SOPAT – An inline technology for process and quality control

An image analysis tool for production and laboratory environments

MADE IN GERMANY

Content

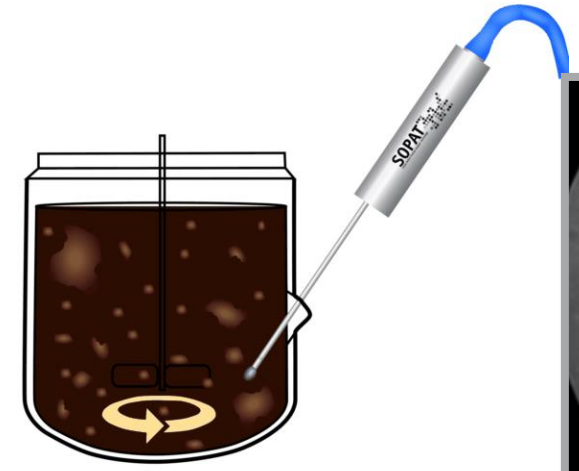
1. What is SOPAT?

And why to use it in the process industry?

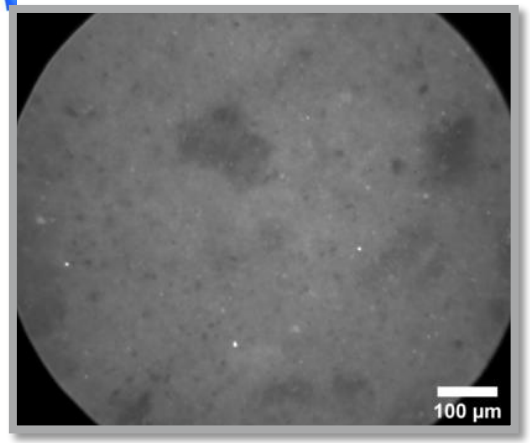
An introductory example

SOPAT provides an inline particle analysis system. The photo-optical approach enables real-time analysis of particle size and shape. With SOPAT you get…

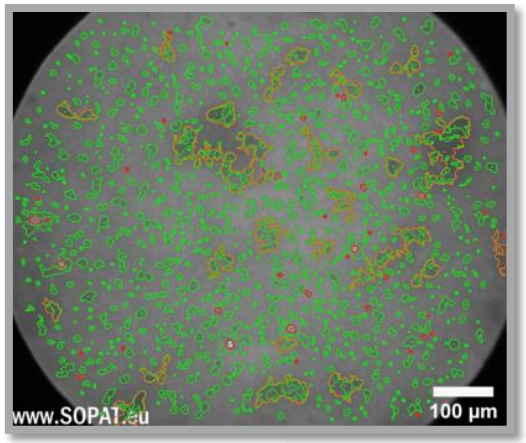
- a tool for inline process optimization
- a tool for inline quality control
- a complementary technique to existing offline particle analysis (like rheology, wet sieving and laser diffraction)
- extended depth of information, e.g. particle concentration, viscosity, colour …



