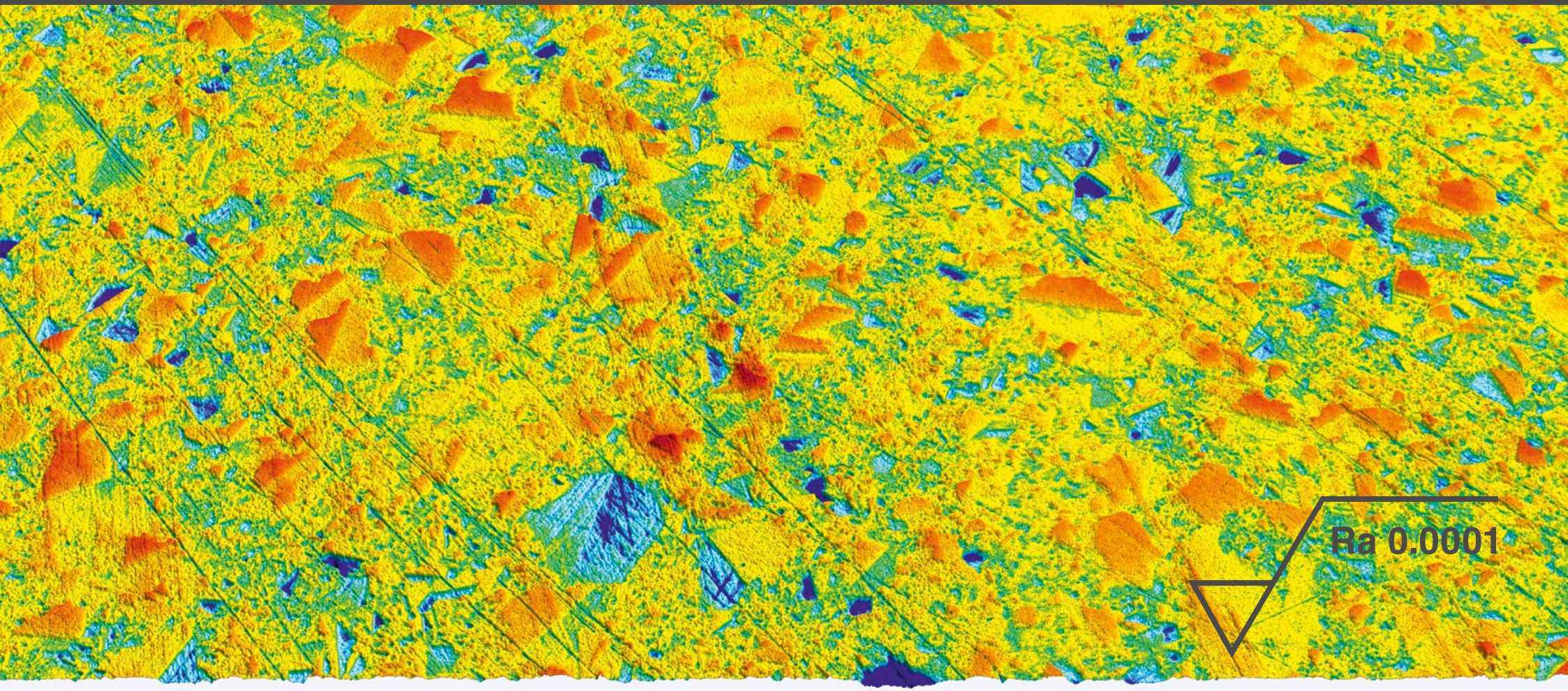
gbs METROLOGY



smart WLI

3D surface **metrology**

optical 3D sensors based on coherence scanning (white-light) interferometry

smartWLI sensor	nimbus8	next	firebolt8	compact	nanoscan	extended range
camera	8.0 MP	1.3 MP / 2.3 MP / 5 MP	8.0 MP	2.3 MP / 5 MP	5 MP	2.3 MP
speed	160 FPS	935 FPS / 169 FPS / 77 FPS	160 FPS	169 FPS / 77 FPS	77 FPS	169 FPS
scanning range	200 µm	200 µm	400 µm	400 µm	400 µm	5 mm
topography reproducibility single scan	< 0.05 nm	< 0.05 nm	< 0.05 nm	< 0.05 nm	< 0.05 nm	< 0.5 nm
topography reproducibility 10 repetitions	< 0.02 nm	< 0.02 nm	< 0.02 nm	< 0.02 nm	< 0.02 nm	–
objective turret	motorized	motorized	–	–	–	–
objectives	2.5x – 115x	5x – 115x	2.5x – 115x	2.5x – 115x	2.5x – 115x	2.5x – 115x
long distance objectives	–	–	10x, 5x, 1.5x	10x, 5x, 1.5x	10x, 5x, 1.5x	10x, 5x, 1.5x

ISO conform specified lateral period limit D_{LIM} for the smartWLI series

	magnification / LED	2.5x	5x	10x	20x	50x	100x	115x
D_{LIM} µm	1.3 MP / 0.5x tube / green	19.83	10.24	4.96	2.74	1.36	0.84	0.73
	2.3 MP / 0.5x tube / green	15.63	8.14	3.94	2.23	1.15	0.75	0.64
	5 MP / 0.5x tube / green	12.63	6.64	3.13	1.84	1	0.66	0.58
	5 MP / 1.0x tube / blue	7.98	4.28	2.00	1.23	0.73	0.51	0.45
	8 MP / 1.x tube / green	-	5.2	2.4	1.46	0.82	0.55	0.49
spatial sampling µm	1.3 MP / 0.5x tube / green	5.2	2.6	1.3	0.65	0.26	0.13	0.11
	2.3 MP / 0.5x tube / green	3.8	1.9	0.96	0.48	0.19	0.1	0.08
	5 MP / 0.5x tube / green	2.8	1.4	0.69	0.35	0.14	0.07	0.06
	5 MP / 1.0x tube / blue	1.4	0.7	0.35	0.175	0.07	0.035	0.03
	8 MP / 1.x tube / green	-	1.0	0.5	0.25	0.1	0.05	0.045
FOV mm^2	1.3 MP / 0.5x tube / green	6.7 x 5.4	3.4 x 2.7	1.6 x 1.4	0.83 x 0.68	0.34 x 0.27	0.16 x 0.14	0.15 x 0.12
	2.3 MP / 0.5x tube / green	7.3 x 4.6	3.7 x 2.3	1.8 x 1.2	0.91 x 0.58	0.37 x 0.23	0.18 x 0.12	0.16 x 0.1
	5 MP / 0.5x tube / green	6.8 x 5.7	3.4 x 2.8	1.7 x 1.4	0.85 x 0.71	0.34 x 0.28	0.17 x 0.14	0.15 x 0.12
	5 MP /1.0x tube / blue	3.4 x 2.8	1.7 x 1.4	0.85 x 0.71	0.43 x 0.36	0.17 x 0.14	0.09 x 0.07	0.075 x 0.06
	8 MP / 1.x tube / green		3.4 x 2.2	1.7 x 1.1	0.85 x 0.55	0.34 x 0.22	0.17 x 0.11	0.15 x 0.1
available systems	1.3 MP / 0.5x tube / green	smartWLI next						
	2.3 MP / 0.5x tube / green	smartWLI Scanner, smartWLI GBScope, smartWLI compact, smartWLI next						
	5 MP / 0.5x tube / green	smartWLI compact, smartWLI next						
	5 MP /1.0x tube / blue	smartWLI nanoscan						
	8 MP / 1.x tube / green	smartWLI nimbus8, SmartWLI firebolt8						

unique advantages of the smartWLI sensors based on superior calculation power

optical 3D sensors with superior resolution

- HD-EPSI (high density extended phase shift interferometry) combines and extends interferometric measurement techniques for noise suppression

increased acceptance angles on shine inclined surfaces

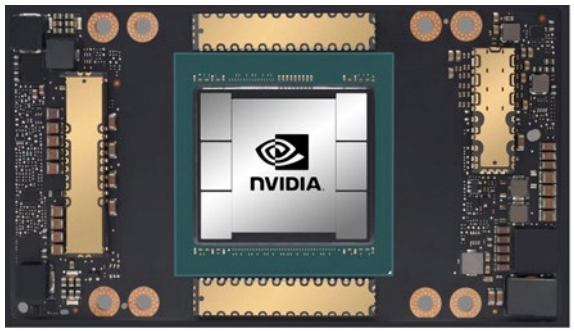
- image correction and contrast enhancement are used to eliminate the camera noise and amplify weak interference signals

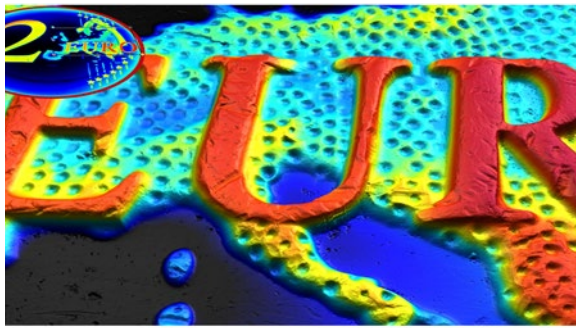
suppression of outliers on fine structures surfaces with a higher aspect ratio

- AQC (advanced quality control) compares the camera signal FFT-based with ideal correlograms and eliminates outliers without filtering the 3D point cloud

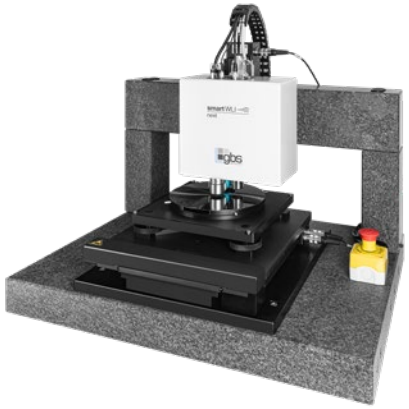
faster measurements and higher resolution save time and money

- CUDA programmed NVIDIA graphic boards are 100x faster than CPUs and enable the use of faster, higher-resolution cameras





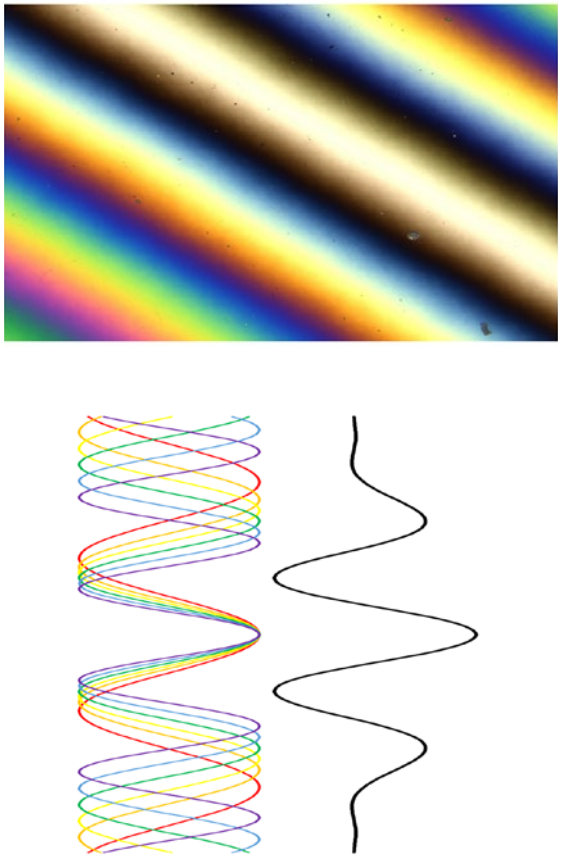
optical 3D profilometer and system building kits



