VTT:n näkemyksiä tulevaisuuden mittaustekniikasta prosessiteollisuudesta

VTT

Wood AI –webinaari
25.8.2020
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Optiset mittaukset –tiimi

VTT ja XAMK Savonlinnan Kuitulaboratorio - pitkäaikainen yhteistyö

Mm. sekoitukseen liittyvien ilmiöiden tutkimuksessa

- VTT toi korkean suorituskyvyn lämpökuvausosaamista Kuitulaboratorion johtamaan FLASH-hankkeeseen vuosina 2013-15

- NewPro (New high reactivity in-line process knowhow for the Finnish fiberproduct business ecosystem) -hankkeessa etsittiin uusia menetelmiä mitata kemikaalien sekoittumista paperikonesovelluksissa. Sekoittumisen tutkimiseen hyödynnettiin mm. mikrometriskaalan IR-lämpökuvausta VTT:n toimesta vuosina 2017-18 sekä EIT-tomografiaa.

Suurnopeuslämpökuvaukset mikroskooppioptiikalla Savonlinnan Kuitulaboratoriolla 7.11.2018

Mittaus: päävirta noin 1% massa (noin +30°C) 50 l/s, kemikaalivirta kuuma vesi (noin +56°C) 1,0 l/s, injektio 3,0 l/s, sekoitus 0 l/s
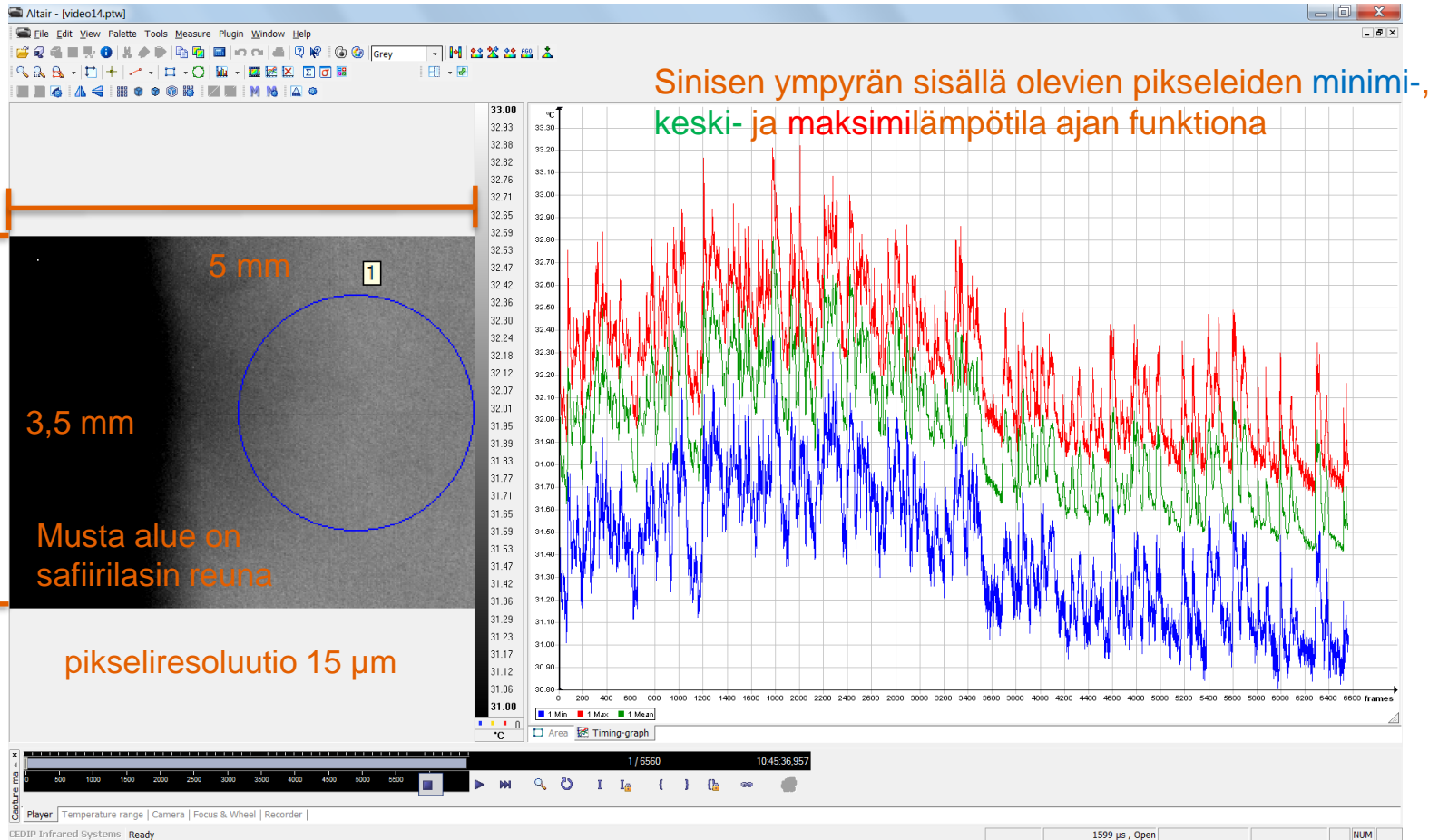
Mikroskooppiobjektiivin etäisyys safiiri-ikkunasta noin 3 cm

IR-video14 (13-kertaisesti hidastettu): kuvankaappausnopeus 328 Hz, integrointiaika 1600 µs:

Trumpjet-sekoitin 2D etäisyydellä ylävirrassa vastapuolella kameraa, D (putken halkaisija) = 200 mm

4

Sinisen ympyrän sisällä olevien pikseleiden minimi-, keski- ja maksimilämpötila ajan funktiona

5 mm

3,5 mm

Musta alue on safiirilasin reuna

pikseliresoluutio 15 µm

Sekoitusindeksien vertailu – keskilämpötila sinisen ympyrän sisällä olevalla alueella

