Optical Inline Inspection:

Surface Inspection Long Products, Inline Roughness Measurement of Coils, Fluorescence based measurement of cleanliness

Prof. Dr. Daniel Carl, Dr. Tobias Schmid-Schirling
International Wrought Copper Council, Dallas US, March 2025

1. Introduction to Fraunhofer IPM
2. Surface inspection
3. Inline roughness measurement
4. Fluorescence based measurement of cleanliness
5. Summary

IWCC Legal Disclaimer

The purpose of this presentation is to guide programs benefiting the copper industry and to provide attendees with information to make independent business decisions.

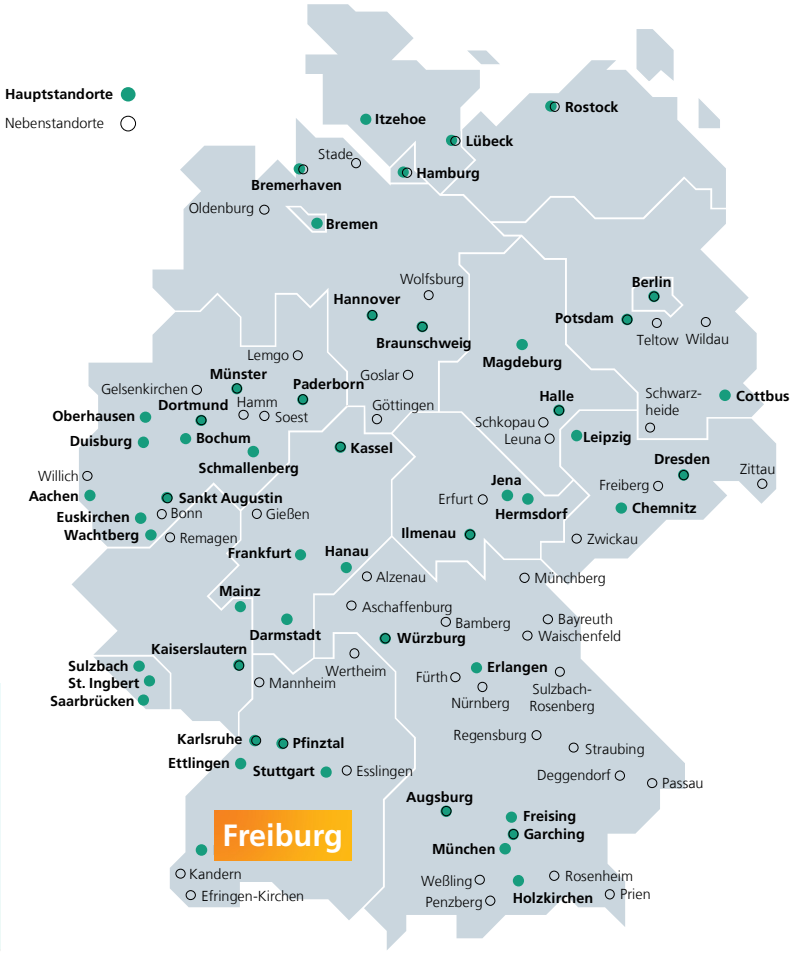
1. **Introduction to Fraunhofer IPM**
2. Surface inspection
3. Inline roughness measurement
4. Fluorescence based measurement of cleanliness
5. Summary

1. Fraunhofer IPM
in the Fraunhofer-Gesellschaft

Fraunhofer-Gesellschaft
Research and development to the benefit of society and economy

- The Fraunhofer-Gesellschaft operates on a global scale and is active in many places in Germany.
- Every single Fraunhofer Institute has great scope for action.

Fraunhofer IPM
- About 260 employees
- Operating Budget 2024
  - 26 Mio. $
  - 40 % industrial revenues
  - 80 % competitively acquired funds

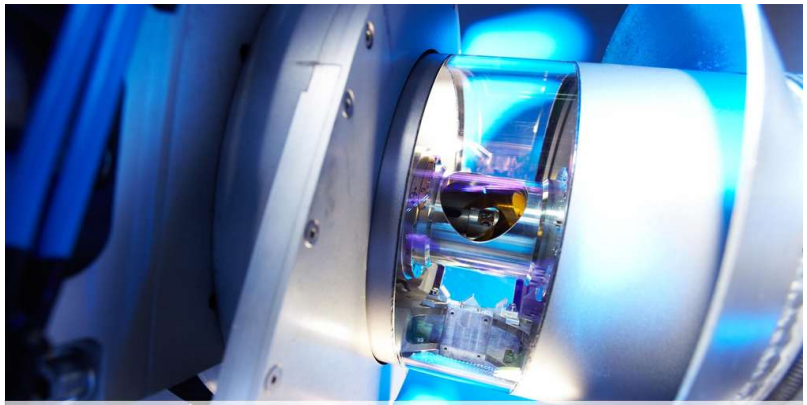


Fraunhofer IPM

1. Fraunhofer IPM

Mission

Extremely fast, precise and robust measuring systems to increase the efficiency of industrial processes.



Laserscanner from Fraunhofer IPM

Measurement train from DB Netze AG

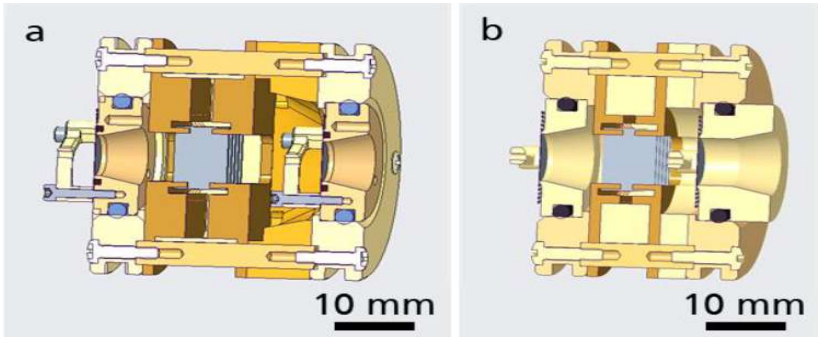
Processes thus become **more economical, sustainable and reliable.**

1. Fraunhofer IPM

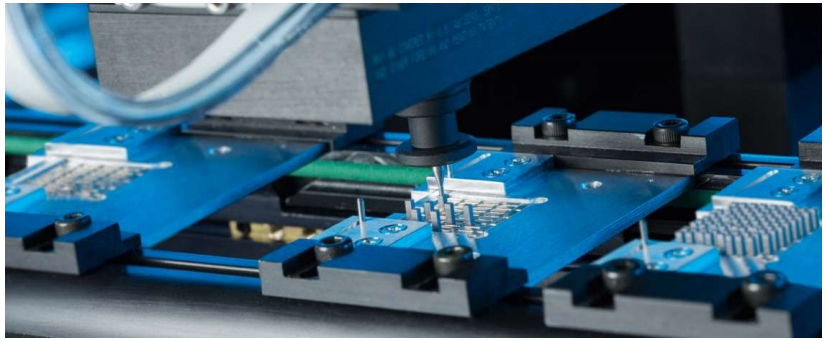
Competences

Photonics

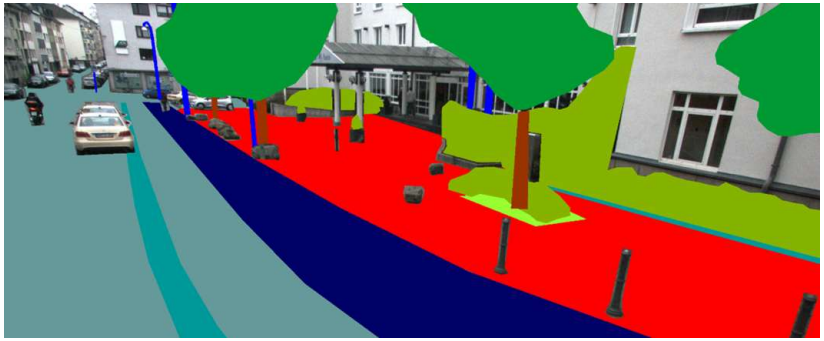
Mechanics



Electronics



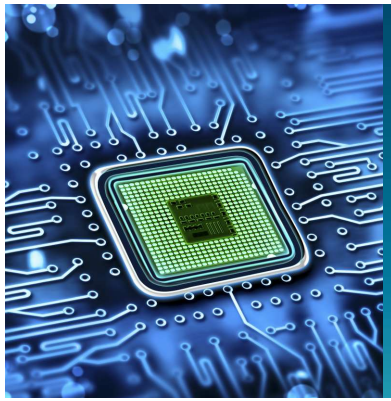
Data processing



Fraunhofer IPM

1. Fraunhofer IPM
Technology and Markets

Surface analysis
- Medical
- Metal working
- Automotive
- Electronics
- …



Inline 3D Inspection
- Chip manufacturing
- Precision metal working
- Additive manufacturing
- …

Automated visual inspection
- Semi-finished parts
- Long products
- …

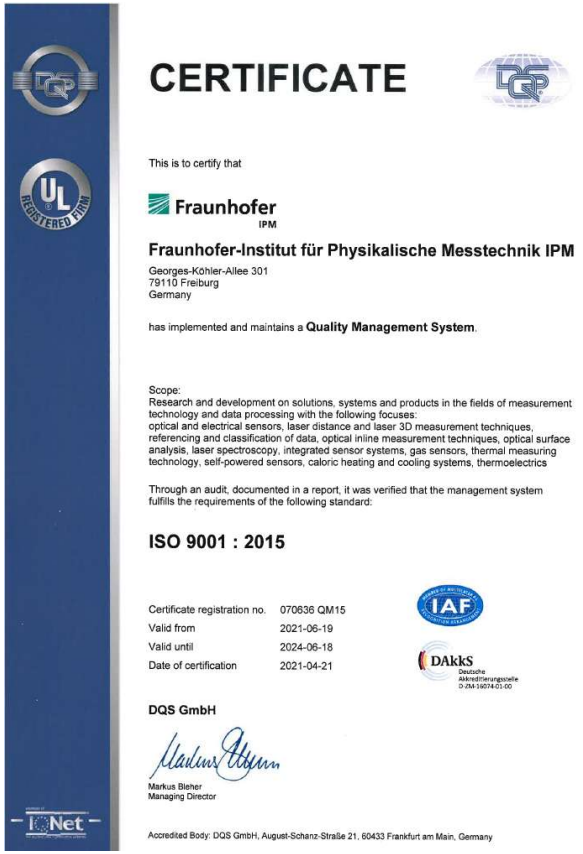
Tracking & Tracing
- Cross-industry technology (focus on automotive)
- Logistics
- App development
- …

Fraunhofer IPM

1. Fraunhofer IPM

Certified quality management

- ISO 9001
- Very high satisfaction of our customers
- Wide range of prizes and awards



CERTIFICATE

This is to certify that

Fraunhofer IPM

Fraunhofer-Institut für Physikalische Messtechnik IPM

Georges-Köhler-Allee 301
79110 Freiburg
Germany

has implemented and maintains a **Quality Management System**.