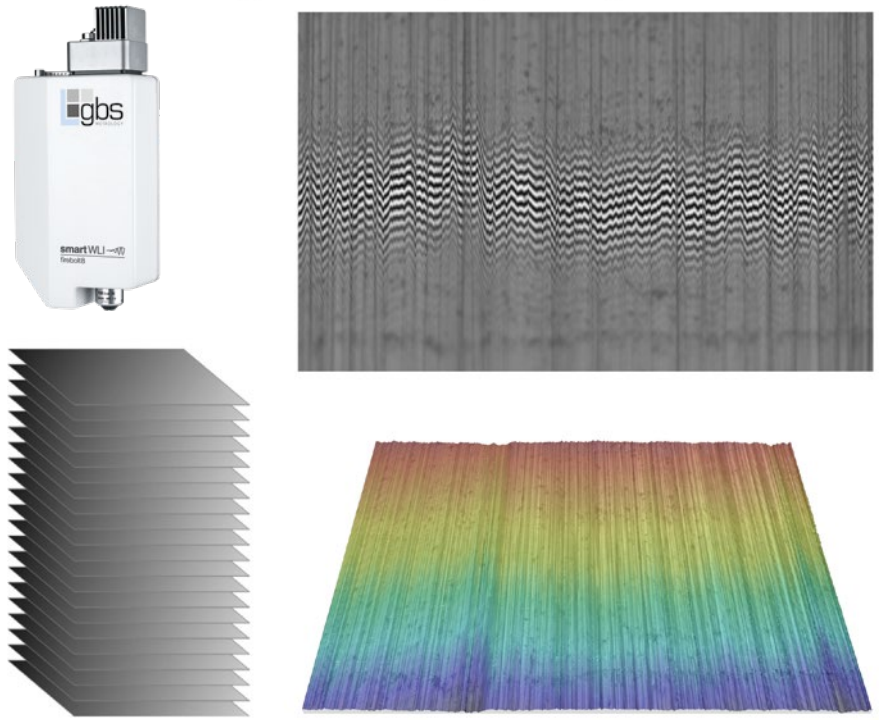
smartWLI sensor	GBScanner	GBScope	system building kits	CylinderInspector3D
sensors	part of the system	part of the system	nimbus8, next, firebolt8, compact, nanoscan, extended range	part of the system
camera	2.3 MP / 169 FPS	2.3 MP / 169 FPS	see sensor specification	4 MP / 77 FPS
scanning range	50 … 200 mm	50 … 200 mm	200 µm … 200 mm	200 µm
manual xy stages	–	–	100 x 100 mm²	360° rotation
motorized xy stages	100 x 100 mm²; 200 x 200 mm², 300 x 300 mm², granite portals			–
tip-tilt	manual	manual	manual / motorized	manual
objective turret	motorized	–	see sensor specification	–
objectives	5x – 115x	2.5x – 115x	see sensor specification	5x – 115x
long distance objectives	–	10x, 5x, 1.5x	see sensor specification	–

coherence scanning (white-light) interferometry

interference on a mirror

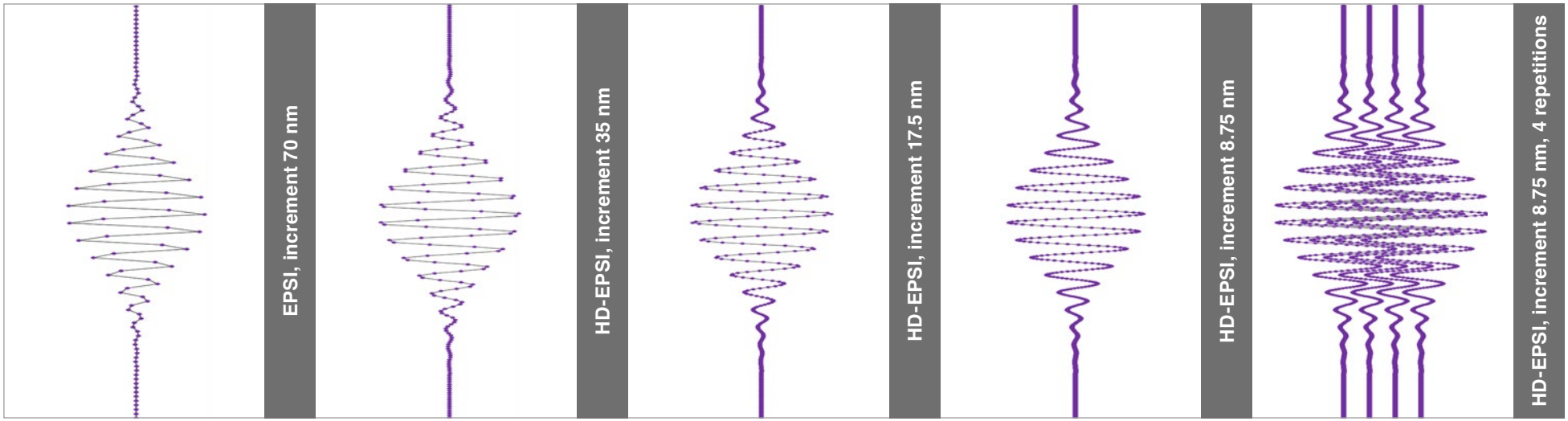


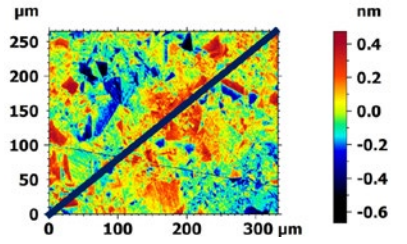
scanning process of a slightly inclined sample surface

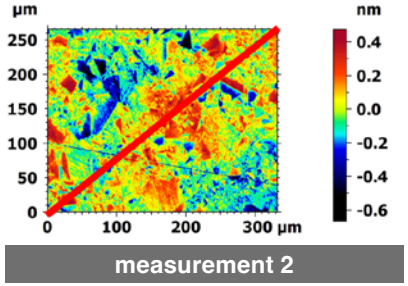


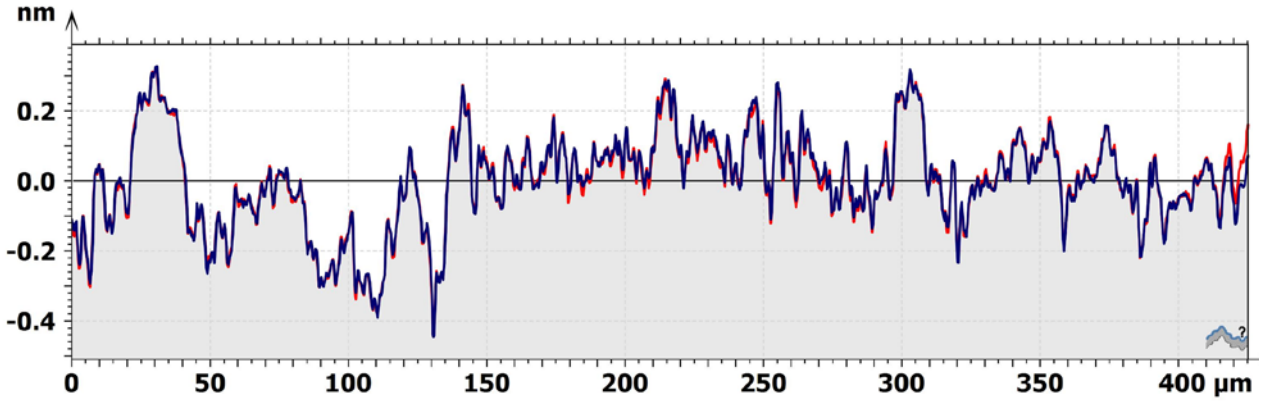
The interference zone has its maximum in the focus plane. Light sources with optimized spectral properties are used to parametrize the interference zone size. The scanner moves the interference lens through the focal plane while the camera captures the interference signal. The software calculates the 3D geometry for each pixel.

superior height resolution based on HD-EPSI and profile averaging



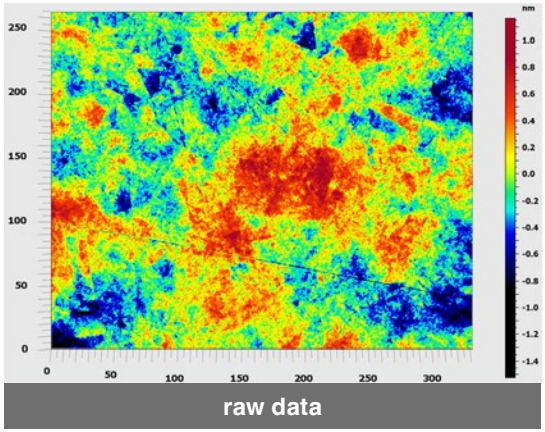


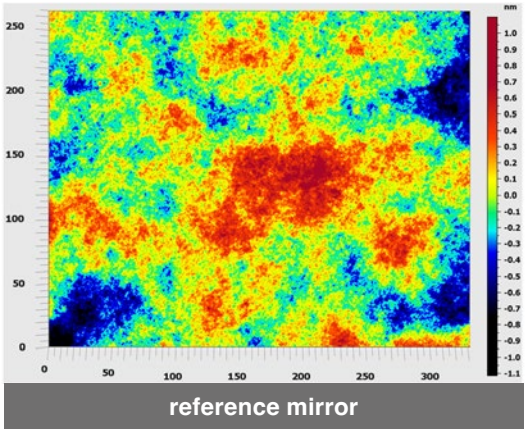


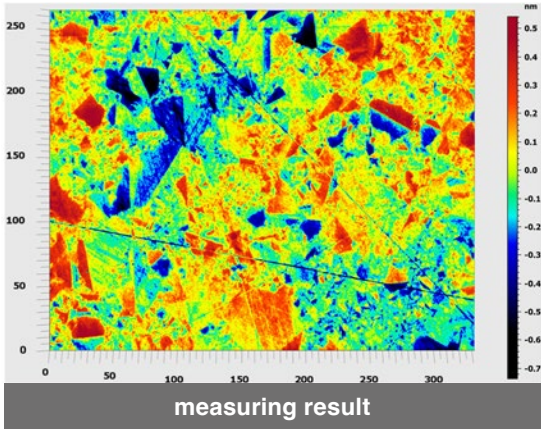


Topography reproducibility / noise evaluation of the smartWLI firebolt 50x
measuring conditions: HD-EPSI. increment 8.75 nm. 40 repetitions
difference evaluation: roughness Rq $\Delta z < 10$ pm (without filtering processes)
topography reproducibility: $< 10/\sqrt{2}$ pm ≈ 7 pm

excellent calibration for superior measurements


raw data


reference mirror

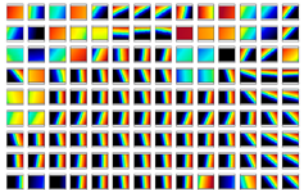

measuring result

excellent calibration for correct measurements

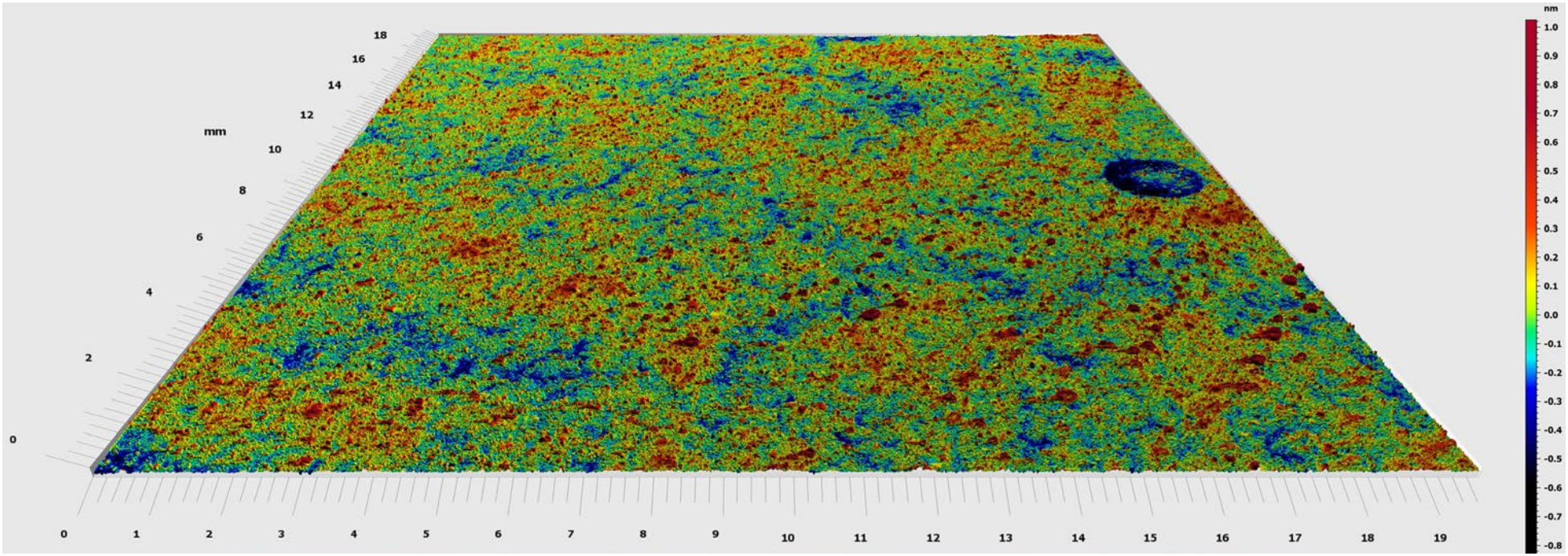
- calibration of piezo movements and capacity-controlled height scanning
- synchronization of scanner and camera
- lateral calibration using magnification specific dot targets
- determination of the effective wavelength from the light source with objective specific corrections
- determination of the coherence length and adapted range selection for HD-EPSI measurements

Sensor and system calibration form the basis for accurate measurements including error-free stitching processes. Internal tests and calibration certificates are included in the scope of delivery.

smartSTITCH the basis for correct high resolution. large area measurements



smartSTITCH for perfect measuring results using hundreds of single scans
XY table movements involve height and tilt errors. smartSTITCH algorithms utilize overlapping regions for height and angle compensation. This reduce stitching errors in roughness, flatness and form measurements below the visible range. The speed-optimized algorithms are integrated into the smartVIS3D scanning software.