video14, main flow 50 l/s, chem 1,0 l/s, inj 3,0 l/s, mix 0 l/s
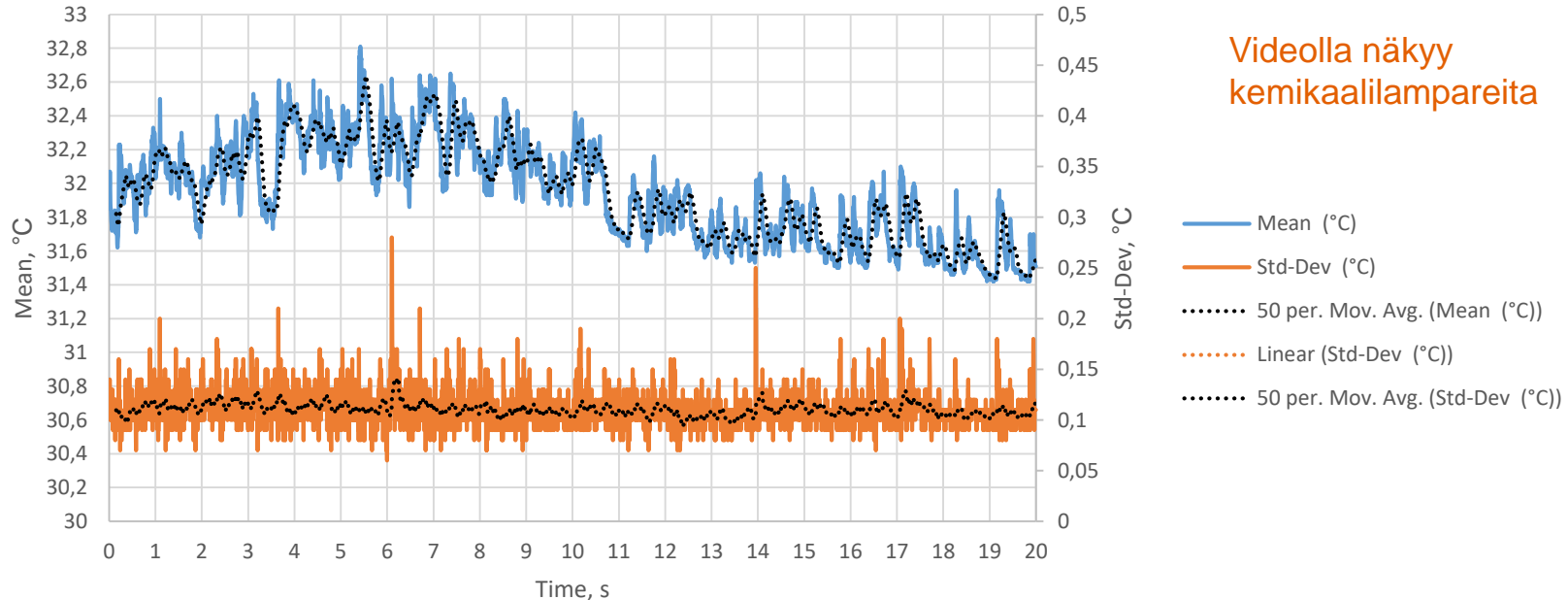
Videolla näkyy kemikaalilampareita

Legend:
- Mean (°C)
- Std-Dev (°C)
- 50 per. Mov. Avg. (Mean (°C))
- Linear (Std-Dev (°C))
- 50 per. Mov. Avg. (Std-Dev (°C))

X-axis: Time, s
Left Y-axis: Mean, °C
Right Y-axis: Std-Dev, °C

Sekoitusindeksien vertailu – keskilämpötila sinisen ympyrän sisällä olevalla alueella

IR-video	Päävirta,	Kemikaalivirta,	Injektiovirta,	Sekoitusvirta,	Keskiarvo,	Keskihajonta,	Sekoitusindeksi
	l/s	l/s	l/s	l/s	°C	°C	=KHaj/KArv
video4	50	1,0	3,0	0	35,48	0,14	**0,39 %**
video5	50	1,0	2	0	35,29	0,04	**0,11 %**
video14	50	1,0	3,0	0	32,05	0,26	**0,82 %**
video16	50	1,0	3,2	0,5	32,50	0,16	**0,50 %**
video18	50	1,0	3,0	1,0	32,95	0,12	**0,35 %**
video20	50	0,8	3,0	1,5	33,03	0,09	**0,26 %**
video34	50	0,4	3,0	1,5	34,14	0,03	**0,08 %**
video36	50	0,45	3,0	1,0	34,51	0,10	**0,28 %**
video38	50	0,45	3,0	0,5	34,78	0,09	**0,27 %**
video40	50	0,4	3,0	0	34,68	0,08	**0,22 %**
video44	50	1,0	3,0	0,5	35,18	0,13	**0,36 %**
video46	50	1,0	3,0	1,0	35,57	0,09	**0,25 %**
video48	50	1,0	3,1	1,5	35,86	0,08	**0,23 %**
video74	50	1,0	6	1	36,50	0,15	**0,40 %**
video77	50	1,0	6	0,5	36,80	0,17	**0,45 %**
video79	50	1,0	6	1,5	36,96	0,10	**0,26 %**
video81	50	1,0	6	0	37,10	0,13	**0,35 %**

Näkyvän valon (visible light, VIS) suurnopeuskuvaukset Savonlinnan Kuitulaboratoriolla 2.-3.10.2018