Scope:
Research and development on solutions, systems and products in the fields of measurement technology and data processing with the following focuses:
optical and electrical sensors, laser distance and laser 3D measurement techniques, referencing and classification of data, optical inline measurement techniques, optical surface analysis, laser spectroscopy, integrated sensor systems, gas sensors, thermal measuring technology, self-powered sensors, caloric heating and cooling systems, thermoelectrics

Through an audit, documented in a report, it was verified that the management system fulfills the requirements of the following standard:

ISO 9001 : 2015

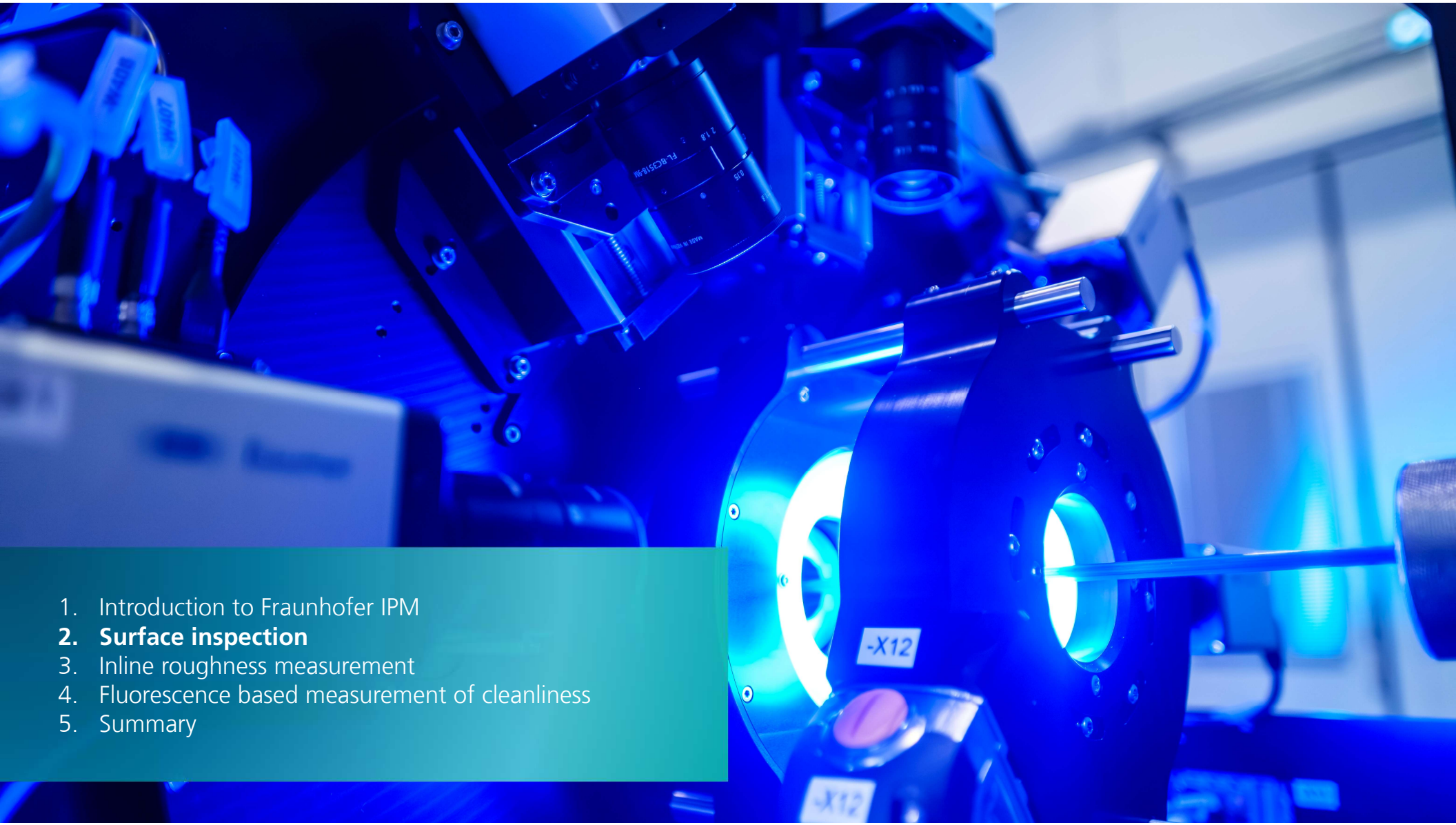
Certificate registration no.	070636 QM15
Valid from	2021-06-19
Valid until	2024-06-18
Date of certification	2021-04-21

DQS GmbH

Markus Bleher
Managing Director

Accredited Body: DQS GmbH, August-Schanz-Straße 21, 60433 Frankfurt am Main, Germany

Fraunhofer IPM



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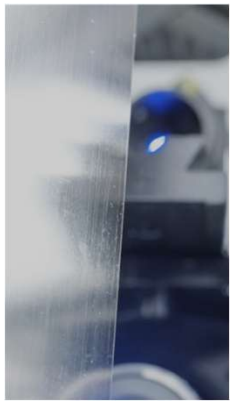
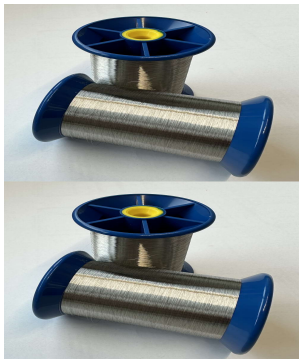
2. Surface Inspection

Inline applications



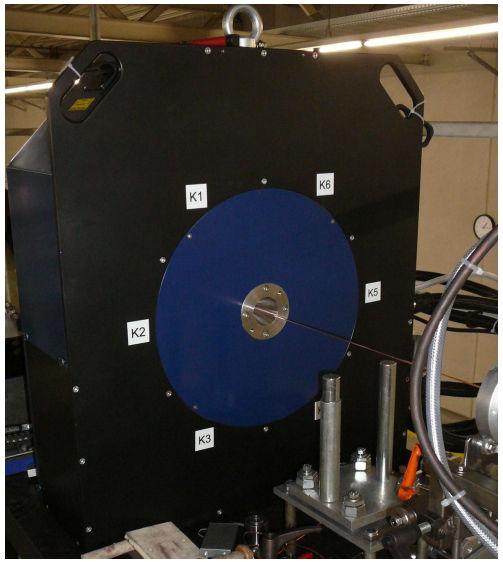


Bulk material	Edges / Blades	Wire	Fine Wire	Positioning

Fraunhofer IPM

2. Surface Inspection

Robust imaging systems



Wire

Glowing profiles

Casted parts

Fraunhofer IPM

2. Surface Inspection

Computer Vision for pattern analysis in industrial processes

Algorithms for component inspection

Object segmentation

Microstructure / texture analysis

Geometry assessment

Defect detection

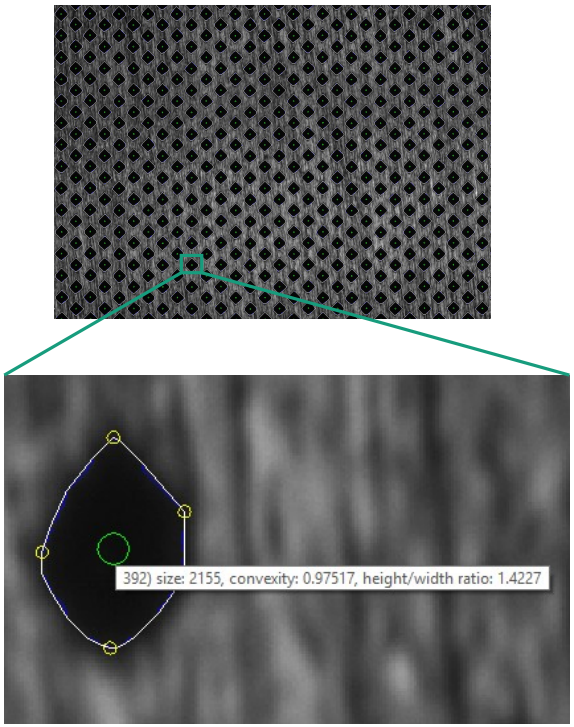
Machine learning algorithms

Image processing hardware for process cycle time evaluation

Load balancing clusters

Graphics processing units

Multi-kernel systems



Fraunhofer IPM

2. Surface Inspection

Single part inspection in Free Fall

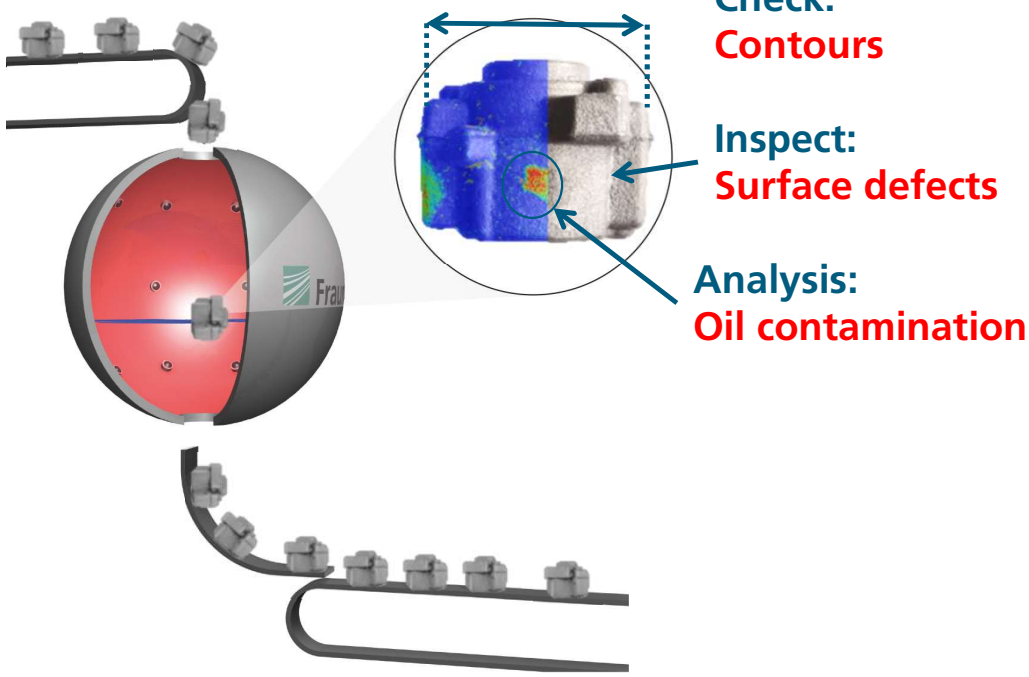
Mass products usually start as semi-finished goods

- Casted, formed, punched or sintered parts
- Standard form of delivery for typical materials (metals, plastics, ceramics, …)

Automated 100%-visual inspection

High return-on-invest:

- Part sorting
- Defective parts detected at early stage
- Energy and material saving
- Overall quality improvement
- Cost reduction in manual inspection



Source: Fraunhofer IPM

2. Surface Inspection

Single part inspection in Free Fall

Measurement campaign at a punching machine in production environment. Source: Fraunhofer IPM.

