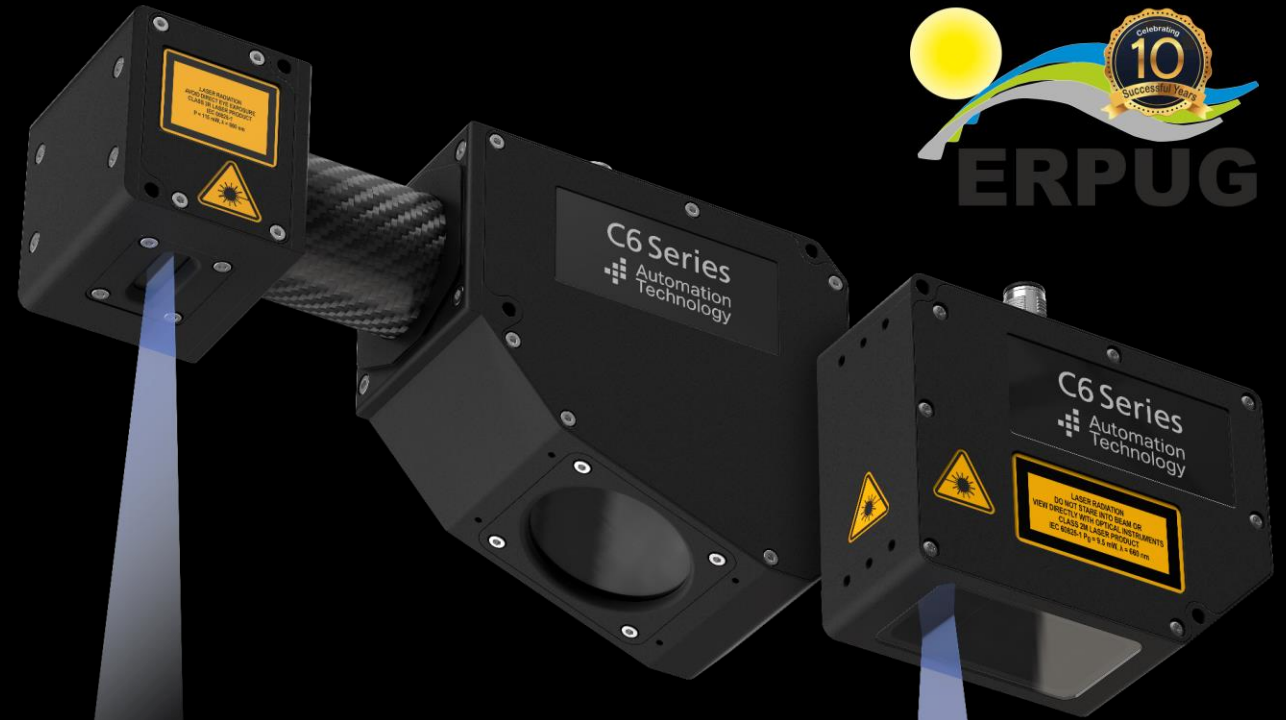
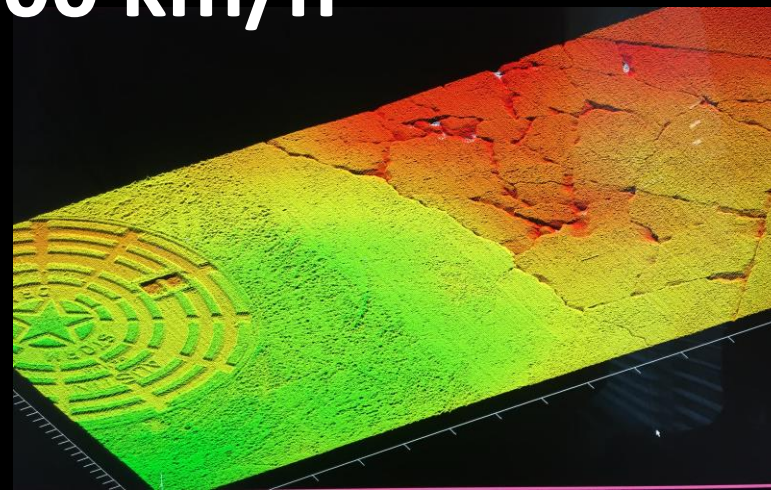