Halogeeni Ringlight testi

4A02956m.avi – hidastetulla suurnopeusvideolla nähdään isokokoinen kuitu
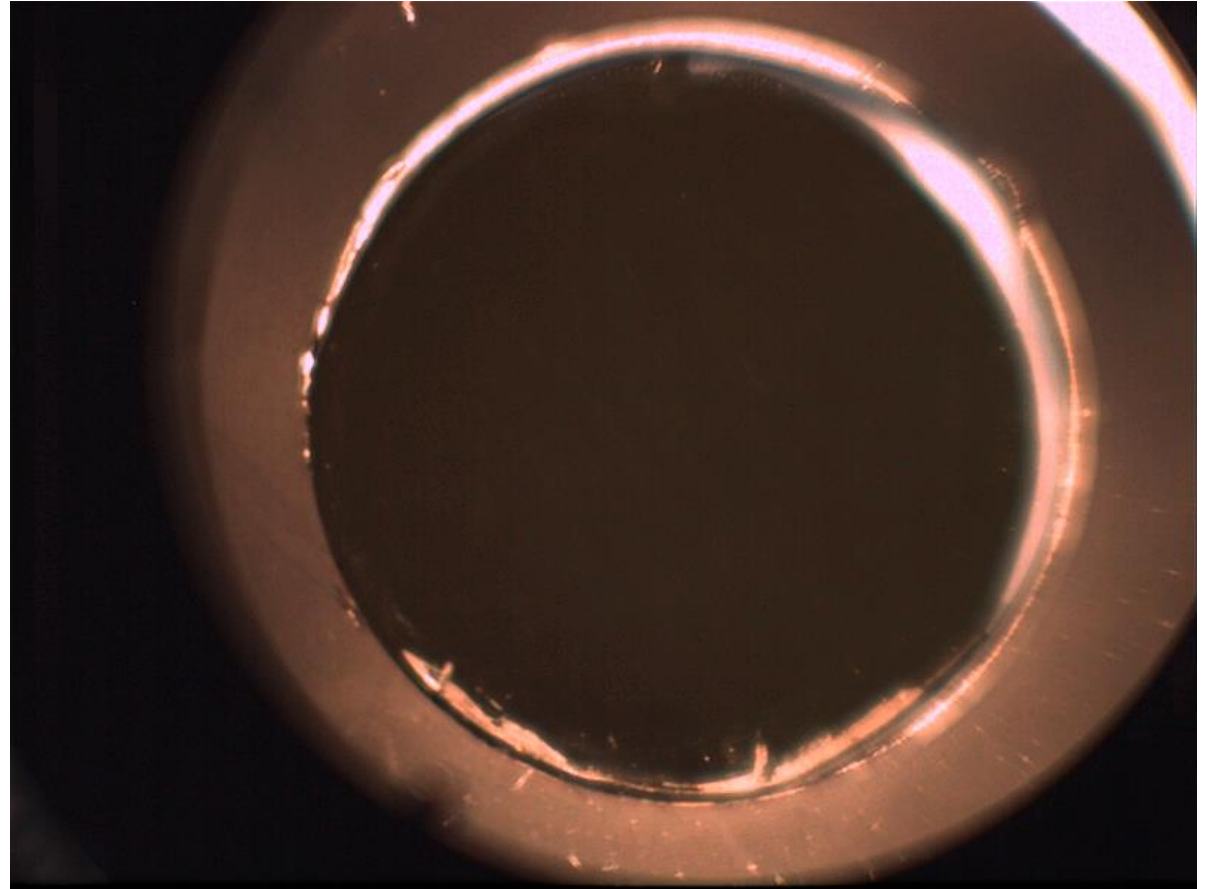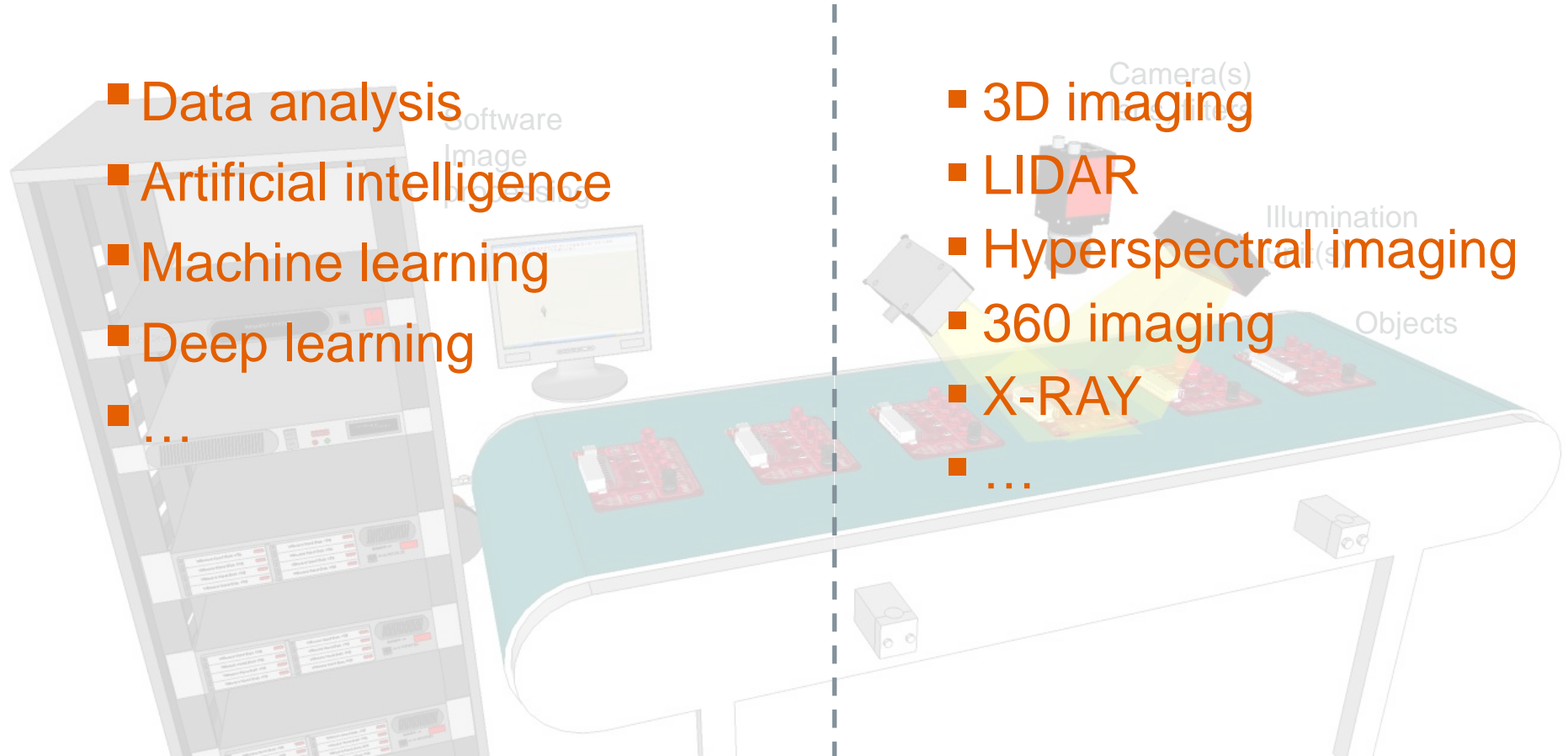
Idea-aihioita tulevaisuuden mittaustekniikoiksi prosessiteollisuudessa
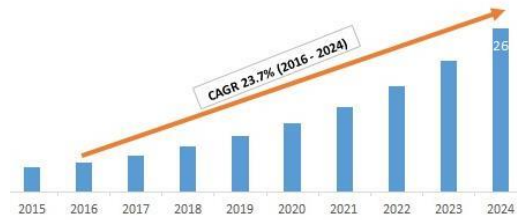
VTT

Machine vision system

- Data analysis
- Artificial intelligence
- Machine learning
- Deep learning
- …

- 3D imaging
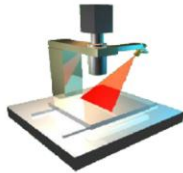- LIDAR
- Hyperspectral imaging
- 360 imaging
- X-RAY
- …

3D imaging

Global 3D Imaging Market Size and Forecast,
2015 - 2024 (US$ Billion)

CAGR 23.7% (2016 - 2024)

