filter, 0.8 mm, End effects managed

Information		
Filter settings	Gaussian filter, 800.00 $\mu\text{m}$ , End eff...	
Parameters	Value	Unit
Rk	0.60868	$\mu\text{m}$
Rpk	0.58861	$\mu\text{m}$
Rvk	0.18039	$\mu\text{m}$
Rpk*	1.2763	$\mu\text{m}$
Rvk*	0.33329	$\mu\text{m}$



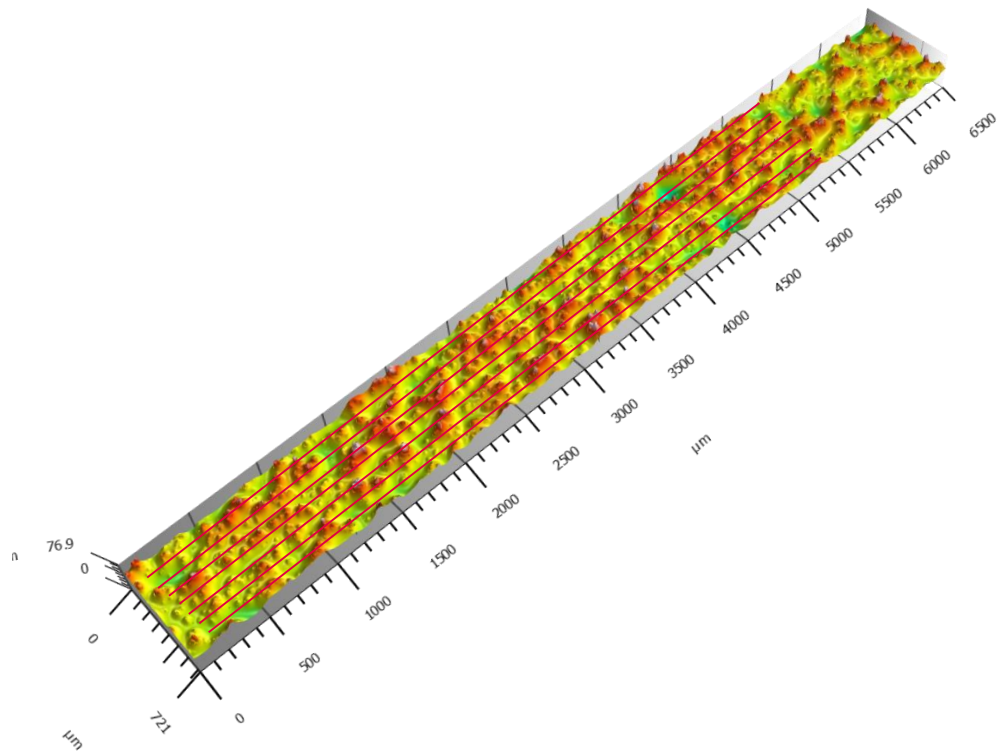
# Applications – Multi-line Roughness ISO 4287

Multi-Line Roughness ISO 4287

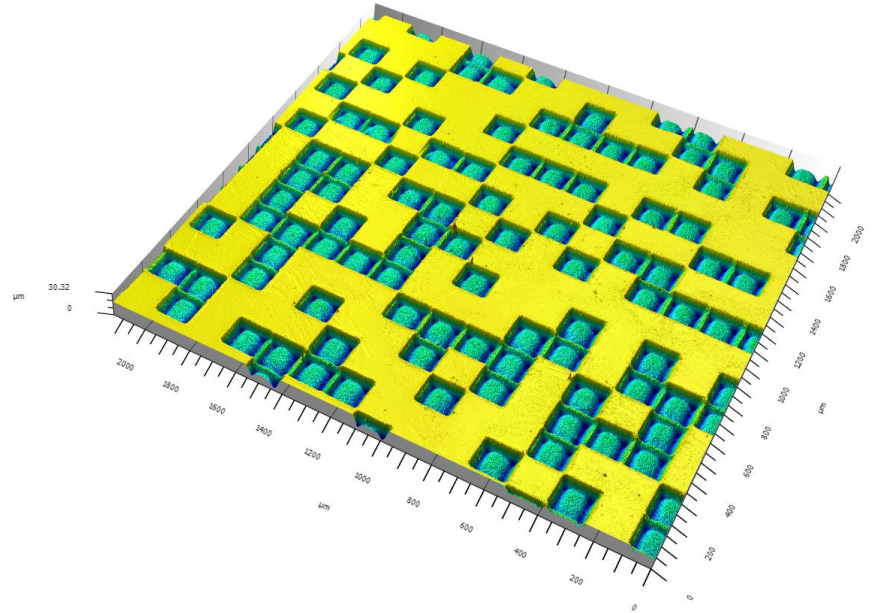
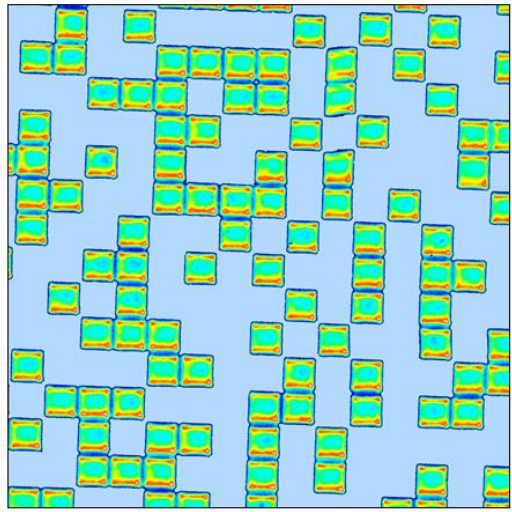


Information		
Profile	Hydro Rauheit > Leveled (Least squares method) > Topography layer (1 / 46)	
Parameters	Value	Unit
Length	4859.4	µm

		Context	Mean	Std dev	Min	Max
<b>ISO 4287</b>						
<b>Amplitude parameters - Roughness profile</b>						
Ra	µm	Gaussian filter, 0.8 mm, End effects managed	0.23156	0.0086245	0.21755	0.24369
Rz	µm	Gaussian filter, 0.8 mm, End effects managed	1.8093	0.038585	1.7148	1.8910
Rp	µm	Gaussian filter, 0.8 mm, End effects managed	1.1999	0.033306	1.1186	1.2721
Rv	µm	Gaussian filter, 0.8 mm, End effects managed	0.60941	0.022726	0.55250	0.67792
Rt	µm	Gaussian filter, 0.8 mm, End effects managed	2.2476	0.079546	2.1117	2.4793
Rq	µm	Gaussian filter, 0.8 mm, End effects managed	0.30941	0.0097059	0.29351	0.32151