Inline measurement

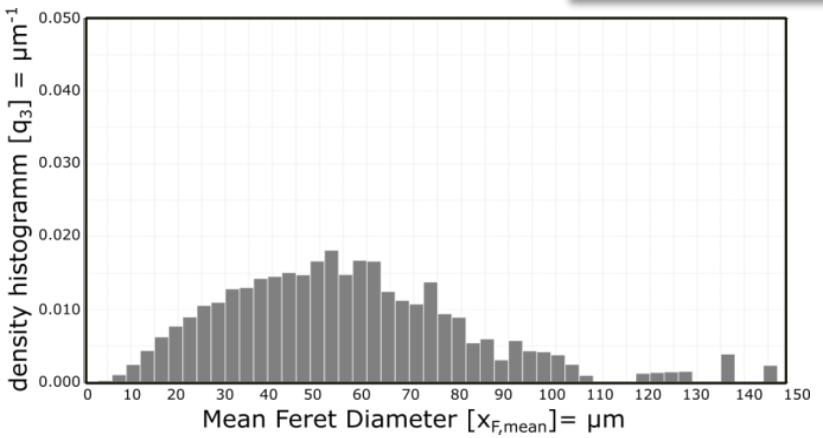


Raw images

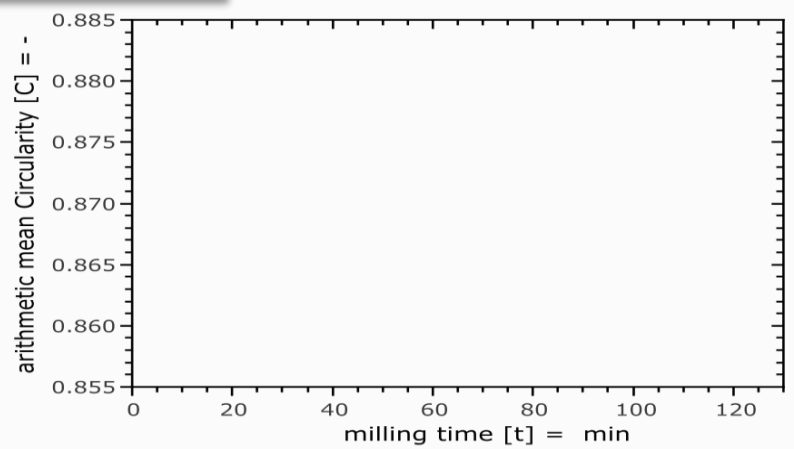


Analysed images

Size distribution



Shape information



Inline analysis – why?

In God I trust, all others bring data!
W. Edwards Deming

Time efficiency

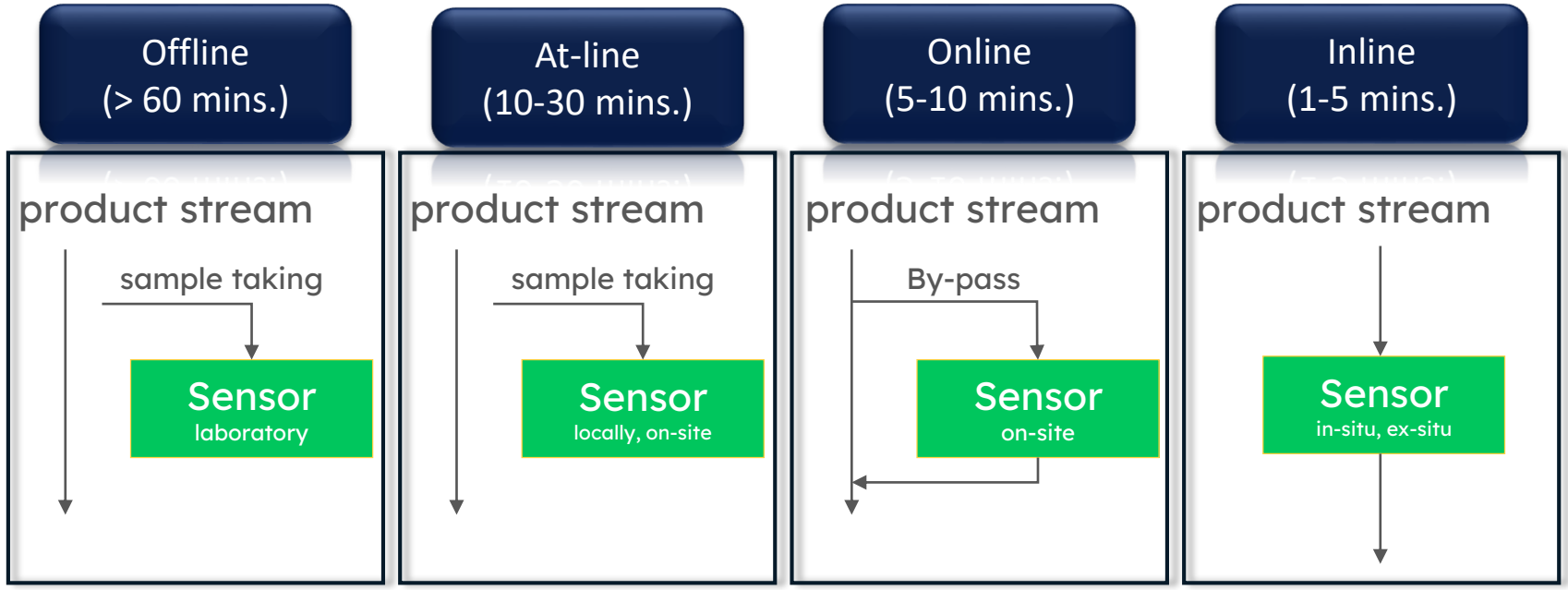
- No dilution
- No sample extraction
- No human factors involved
- No delay between process & analysis