Fraunhofer IPM

2. Surface Inspection

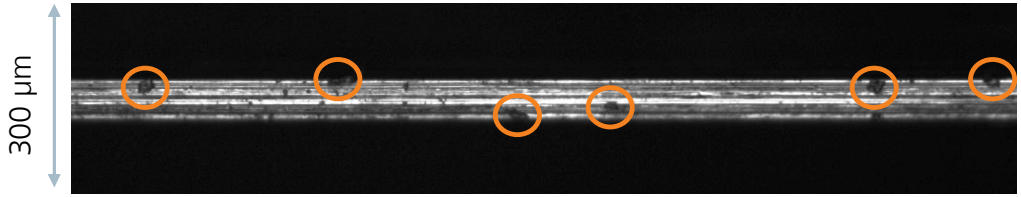
Customized inline microscopy for edges and blades

Flawless surface of required for edges and blades

State of the Art: Detection of bubbles, scratches, … by random testing

Inline Microscopy

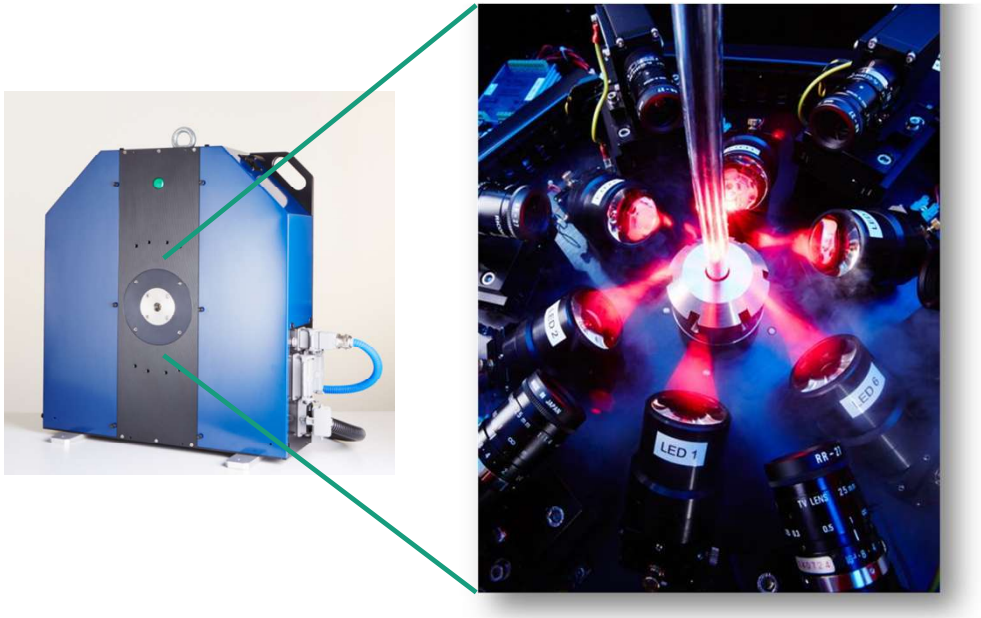
- Optical resolution < 2 µm
- Multi-camera arrangement
- 30 m / min feed
- ~ 400 images / sec
- Combination of rule based and deep learning algorithms



Fraunhofer IPM

2. Surface Inspection

Inline surface analysis for wire and bars



WIRE-HR

360° degree view

- Six cameras placed around the wire
- Depth of field for 60° circumference in focus

Customized LED illumination

- Power > 10^5 W/m² (100x sun)
- Flash duration down to 1 µs
- 1 µs corresponds to e. g. 30 µm pixel resolution at 30 m/s drawing speed

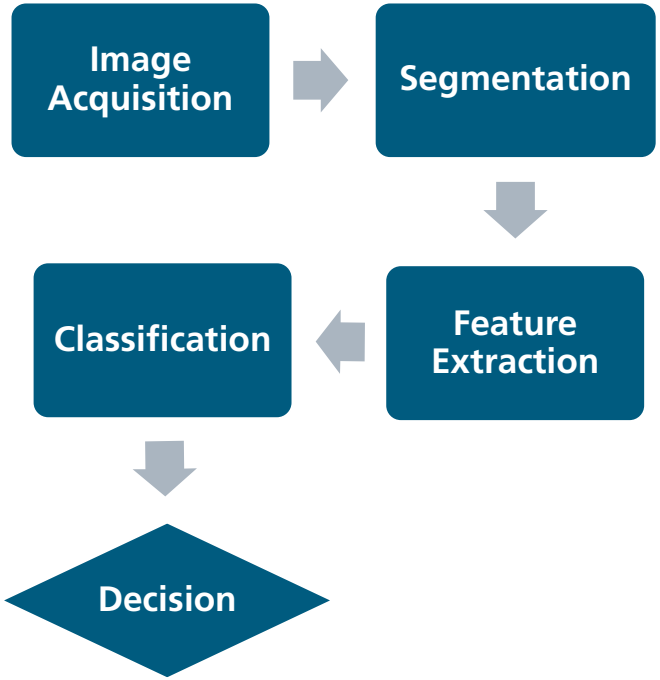
Motorized camera positioning for sharp images at various diameters

Fraunhofer IPM

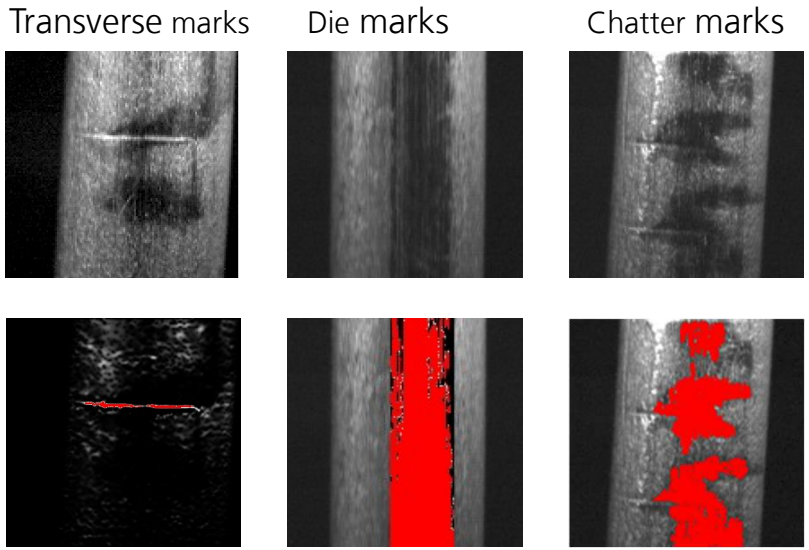
2. Surface Inspection

Inline surface analysis for wire and bars

Evaluation approach



Examples of defect detection

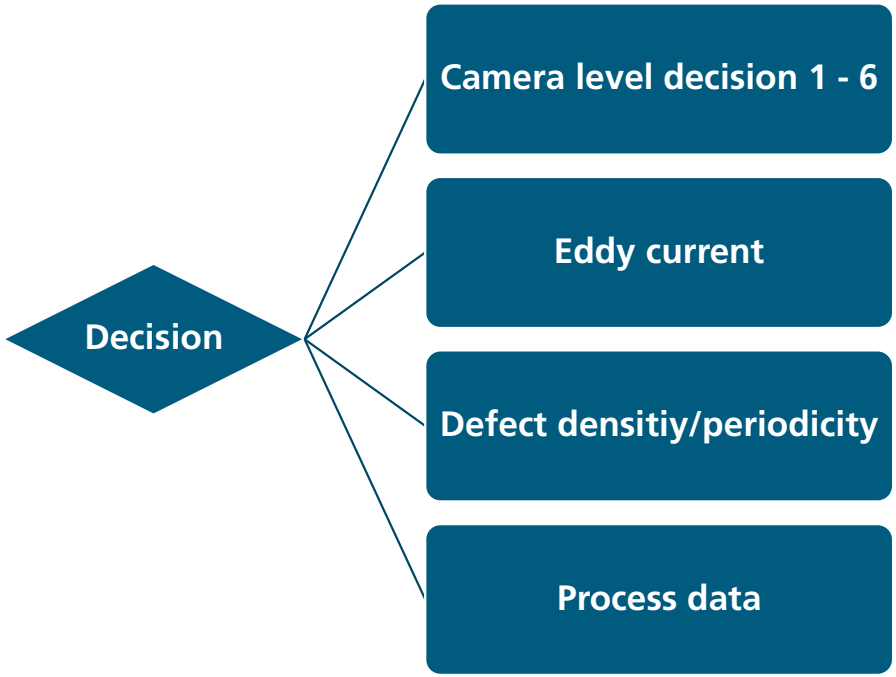


Fraunhofer IPM

2. Surface Inspection

Inline surface analysis for wire and bars

Decision approach



Example system GUI

2. Surface Inspection

Inspection of ultrafine wire

FineWireInspect

Surface quality assessment for thin wire

Stray light analysis

Wire diameter 10 µm – 60 µm

Drawing speed 30 m/s

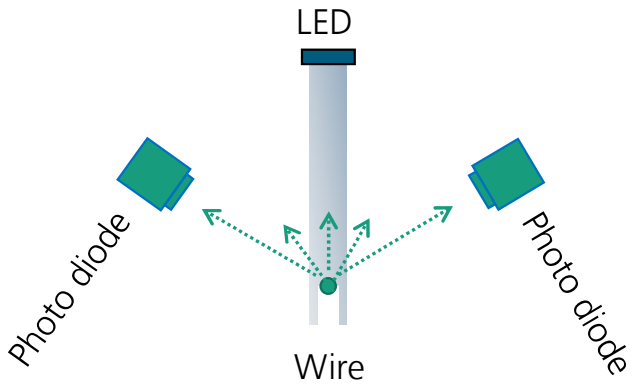
Steel and copper

Fraunhofer IPM

2. Surface Inspection

Inspection of ultrafine wire

Measurement principle



Assumption: wire surface homogeneous

Measurement signal: intensity of specular reflection

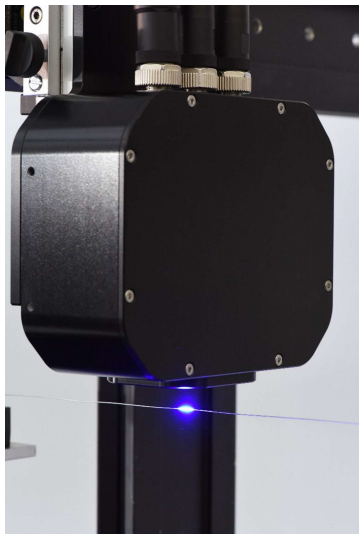
Homogeneously smooth surface: (almost) constantly high signal

Inhomogeneously rough surface: rapidly variing, low signal

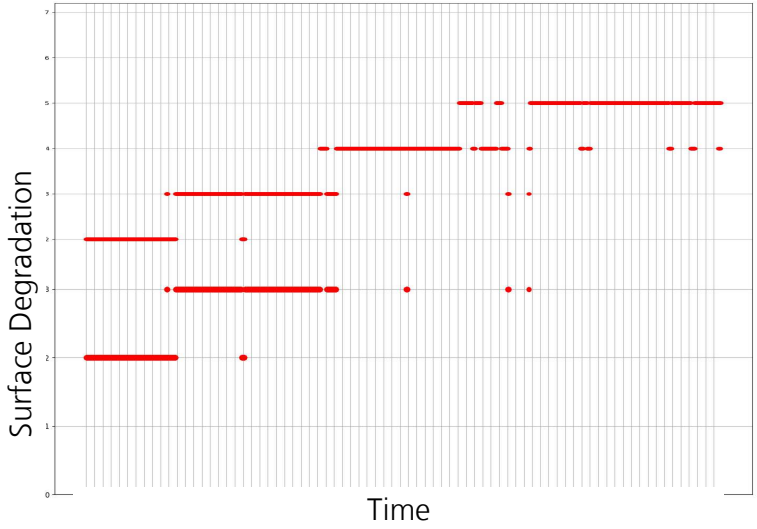
2. Surface Inspection

Inspection of ultrafine wire

Measuring head



Result plot



Specular reflectance analysis provides a time resolved measure of mean surface quality

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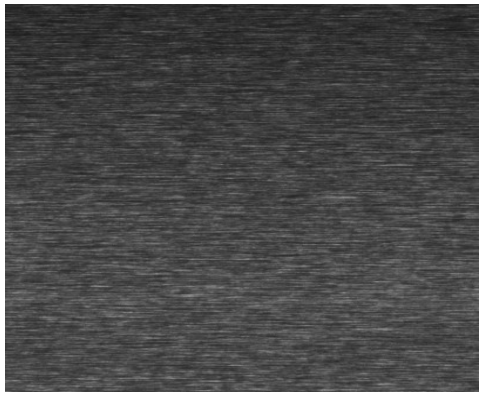
2. Surface Inspection