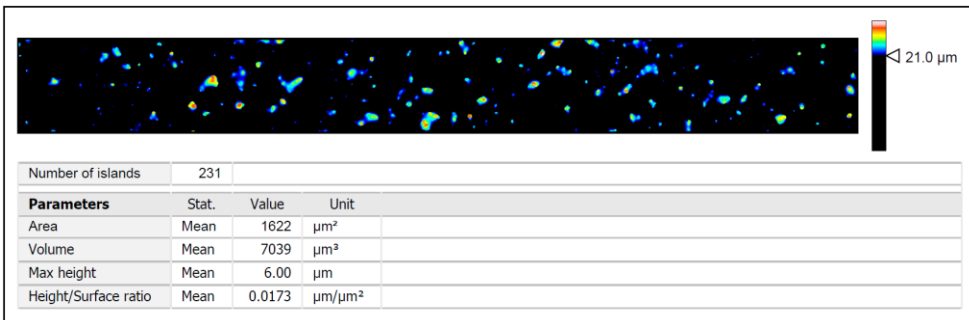


# Applications – Data Matrix Code – Volume/Depth

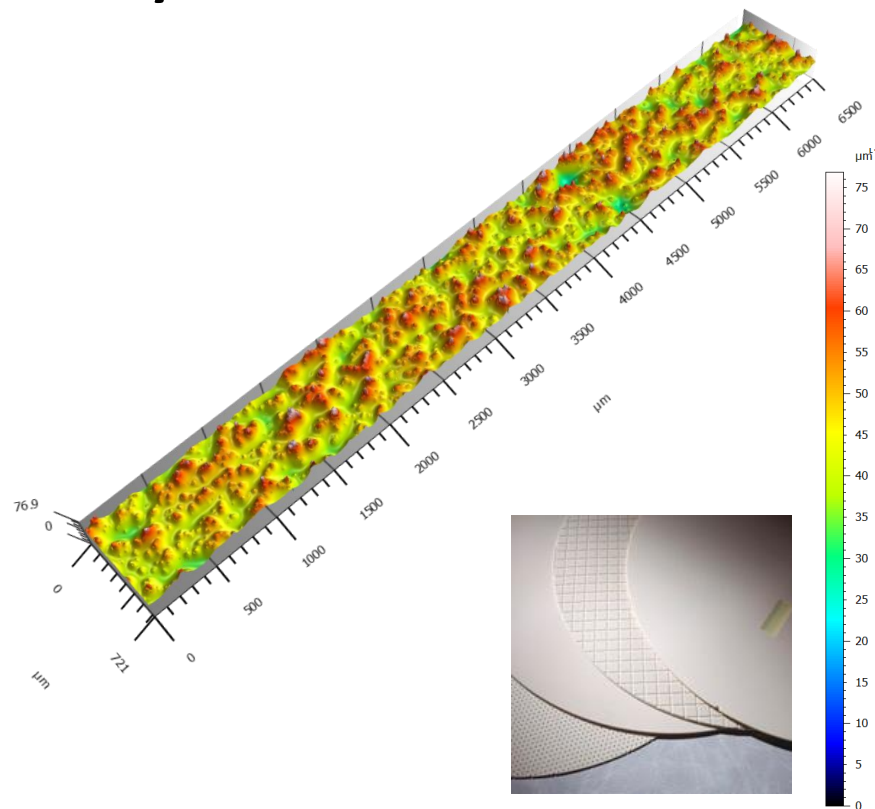


Number of islands	61		
Threshold	14.310	µm	
<b>Parameters</b>	<b>Stat.</b>	<b>Value</b>	<b>Unit</b>
Area	Mean	31889	µm <sup>2</sup>
Volume	Mean	212404	µm <sup>3</sup>
Max height	Mean	10.403	µm
Height/Surface ratio	Mean	0.0088829	µm/µm <sup>2</sup>

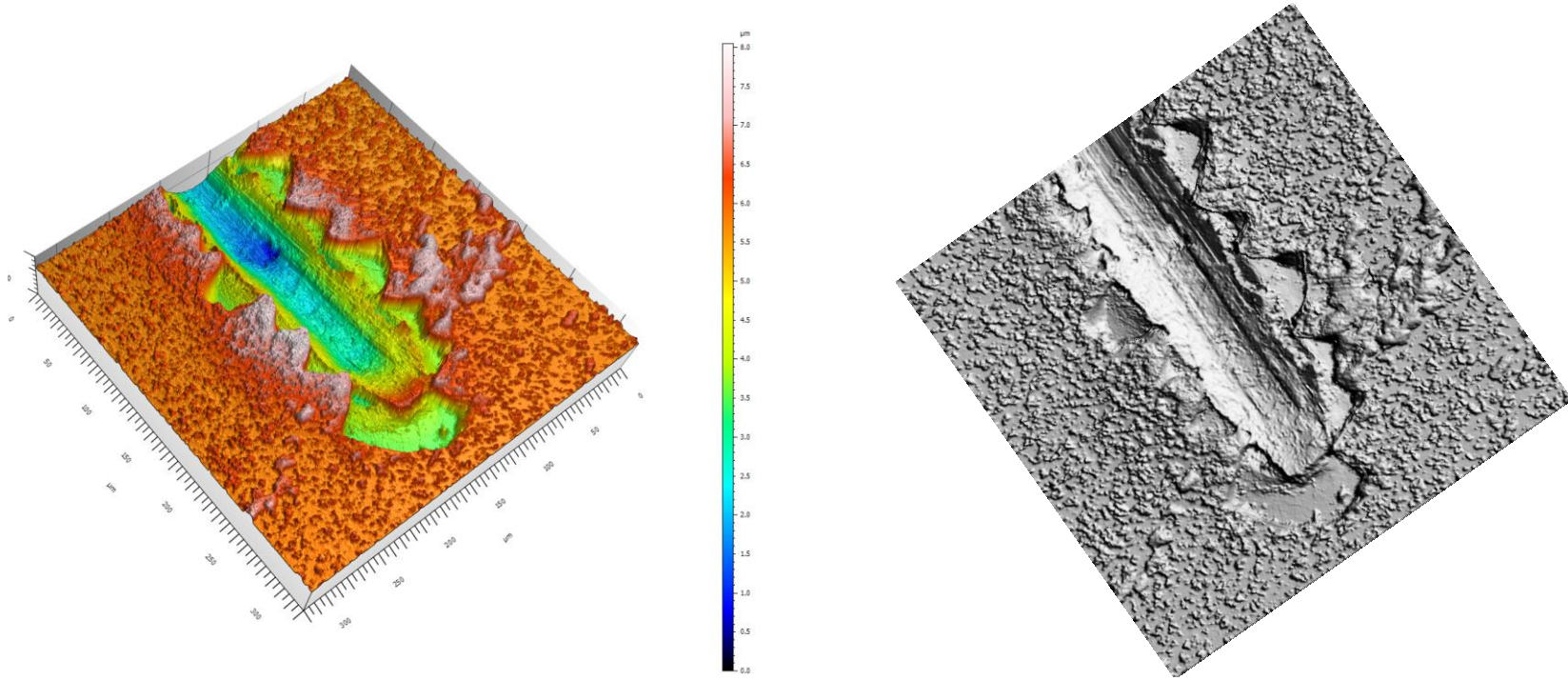
# Applications – Polishing Pad - Particle analysis



Statistics over all grains - Binarized image after thresholding (21 μm)			
<b>Global information</b>	Value		
Number of grains	231		
Total area occupied by the grains	374793 μm <sup>2</sup> (8.00%)		
<b>Grain parameters</b>	Unit	Mean	Std dev
Area	μm <sup>2</sup>	1622	2816
Perimeter	μm	131	138
Min diameter	μm	22.7	21.2
Max diameter	μm	45.2	46.5
Roundness		0.575	0.191

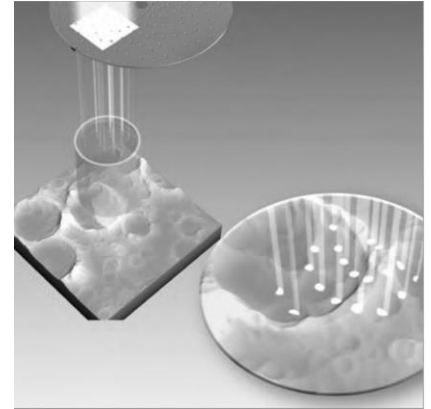
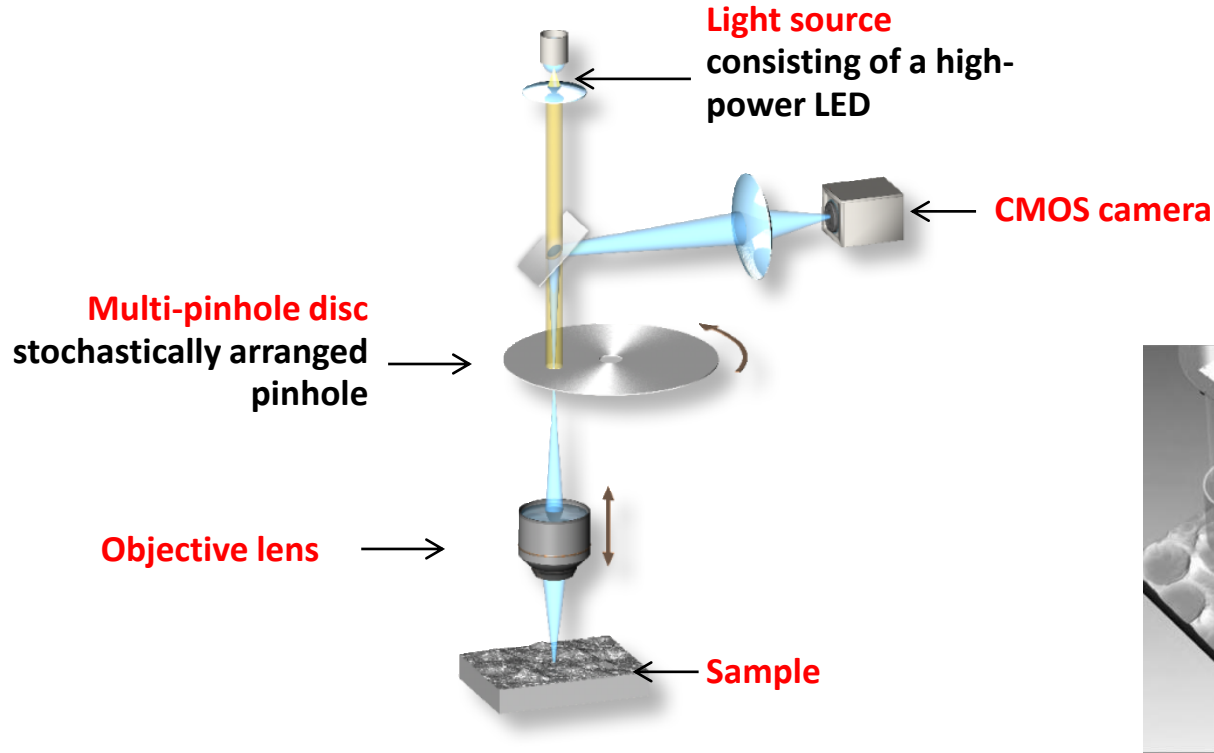