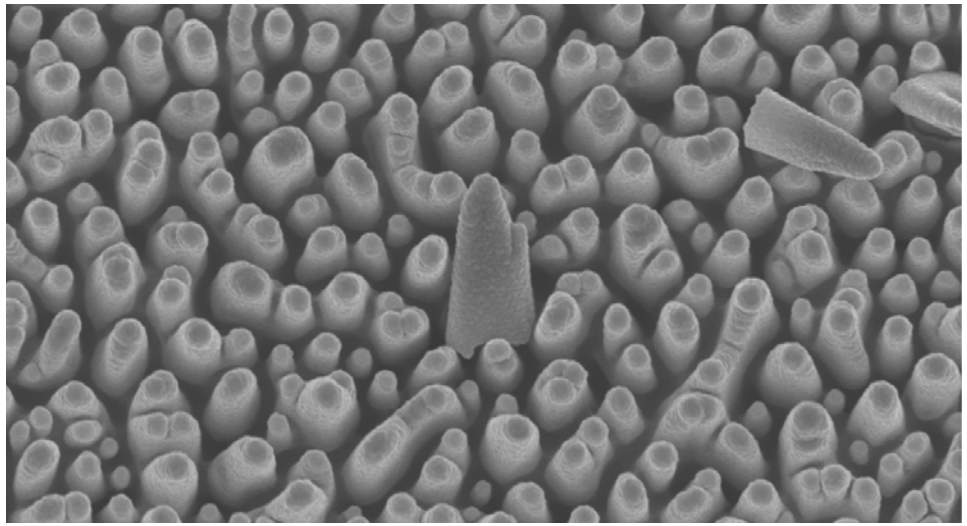


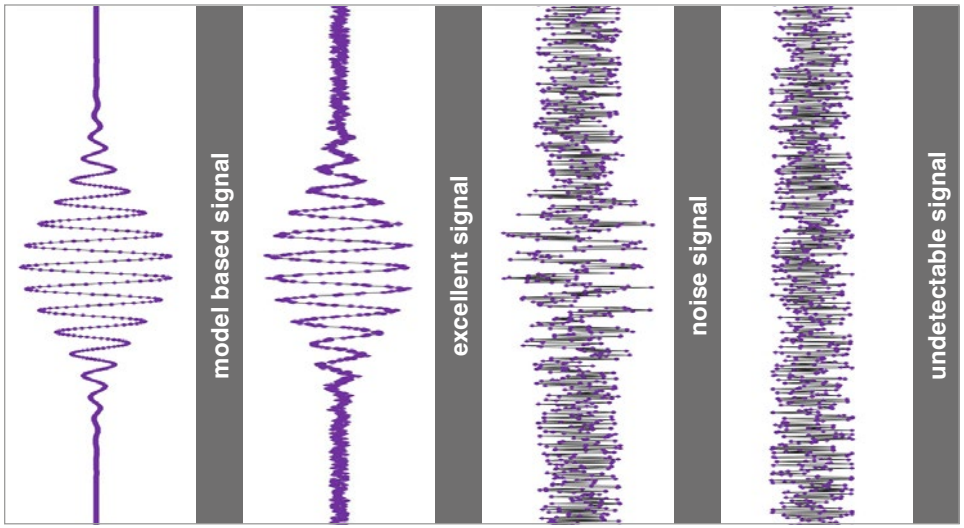
raw data

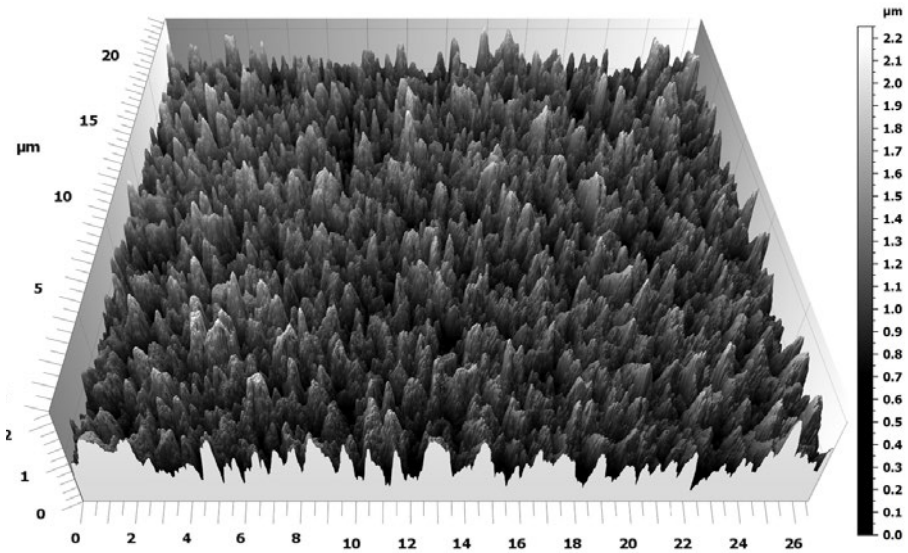
height compensation

height and angle compensation

outlier free scanning – black silicon

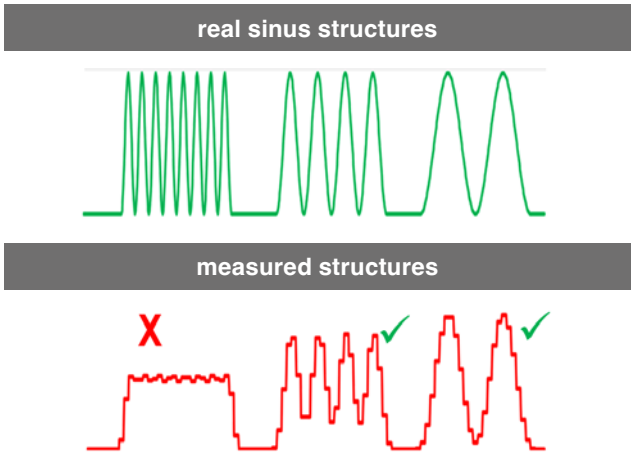






AQC (advances quality control)
Computing power is used to continuously check the camera signal of each pixel in real time and quantify the agreement with an ideal interference signal. If vibrations, interference, and multiple reflections disrupt the signal to the point where the agreement falls below a certain threshold, the height is not calculated and the position remains invalid. This reduces the overall noise level, simplifies the measurement of smooth, inclined geometries, and enables the measurement of finely textured surfaces with high aspect ratios.

excellent and objective tested lateral resolution / smartWLI nanoscan 115x objective

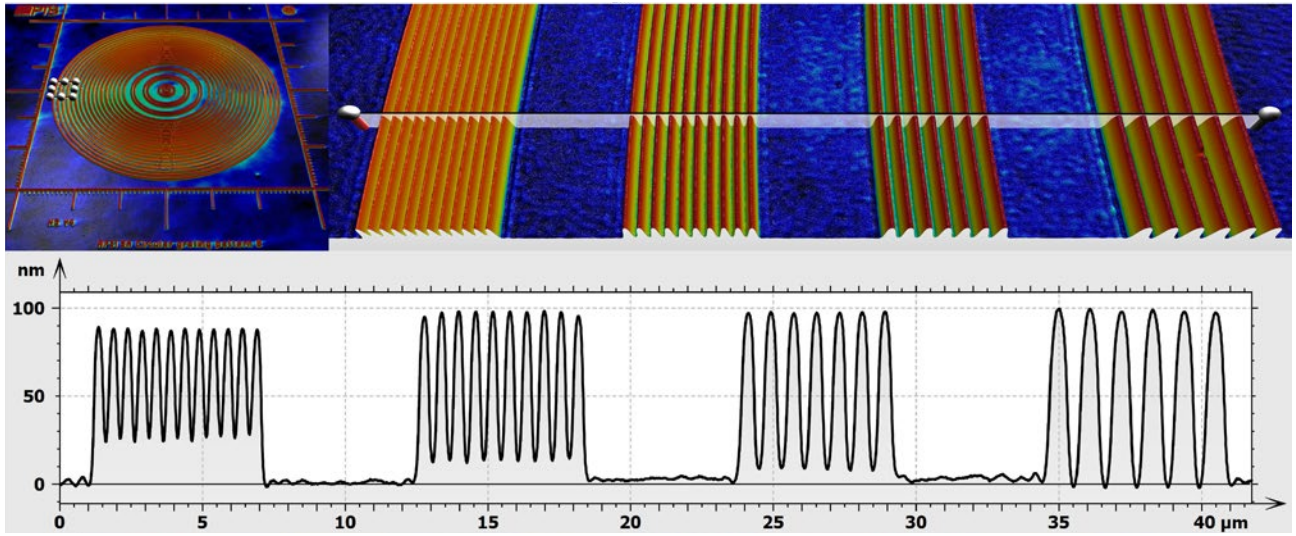


the lateral period limit D_{LIM}:
The lateral period limit is the wavelength once the amplitude of the measured profile drops below 50% of the real height (→ see ISO 25178 – 604).

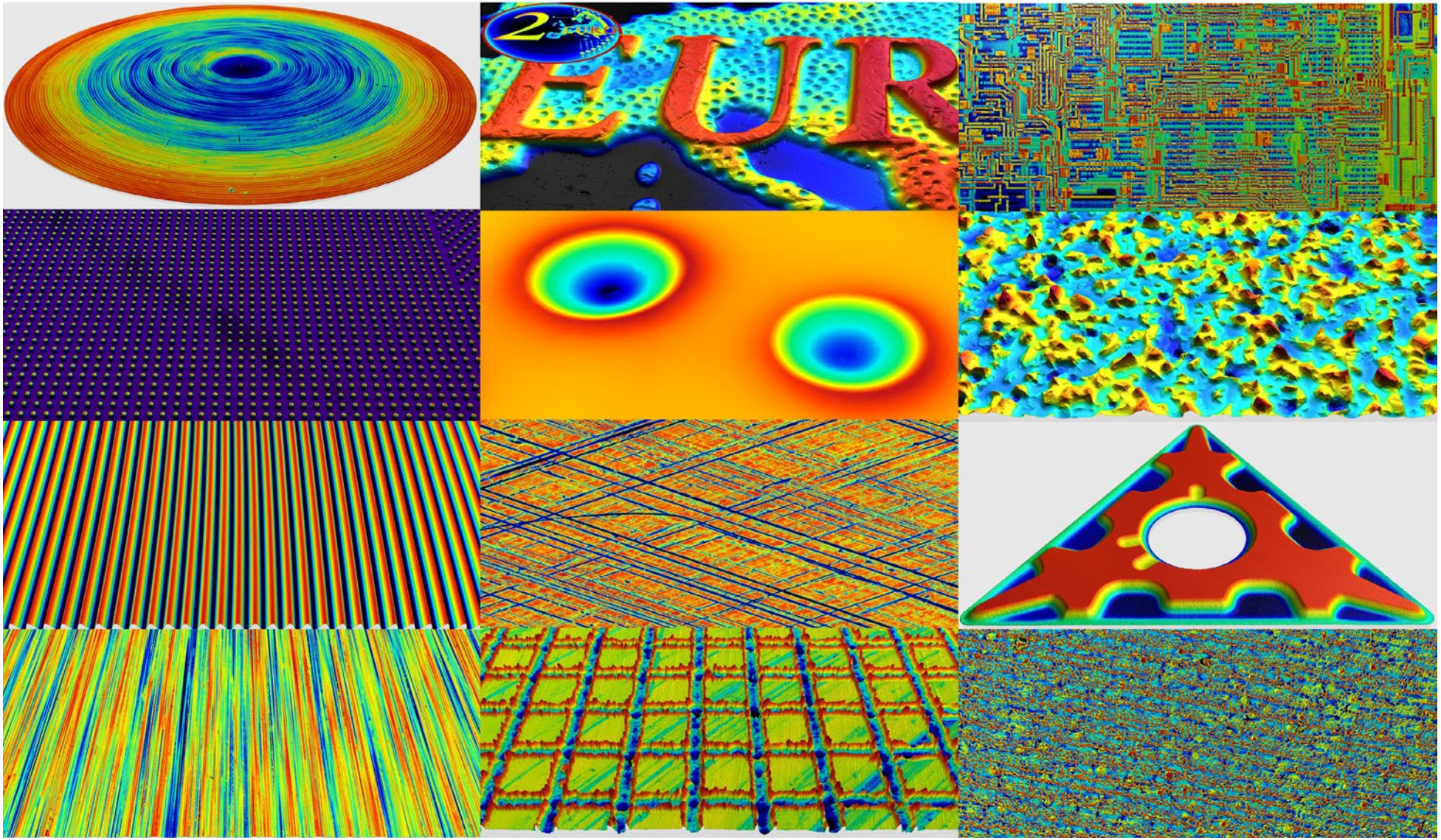
intention of surface metrology:
The intention of surface metrology is in contrary to the microscopy not to resolve (see) structures but realize correct measurements. The lateral period D_{LIM} limit allows to specify, compare and select optical 3D profiler's objective and correctly.