2015 2016 2017 2018 2019 2020 2021 2022 2023 2024

Source: Variant Market Research

Laser triangulation **Stereo imaging** **Structured light** **Photometric stereo** **3-D from silhouette**
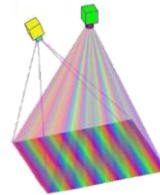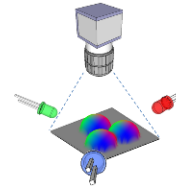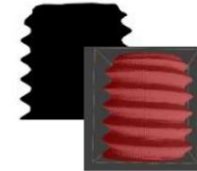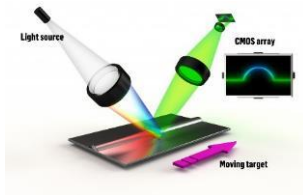
Line Confocal Imaging **Covered Stereo Reflectometry** **Time-of-flight** **LIDAR**
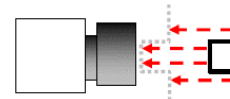
3D imaging – examples:
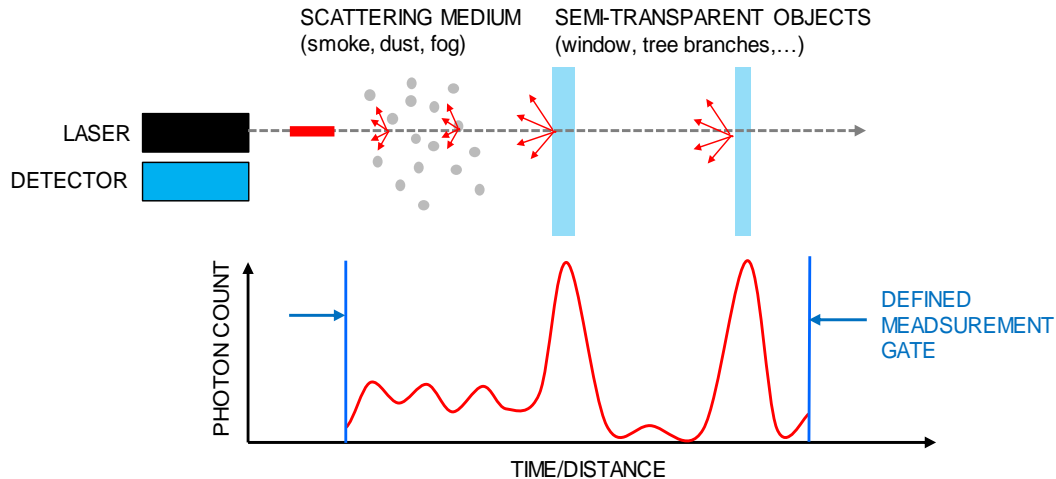## *photometric stereo for on-line particle size analysis*
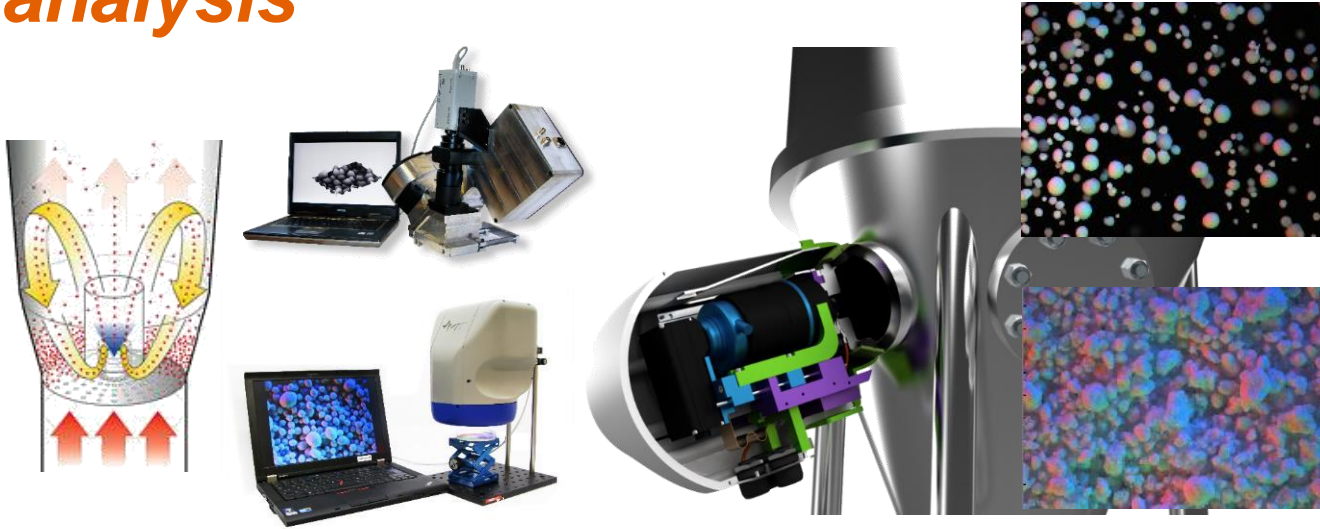
3D imaging examples:
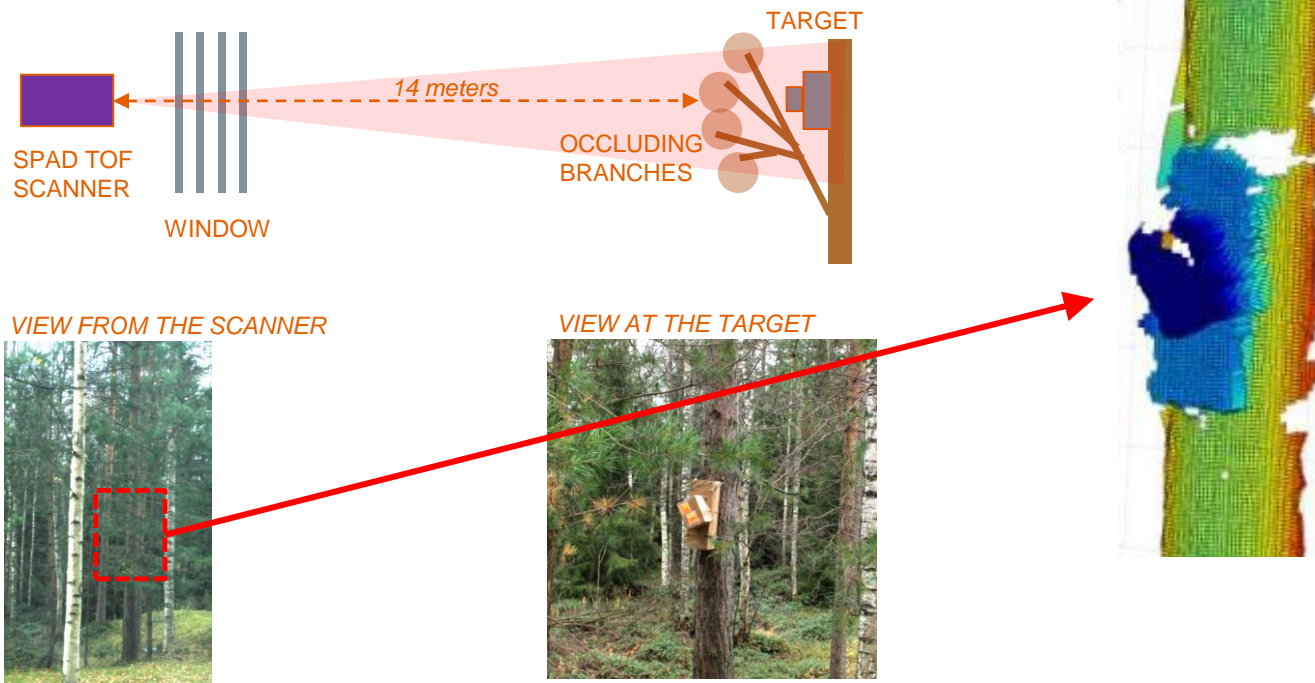## *photometric stereo for paper surface analysis*
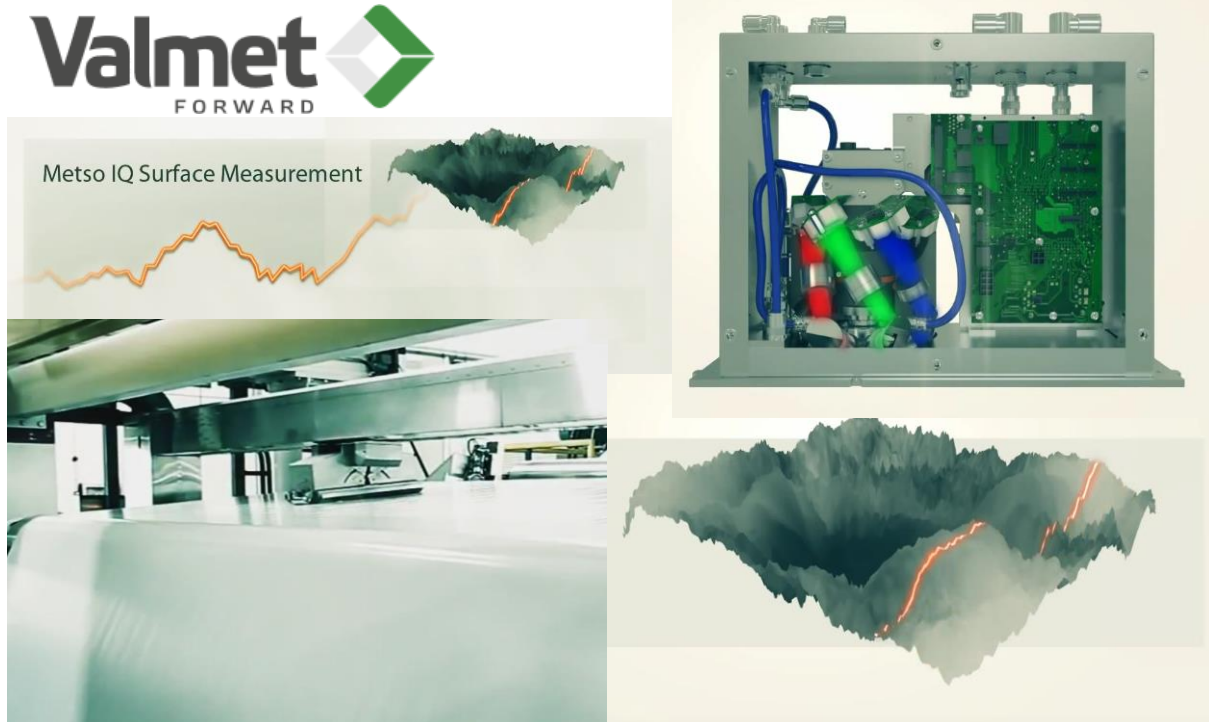
3D imaging – examples: *SPAD TOF 3D scanning*