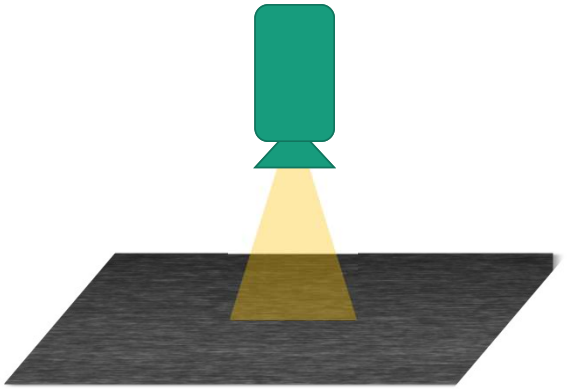
High accuracy positioning and single item traceability

Motivation: tracking the position of endless material with sub-mm accuracy



Based on microstructure
(markerfree)

Interruption / separation possible



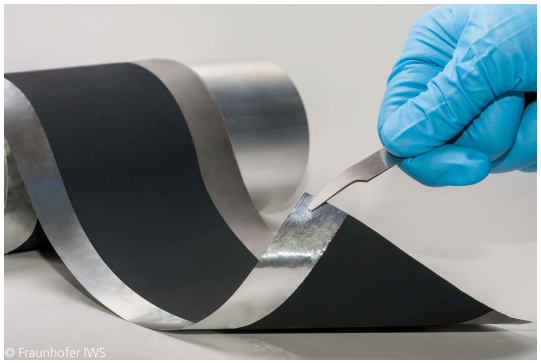
Contactless

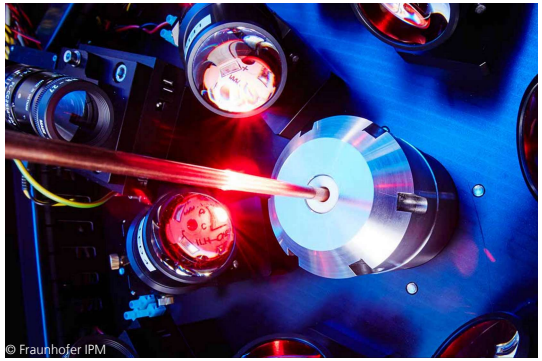
Fraunhofer IPM

2. Surface Inspection

High accuracy positioning and single item traceability

Applications





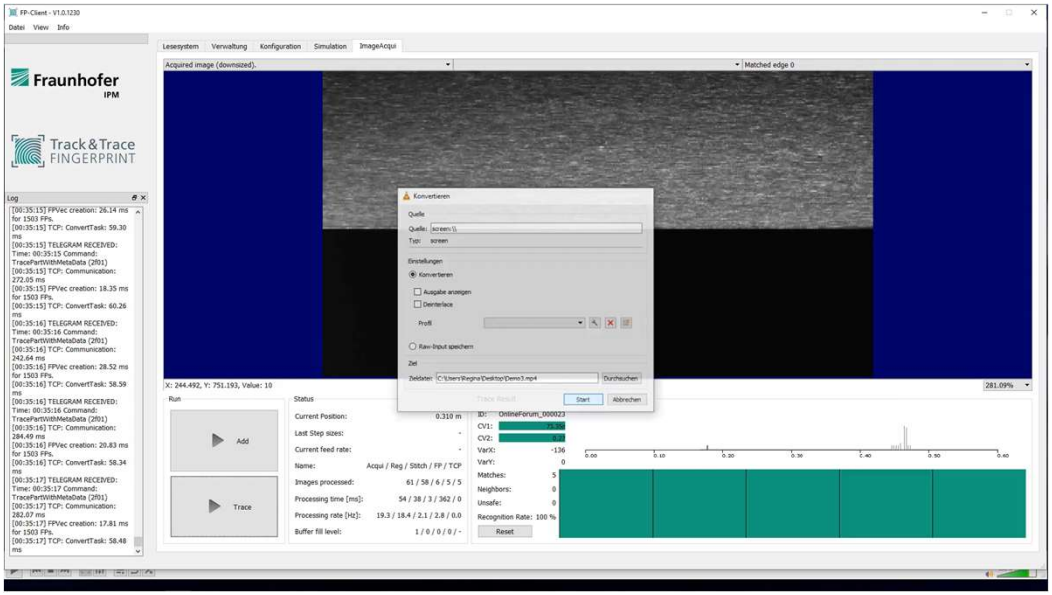
Fraunhofer IPM

2. Surface Inspection

High accuracy positioning and single item traceability

Prototypes

High accuracy positioning system on a coating line

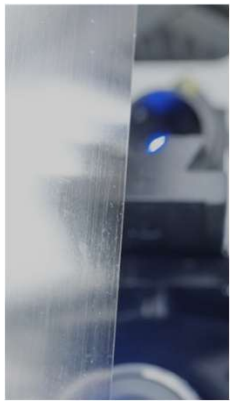


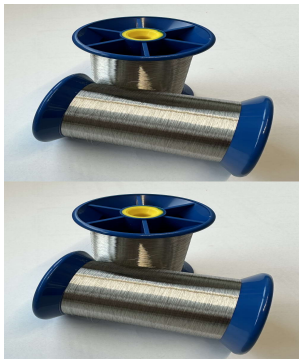
High accuracy positioning monitoring

Fraunhofer IPM

2. Surface Inspection

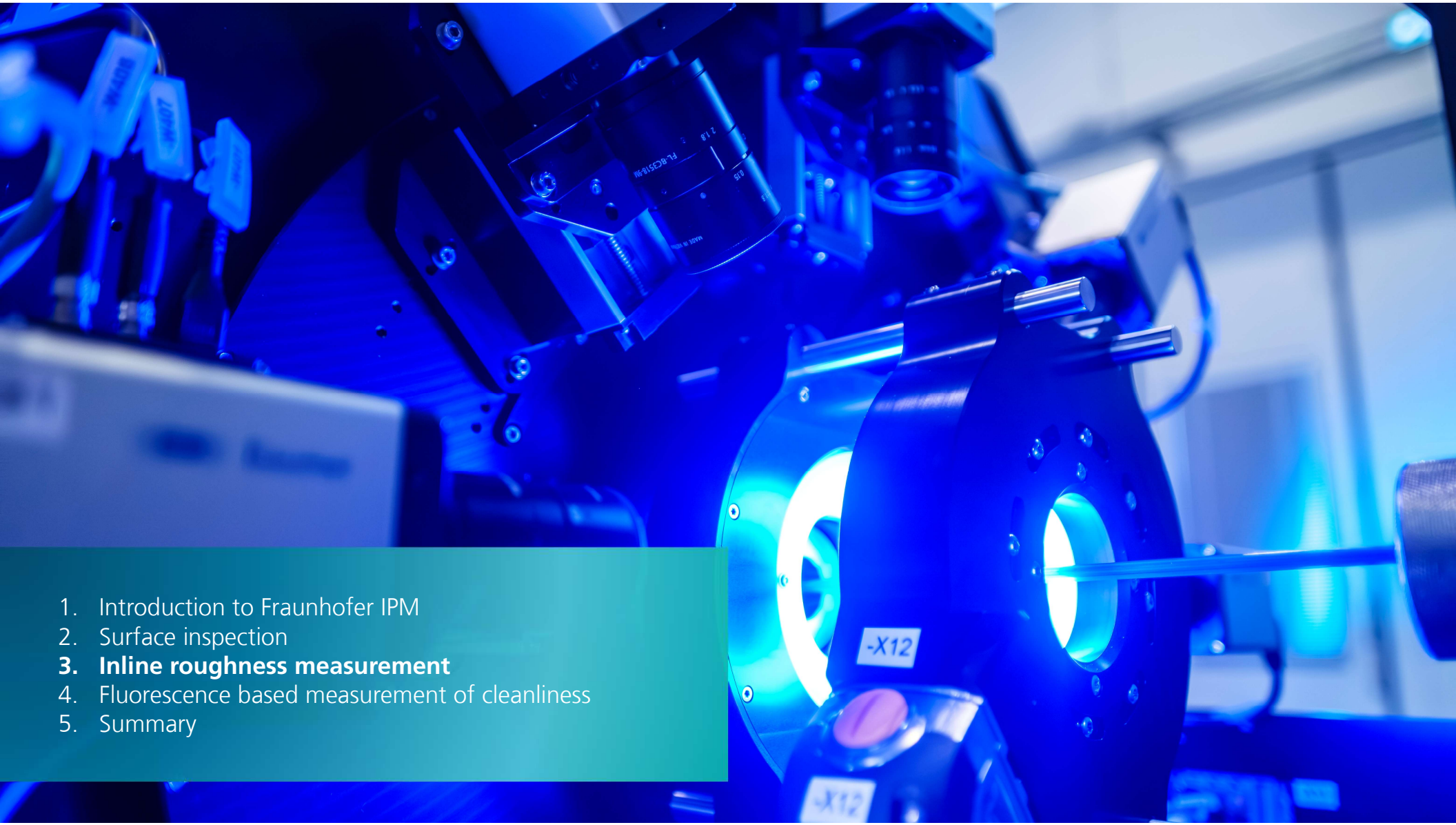
Inline applications





Bulk material	Edges / Blades	Wire	Fine Wire	Positioning

Fraunhofer IPM



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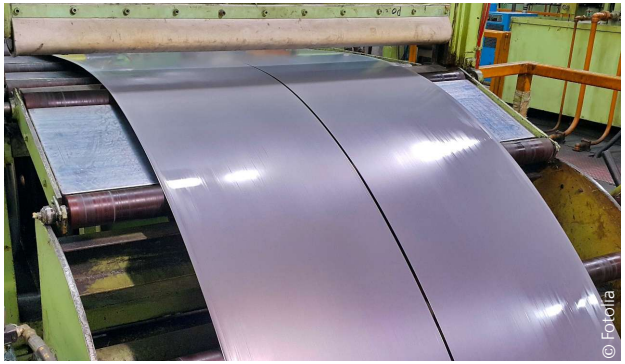
3. **Inline roughness measurement**
4. Fluorescence based measurement of cleanliness
5. Summary

3. Inline Roughness Measurement with Laser-Speckles

Applications



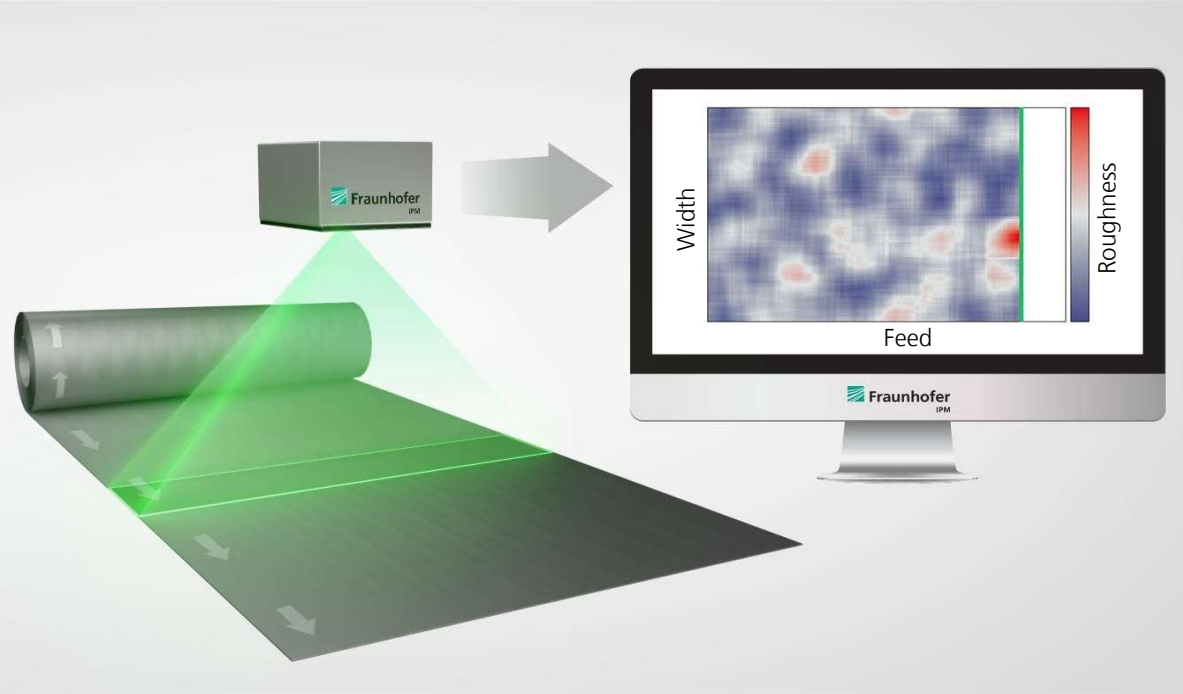
Fraunhofer IPM

3. Inline Roughness Measurement with Laser-Speckles

Applications

Different Surface Types:

- Grinding
- Spark Erosion
- Milling
- Grit Blasting
- Casting
- Hot-Dip Galvanizing
- …

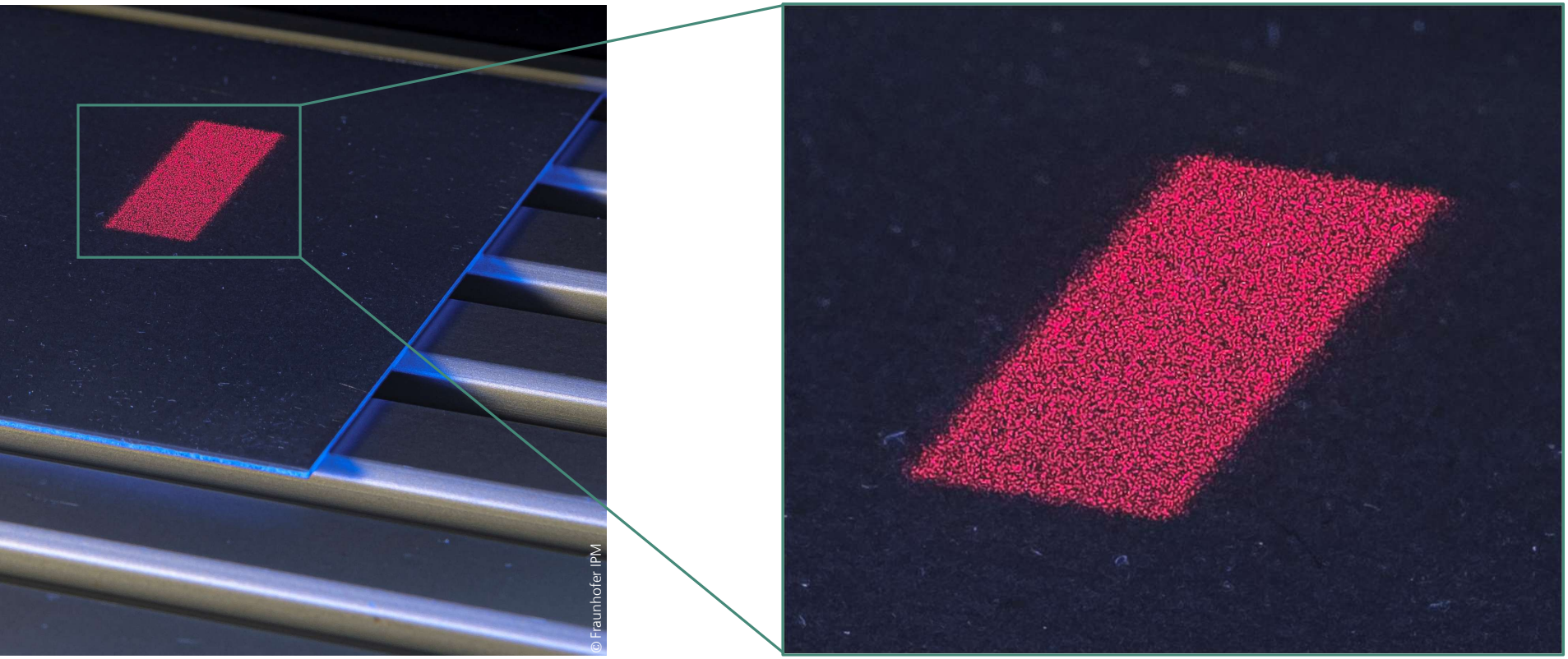


Vision

Fraunhofer IPM

3. Inline Roughness Measurement with Laser-Speckles

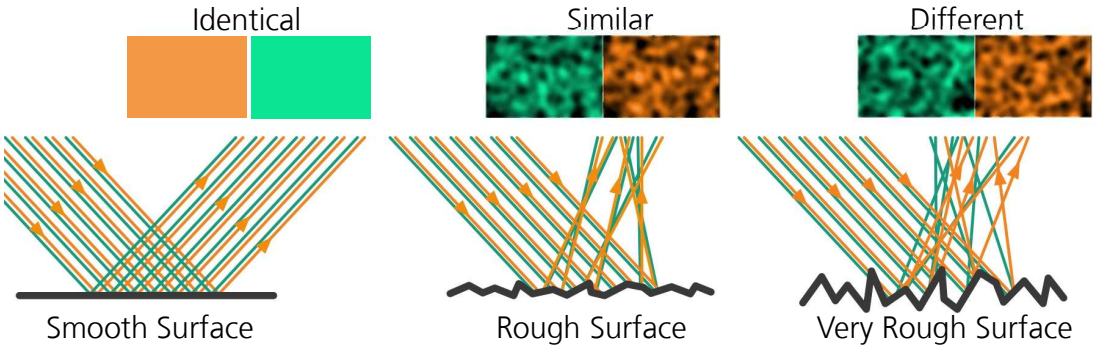
Speckles?



Fraunhofer IPM

3. Inline Roughness Measurement with Laser-Speckles

Spectral speckle correlation



$$\gamma_{12} \approx e^{\left(-c\sigma\left[\frac{\lambda_1-\lambda_2}{\lambda_1\lambda_2}\right]\right)^2}$$

σ = Surface Roughness

λ = Wavelength

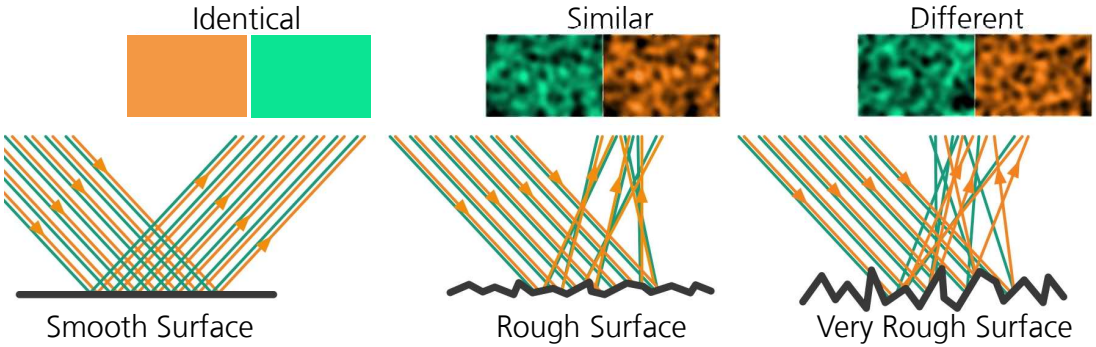
γ = Correlation

c = Constant

Fraunhofer IPM

3. Inline Roughness Measurement with Laser-Speckles

Spectral speckle correlation



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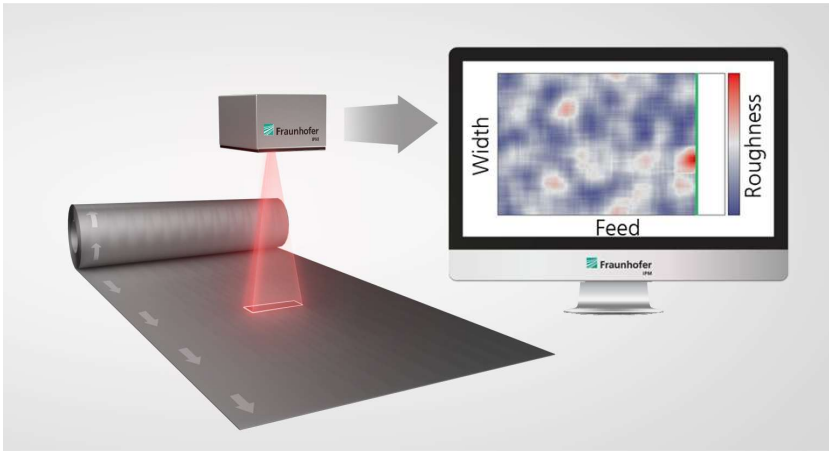


Vision

Measure large areas fast and in-line

Fraunhofer IPM

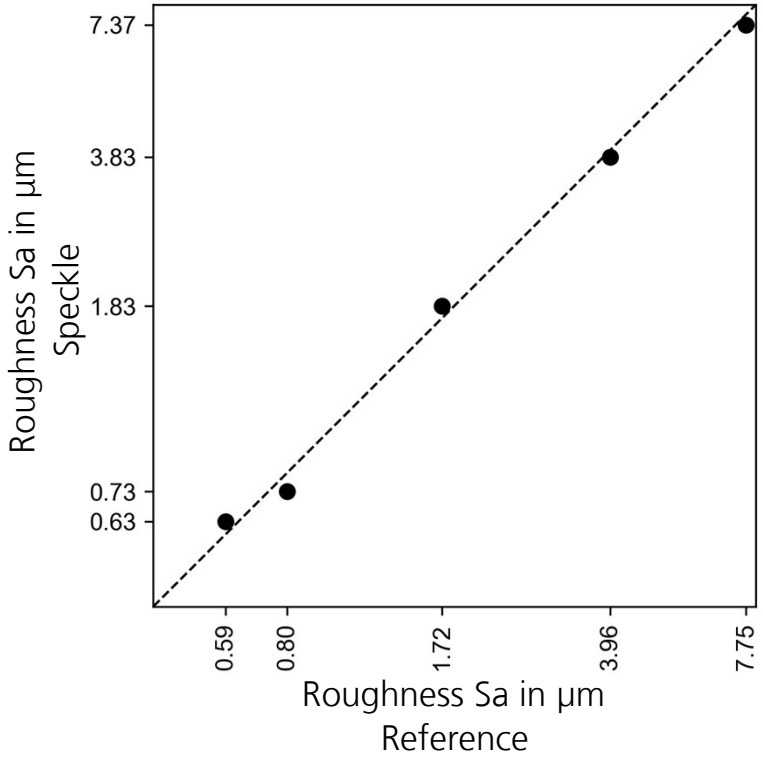
3. Inline Roughness Measurement with Laser-Speckles

Measurement results

The measurement method is suitable for:

- A wide range of wavelengths
- Different surface types and roughness

Comparison samples with multiple roughness

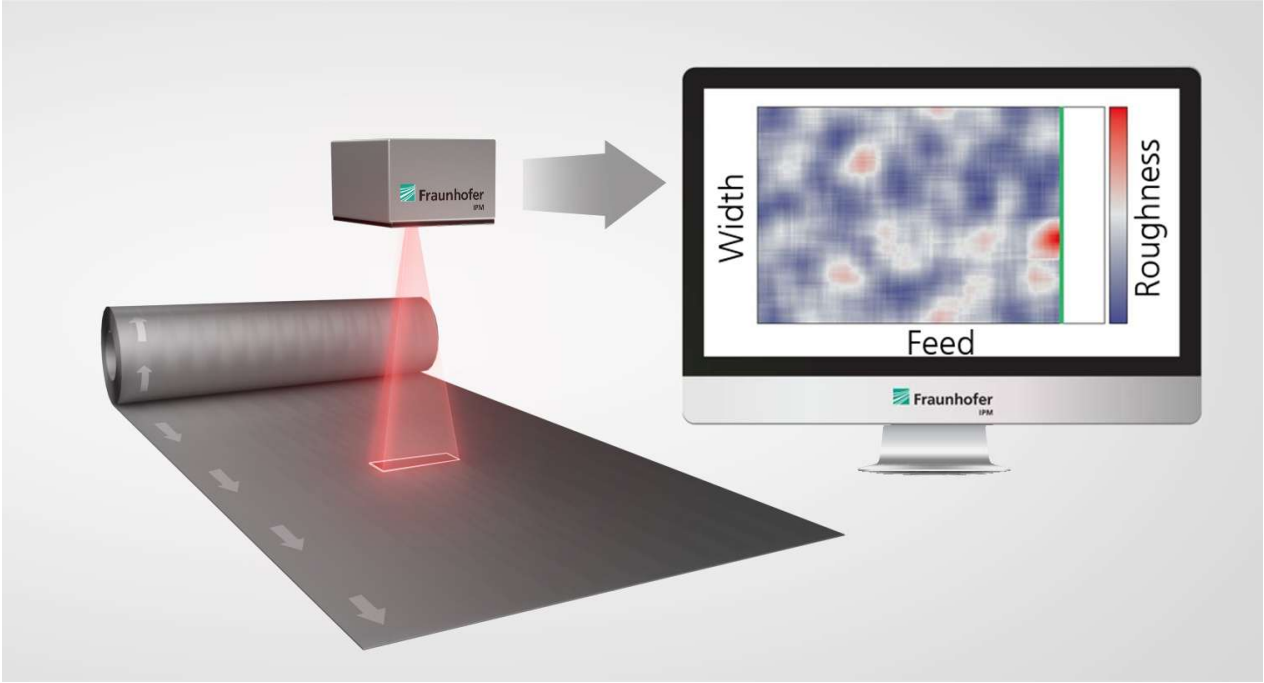


Fraunhofer IPM

3. Inline Roughness Measurement with Laser-Speckles

Specifications

- Area measurements
- Spacially resolved results
- Fast measurements
- In motion
- Wide measuring range
- Suitable for in-line / near-line
- Any processing direction
- Large working distance
- Robust against distance changes

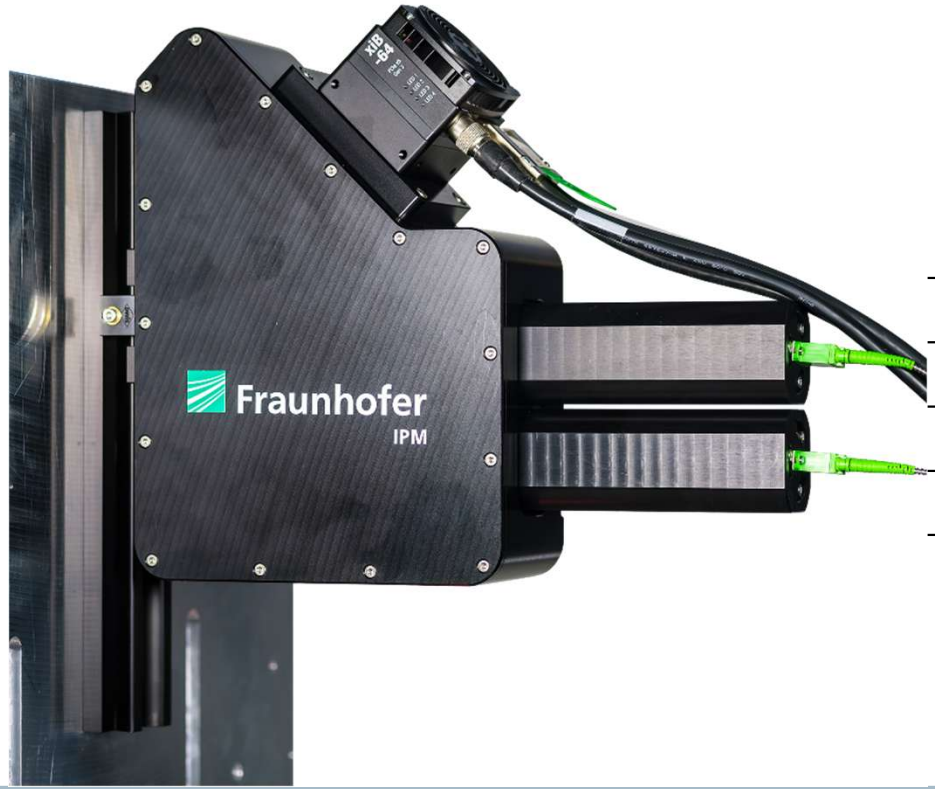


Vision

Fraunhofer IPM

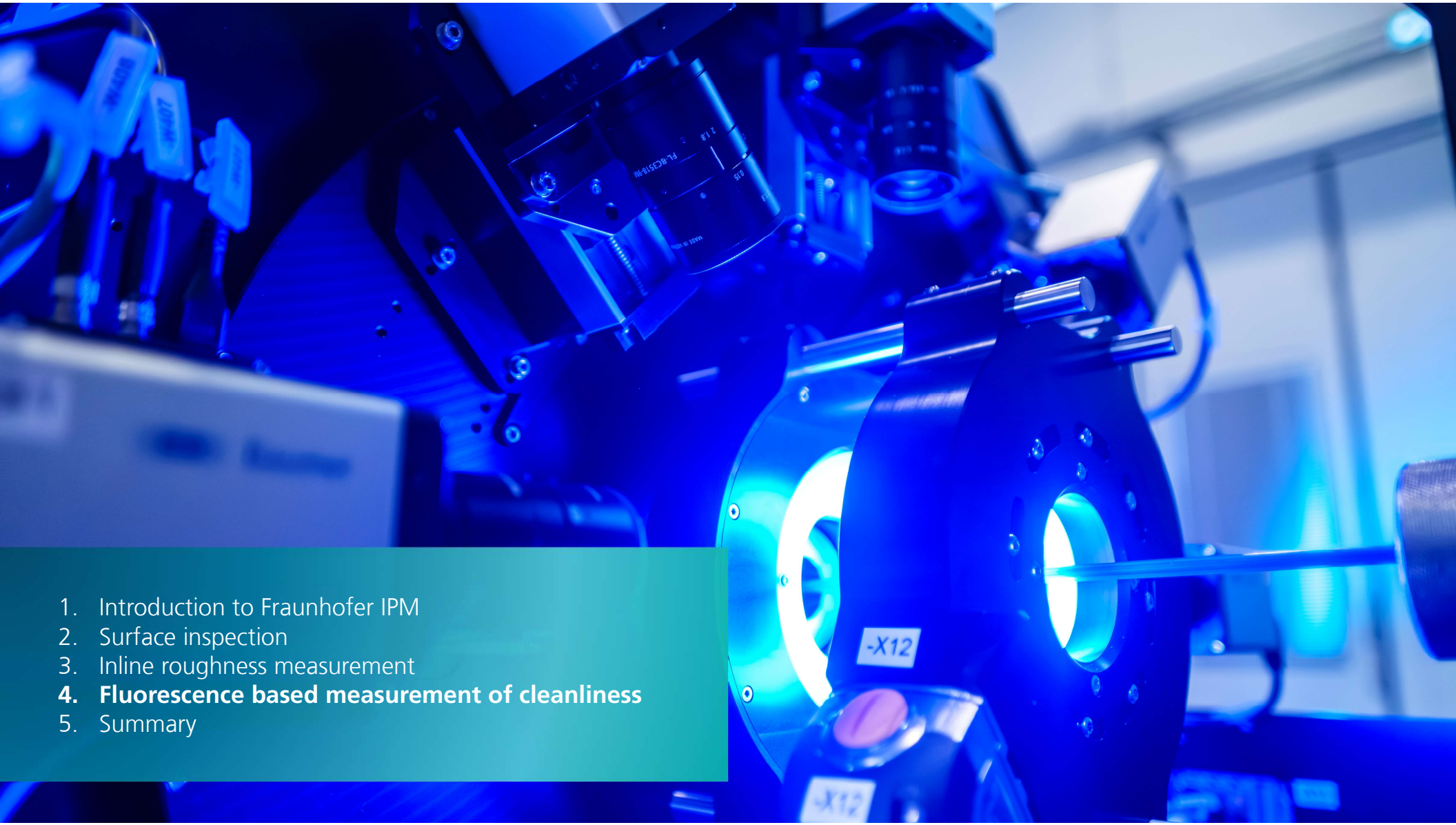
3. Inline Roughness Measurement with Laser-Speckles

Prototyp



	Fast	Extensive
Measuring range	0.6 µm Sa .. 2 µm Sa	
Working distance	400 mm ± 5 mm	
Field of view	~ 5 mm²	~ 10 cm²
Feeding rate	~ 1000 m/min	~ 2 m/min
Spacial resolution	%	2,5 mm

Fraunhofer IPM



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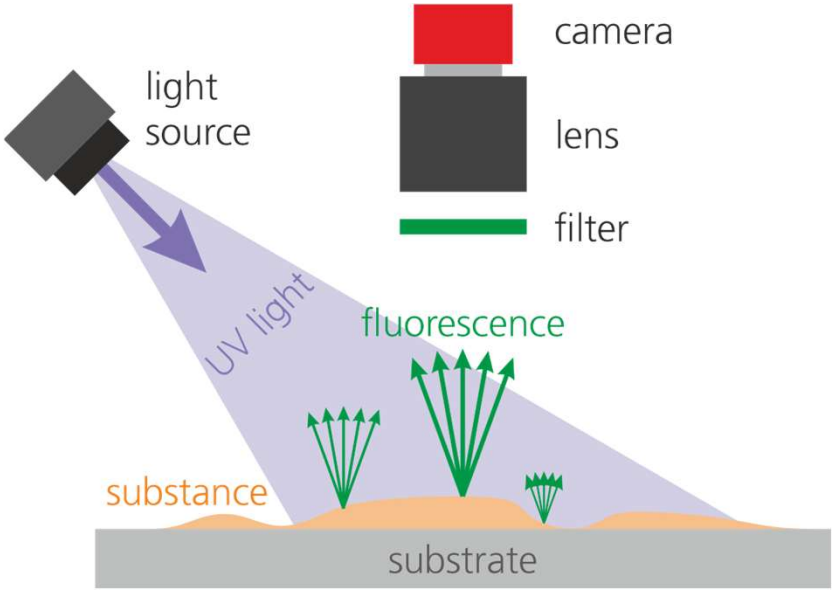
4. Fluorescence based measurement of cleanliness and oil cover