Dr. Athinodoros Klipfel
Head of Sales



Submillimeter Resolution Pavement Scans at up to 100 km/h



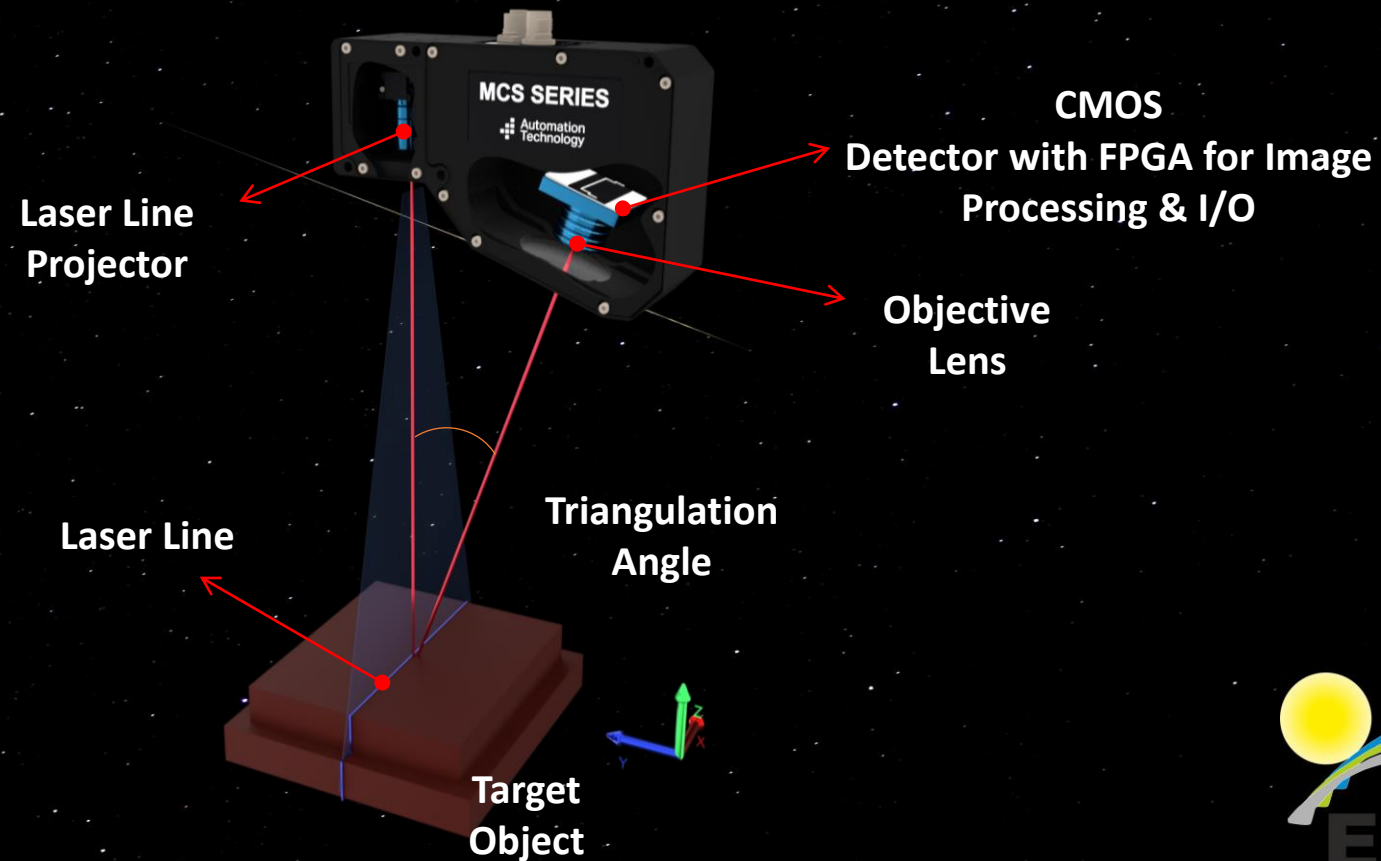
Submillimeter Resolution Pavement Scans at up to 100 km/h

CONTENTS

- The profile scan principle of Laser triangulation
- Requirements and technology limitations for high-speed submillimeter pavement scans
- WARP: A new technology pushing the speed limits of laser triangulation
- Additional functions for high speed pavement scans
- Application examples of submillimeter resolution pavement scans

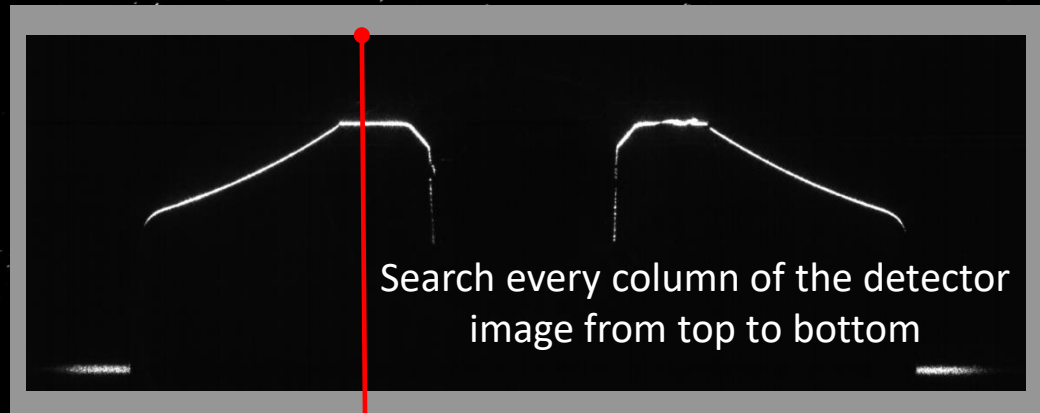
Submillimeter Resolution Pavement Scans at up to 100 km/h