- **SPAF TOF = Single Photon Avalanche Diode Time-of-Flight**
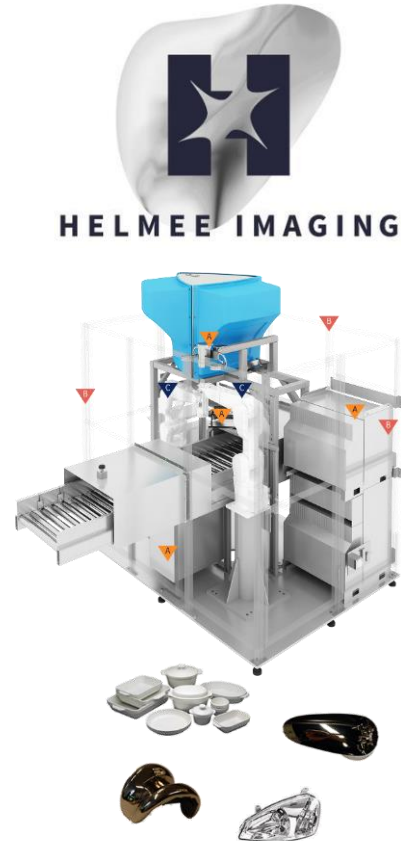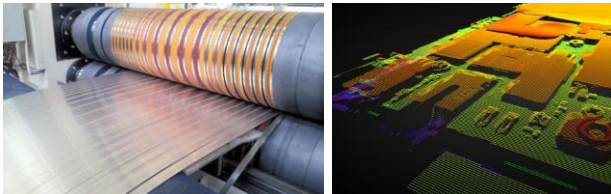
- **Pointwise measurement, image by scanning**

3D imaging – examples:
3D scanning of objects through foliage

TARGET

14 meters

SPAD TOF SCANNER

WINDOW

OCCLUDING BRANCHES

*VIEW FROM THE SCANNER*

VIEW AT THE TARGET

3D imaging – commercialization examples: *3D of glossy objects and surfaces*

Hyperspectral imaging

Fabry-Perot (FPI) technology for miniaturizing optical sensors

- ✓ FPI is a tunable optical filter – electrical actuation changes the passband wavelength

- ✓ VTT develops miniaturized spectrometers based on tunable FPIs, for both imaging and non-imaging application

- ✓ FPI-based microspectrometers and hyperspectral imagers can be scaled to volume production
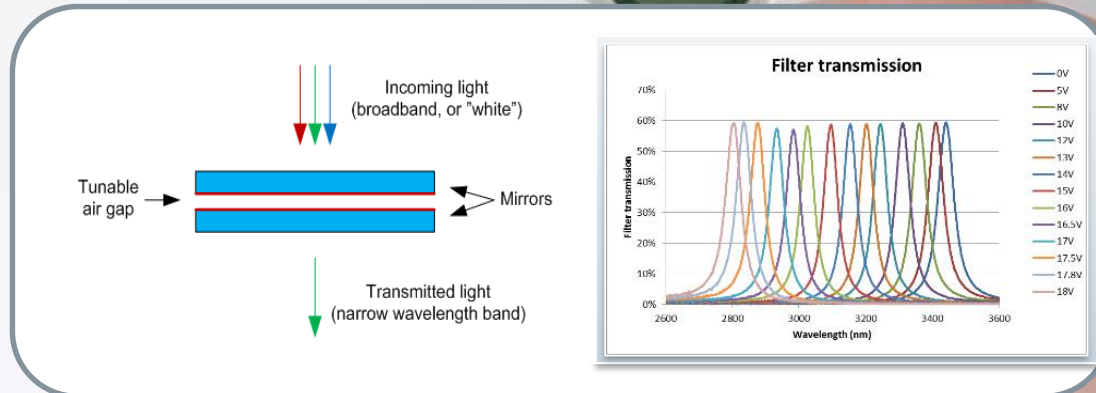
Hyperspectral imaging

Realizing sensor prototypes for novel applications

System-level expertise built over the past years in R&D- and customer projects

Mobile and hand-held

Hyperspectral iPhone demo (2016)

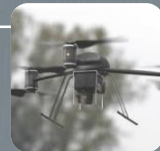**MEMS-based** hyperspectral imager demo (2012)

Mobile CO2 sensor demo (2014)

Space and environmental sensing

Hyperspectral imagers for space instruments
- Aasi-1 (2014-2017)
- PICASSO Vision (2015- 2018)
- Hello World SWIR HIS 2018
- Altius UV imager 2018