# Applications – Coated Surface – Defect analysis



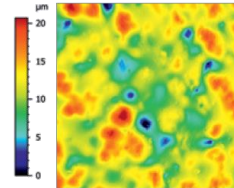
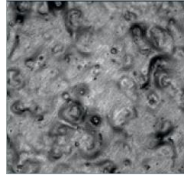
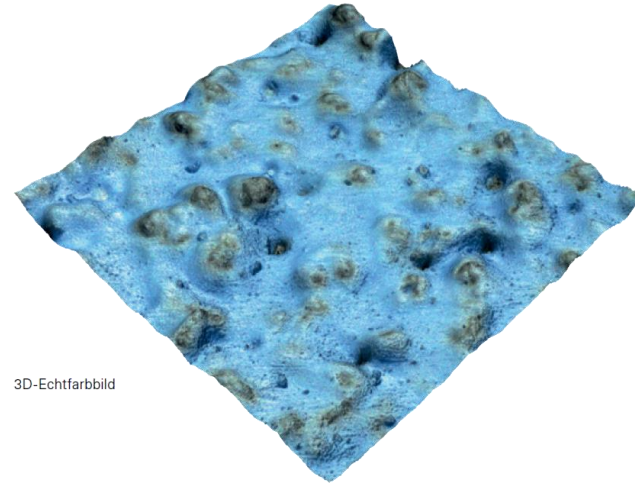
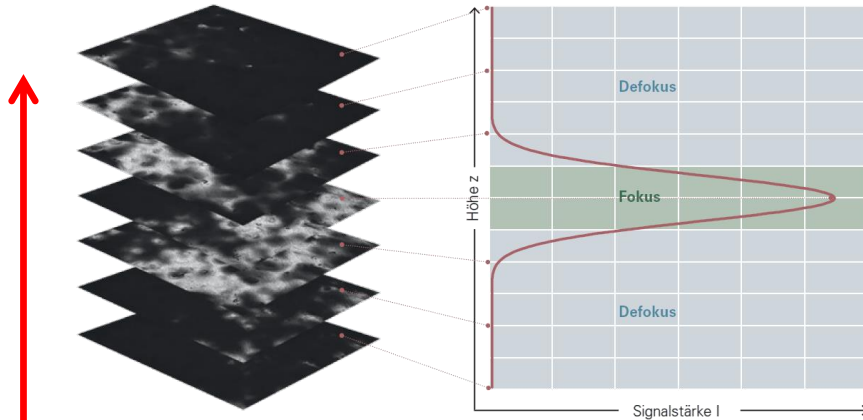
**MarSurf CM**

# MarSurf CM - Confocal construction





# MarSurf CM - Confocal image analysis

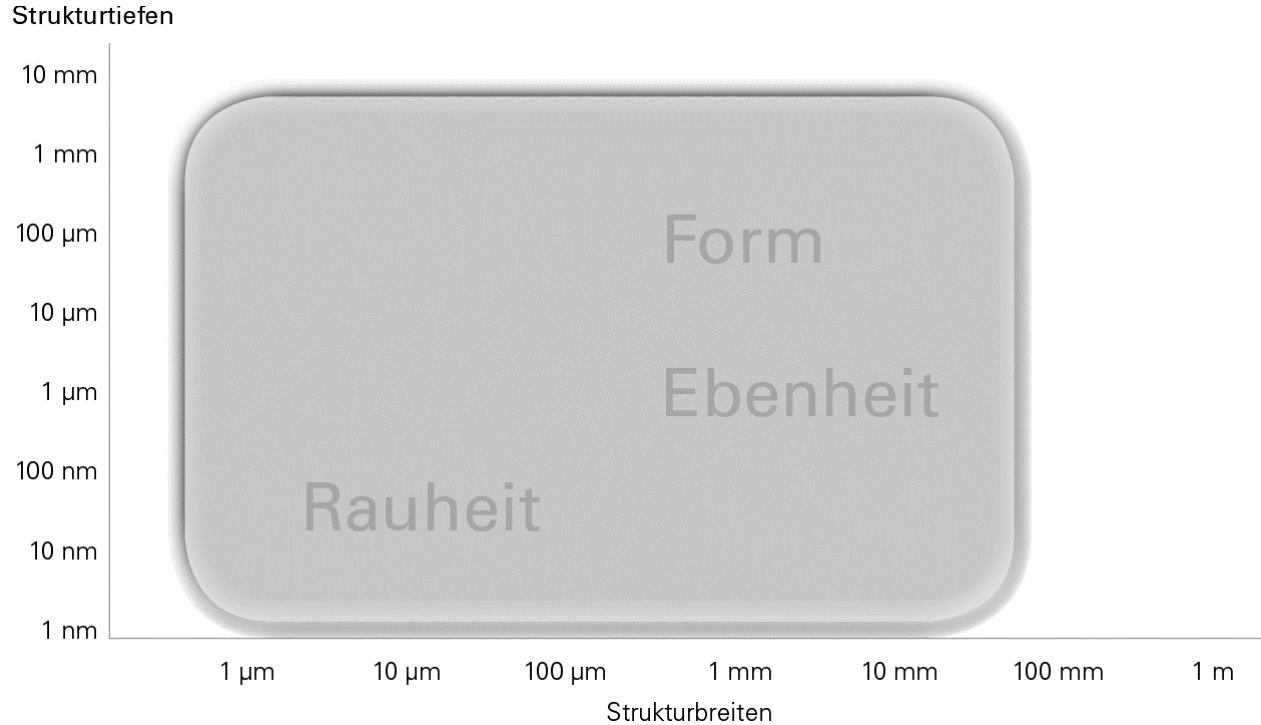


typical measuring time: 2-10s

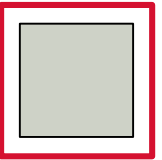
deep-focused images

real 3D information

# MarSurf CM fields of application



- Roughness (3D/2D)
- Form (3D/2D)
- Topography
- Long waviness
- Flatness
- Wear



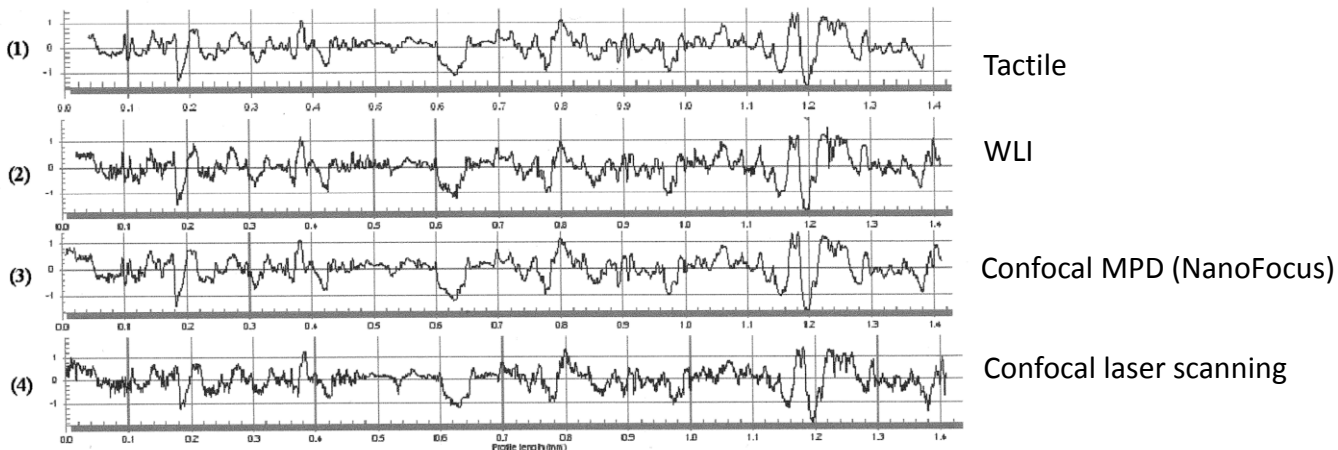


# MarSurf Technology - Profile accurate surface measurement

99% correlation  
between a tactile and  
an optical  
measurement with the  
MarSurf CM

Comparative study:  
Correlations of topography measurements of  
NIST SRM 2460 standard bullets  
by four techniques, Meas. Sci. Technol., London  
2006

## Correlation between stylus profilometry and optical technologies



**Figure 2.** The profile of a standard bullet is measured by four techniques. 1) Stylus instrument,  $CCF_{max} = 99.6 \%$ ; 2) Interferometric microscope,  $CCF_{max} = 92.1 \%$ ; 3) Nipkow disk confocal microscope,  $CCF_{max} = 99.0 \%$ ; 4) Laser scanning confocal microscope,  $CCF_{max} = 95.3 \%$ . The vertical unit is  $\mu\text{m}$ , the horizontal unit is mm.