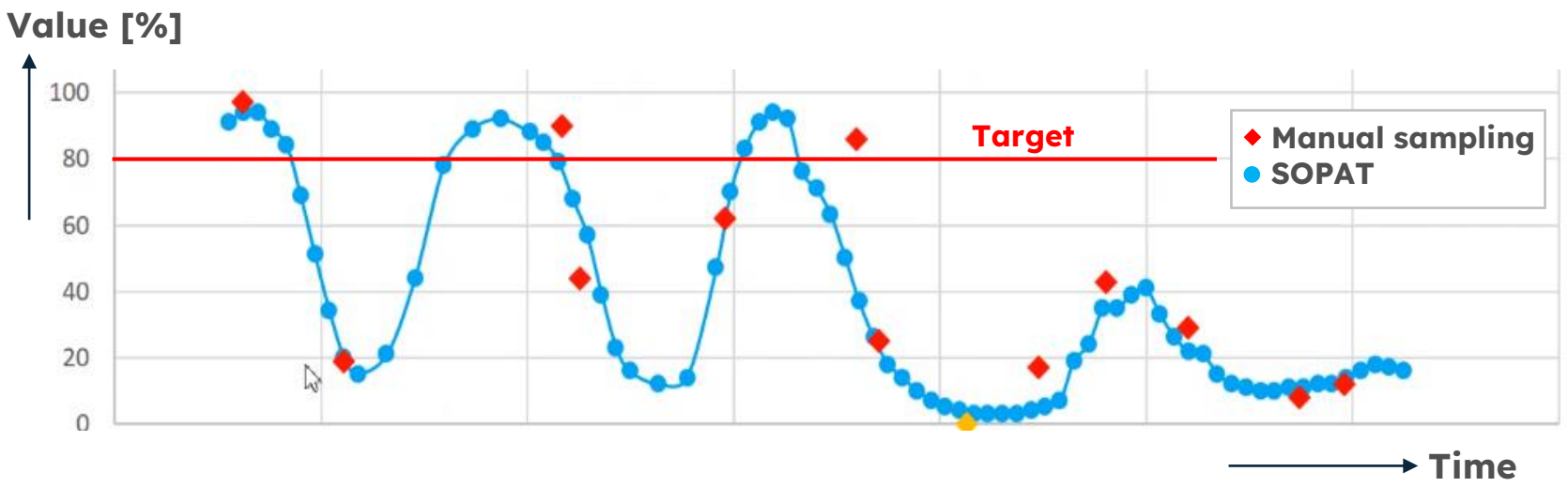
Accuracy

- Objective and direct method
- Comparison to laboratory methods

Operator response time

- Much faster reaction times
- Continuous live image (“SOPAT-TV”)





Bioprocess Scientific Publications

Ongoing **cooperation** between Technical University of Berlin – Bioprocess Engineering Department and **SOPAT**

Technische Universität Berlin

Institute of Biotechnology
Technische Universität Berlin
Bioprocess Engineering

Fermentation broth components influence droplet coalescence and hinder advanced biofuel recovery during fermentation, 2015

— Authors: Heeres, A., Schroën, K., Heijnen, J., van der Wielen, L. und Cuellar, M. — Biotechnology Journal, 10(8): 1206-1215 Developments in synthetic biology enabled the microbial production of long chain hydrocarbons, which can be used as advanced biofuels in aviation or transportation. Currently, these fuels are not economically competitive