selection criteria:

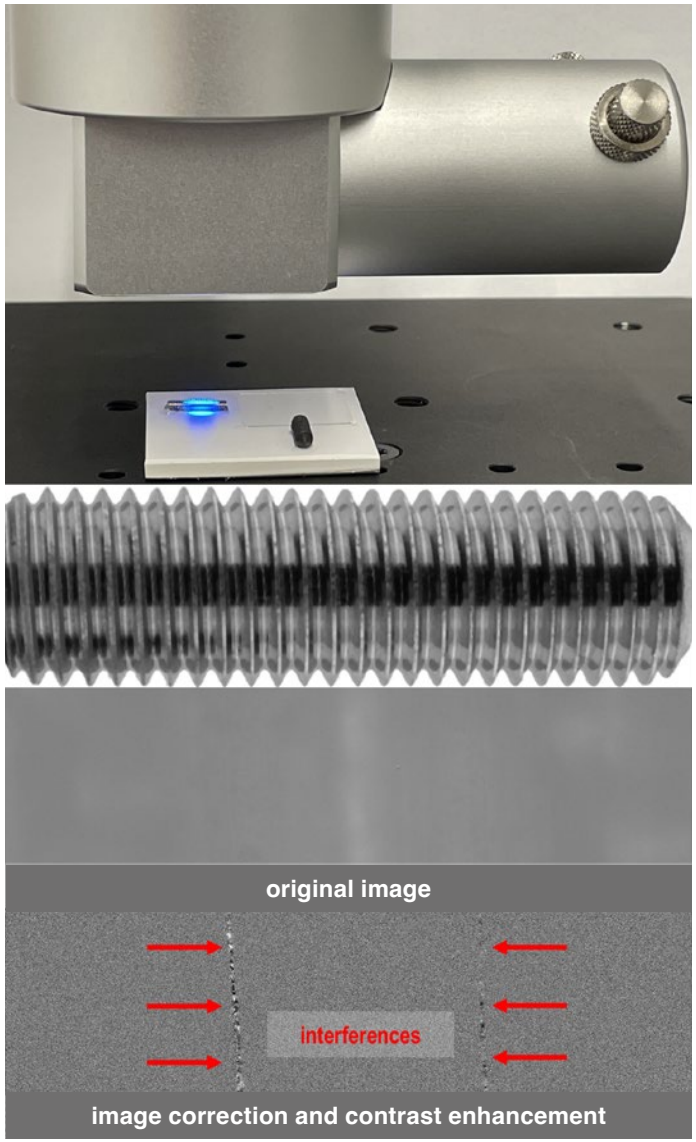
roughness measurements:	D_{LIM} < Ral (autocorrelation length → see TracOptic praxis guide optical roughness measurement)
feature seize:	D_{LIM} < ½ xy dimensions (D_{LIM} is only a 50% criterion and must be smaller)

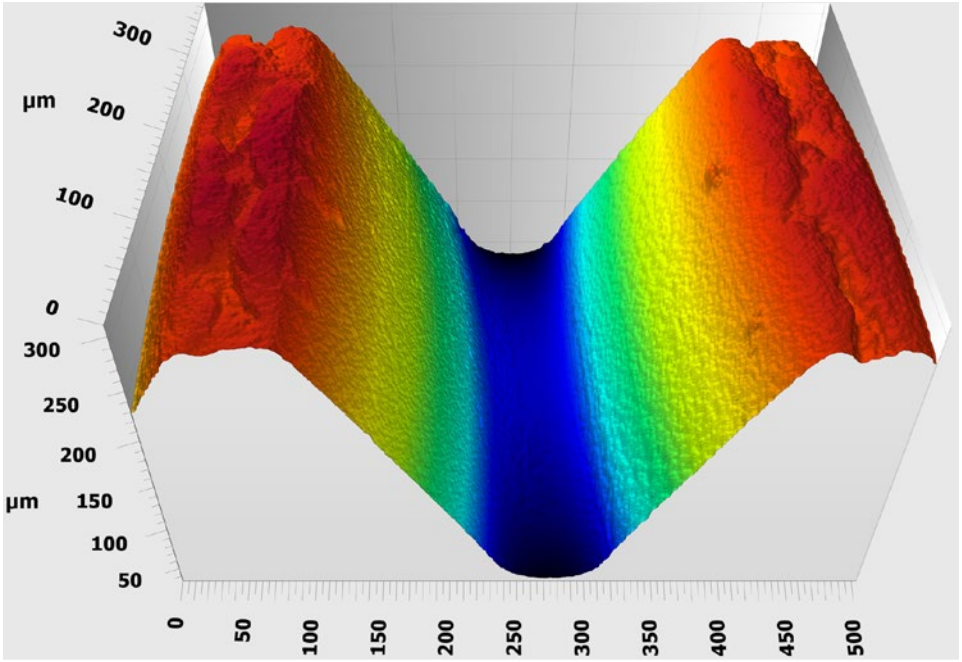


application examples for smartWLI profilers



increased acceptance angles

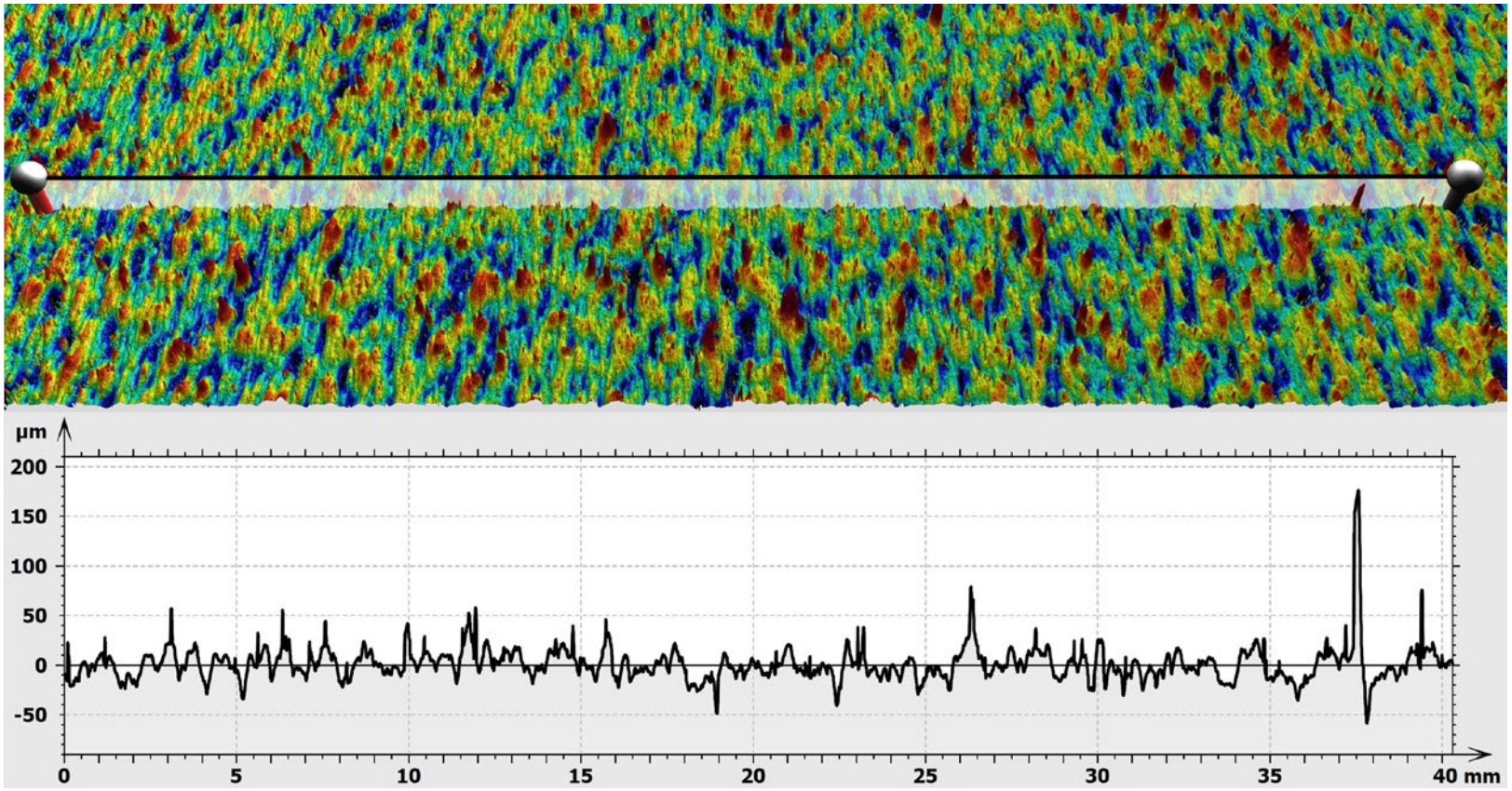




tests on a shine stainless steel M2 screw using a 10x LD objective:
Screws are inexpensive, freely available, and have a standardized geometry with a flank angle of 60°. Due to the lack of standards and standardized tests, such objects allow for a good comparison of optical 3D profilers.

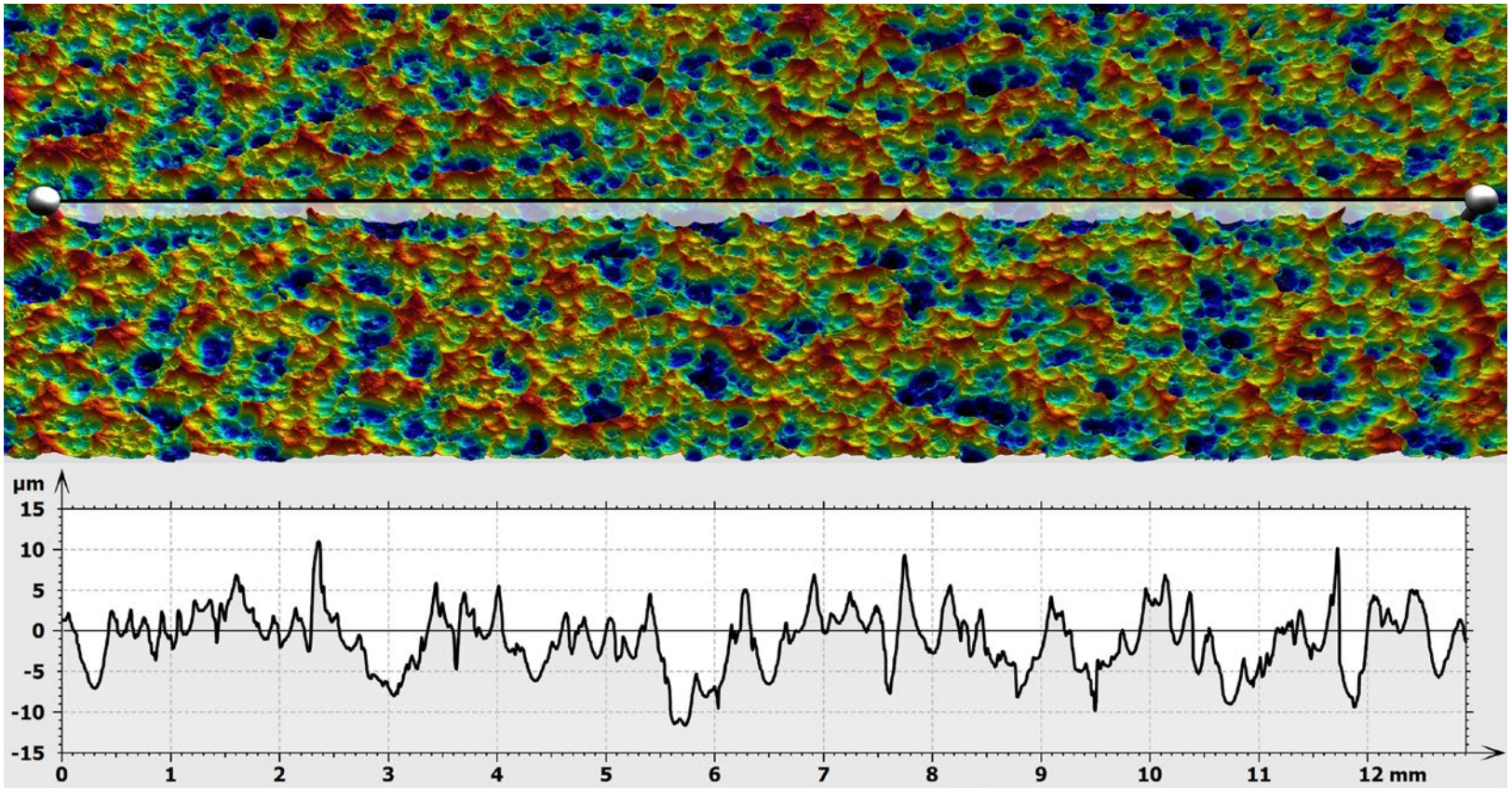
image correction and contrast enhancement:
Not visible in the grabbed camera images - the contrast enhancement shows the interference zone and enables the interferometric calculation of the 3D data.