CCF(ACF): Auto-Correlation-Function

# MarSurf CM Accuracy

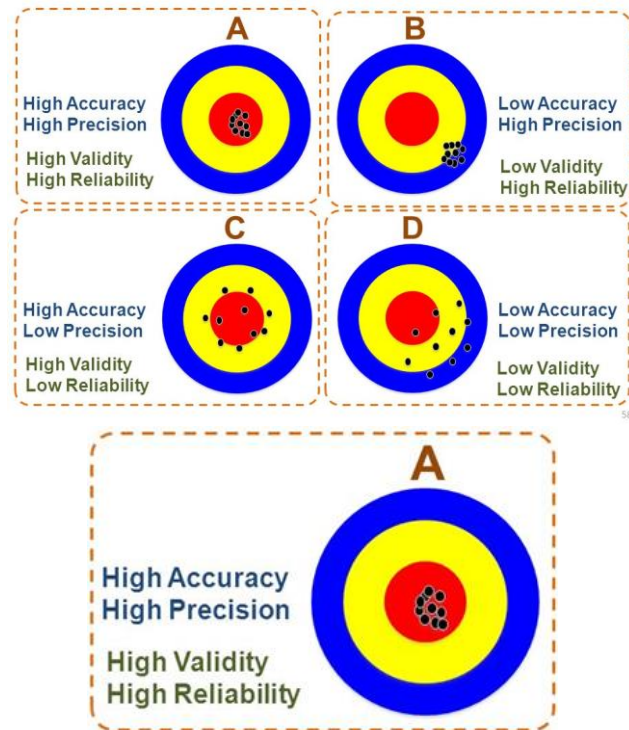
## Accuracy<sup>1,2</sup>

		Standard	Uncertainty, standard deviation
Measurement uncertainty by the example of step height measurement <sup>2,3,4,5,6</sup>	with objective lens 800 XS	Step = 75 $\mu\text{m}$	$U = 0.320 \mu\text{m}, \sigma = 0.050 \mu\text{m}$
		Step = 10 $\mu\text{m}$	$U = 0.060 \mu\text{m}, \sigma = 0.020 \mu\text{m}$
		Step = 1 $\mu\text{m}$	$U = 0.030 \mu\text{m}, \sigma = 0.004 \mu\text{m}$
Measurement uncertainty by the example of roughness measurement <sup>2,3,4,5</sup>	with objective lens 800 XS	$R_a = 1.63 \mu\text{m}$	$U = 0.040 \mu\text{m}, \sigma = 0.004 \mu\text{m}$
		$R_a = 0.58 \mu\text{m}$	$U = 0.024 \mu\text{m}, \sigma = 0.0066 \mu\text{m}$
		$R_a = 0.23 \mu\text{m}$	$U = 0.010 \mu\text{m}, \sigma = 0.0050 \mu\text{m}$
	with objective lens 320 S	$R_a = 0.079 \mu\text{m}$	$U = 0.010 \mu\text{m}, \sigma = 0.0022 \mu\text{m}$
	with objective lens 160 XS	$R_a = 0.079 \mu\text{m}$	$U = 0.003 \mu\text{m}, \sigma = 0.0004 \mu\text{m}$

L: long working distance  
S: normal working distance  
XS: short working distance

- 1) VIM 2012
- 2) with image acquisition module 1200x1200 with fine positioning unit
- 3) U according to ISO/IEC GUIDE 98-3:2008(E), GUM:1995,  $K=1.96$  (level of confidence 95%)
- 4)  $\sigma$  determined with 25 measurements
- 5) Measured in best possible conditions using PTB certified standards. Results only apply for the standards used.
- 6) Evaluation according to ISO 4287

## Accuracy vs. Precision





# MarSurf CM – Product line



MarSurf CM *explorer*



MarSurf CM *expert*



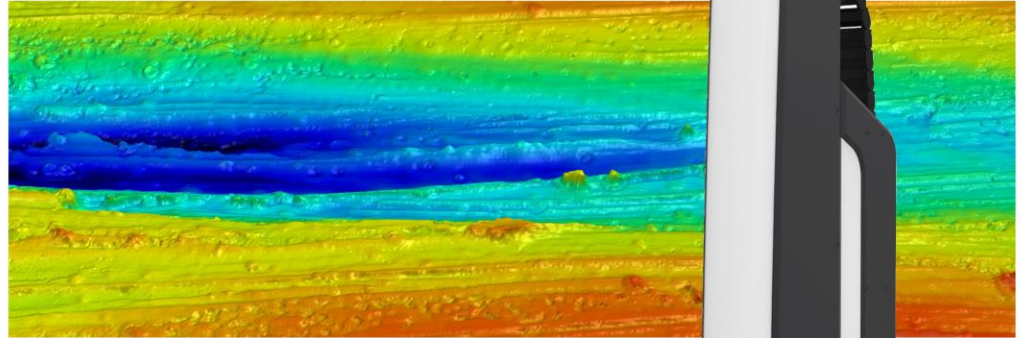
MarSurf CM *mobile*



MarSurf CM *select*

# MarSurf CM explorer - Flexible all-round measurement solution

- Compact design
- Robust and reliable
- High measuring speed – even at full resolution
- User-friendly concept
- Safety through collision detection in all directions to protect the workpiece and measuring system
- High Dynamic Range (HDR) function 16 Bit
- Consistently high resolution even with large measuring areas thanks to HD stitching

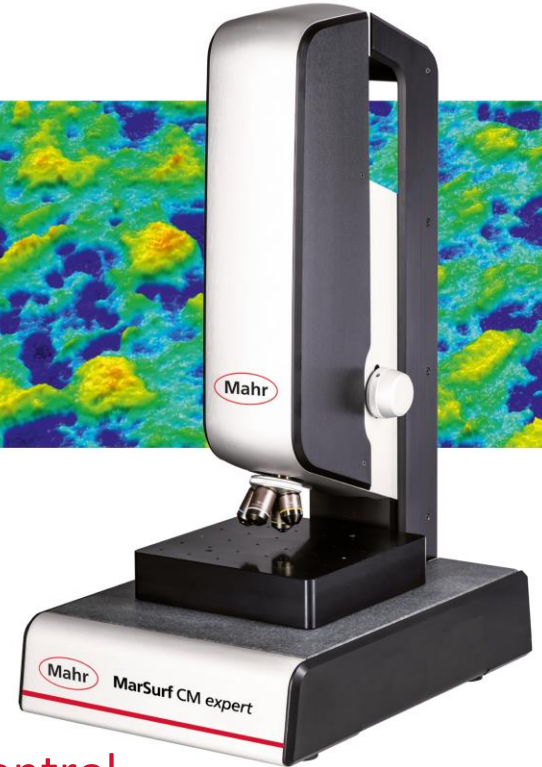
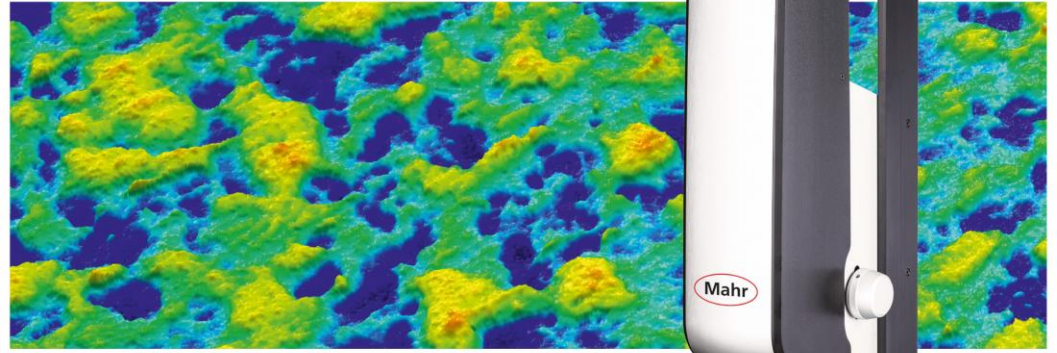