The Profile Scan Principle of Laser Triangulation



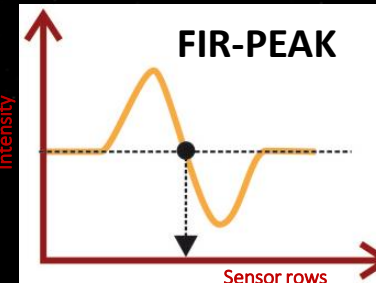
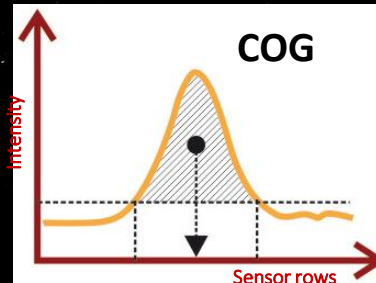
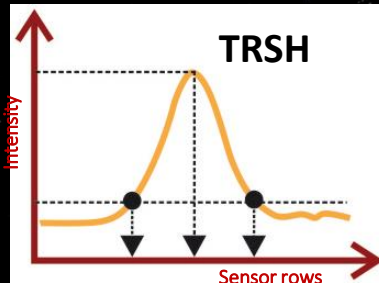
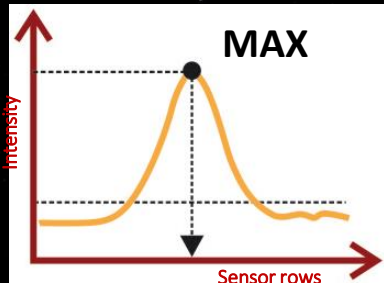
Submillimeter Resolution Pavement Scans at up to 100 km/h

The Profile Scan Principle of Laser Triangulation



Profile Extraction Algorithms

- MAX: find the maximum intensity peak position
- THRESH: threshold the Gauss reflection and find its average position
- COG: calculate the Center of Gravity of intensity peak position
- FIR-PEAK: calculate the first derivative (steepness) of the Gauss reflection and find the zero crossing position



Submillimeter Resolution Pavement Scans at up to 100 km/h

REQUIREMENTS

- Pavement scans with resolution $< 1\text{mm}$ at high travel speed require high-speed 3D laser profiling technology, e.g. for **0.5mm resolution** at **100 km/h** the profile speed must be at least **56 kHz**

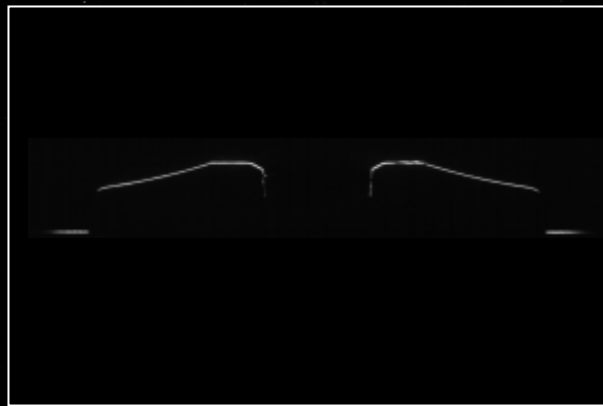


Submillimeter Resolution Pavement Scans at up to 100 km/h

LIMITATIONS

Existing Laser triangulation technology is based on transfer of CMOS detector image to FPGA for processing and height profile extraction

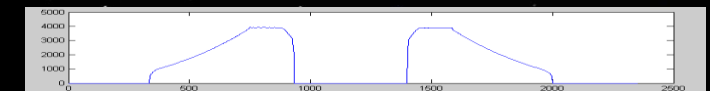
CMOS Detector



FPGA

Profile Extraction Algorithms

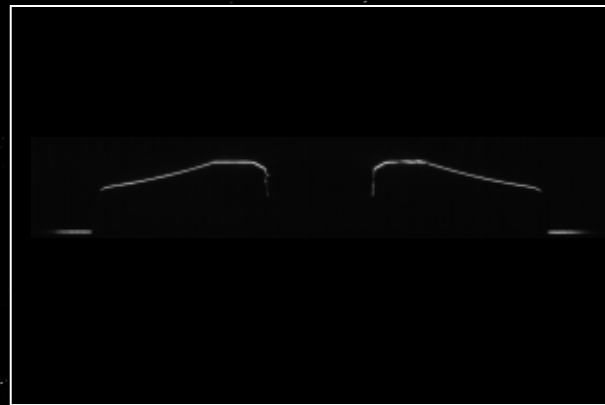
Height Profile Output



Submillimeter Resolution Pavement Scans at up to 100 km/h

LIMITATIONS

The profile speed depends on the number of pixels readout of the CMOS detector and transferred to the FPGA for processing. Example:

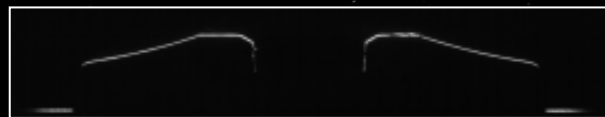


Full CMOS Detector
Readout



Resulting Profile Speed

1000 Hz



Partial CMOS
Detector Readout



10000 Hz

Submillimeter Resolution Pavement Scans at up to 100 km/h

LIMITATIONS

The CMOS detector region to be readout depends on the target surface geometry.

- For flat target objects and surfaces a detector region with small height may be readout resulting to high profile speed. However, this can work reliably only under the following conditions:
 - the target surface remains flat (no curvature)
 - the target surface profile remains aligned to the detector (no skew)
 - the distance between target surface and the detector remains constant