metal printed surface



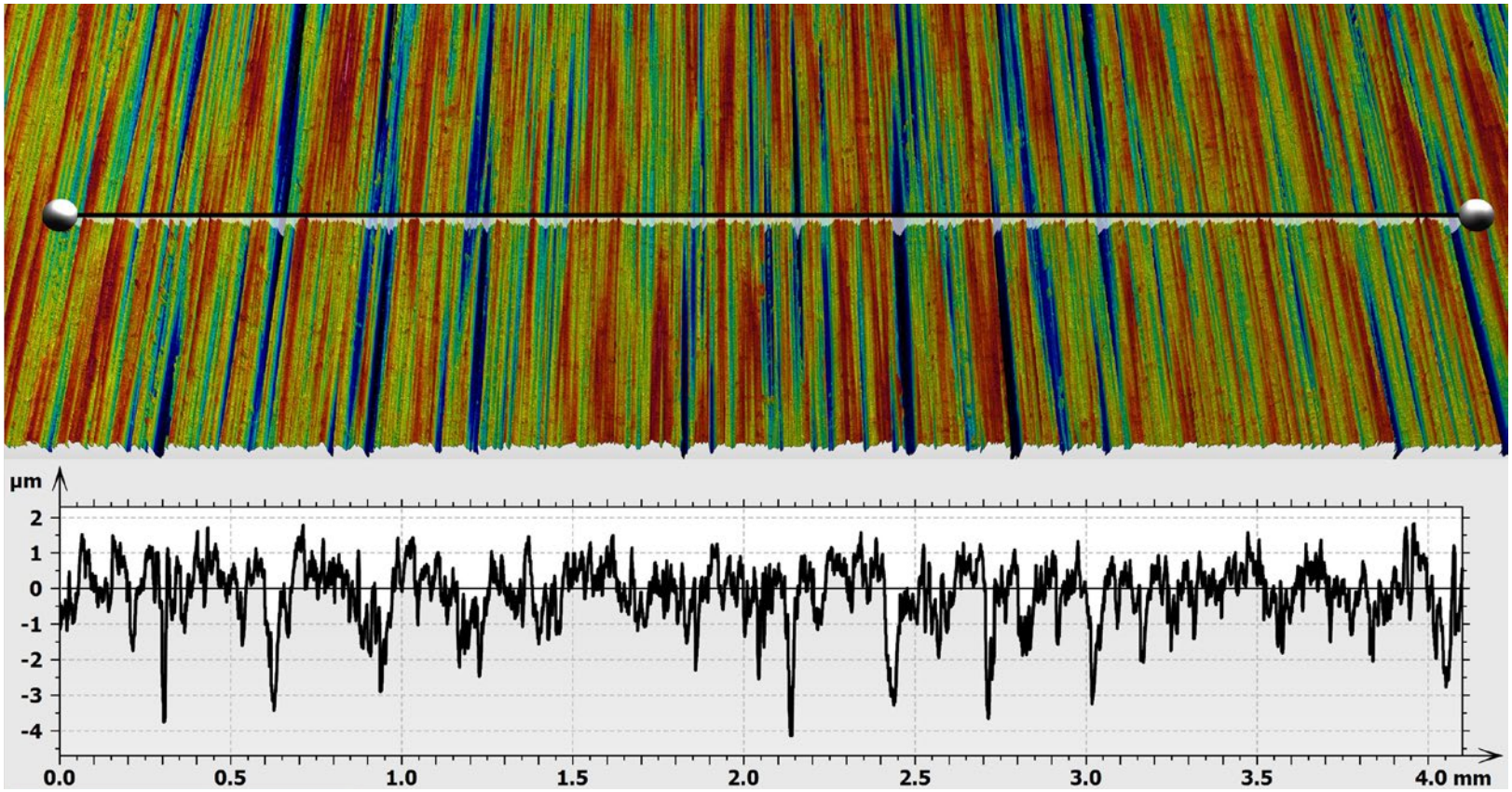
ISO 21920 setting class Sc5 (upper tolerance limit U: Ra > 10 µm)					
nesting index N_{ic} / cutoff λ_c	8 mm	sampling distance d_x	< 5 µm	measured height parameter	
evaluation length l_e	40 mm	section length l_{sc}	8 mm	Rz	118 µm
nesting index N_{is} / cutoff λ_s	25 µm	number of sections	5	Ra	11.0 µm

blasted aluminum surface



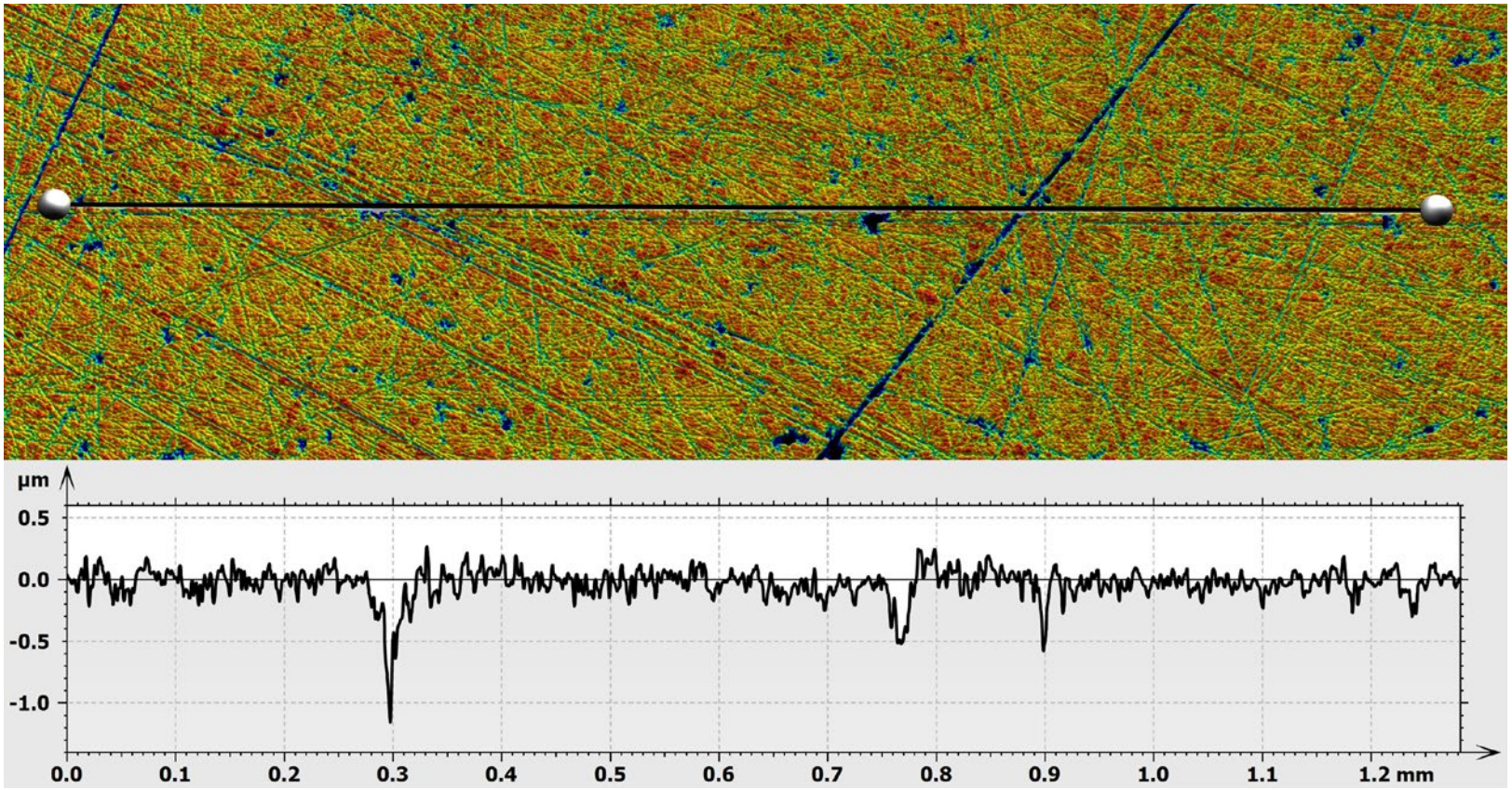
ISO 21920 setting class Sc4 (upper tolerance limit U: 2 < Ra ≤ 10 µm)					
nesting index N_{ic} / cutoff λ_c	2.5 mm	sampling distance d_x	< 1.5 µm	measured height parameter	
evaluation length l_e	12.5 mm	section length l_{sc}	2.5 mm	Rz	16.4 µm
nesting index N_{is} / cutoff λ_s	8 µm	number of sections	5	Ra	2.61 µm

grind surface



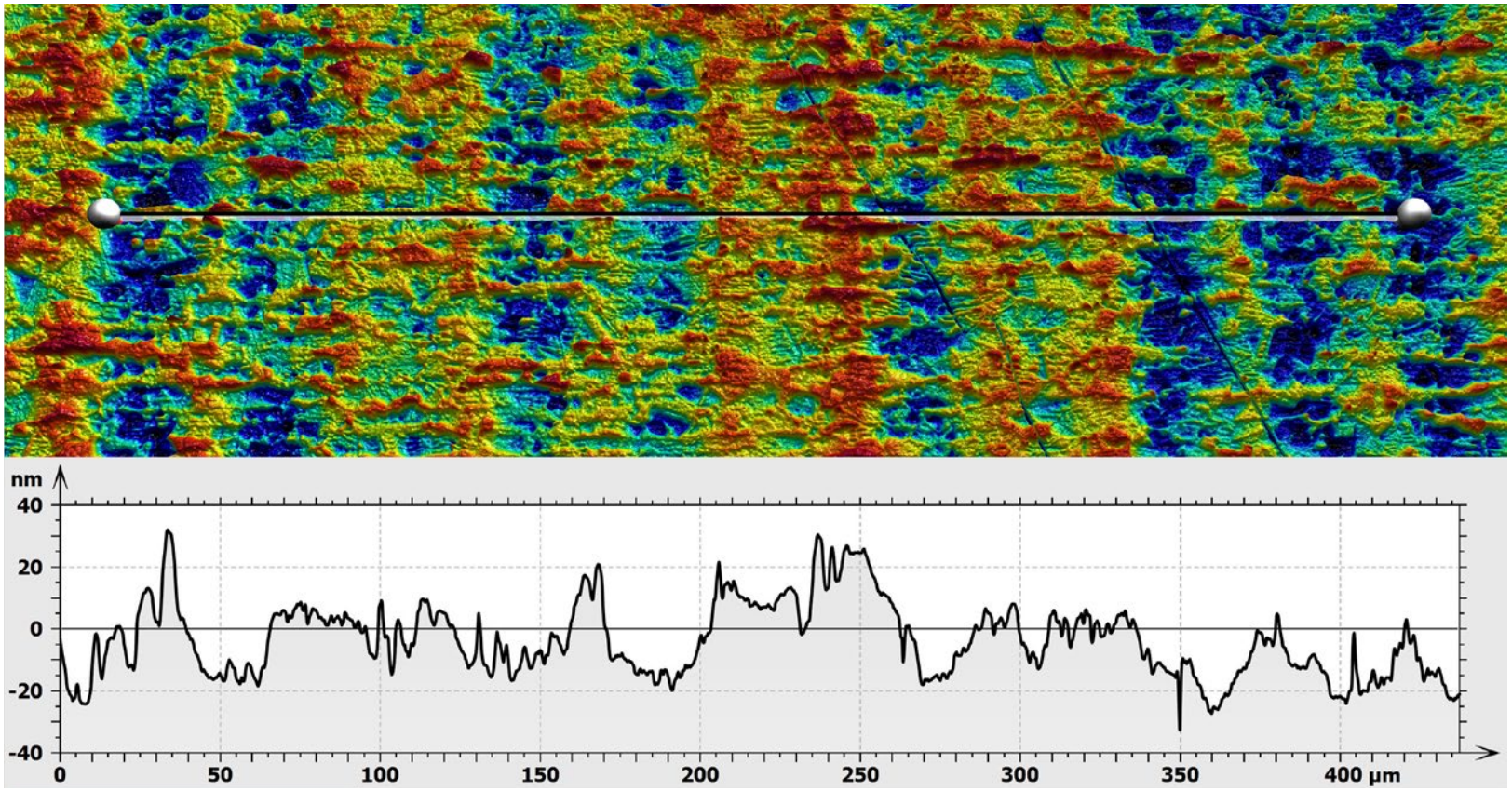
ISO 21920 setting class Sc3 (upper tolerance limit U: 0.1 < Ra ≤ 2 µm)					
nesting index N_{ic} / cutoff λ_c	0.8 mm	sampling distance d_x	< 0.5 µm	measured height parameter	
evaluation length l_e	4 mm	section length l_{sc}	0.8 mm	Rz	4.48 µm
nesting index N_{is} / cutoff λ_s	2.5 µm	number of sections	5	Ra	0.637 µm