Drone hyperspectral imagers for forestry, precision agriculture, gas sensing and UV-Raman
Visible-VNIR (2011), SWIR (2016), UV (2016)

Skin cancer hyperspectral imager (2014-2017)

Health and diagnostics

Hyperspectral microscope
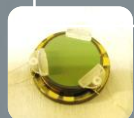Imaging of cells, micro well arrays & fluorescence imaging (2016)

Fundus camera
Detection of glaucoma and diabetes, oxygen saturation (hypoxia, apnea)

Brain surgery spectral imaging integrated to the Zeiss Pentero brain surgery microscope
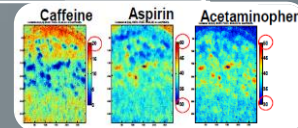
Stand-off - and and chemical detection

Thermal IR hyperspectral imager (2014)
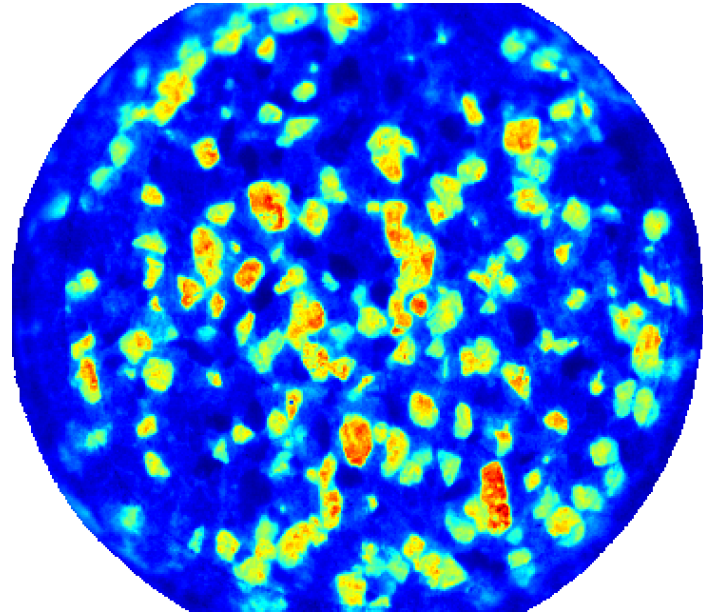
UV-FPI Raman stand-off trace detection (2014)

SO_2/NO_x ship emission HIS (2016)

Caffeine Aspirin Acetaminophen

Chemical imager for 1-2.5 µm
Distribution of active ingredients

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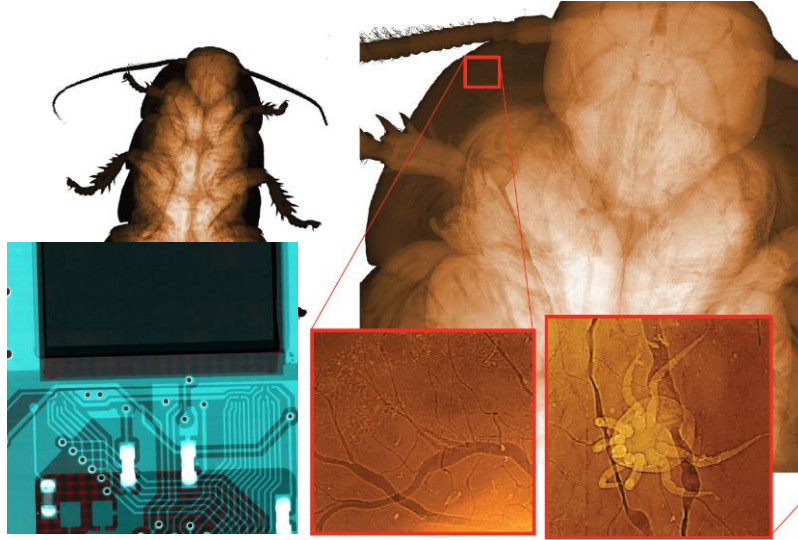# Hyperspectral imaging examples: *Chemical Imaging*

Special imaging methods – examples: *360 degree imaging*

- Omnidirectional imaging application examples:
    - LIDAR/TOF 3D scanners
    - 360 degree 3D stereo for environment perception of automatic vehicles
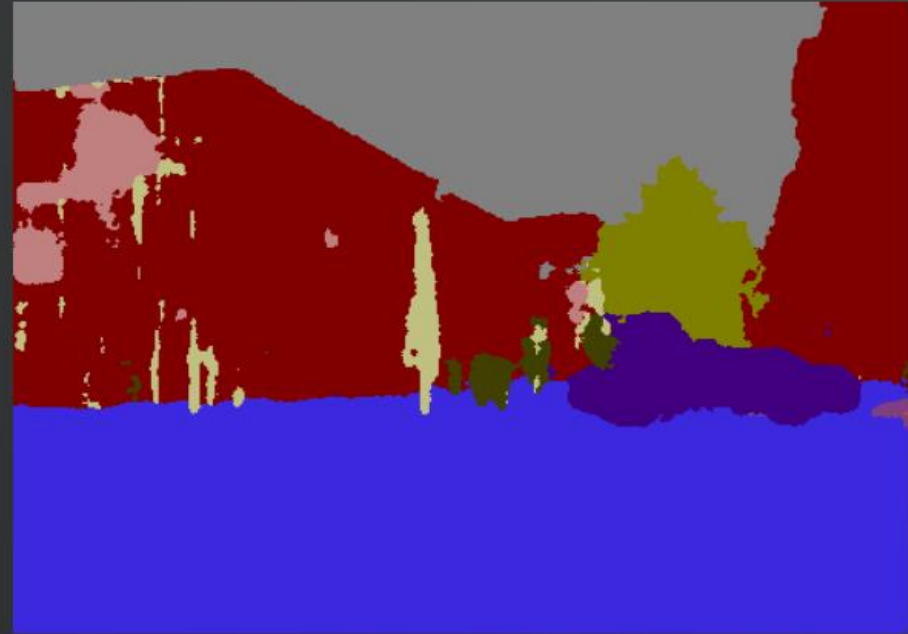   - 360 degree thermal vision
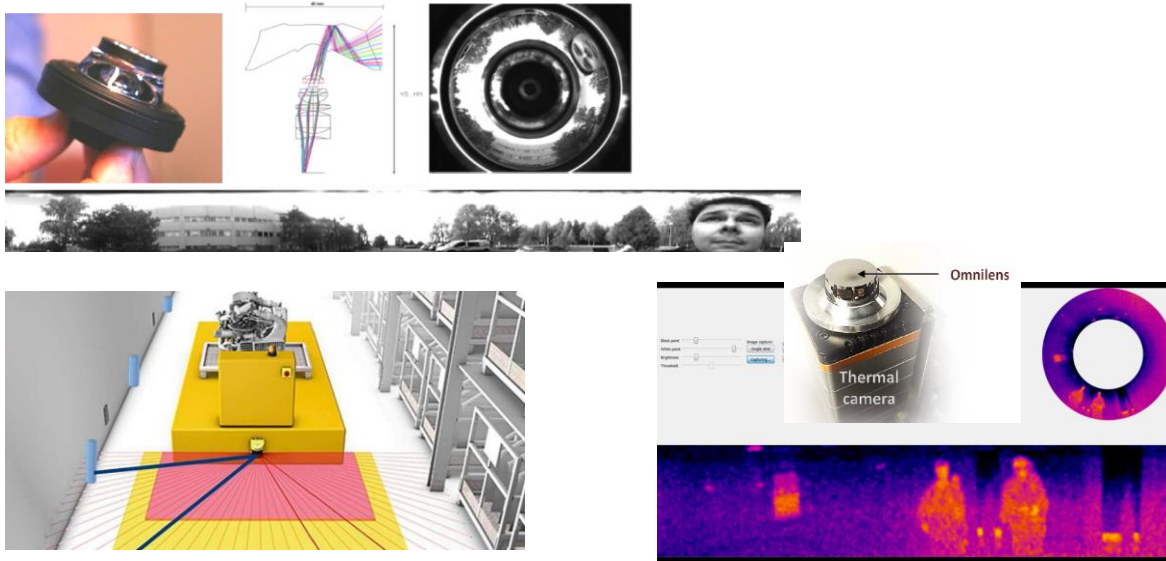
Special imaging methods – examples:
Novel X-RAY sensor by VTT spin-off Advacam