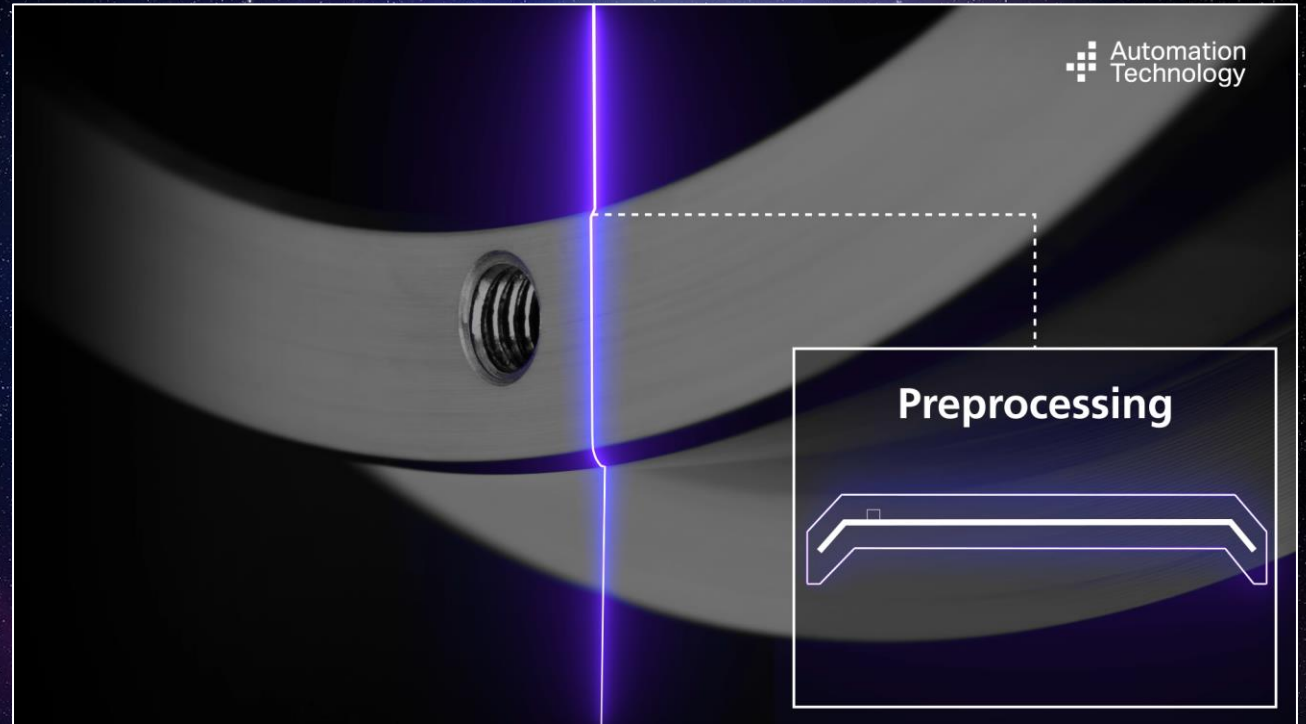
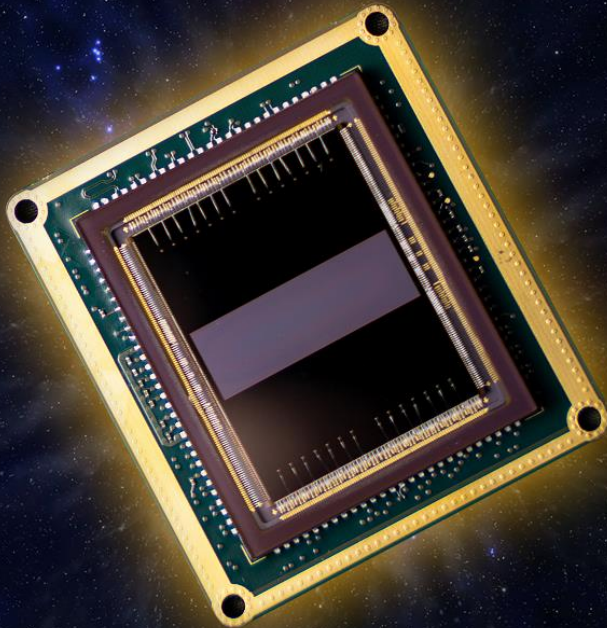
High speed pavement scans are not feasible as these conditions cannot be met in practice



Submillimeter Resolution Pavement Scans at up to 100 km/h

Widely Advanced Rapid Profiling (WARP)

- Integrated pre-processing on CMOS imager
- On-sensor detection of the laser line profile
- Profile speed is boosted up to 200 kHz @ 3K resolution (3072 pixels per line)



NEW TECHNOLOGY FOR LASER TRIANGULATION!

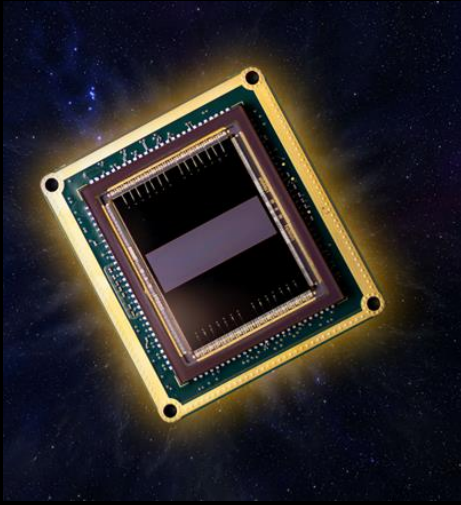


Submillimeter Resolution Pavement Scans at up to 100 km/h

Widely Advanced Rapid Profiling (WARP)