polished steel



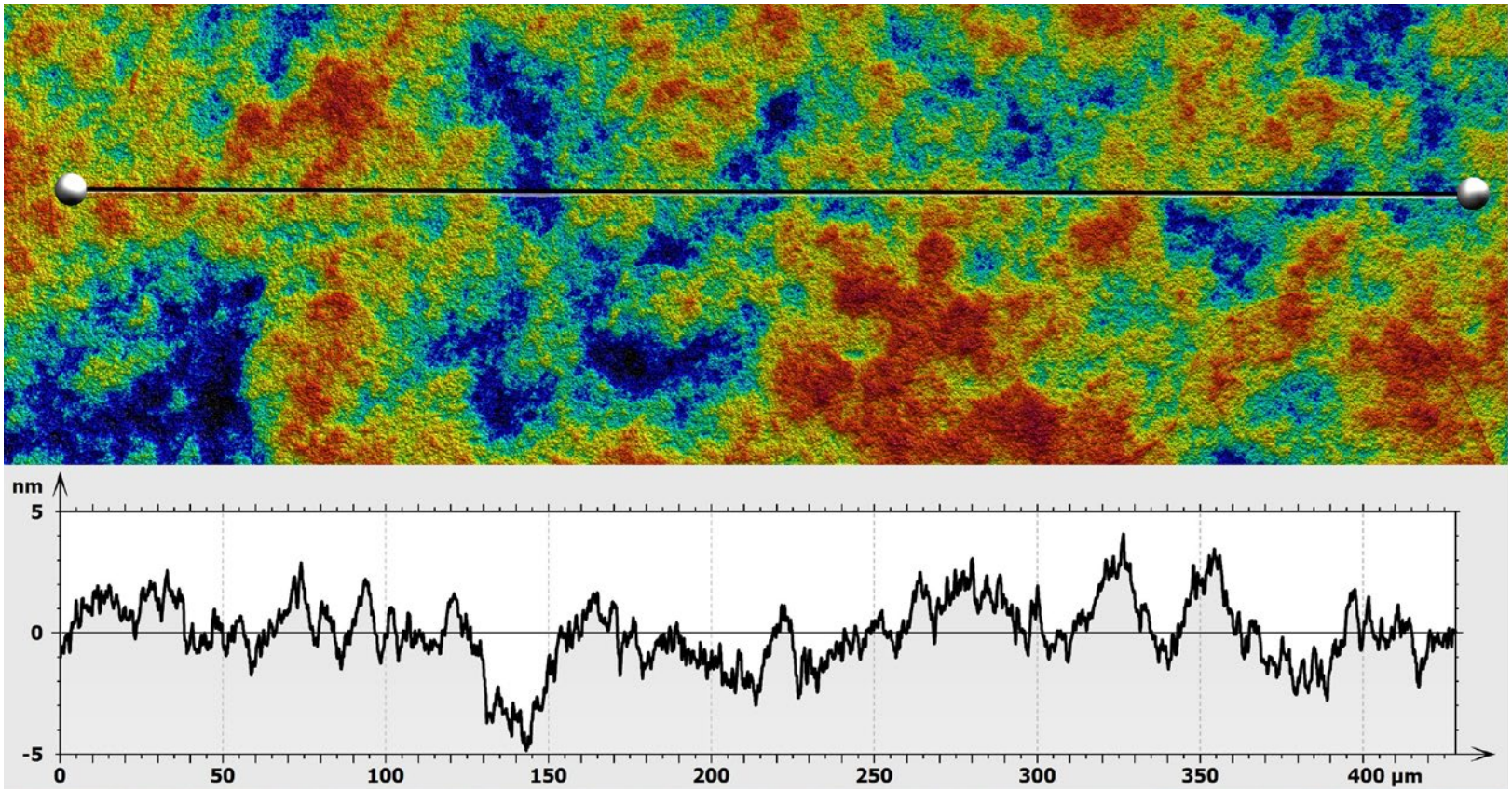
ISO 21920 setting class Sc2 (upper tolerance limit U: 0.02 < Ra ≤ 0.1 µm)					
nesting index N_{ic} / cutoff λ_c	0.25 mm	sampling distance d_x	< 0.5 µm	measured height parameter	
evaluation length l_e	1.25 mm	section length l_{sc}	0.25 mm	Rz	0.669 µm
nesting index N_{is} / cutoff λ_s	0.25 µm	number of sections	5	Ra	0.0767 µm

chromed surface



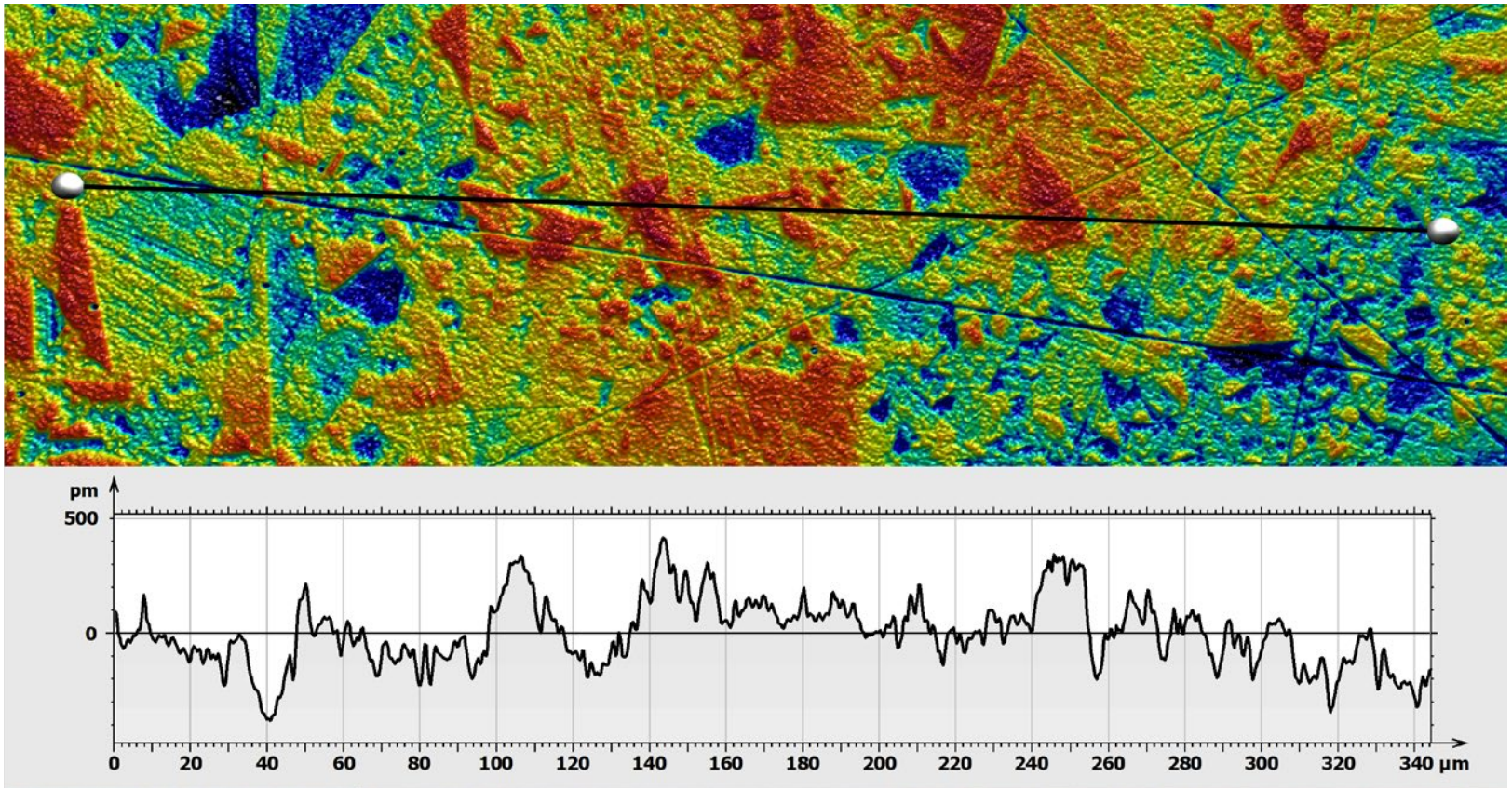
ISO 21920 setting class Sc1 (upper tolerance limit U: Ra < 0.1 µm)					
nesting index N_{ic} / cutoff λ_c	0.08 mm	sampling distance d_x	< 0.5 µm	measured height parameter	
evaluation length l_e	0.4 mm	section length l_{sc}	0.08 mm	Rz	32.2 nm
nesting index N_{is} / cutoff λ_s	0.08 µm	number of sections	5	Ra	6.45 nm

polished wafer



ISO 21920 setting class Sc1 (upper tolerance limit U: Ra < 0.1 µm)					
nesting index N_{ic} / cutoff λ_c	0.08 mm	sampling distance d_x	< 0.5 µm	measured height parameter	
evaluation length l_e	0.4 mm	section length l_{sc}	0.08 mm	Rz	4.02 nm
nesting index N_{is} / cutoff λ_s	0.08 µm	number of sections	5	Ra	0.770 nm

super polished SiC mirror

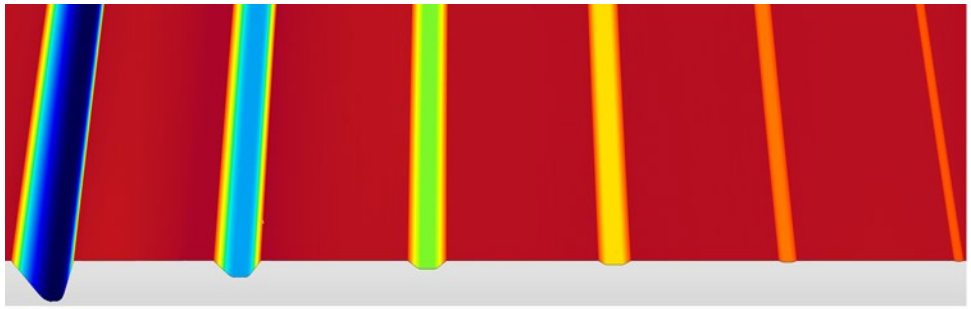


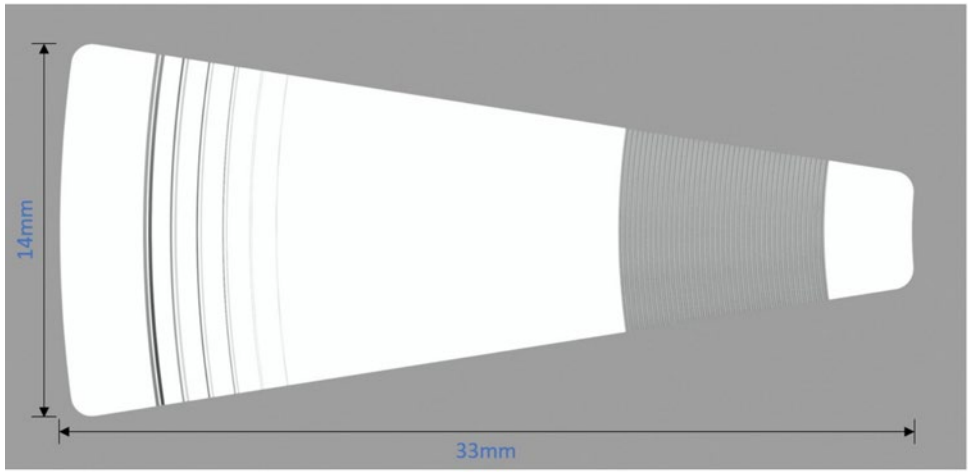
ISO 21920 setting class Sc1 (upper tolerance limit U: Ra < 0.1 µm)					
nesting index N_{ic} / cutoff λ_c	0.08 mm	sampling distance d_x	< 0.5 µm	measured height parameter	
evaluation length l_e	0.4 mm	section length l_{sc}	0.08 mm	Rz	456 pm
nesting index N_{is} / cutoff λ_s	0.08 µm	number of sections	5	Ra	80.2 pm