3D measuring system for research & QA



# MarSurf CM expert - Automated high-end measuring system

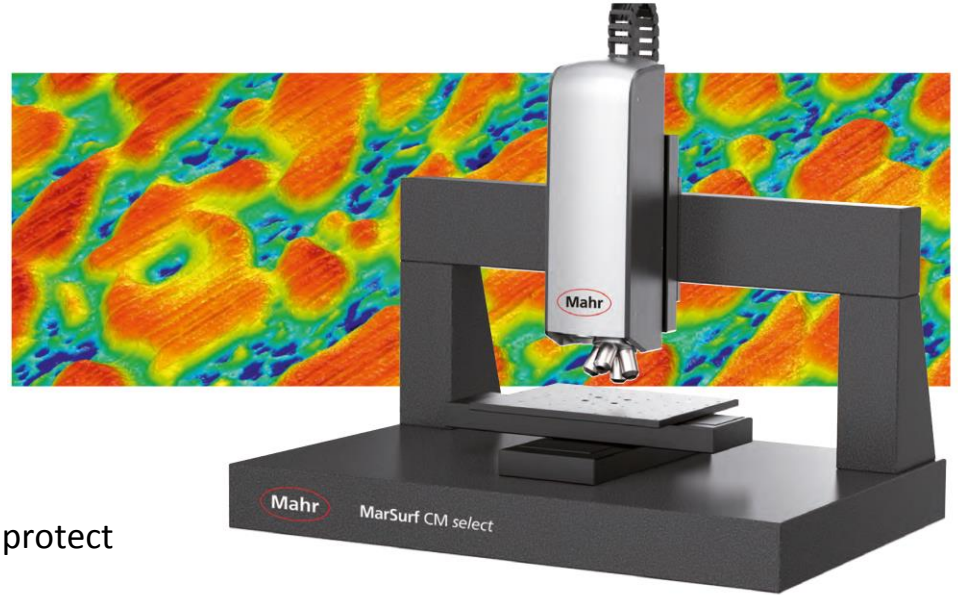
- Extended work area in xyz direction
- User-independent series measurements using automation software
- High measuring speed – even at full resolution
- User-friendly concept
- Safety through collision detection in all directions to protect the workpiece and measuring system
- High Dynamic Range (HDR) function 16 Bit
- Consistently high resolution even with large measuring areas thanks to HD stitching



3D measuring system for research, QA and production control

# MarSurf CM select - Tailor-made surface measurement

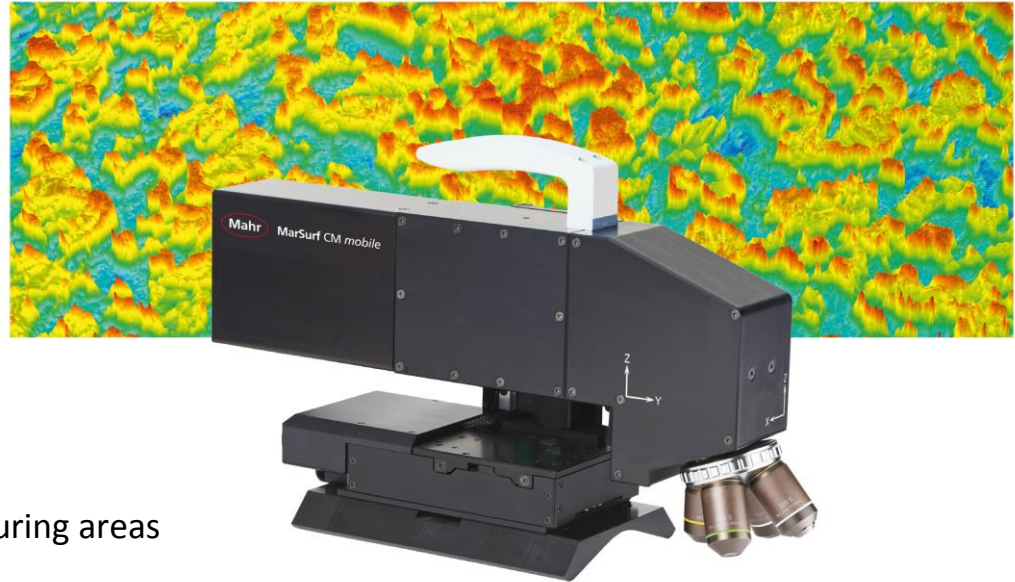
- Designed for continuous operation
- Automation software with industrial interfaces for transfer to QA systems
- Individually configurable to your sample size (modular system)
- multi-sensor technology
- High measuring speed - even at full resolution
- User-friendly concept
- Safety through collision detection in all directions to protect the workpiece and measuring system
- High Dynamic Range (HDR) function 16 Bit
- Consistently high resolution even with large measuring areas thanks to HD stitching



3D measuring system for QA & production

# MarSurf CM mobile - Ready for use anywhere

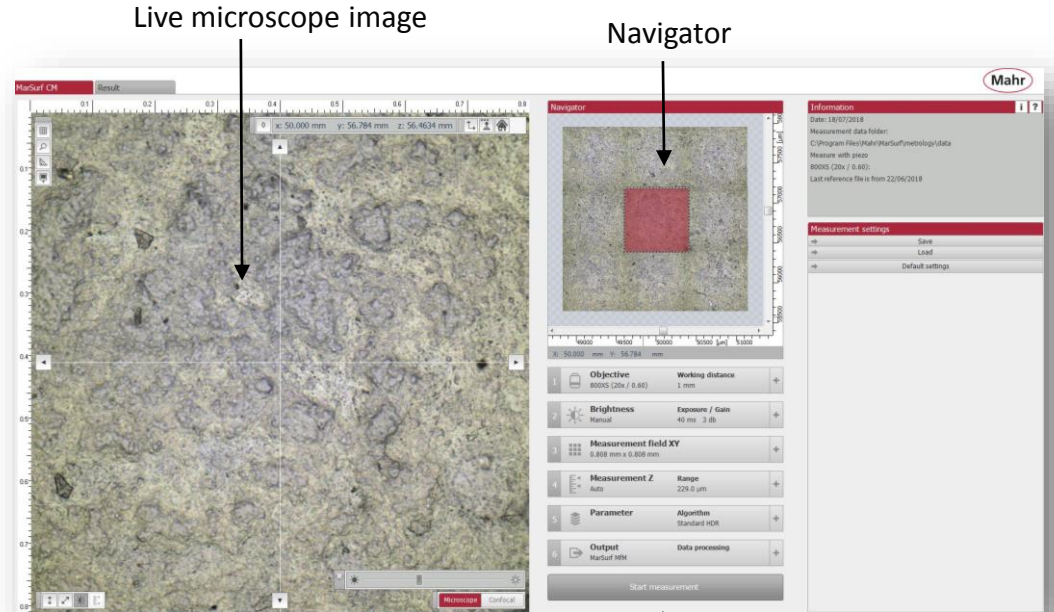
- Mobile use enables testing directly on the component/tool - even with minimum tool life
- High measuring speed
- Compact system (5kg) with motorized axes for HD stitching
- Motorized xyz-axis
- Robust and reliable for use in production
- High measuring speed – even at full resolution
- User-friendly concept
- Consistently high resolution even with large measuring areas thanks to HD stitching



## Mobile Solution

# MarSurf MSW – Acquisition Software

- Measurements by one click
- Access to real raw data
- Navigation function
- Snapshot Technology (Auto-Intensity, Auto-Range)
- HD-Stitching
- Shape-Tracing



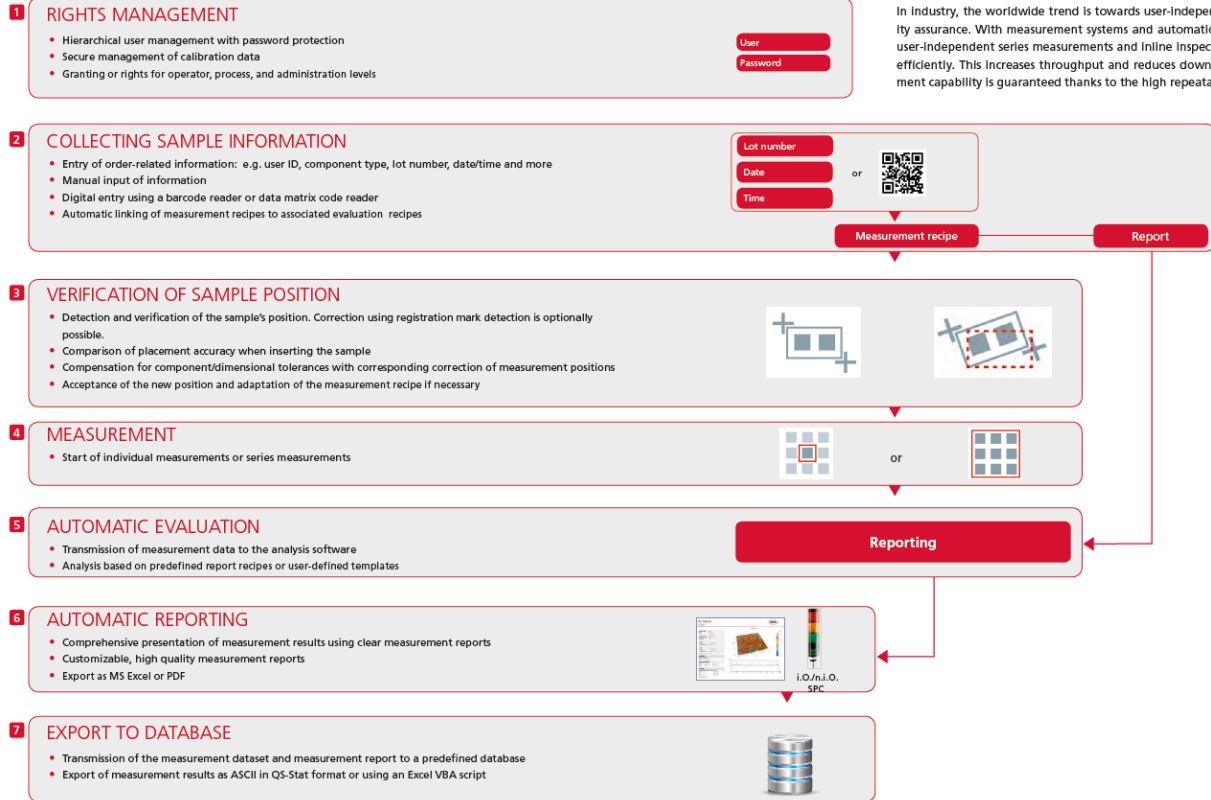
Automatic/Manual adjustment of the measurement parameters