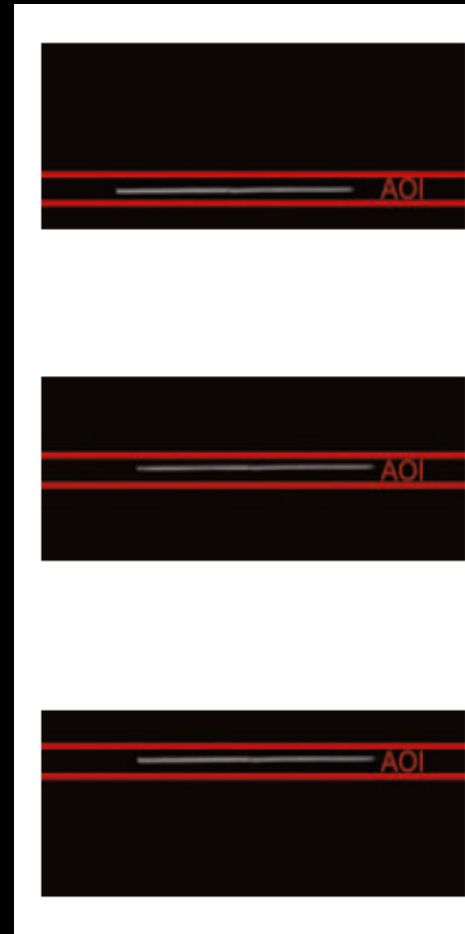
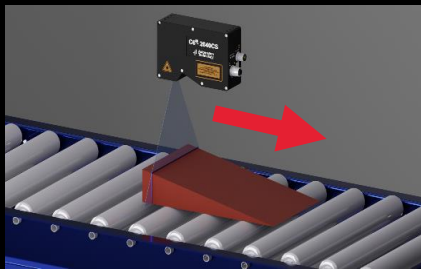
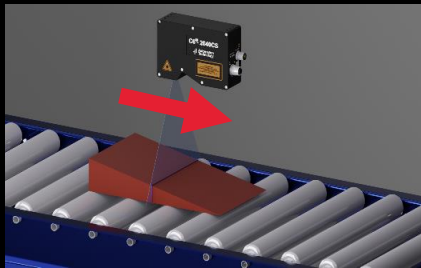
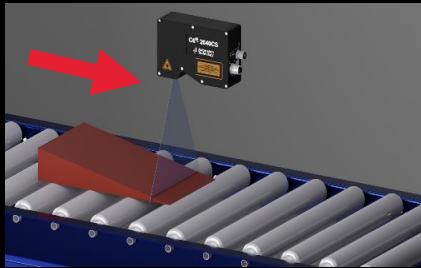
For every column of the detector image only a small part **around the position of laser line reflection** is transferred to the FPGA for further processing

The image readout follows the laser profile like a sleeve.



Submillimeter Resolution Pavement Scans at up to 100 km/h

Widely Advanced Rapid Profiling (WARP) combined with Region Tracking



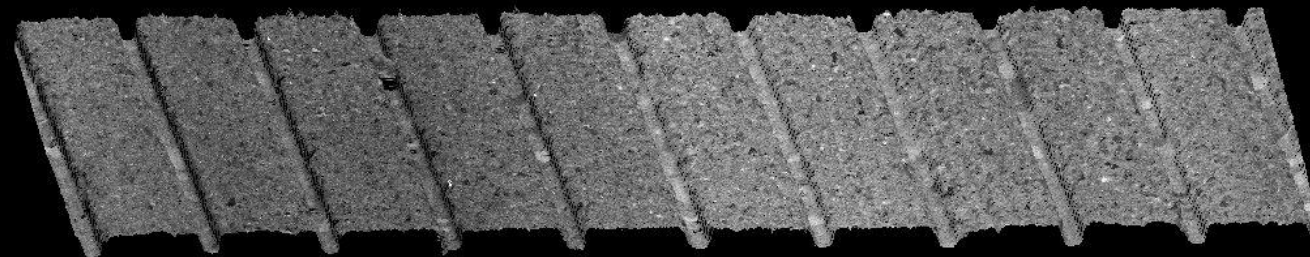
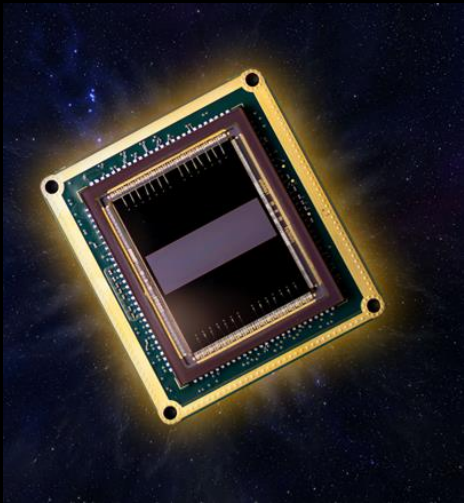
The position of readout region is automatically updated to track the line position in the detector image, when the distance from the target surface is changing during travel.

Submillimeter Resolution Pavement Scans at up to 100 km/h

Advantages of Widely Advanced Rapid Profiling (WARP)

High profile speed independent of the:

- Target surface shape
- Target surface profile alignment to the detector
- Target surface distance to the detector (with the help of Region Tracking)
- Target surface color and reflectivity