READ MORE »

Gas bubble induced oil recovery from emulsions stabilised by yeast components, 2016

— Authors: Heeres, A. S., Heijnen, J., van der Wielen, L. A. M. und Cuellar, M. C. — Chemical Engineering Science, 145: 31-44 (link) In the search for advanced biofuels, microorganisms have been developed that make and secrete long chain hydrocarbons, resulting in a four phase fermentation mixture (cells, aqueous

READ MORE »

Single-cell-based monitoring of fatty acid accumulation in Crypthecodinium cohnii with three-dimensional holographic and in situ microscopy, 2017

— Authors: Marbà-Ardébol, A.-M., Emmerich, J., Neubauer, P. und Junne, S. — Process Biochemistry, 52: 223-232 (link) To date, on line monitoring in bioprocesses is restricted to conventional parameters. Presently, advances in microscopy allow the monitoring of single-cell size distributions in a bypass or in situ. These data provide information

READ MORE »

Real-time monitoring of the budding index in Saccharomyces cerevisiae batch cultivations with in situ microscopy, 2018

Microbial Cell Factories (link) — Authors: Marbà-Ardébol, M.-A., Emmerich, J., Muthig, M., Neubauer, P. und Junne, S. — Background The morphology of yeast cells changes during budding, depending on the growth rate and cultivation conditions. A photo-optical microscope was adapted and used to observe such morphological changes of individual cells directly

READ MORE »

Monitoring of the single-cell morphology for the evaluation of microbial eukaryotic bioprocesses, 2018

Technische Universität Berlin (link) — Authors: Marbà Ardébol, A. M. — Die Zellmorphologie wird nicht nur durch den Zellzyklus, die Alterungs- oder individuelle Eigenschaften beeinflusst, sondern auch durch Umweltbelastungen, wie sie z.B. im großen Maßstab auftreten. Die Zellmorphologie kann ein geeignete Parameter für eine in situ Messung sein, da sie sich dynamisch

READ MORE »

Techno-economic assessment of the use of solvents in the scale-up of microbial sesquiterpene production for fuels and fine chemicals, 2018

Modeling and Analysis — Authors: Pedraza-de la Cuesta, S., Knopper, L., van der Wielen, L. A. M., und Cuellar, M. C. — Sesquiterpenes are a group of versatile, 15-carbon molecules with applications ranging from fuels to fine chemicals and pharmaceuticals. When produced by microbial fermentation at laboratory scale, solvents are often

READ MORE »

Optical inline analysis and monitoring of particle size and shape distributions for multiple applications: Scientific and industrial relevance, 2019

Chinese Journal of Chemical Engineering 27 (2), S. 257-277 (link) — Authors: Emmerich, J., Tang Q., Wang, Y., Neubauer, P., Junne, S. und Maaß, S. — Particles occur in almost all processes in chemical and life sciences. The particle size and shape influence the process performance and product quality, and in turn

READ MORE »

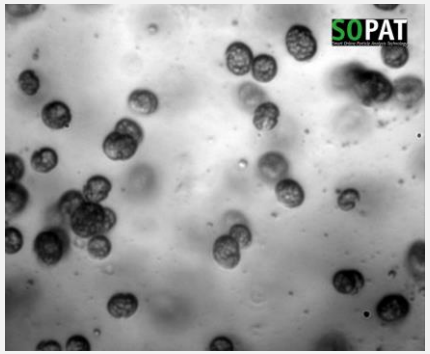
In Situ Microscopy for Real-time Determination of Single-cell Morphology in Bioprocesses, 2019

— Authors: Marbà-Ardébol, A. M., Emmerich, J., Muthig, M., Neubauer, P. & Junne, S. — Journal of Visualized Experiments, 154, S. 1-9 (link) In situ monitoring in microbial bioprocesses is mostly restricted to chemical and physical properties of the medium (e.g.,pH value and the dissolved oxygen concentration). Nevertheless, the morphology of