VTT

- Zero noise, ultra-high contrast for light materials and small absorption differences
- Energy sensitivity ➔ "Color X-ray"
- Edgeless sensor ➔ sensor matrix for large area
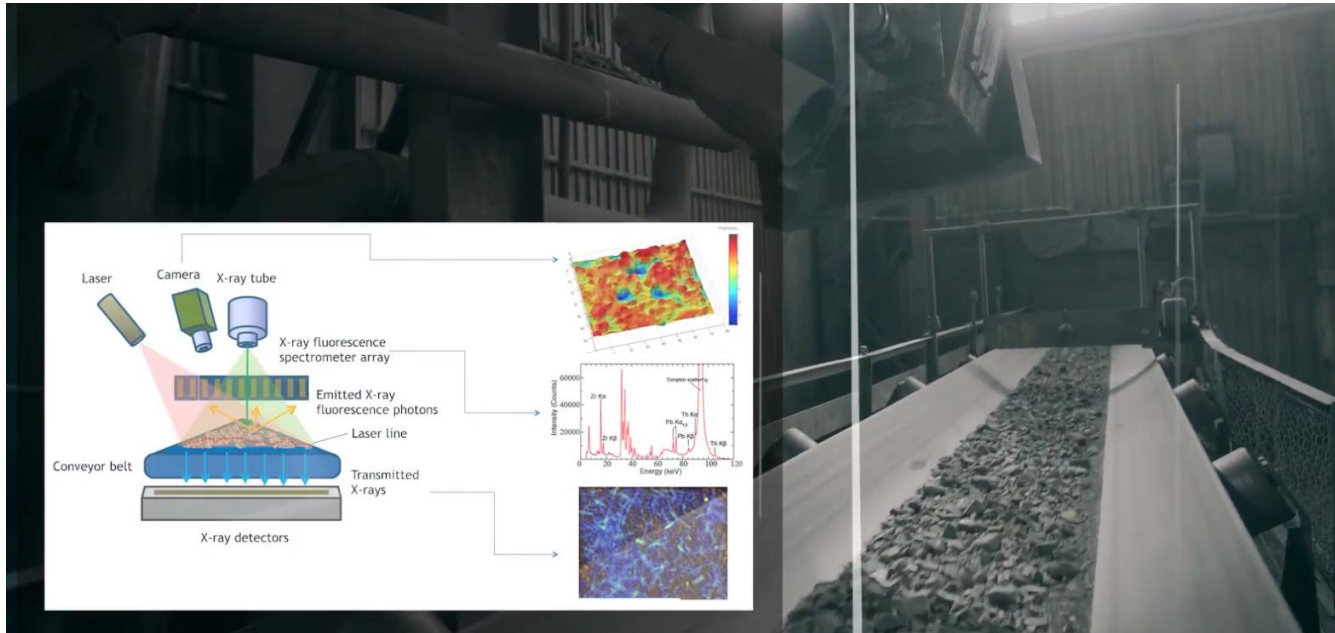- Laboratory for application studies now in VTT Oulu

Machine/deep learning/AI

| Sky | Building | Pole | Road | Road | Pavement | Tree | Sign | Fence | Vehicle | Pedestrian | Bike |

→ http://mi.eng.cam.ac.uk/projects/segnet/demo.php#demo
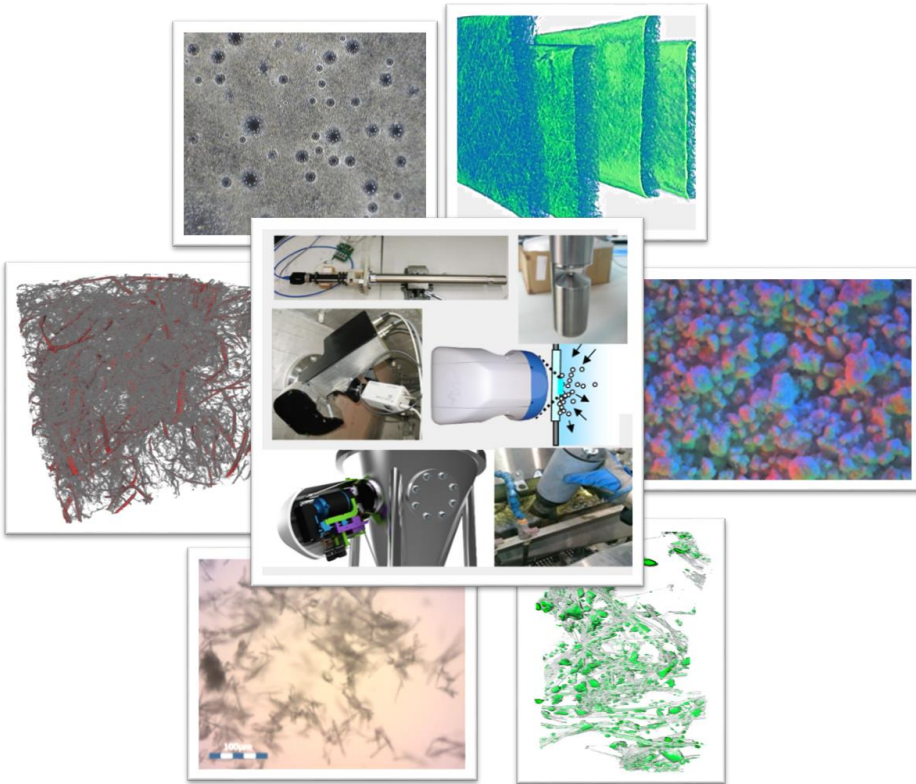
Sensor fusion and machine learning example:X-MINE