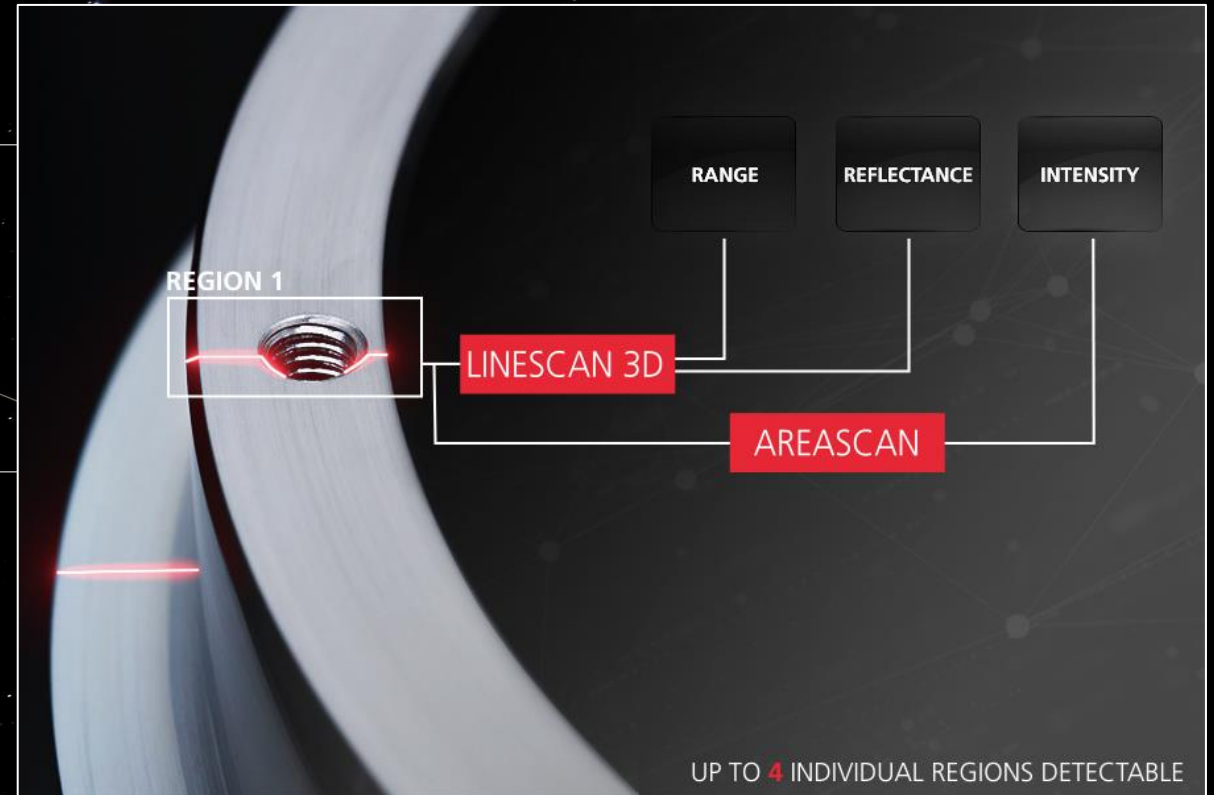
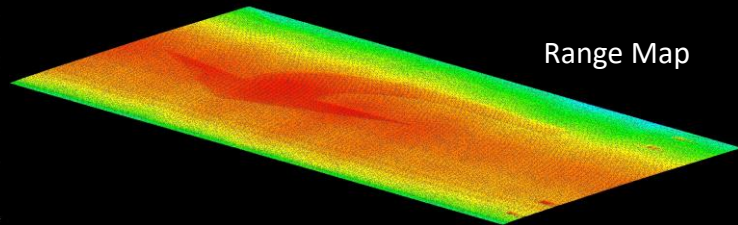


Submillimeter Resolution Pavement Scans at up to 100 km/h

Additional Functions:

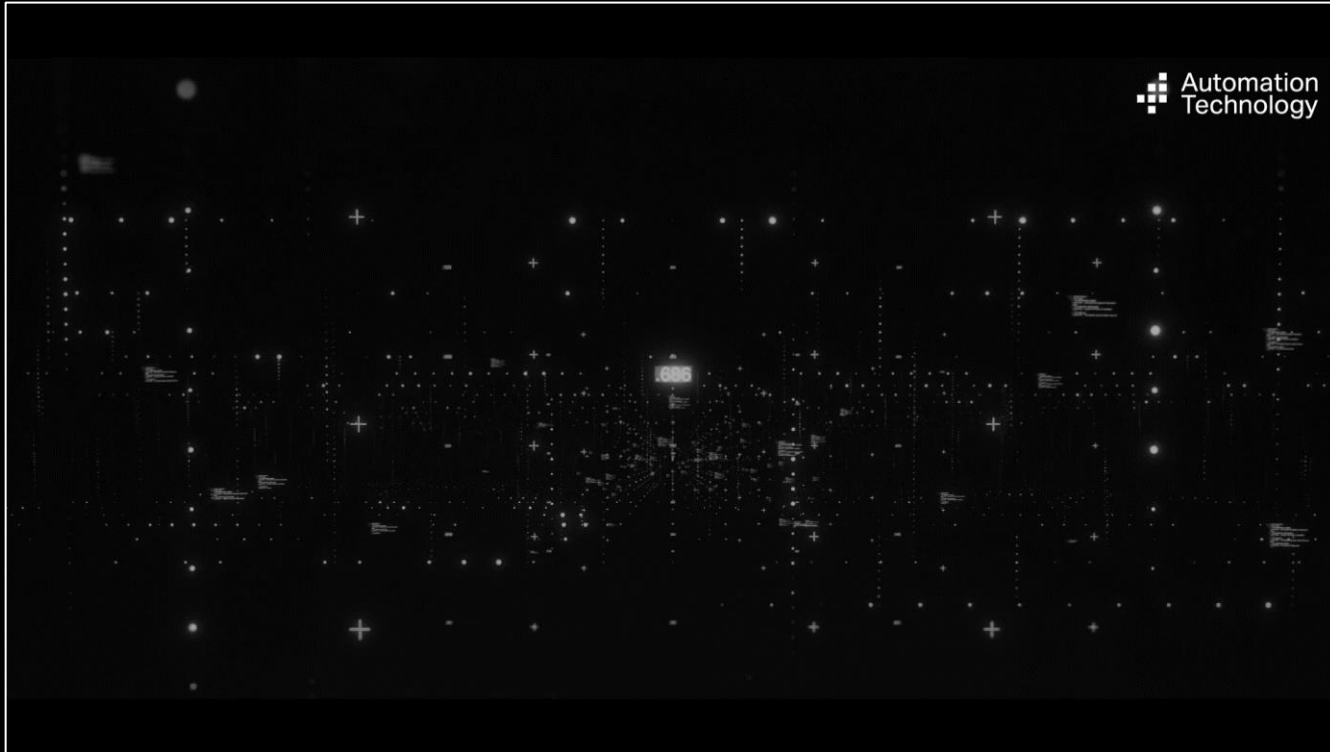
MULTIPART

- Simultaneous output of up to 10 different features
- Allows additional output of reflectance or scatter data.



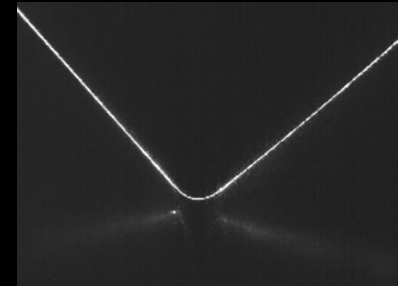
Submillimeter Resolution Pavement Scans at up to 100 km/h

Additional Functions:

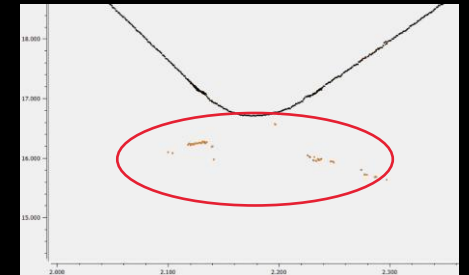


MULTIPEAK

- Detection of up to four different peaks
- Helps to reduce laser interference and secondary reflections on shiny surfaces (e.g. metals)
- Improves the scan quality on transparent / translucent surfaces (e.g. glass, plastics)



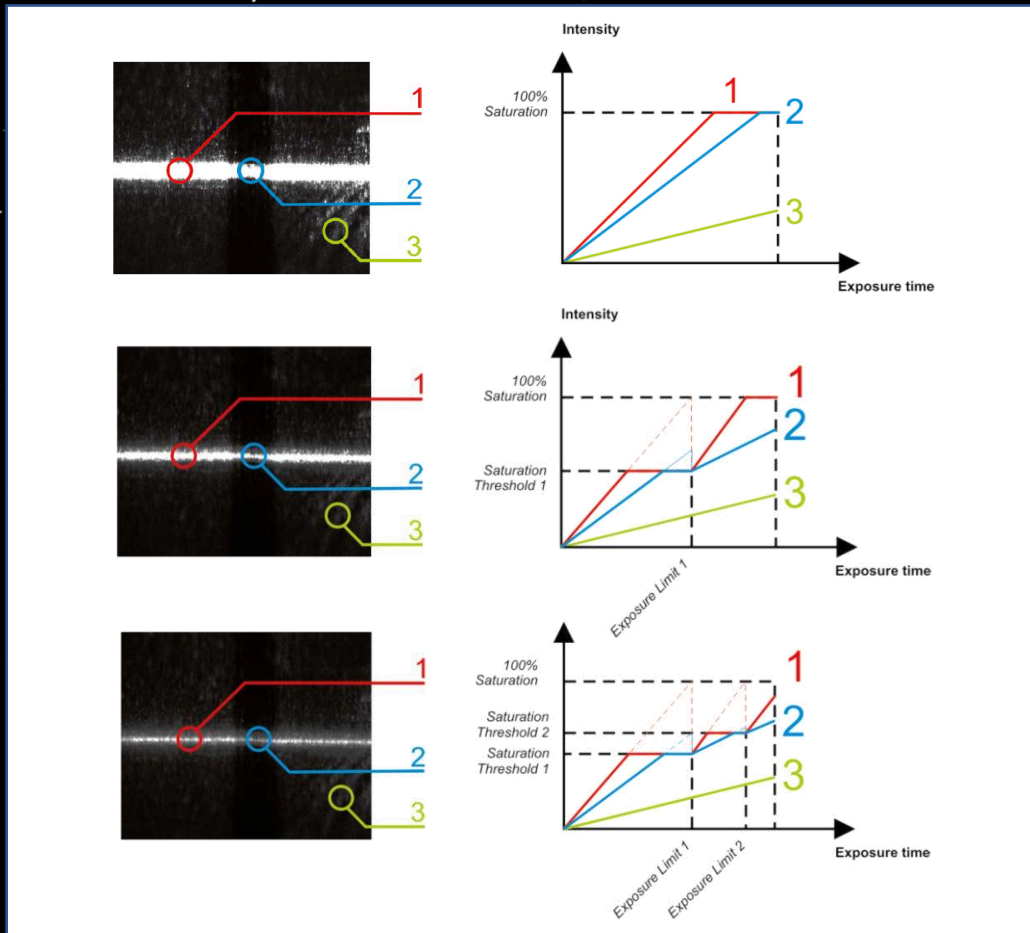
Sensor Image with secondary laser reflection