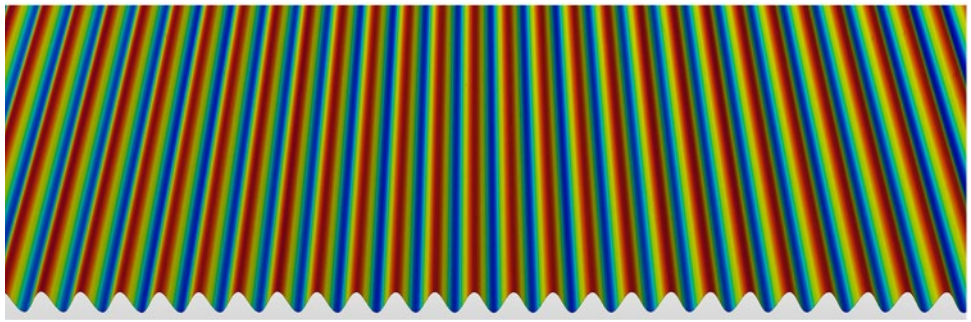
UCS-1 (universal confirmation standard)

groove depth d		
groove number	nominal depth in µm	uncertainty in µm
1	50	0.05
2	20	0.04
3	10	0.03
4	5	0.03
5	2	0.03
6	1	0.03

sinus structure – Ra	
nominal value in µm	uncertainty in µm
0.16	0.01

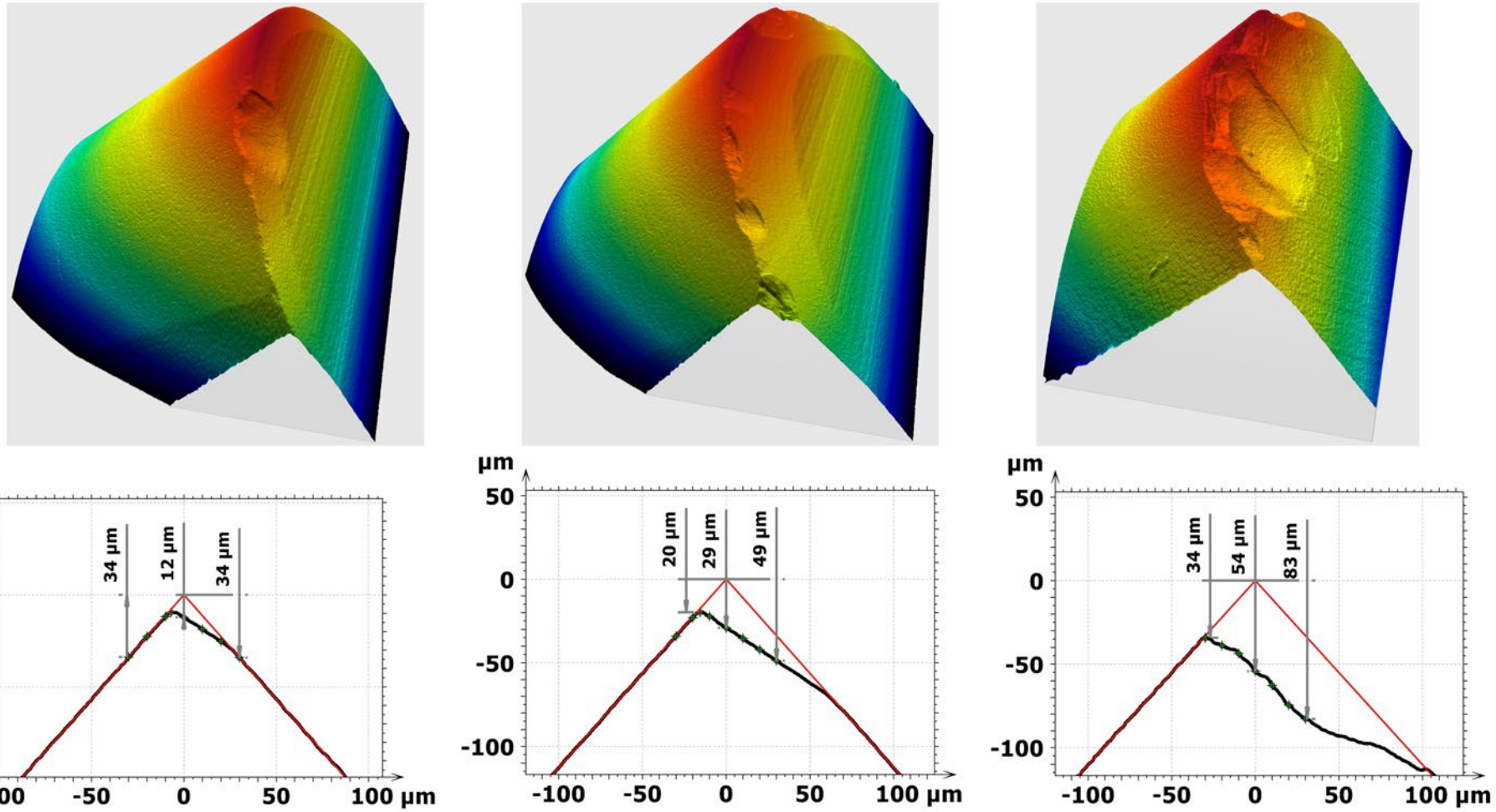






advantages of the universal confirmation standard UCS-1:
The UCS-1 is available with traceable factory calibration and is suitable not only for optical 3D profilers but also for tactile instruments. Maximum flank angles of 20° enable measurements and calibrations with tactile profilometers. A hardened stainless-steel block offers high corrosion and scratch resistance. Thanks to its long service life and easy cleaning, it is ideal for daily use in industrial environments. Seven steps, a sinusoidal zone for roughness measurements, and a smooth zone for topography reproducibility tests allow for flexible use of the surface standard.

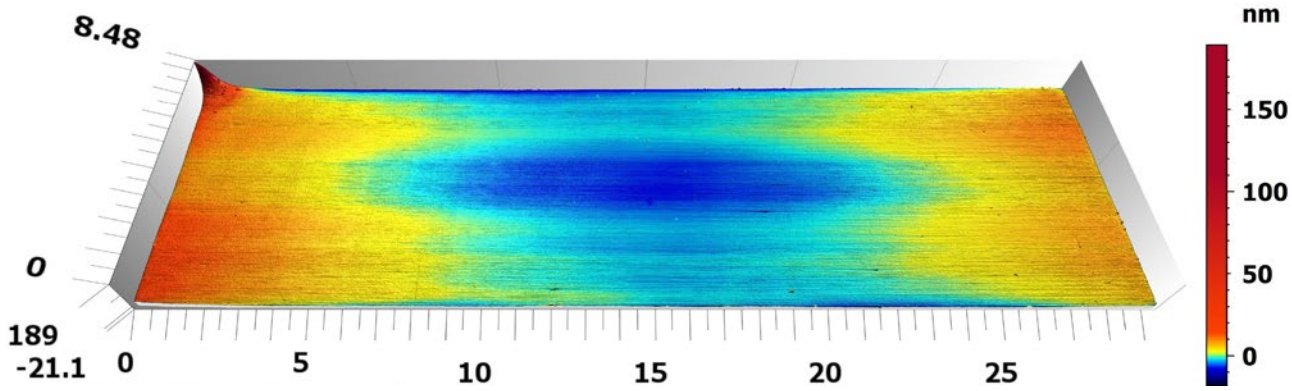
cutting edges

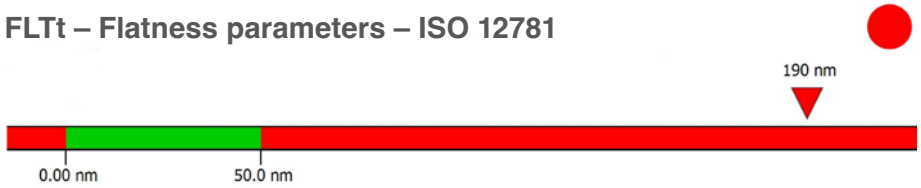


wear measurement and characterization of cutting edges

Through image correction and contrast enhancement, the smartWLI systems are able to analyse even very weak interference signals on inclined microgeometries and can be used with lenses with moderate magnification to measure cutting edges.

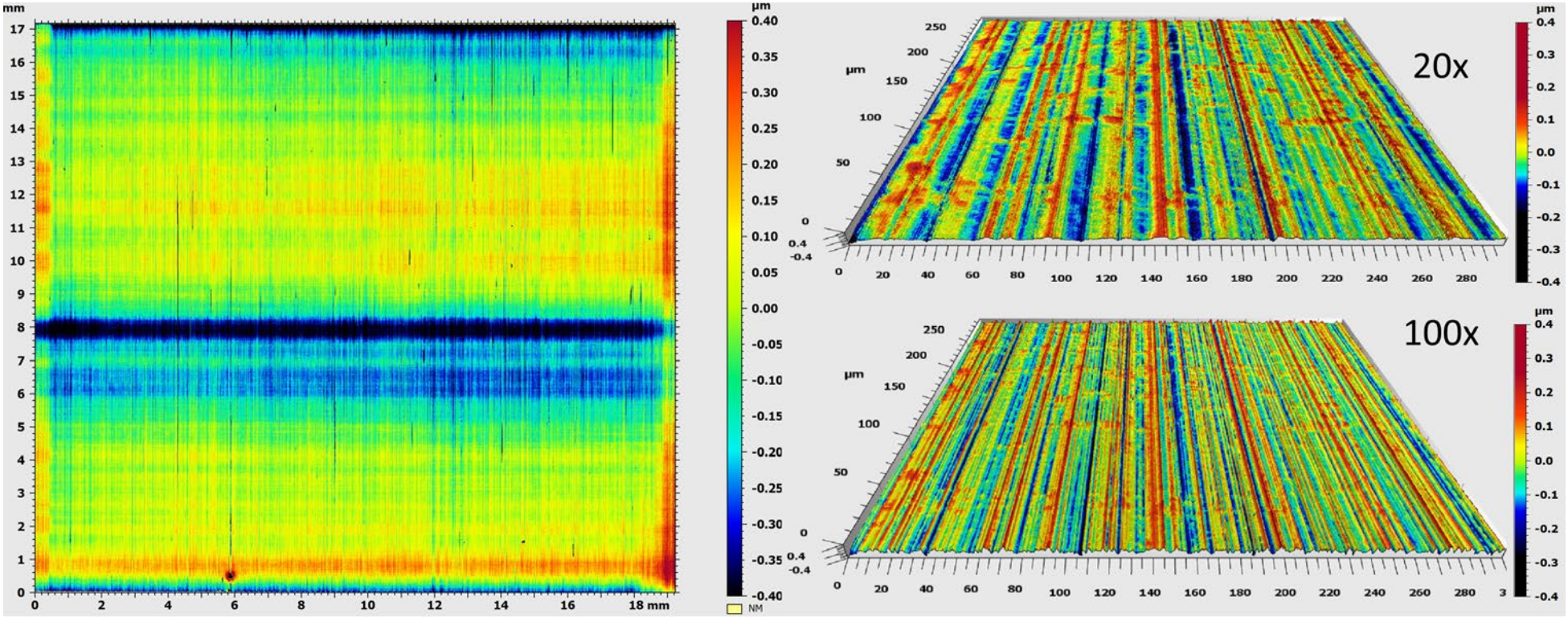
carbide gauge block





damaged gauge block
Gauge blocks are important for verifying the accuracy of measuring instruments. Optical profilers from the smartWLI series can be used to verify gauge blocks. The material is corrosion-resistant, but a fall from the table onto the flour floor caused damage to the edge.