The principle of fluorescence



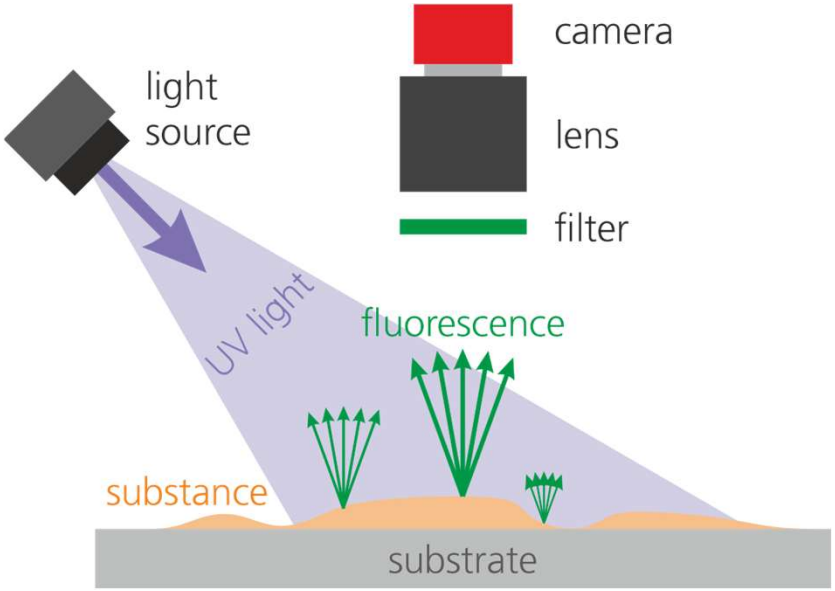
Cleaned, blank metal
(no fluorescence)

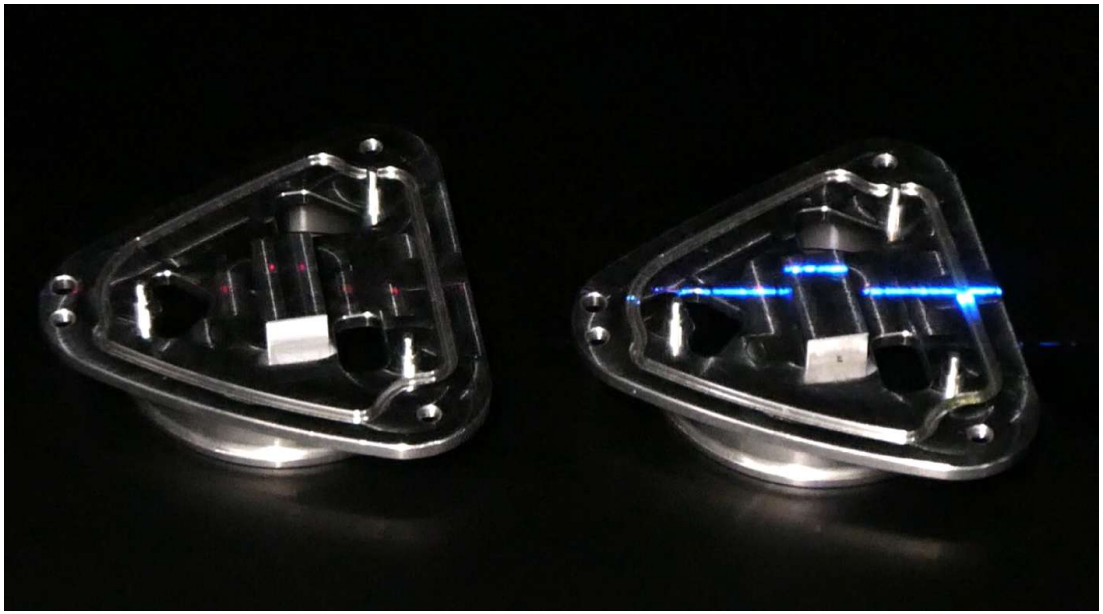
Oil coated
(strong fluorescence)

Fraunhofer IPM

4. Fluorescence based measurement of cleanliness and oil cover

The principle of fluorescence





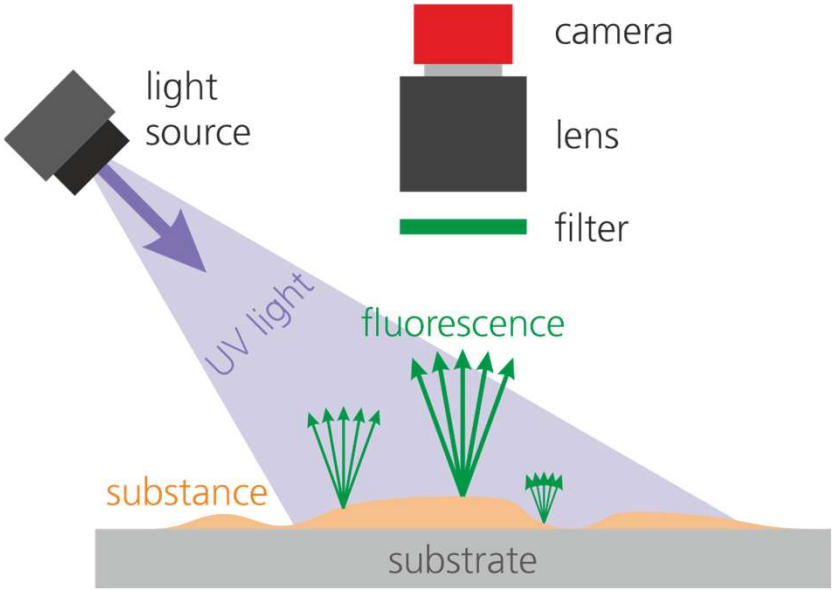
Cleaned, blank metal
(no fluorescence)

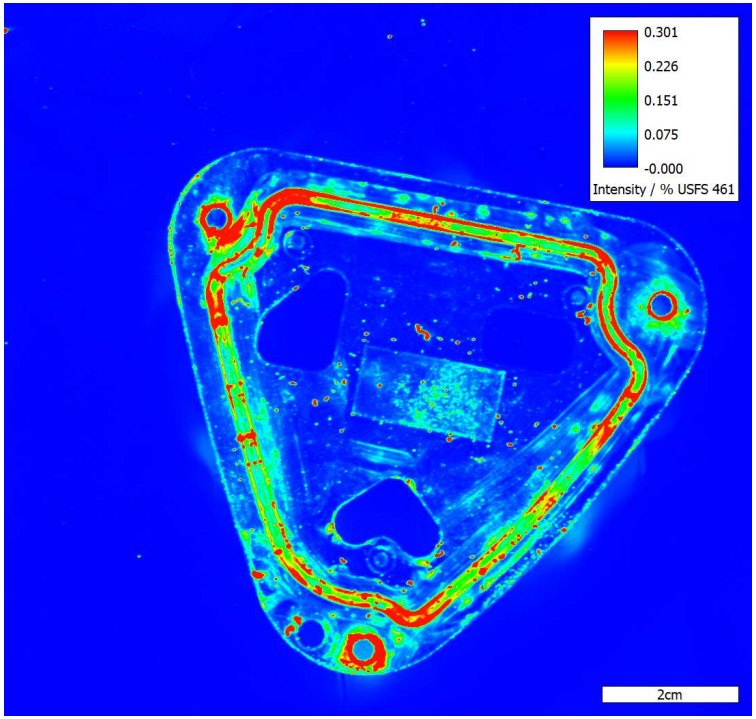
Oil coated
(strong fluorescence)

Fraunhofer IPM

4. Fluorescence based measurement of cleanliness and oil cover

The principle of fluorescence





Purity check of housing for electronic component:
Oil residues in the glue groove – extremely critical!

Fraunhofer IPM

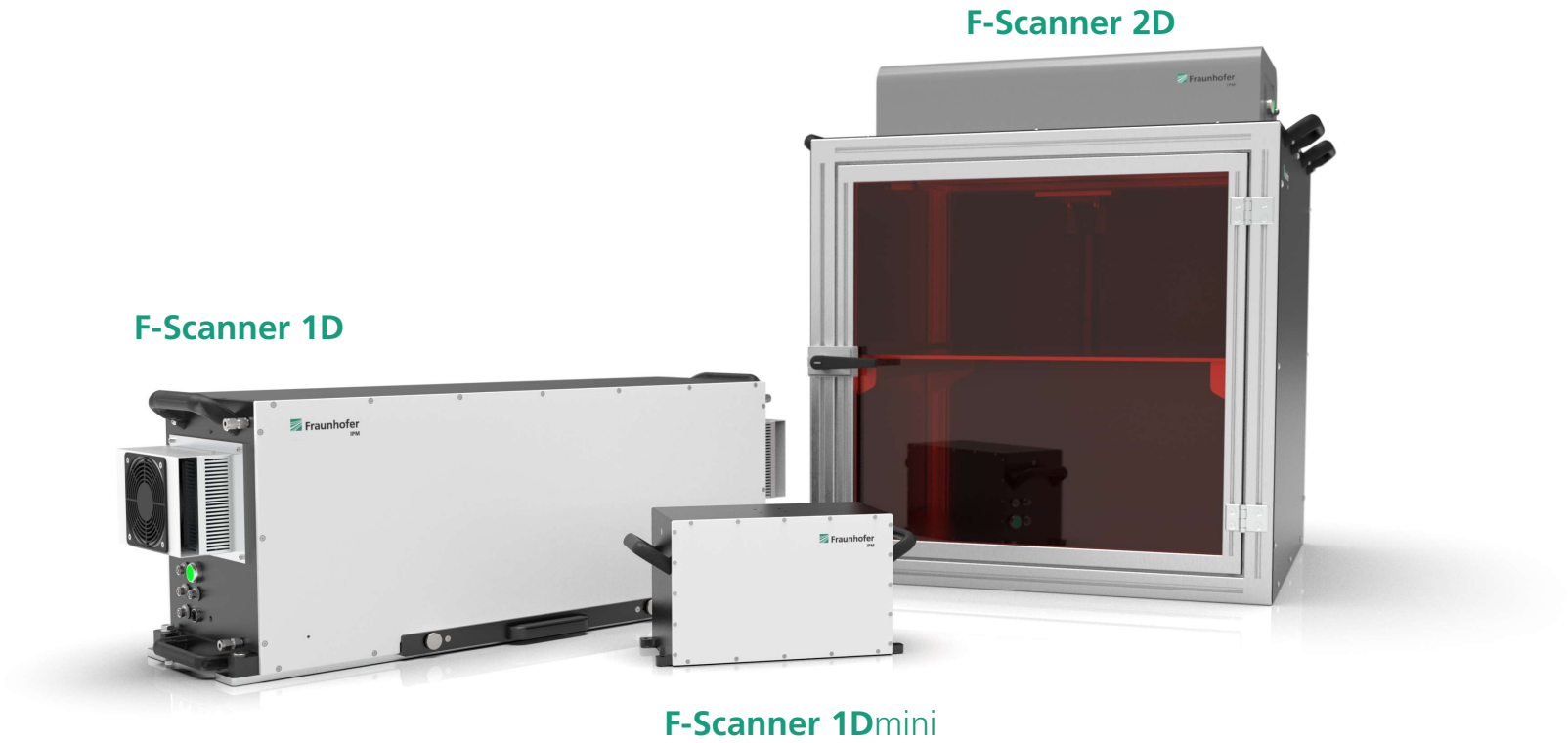
4. Fluorescence based measurement of cleanliness and oil cover

Fluorescence measurement technology: Fields of application

Inspection of coatings	Detection of contaminations
blank lubrication in car body manufacturing	… most organic process additives
coating of strip metal	electronics manufaturing
passivation of aluminum	glued housing parts
functional coatings on glass	graphite coating
inspection of foils	galvanization
application of release agent	welding applications