Profile data of secondary laser reflection are output separately

Submillimeter Resolution Pavement Scans at up to 100 km/h

Additional Functions:



MULTISLOPE

- Increase dynamic range of sensor up to 90dB
- Prevents sensor intensity saturation for precise laser detection
- Allows to scan any parts from white to black and from dull to shiny without intensity saturation
- No need to adjust the exposure time or laser power when the part reflectivity changes

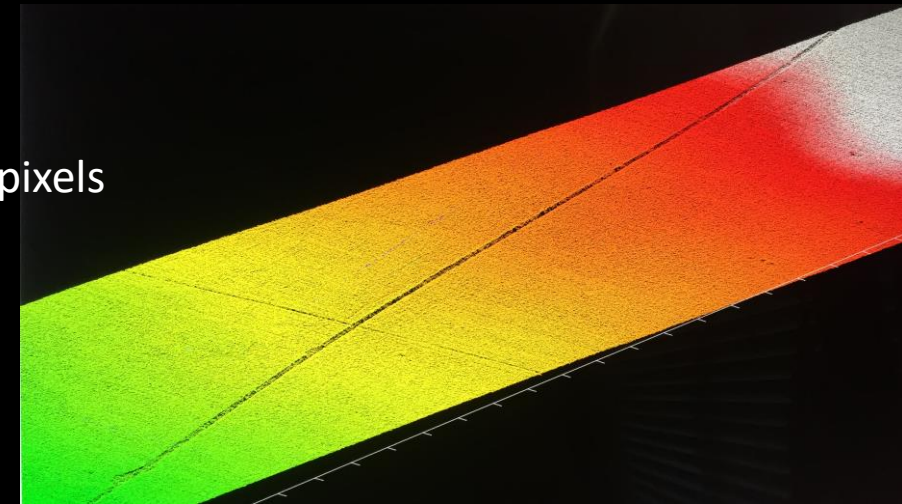
Optimized Image Quality – No Saturation

Submillimeter Resolution Pavement Scans at up to 100 km/h

Applications of **Widely Advanced Rapid Profiling (WARP)** on Pavement Scanning

Example #1

- Travel Speed 100 km/h
- Scan width 3m (2 cameras with X-FOV 1.5 m each)
- WARP imager C6-3070-WARP profile speed: 58 kHz @ Region 3072 x 102 pixels
- Resolution X and Y: 0.5 mm
- Triangulation angle: 15°
- Resolution Z: 0.03 mm (with 6 subpixels)
- Z-Range without Region Tracking: ca. 0.2 m
- Z-Range with Region Tracking: up to ca. 2 m depend. on LASER DOF

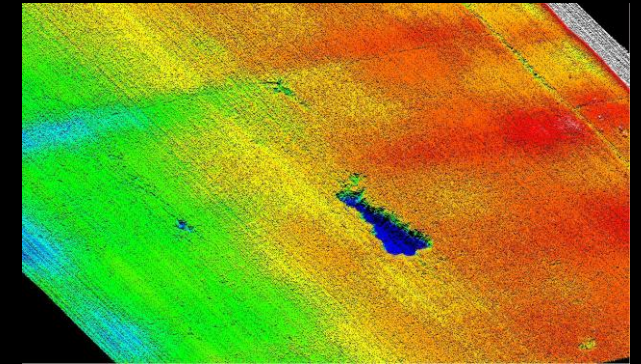


Submillimeter Resolution Pavement Scans at up to 100 km/h

Applications of **W**idely **A**dvanced **R**apid **P**rofilin**G** (**WARP**) on Pavement Scanning

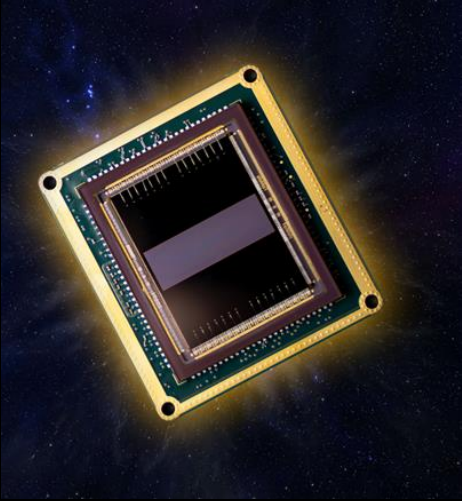
Example #2

- Travel Speed 100 km/h
- Scan width 4m (2 cameras with X-FOV 2 m each)
- WARP imager C6-3070-WARP profile speed: 40 kHz @ Region 3072 x 156 pixels
- Resolution X and Y: 0.7 mm
- Triangulation angle: 15°
- Resolution Z: 0.04 mm (with 6 subpixels)
- Z-Range without Region Tracking: ca. 0.4 mm
- Z-Range with Region Tracking: up to ca. 3 m depend. on LASER DOF



Submillimeter Resolution Pavement Scans at up to 100 km/h

SUMMARY



- The Widely Advanced Rapid Profiling technology (WARP) enables the scanning of road pavement with submillimeter resolution at travel speed up to 100 km/h.
- The unprecedented combination of 3072 points per profile with a profile speed up to 200kHz generates high density 3D point clouds enabling a precise and reliable analysis of cracks, ruts, and texture of the road surface.
- WARP is a revolutionary technology contributing to an improved 3D pavement analysis.



THANK YOU! QUESTIONS?

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