# MarSurf MfM – Evaluation Software

- 1-click-evaluation
- Protocol function
- ISO-compliant parameters
- Multiple 2D-, 3D- and 4D analysis functions
- Transparent data processing
- Industry standard solution



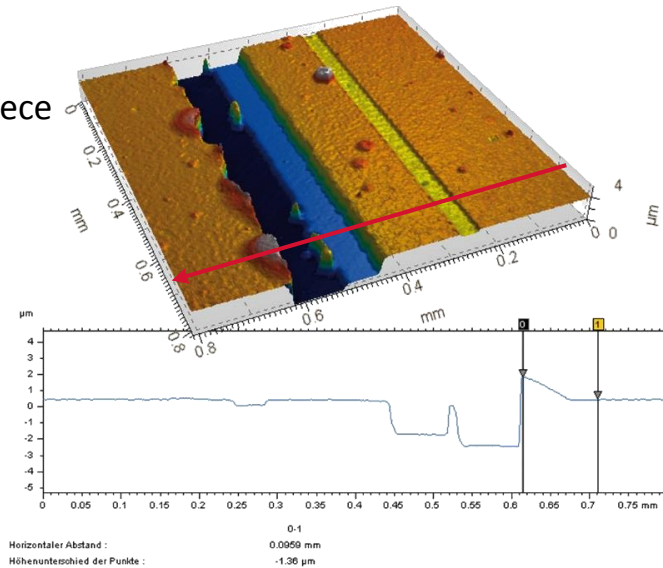
# MarSurf ASW – Automation Software



In Industry, the worldwide trend is towards user-independent, automated quality assurance. With measurement systems and automation software from Mahr, user-independent series measurements and Inline Inspections can be carried out efficiently. This increases throughput and reduces downtime. Measuring equipment capability is guaranteed thanks to the high repeatability of measurements.

# MarSurf CM - Advantages of confocal technology

- Non-destructive, material-independent surface detection
- No sample preparation necessary
- Physical principle for data acquisition
- Measurement of transparent materials
  
- High measurement speed– even at full resolution
- Reliability due to collision detection in all directions to protect your workpiece and measuring system
- High Dynamic Range (HDR) function 16 Bit
- Consistently high resolution thanks to HD stitching even with large measuring area
- User-friendly concept
- Optimum documentation due to a combination of imaging and measuring value acquisition
- Reliable, robust and industrial-strength



**MarSurf CP/CL**



# Technology - Platforms

MarSurf CM

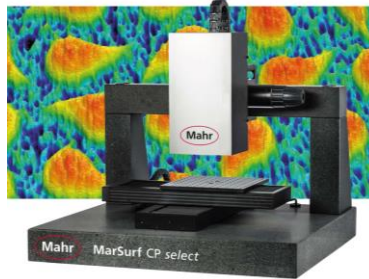


## 3D microscopy

- 3D roughness
- 3D structure
- Wear & tribology



MarSurf CP

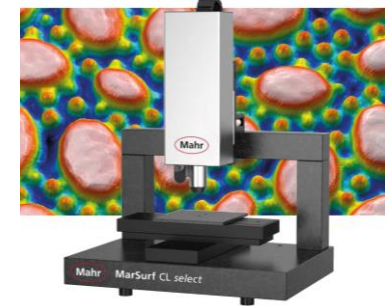


## 2D/3D profilometry

- 2D/3D form
- Defect detection
- Roughness



MarSurf CL

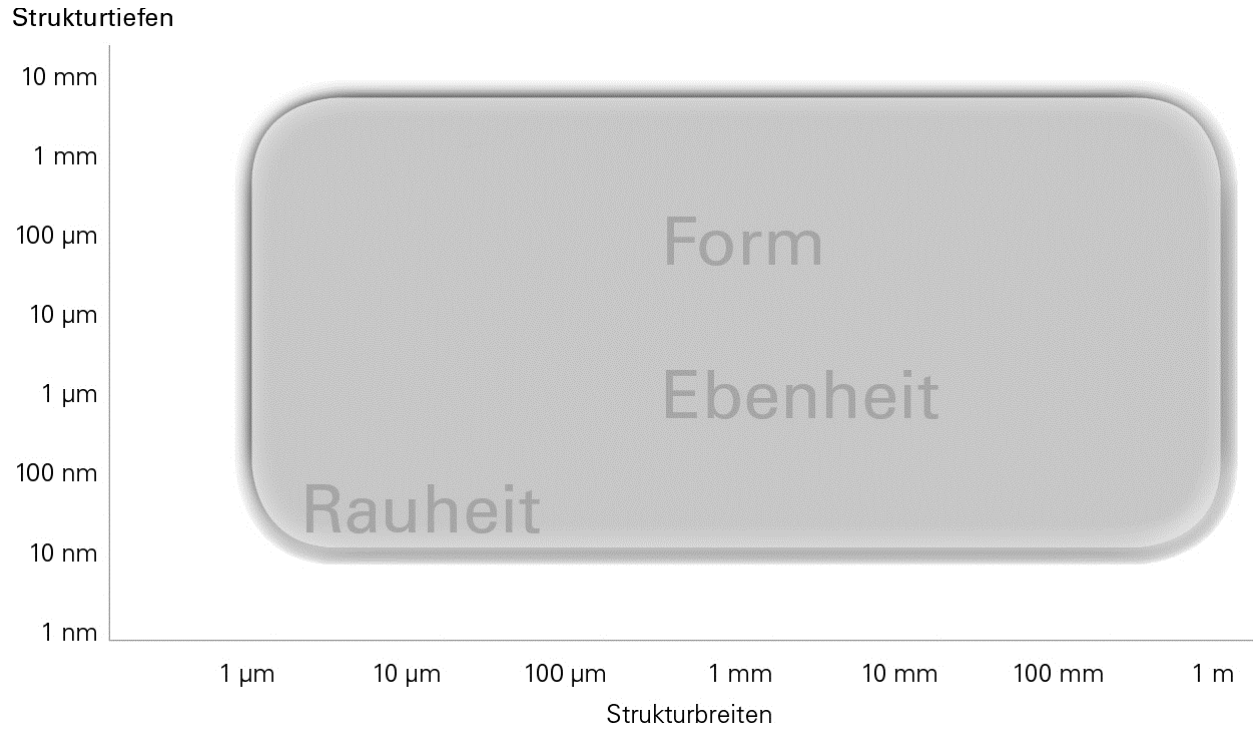


## 3D profilometry

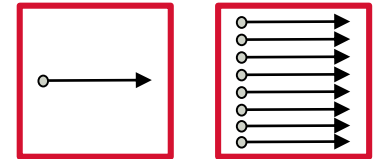
- 3D form
- Defect detection
- Production control