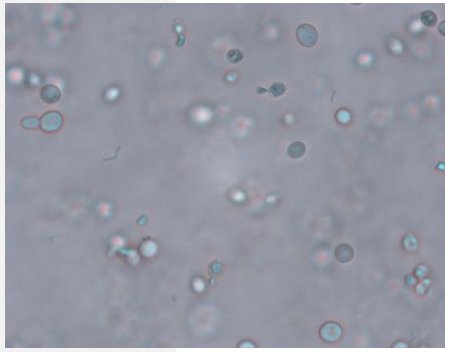
READ MORE »

Bioprocess
Images with SOPAT

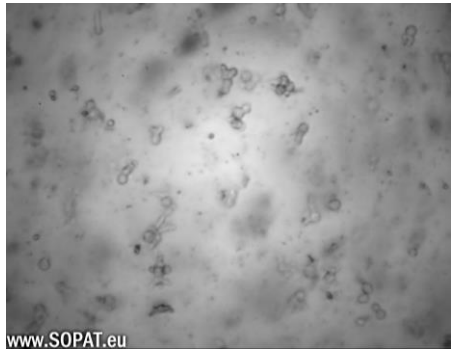
C. Cohnii



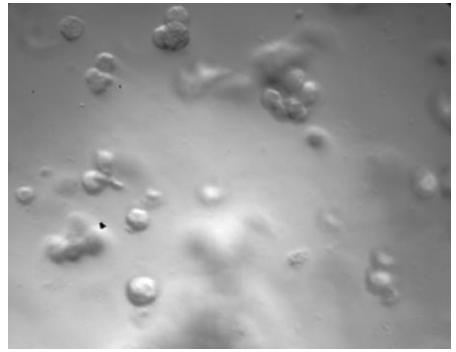
S. cerevisiae

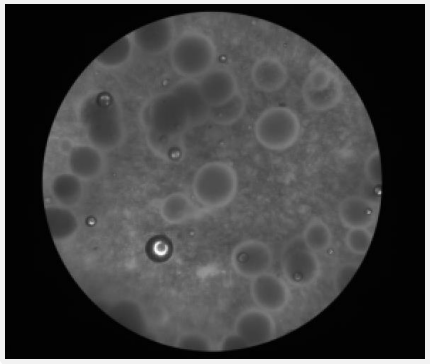


P. chrysogenum

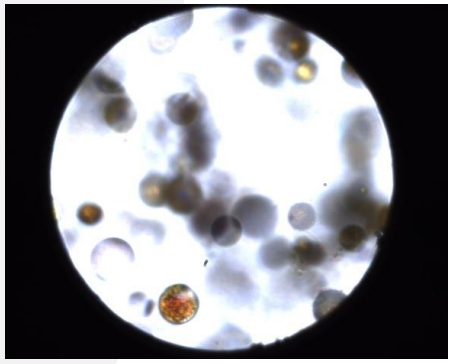


CHO Cells

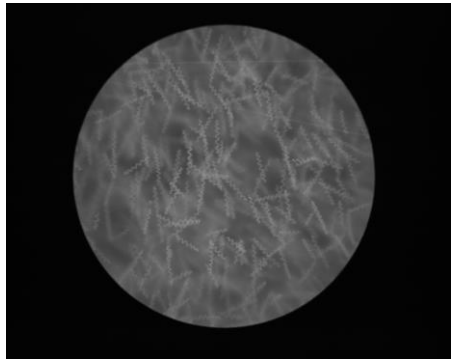




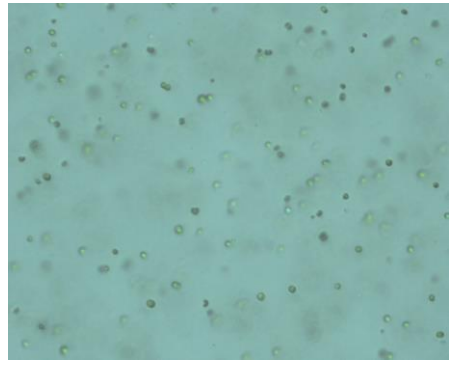
Filamentous funghi



H. Pluvialis



Spirulina sp.