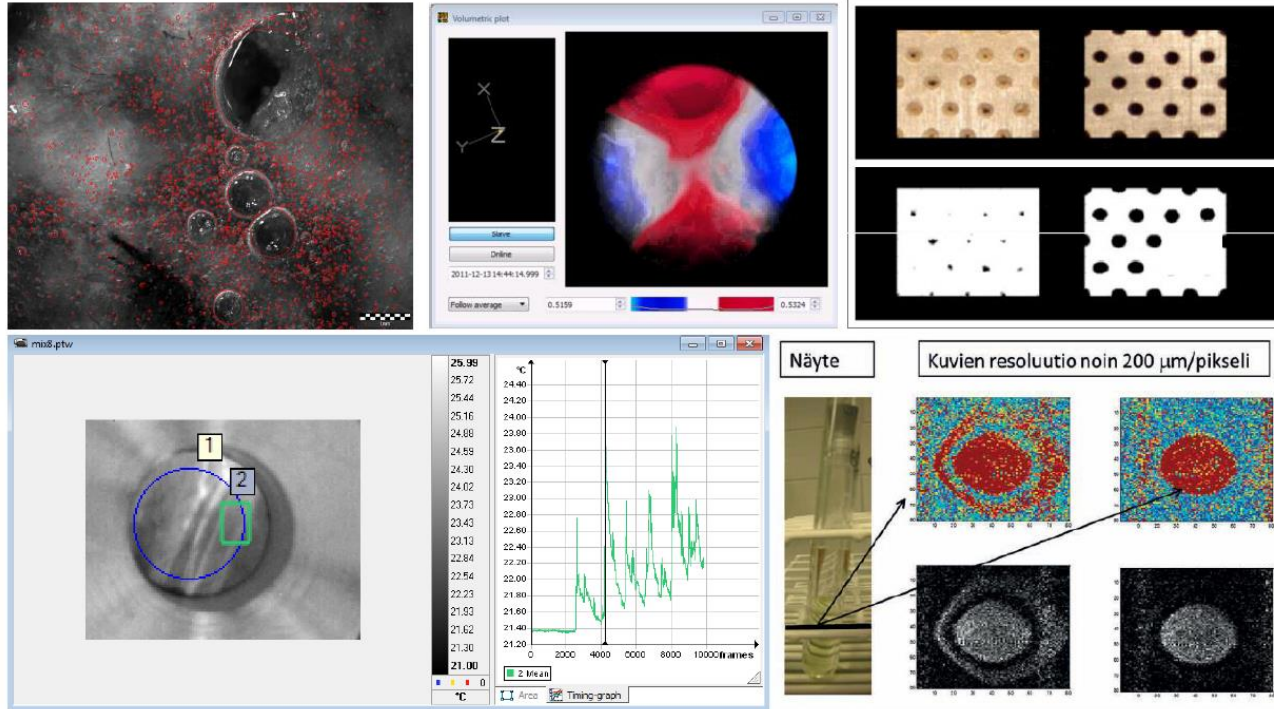- Fusion of XRT, XRF and 3D information to perform mineral sorting based on machine learning

BIOGROWTH
Kuvantavien tekniikoiden roadmap selvitys

Fiber laboratory - current status

State-of-the-art review

Traditional machine vision
- Machine vision cameras
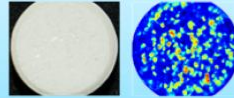- Smart cameras
- Illumination and optics

Hyperspectral imaging
- Spatial scanning
- Spectral scanning
- Snapshot HSI
- Spatio-spectral scanning
- Multispectral imaging

Non-VIS range imaging
- Infrared cameras
- Thermal imaging
- X-ray Imaging

3D imaging
- Laser profilometry
- Structured light
- Stereo 3D imaging
- TOF 3D imaging
- Micro-topography
- Deflectometry

Microscopy
- Optical microscopy
- In-situ microscopy
- Electron microscopes

Tomography
- Computed Tomography
- Optical Coherence Tomography
- Magnetic Resonance Imaging
- Ultrasound imaging

Special imaging
- Event camera
- Gated imaging
- Particle Image Velocimetry
- Light field cameras
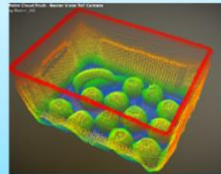
Support or related technologies
- Housing and cleaning
- Connectivity
- Storage
- Image analysis

Imaging roadmap

Application area	Spectral imaging	Microscopy	MRI/NMR	X-ray	Thermal imaging
In-line LC/MC	●	●	●	●	●
Process gas analysis	●				
Offline analysis	●	●		●	
Living biomass	●				
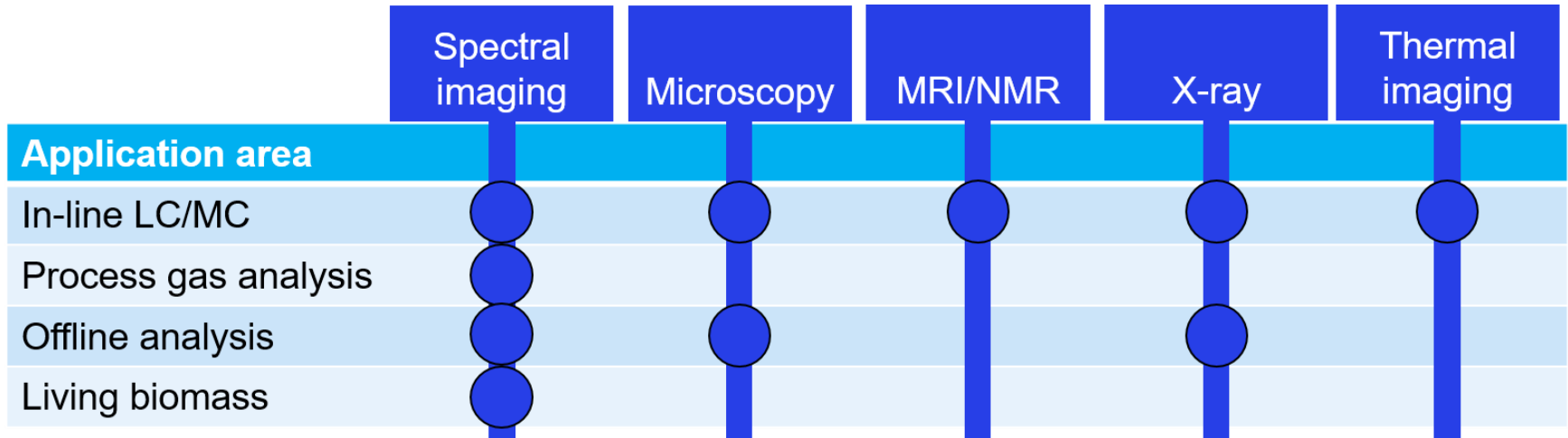
Development paths
Example: Hyperspectral imaging

IDENTIFICATION OF PARAMETERS TO MEASURE → FEASIBILITY /LAB STUDIES → HYPER SPECTRAL CAMERA → MULTI SPECTRAL/ DEDICATED CAMERA

bey°nd
the obvious

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