4. Fluorescence based measurement of cleanliness and oil cover

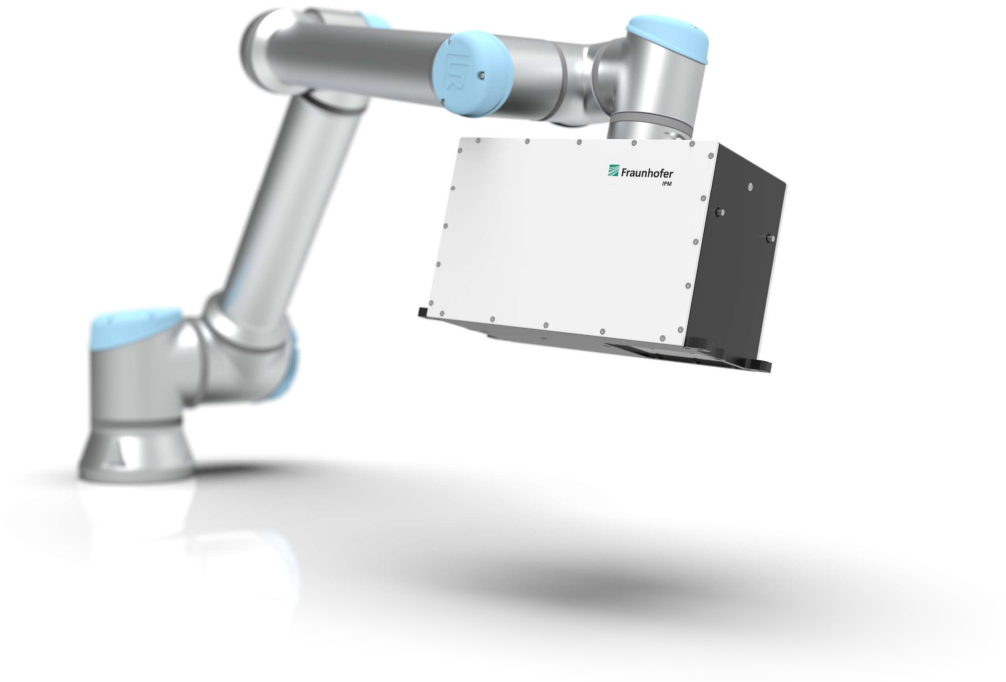
F-Scanner family



Department Production Control

Fluorescence measurement technology: F-Scanner $1D_{mini}$ – robot driven fluorescence scanner

- Designed for use on the robot and in confined environments.
- lightweight 8 kg
- 266 lines per second @ 4000 RPM
- 65° aperture angle
- active SNR improvement by lock-in



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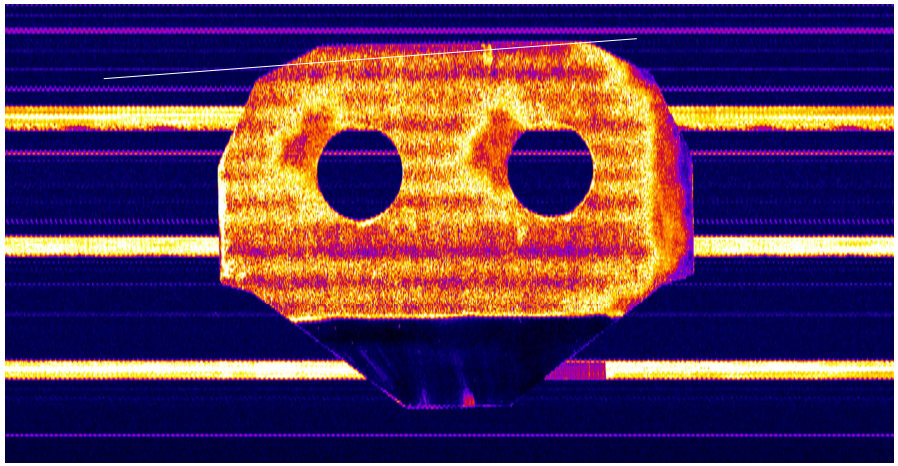
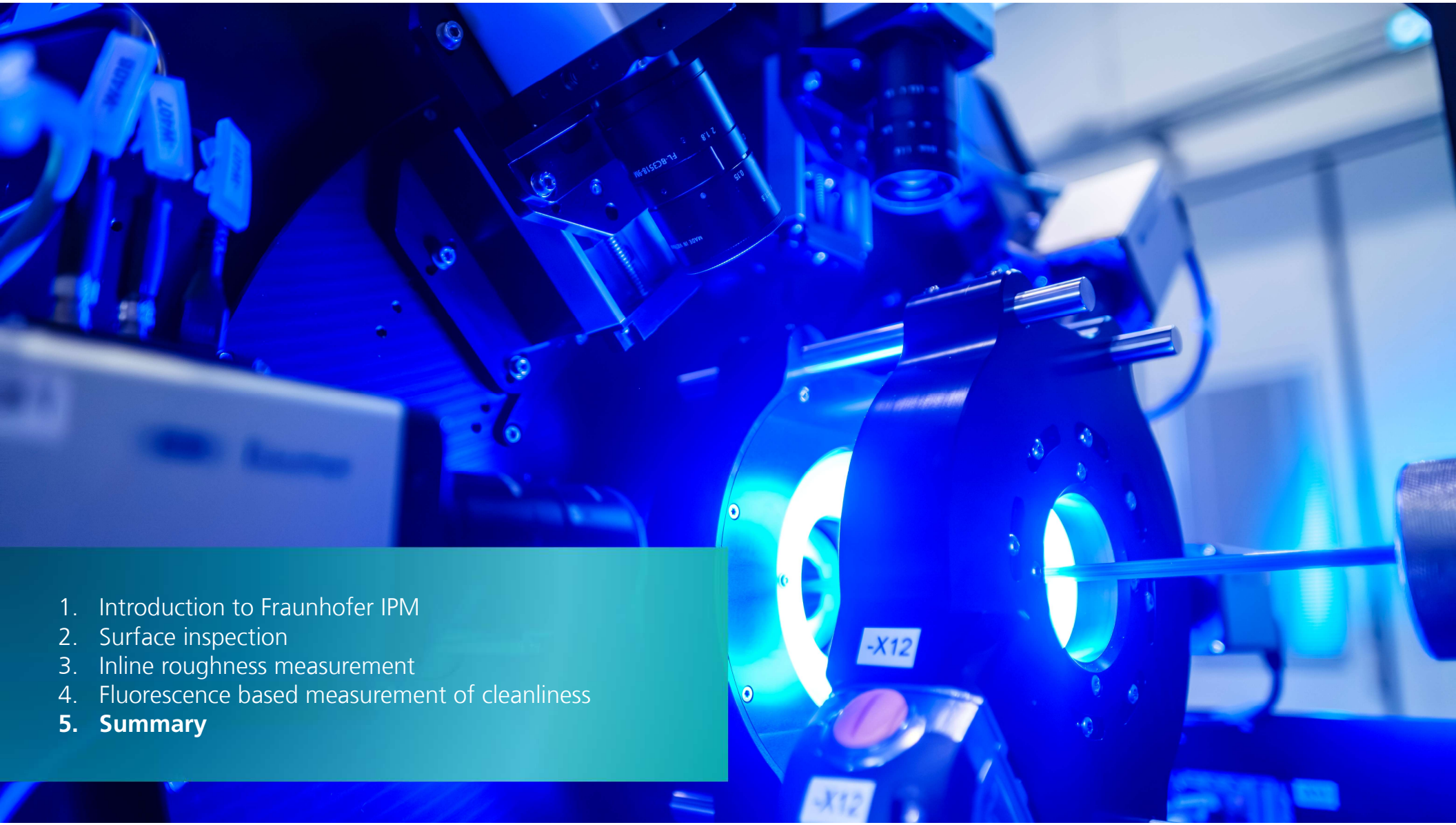
4. Fluorescence based measurement of cleanliness and oil cover

F-Scanner – inline solution for fast moving belts



- Typical field-of-view 300 mm to 2000 mm
- Lateral resolution 500 µm to 2 mm
- 200 – 400 lines per second
- Feeding rate up to 2 m/s



1. Introduction to Fraunhofer IPM
2. Surface inspection
3. Inline roughness measurement
4. Fluorescence based measurement of cleanliness
5. **Summary**

Summary
Fraunhofer IPM

Fast, precise and robust measurement solutions for industry.

Meeting the highest quality standards.

Fraunhofer IPM

We look forward to working with them.«

From lab to industry.

Visit us on the Web
https://www.ipm.fraunhofer.de/en/bu/production-control-inline-measurement-techniques.html

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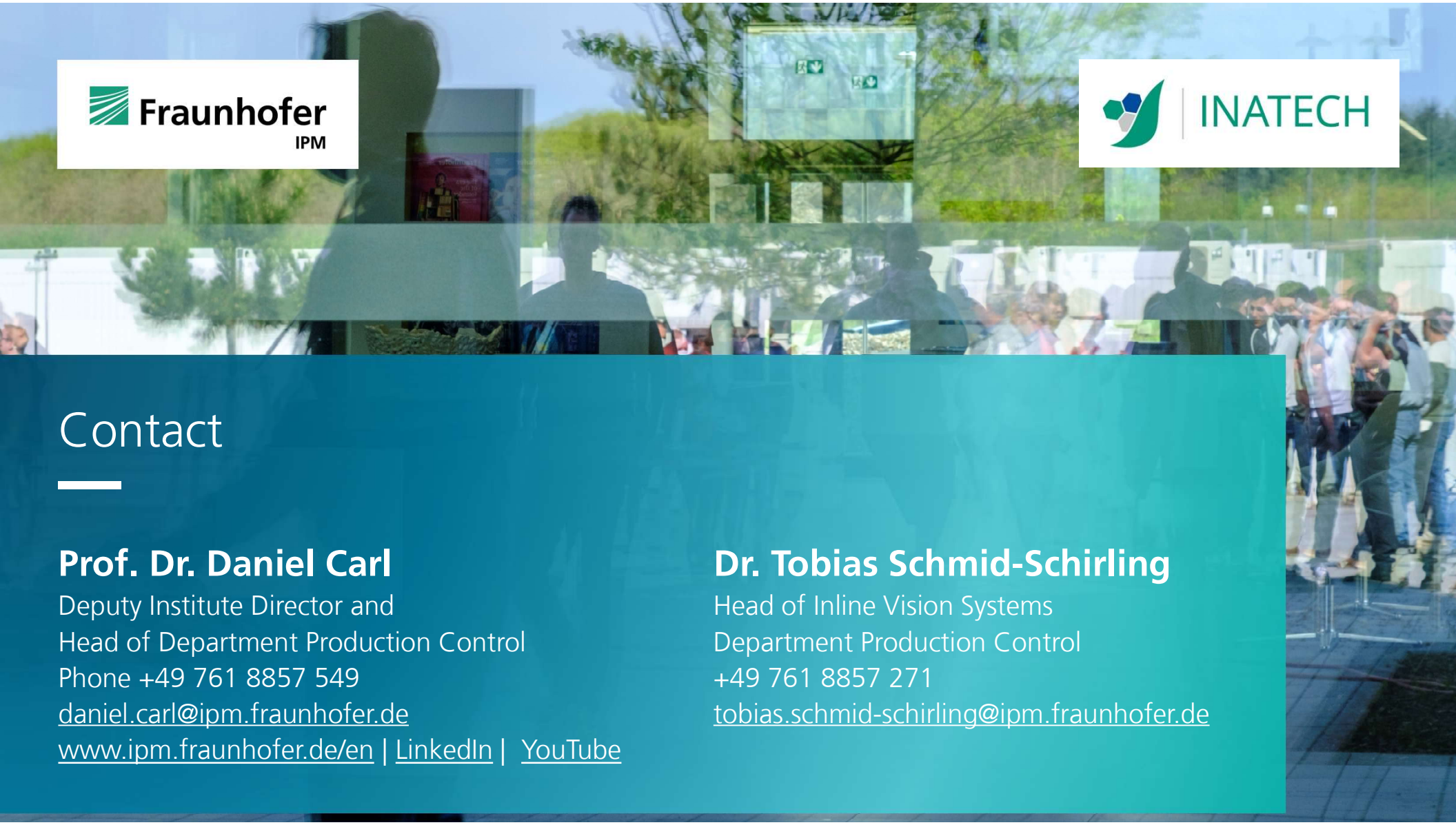

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