# MarSurf CP & CL fields of application

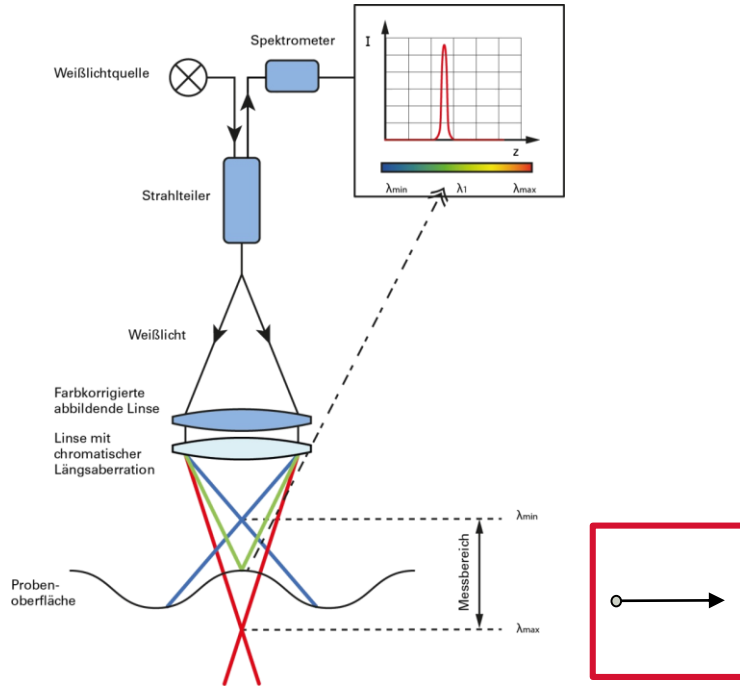


- Roughness (2D)
- Form (2D/3D)
- Long waviness
- Flatness



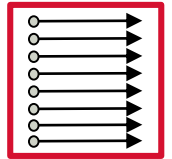
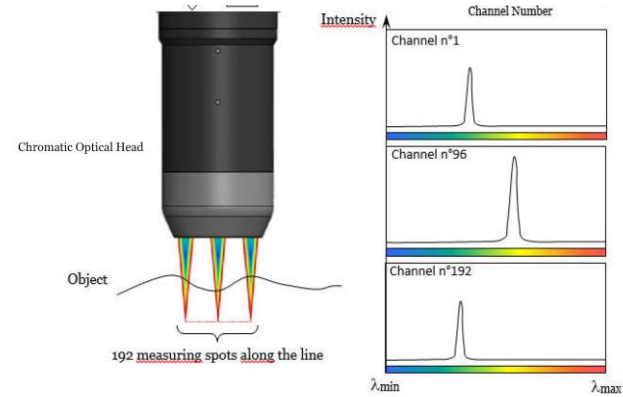
# MarSurf CP & CL technology

## Chromatic sensor CP



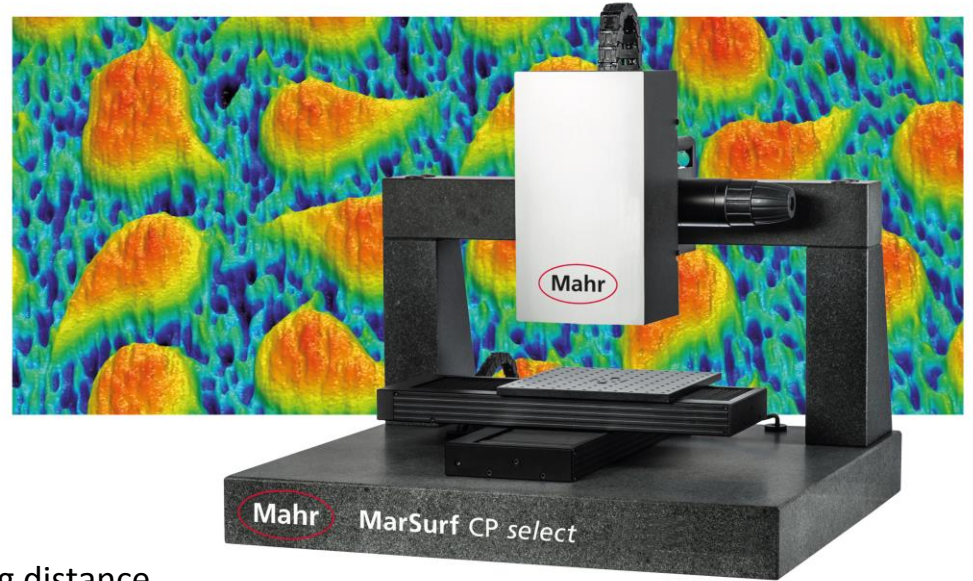
## Chromatic sensor CL

- 192 channels



# MarSurf CP select - Optical 2D/3D profilometry

- Customizable (modular system)\*
- Different sensor combinations
- Large-area 3D measurements
- Very high measuring speed
- User-independent series measurements using automation software
- Excellent acceptance of steep flanks
- Coating thickness measurement and measurement of transparent materials
- Large height measurement range with large working distance
- Production-optimized structure
- Robust and reliable
- User-friendly concept



Flexible profilometer for quality control

# MarSurf CP select - Sensors

## Sensors

Point sensors	Type	Name	Measurement range (mm)	Working distance (mm)	Diameter of measurement spot ( $\mu\text{m}$ )	Lateral resolution ( $\mu\text{m}$ )	Vertical resolution ( $\mu\text{m}$ )	Vertical resolution <sup>1</sup> ( $\mu\text{m}$ )	Measurement angle <sup>2</sup> (°)	Thickness measurement range <sup>3</sup> (mm)	Measurement rate (k/Hz)	Light source
	Chromatic sensors (CLA) <sup>4,5</sup>	CLA 0.6	0.6	6.5	4	2	0.020	0.006	90 $\pm$ 30	0.9	4	LED
CLA 1		1	19.1	3.5	1.8	0.035	0.010	90 $\pm$ 45	1.5			
CLA 3		3	22.5	12	6	0.100	0.030	90 $\pm$ 30	4.5			
CLA 6		6	35	16	8	0.200	0.060	90 $\pm$ 25	9			
CLA 10		10	70	24	12	0.300	0.100	90 $\pm$ 20	15			