N. salina

2. Our Portfolio & Decision Tree

1. Microscopic probe (MM-2)
2. VI-probes (Ma, Pl, Sc, Pa, ChocoScope, MicroBubbleScope)

Decision Tree

The SOPAT portfolio is highly customizable and therefore quite diverse. The decision which system configuration is best for a specific customer needs to be based on several parameters.

- Particle size range?
- ATEX Zone 1/non-ATEX?
- System pressure? Temperature?
- Ambient temperature?
- Immersion depth?
- Illumination type?
- pH? Probe material?
- Fouling?
- Dilution?
- Particle velocity?
- Coloured particles?

	Microscopic	Mesoscopic				Special		Macroscopic	
Product model	**MM-2**	**Ma**	**Pl**	**Sc**	**Pa**	**CS***	**$_{\mu}$BS***	**Kr**	**InView**
Measurement range [µm]	0.5 – 75	1.5 – 250	2 – 300	9 – 1,100	15 – 2,300	2 – 320	9 – 1,100	30 – 7,700	50 – 50,000
Field of View (diag.) [mm]	0.17	0.58	0.71	2.6	5.45	0.75	2.6	18	customizable
Tube length [mm]	734	220 – 2,000				220		220 – 2,000	n/A
Tube diameter [mm]	76	12						20	n/A
Pressure range [bar]	0.5 – 3	0.01 – 320				0.01 – 10		0.01 – 250	n/A
Process temperature [°C]	0 – 200	-10 – 450				-10 – 130		-10 – 450	n/A
Ambient temperature [°C]	0 – 40								-10 – 50
Probe window	Quartz	Sapphire							Al_2O_3
Probe housing	1.4404 (316L)								
Probe tube	1.4404 (316L)								n/A
Weight (w/o cable) [kg]	8	4.5							3
Focus	Manual	Electronic							Manual
Frame rate [Hz]	15								
Image resolution [MP]	5								
Power input [VA]	141 (50-60 Hz)								
Certifications	CE, CIP/SIP, IP65	CE, CIP/SIP, IP65/IP68, ATEX				CE, CIP/SIP, IP65		CE, CIP/SIP, IP65/IP68	CE, IP52, ATEX

SOPAT MM-2

Microscopic transmission

Some specs

- Measurement range 0.5 – 75 µm
- FOV (diag.) 170 mm
- Pressure range 0.5 – 3 bar
- Color camera
- Motorised measurement gap control
- At-line and inline flow cells
- Cooling tube included for higher process temperatures
- Support rack
- IP 65 protection

Often used for

- Biological processes
- Dense emulsions
- Opaque suspensions

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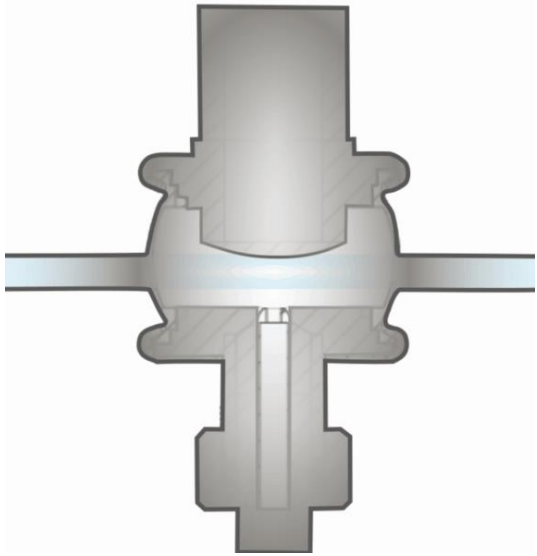
Flow cell type	Volume [mL]	Process
MFC	320	At-line, inline
MIFC	2-3	At-line