fine grind surface

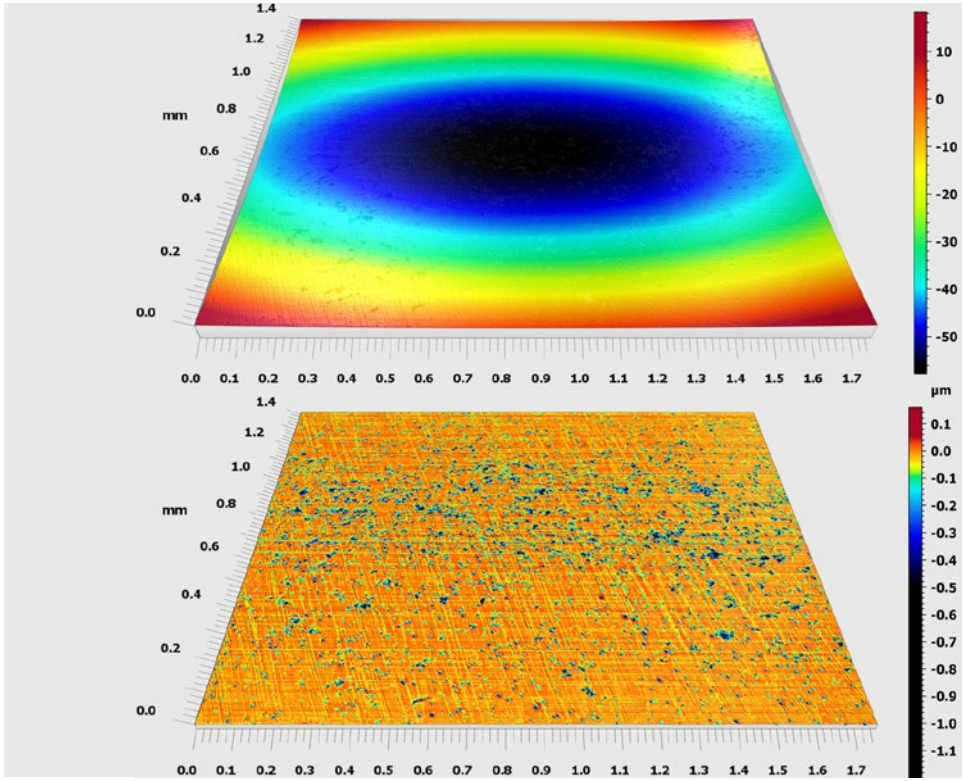


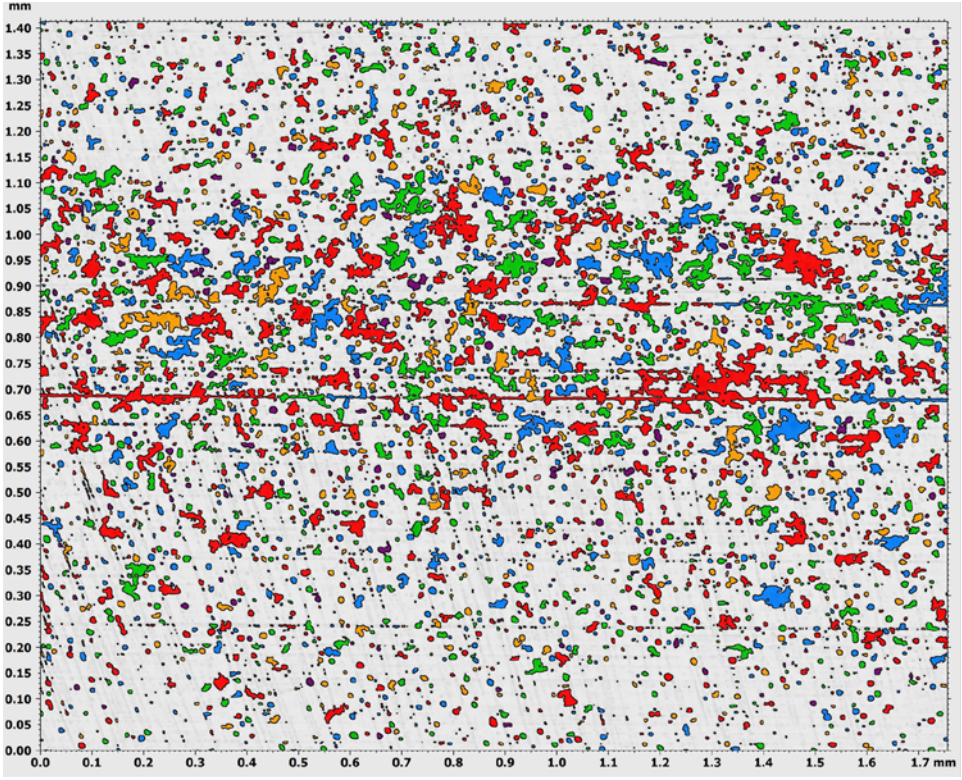
behind the limitation of roughness measurements

Area B of the stainless-steel master used in the TracOptic project would fall into the Sc2 setting class. The smartWLI next optical profiler used offers the following advantages over a stylus profiler:

- 3D measurements enable a deeper understanding of surface structures compared to 2D profiles
- The larger scan can be used for flatness and shape measurements as well as for locating and measuring defects with unknown positions
- the possibility of measuring areas of several cm² with the resolution of tactile measuring systems
- high-magnification lenses have approx. 10x higher lateral resolution compared to tactile measuring systems
- smartWLI sensors achieve approx. 100x better height resolution compared to tactile systems

ball bearing



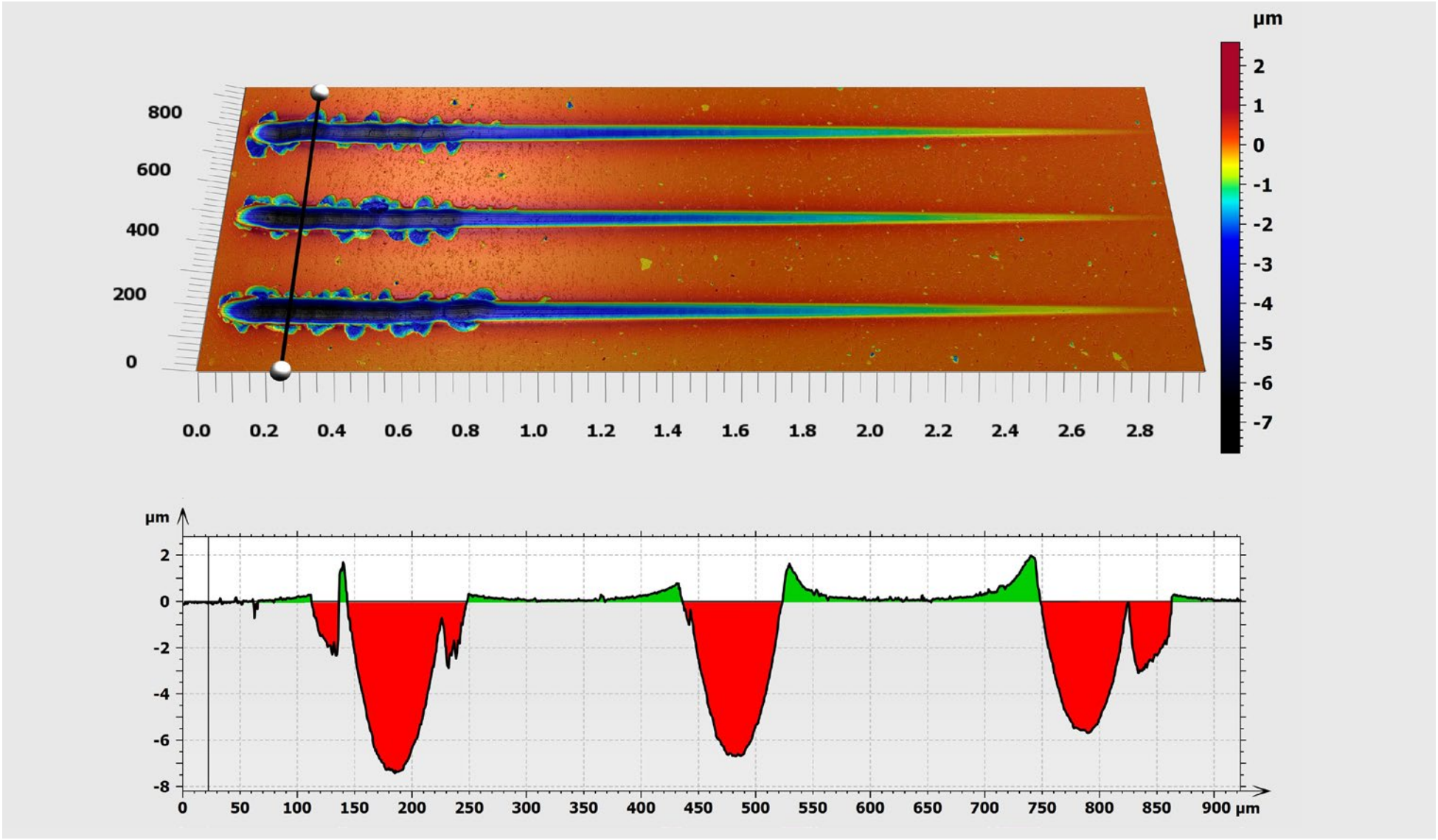


analysis of the corrosion

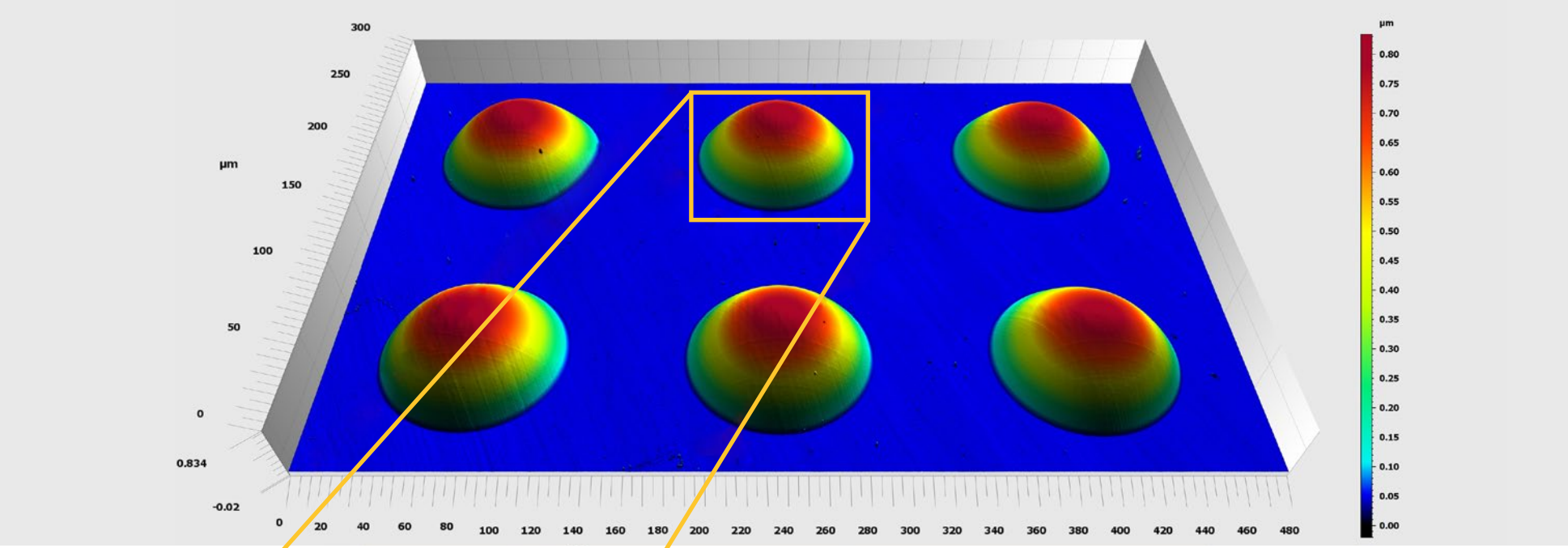
The “particle analysis” feature of the MountainsMap® software package enables classification and statistical evaluation of surface structures. Elevation thresholds, watershed models, edge detection or circular models can be used to identify structures. Area, volume, depth/height and aspect ratio can be used for statistical evaluation.

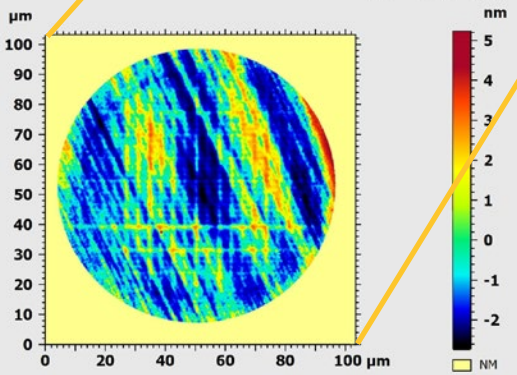
Information	
Method	Threshold detection
Particles to detect	Below a threshold value
Number of particles	4530
Coverage	19.5 %
Density	1826 Particles/mm²

tribological tests



micro lenses





ISO 25178-2 – Roughness (S-L)
S-filter (λ_c): Gaussian, 2.5 μm
L-filter (λ_c): Gaussian, 0.08 mm, Ends not cut
Height parameters
Sa 0.720 nm

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