1) reduced measurement range

2) larger measurement angle possible for scattering surfaces

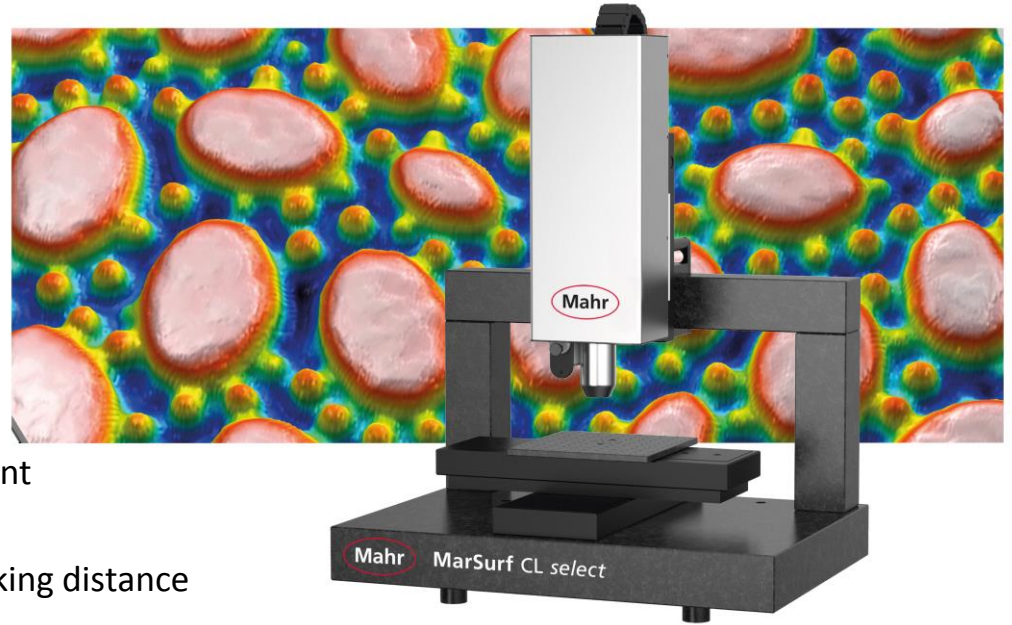
3) refraction index = 1.5

4) other controllers upon request

5) two sensors can be held in one holder

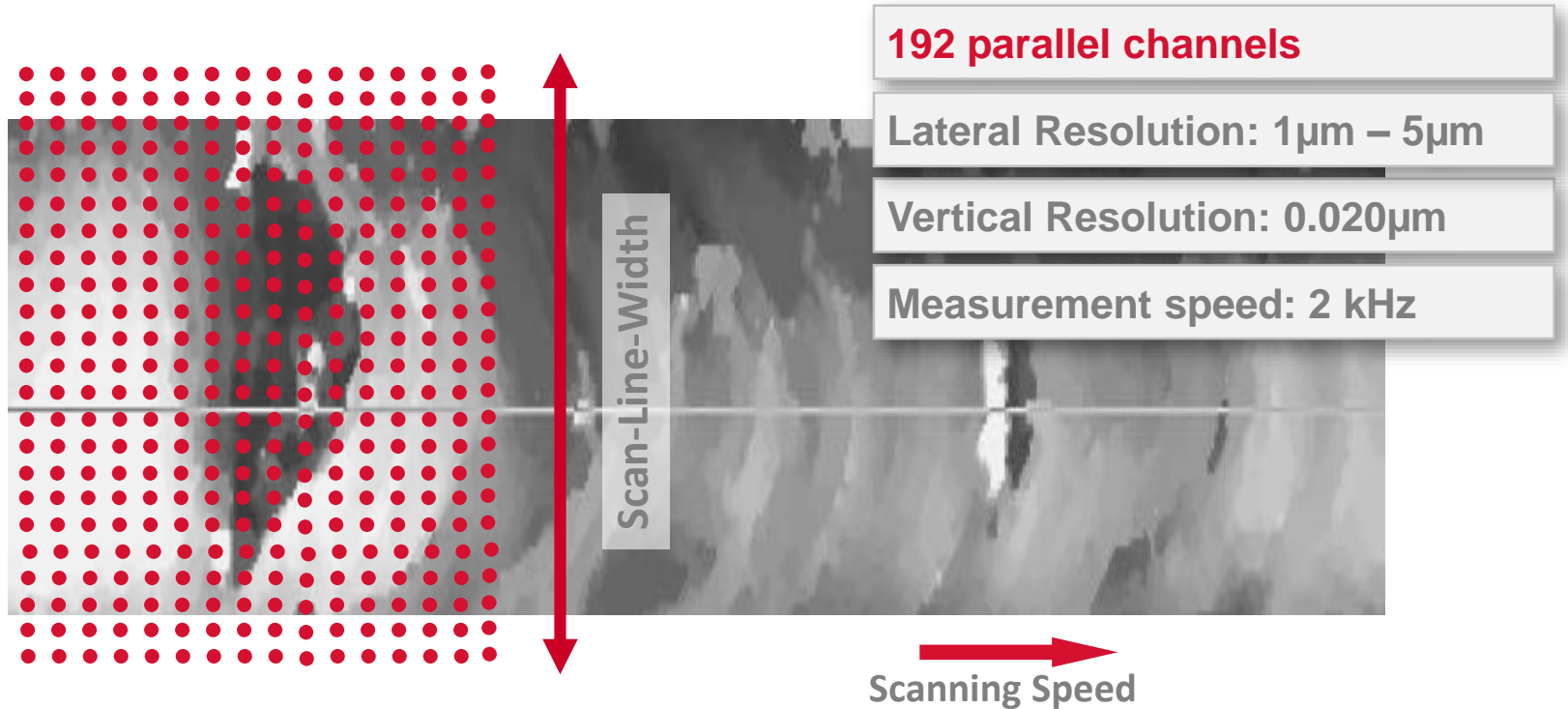
# MarSurf CL select - Optical 2D/3D profilometry

- Optimized for large area measurements
- Customizable (modular system)\*
- Large-area 3D measurements
- Very high measuring speed
- User-independent series measurements using automation software
- Excellent acceptance of steep flanks
- Coating thickness measurement and measurement of transparent materials
- Large height measurement range with large working distance
- Production-optimized structure
- Robust and reliable
- User-friendly concept



Fast line sensor for large-area measurement tasks

# MarSurf CL *select* – Line sensor with 192 channels



# MarSurf CL select - Sensors

## Sensors

Line sensors	Type	Name	Measurement range (mm)	Line length (mm)	Working distance (mm)	Diameter of measurement spot (µm)	Lateral resolution (µm)	Vertical resolution (µm)	Measurement angle <sup>1</sup> (°)	Thickness measurement range <sup>2</sup> (mm)	Measurement rate (kHz)	Light source
	Chromatic sensors CLS <sup>3</sup>	CLS 0.2	0.2	0.96 ± 0.01	5.3 ± 0.2	2	1	0.020	90 ±44	0.28	2	LED
CLS 1		0.95	1.91 ± 0.01	18.5 ± 0.2	4	2	0.080	90 ±33	1.35			
CLS 4		3.9	4.78 ± 0.02	41 ± 0.2	10	5	0.320	90 ±20	5.5			

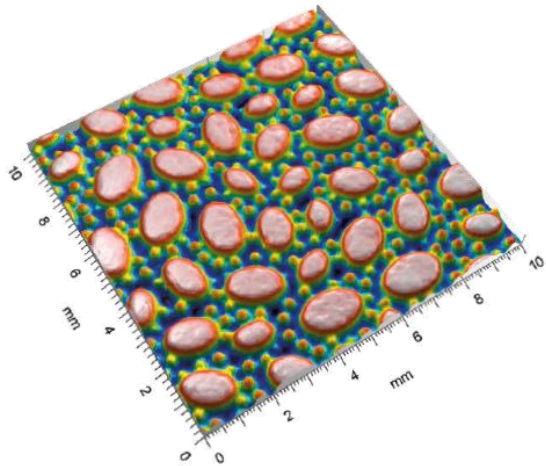
1) larger measurement angle possible for scattering surfaces

2) refraction index = 1.5

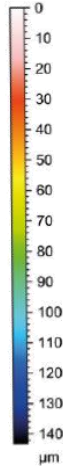
3) other sensors upon request



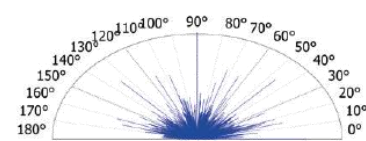
# MarSurf CL *select* – Applications



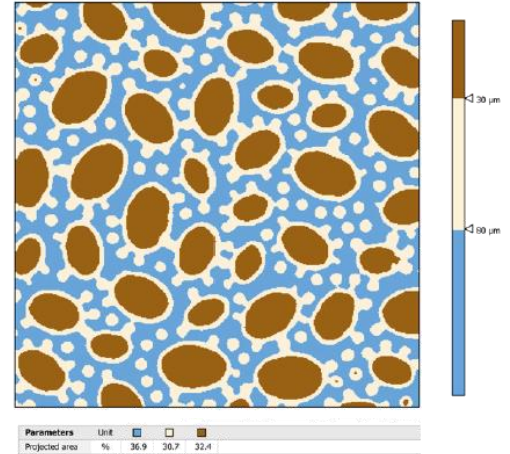
Automotive: Dekor, Interieur



ISO 25178		
Height Parameters		
Sa	35.7 μm	Arithmetic mean height
Sp	69.8 μm	Maximum peak height
Sv	83 μm	Maximum pit height
Sz	153 μm	Maximum height
Feature Parameters		
S10z	124 μm	Ten point height
Functional Parameters (Stratified surfaces)		
Sk	36.9 μm	Core roughness depth
Spk	19.5 μm	Reduced summit height
Svk	47.3 μm	Reduced valley depth



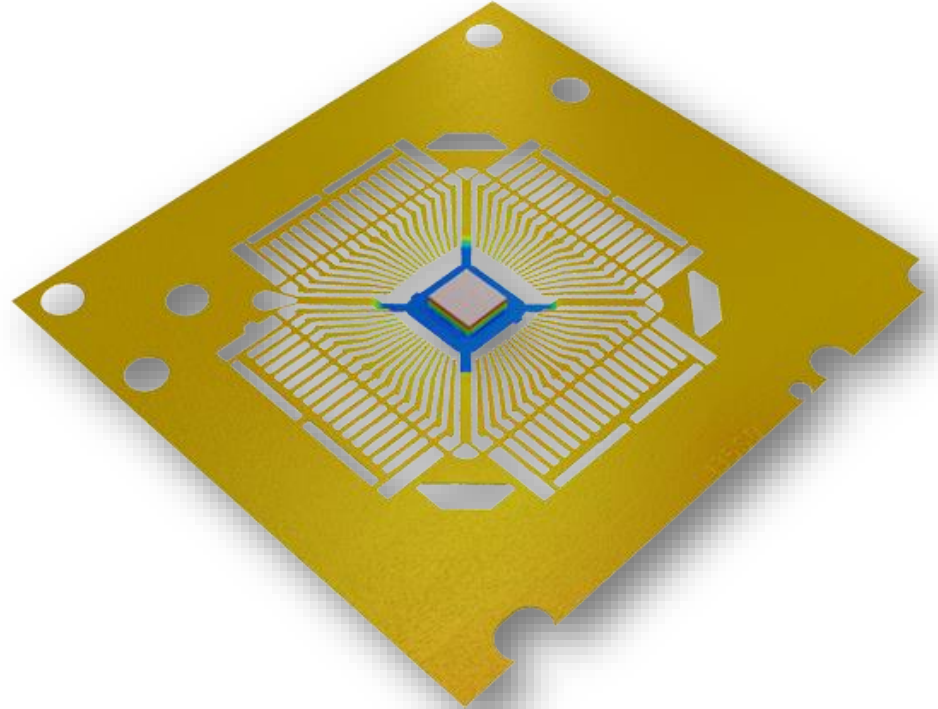
Parameters	Value	Unit
Isotropy	86	%



Parameters	Unit	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Projected area	%	36.9	30.7	32.4

# MarSurf CP/CL *select* – Advantages

- **Non-contact and non-destructive measurement**
- **Combination of high precision and high measurement speed**
- **Coating thickness measurement and measurement of transparent materials**
- **Precise detection with varying degrees of reflection and inclinations**
- **Compact design: robust and reliable**
- **Ideal for quality assurance and process control**





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