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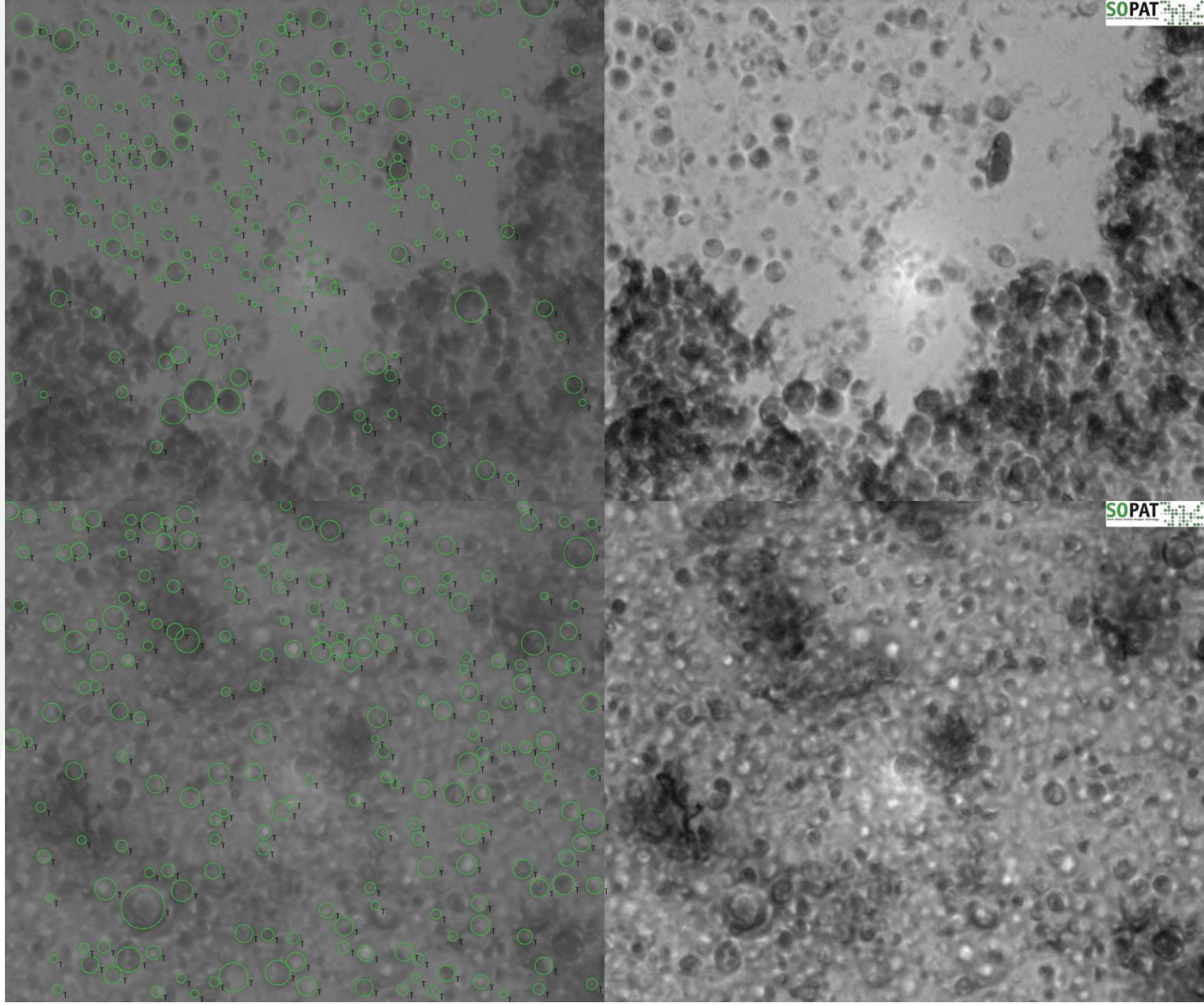

SOPAT VI 12 mm

Ma, Pl, Sc, Pa probes

Some specs

- Standard length 320 mm
- Ceramat WA155 compatible
- Different materials available
- Pressure range 0.01 – 320 bar
- Temperature range -10 – 450°C
- Monochrome, color camera possible
- IP 65 protection, IP 68 possible

Often used for

- Crystallization, granulation
- Emulsions, suspensions, slurries
- Polymerisation, fermentation
- Flotation, foaming, grinding
- …and more…

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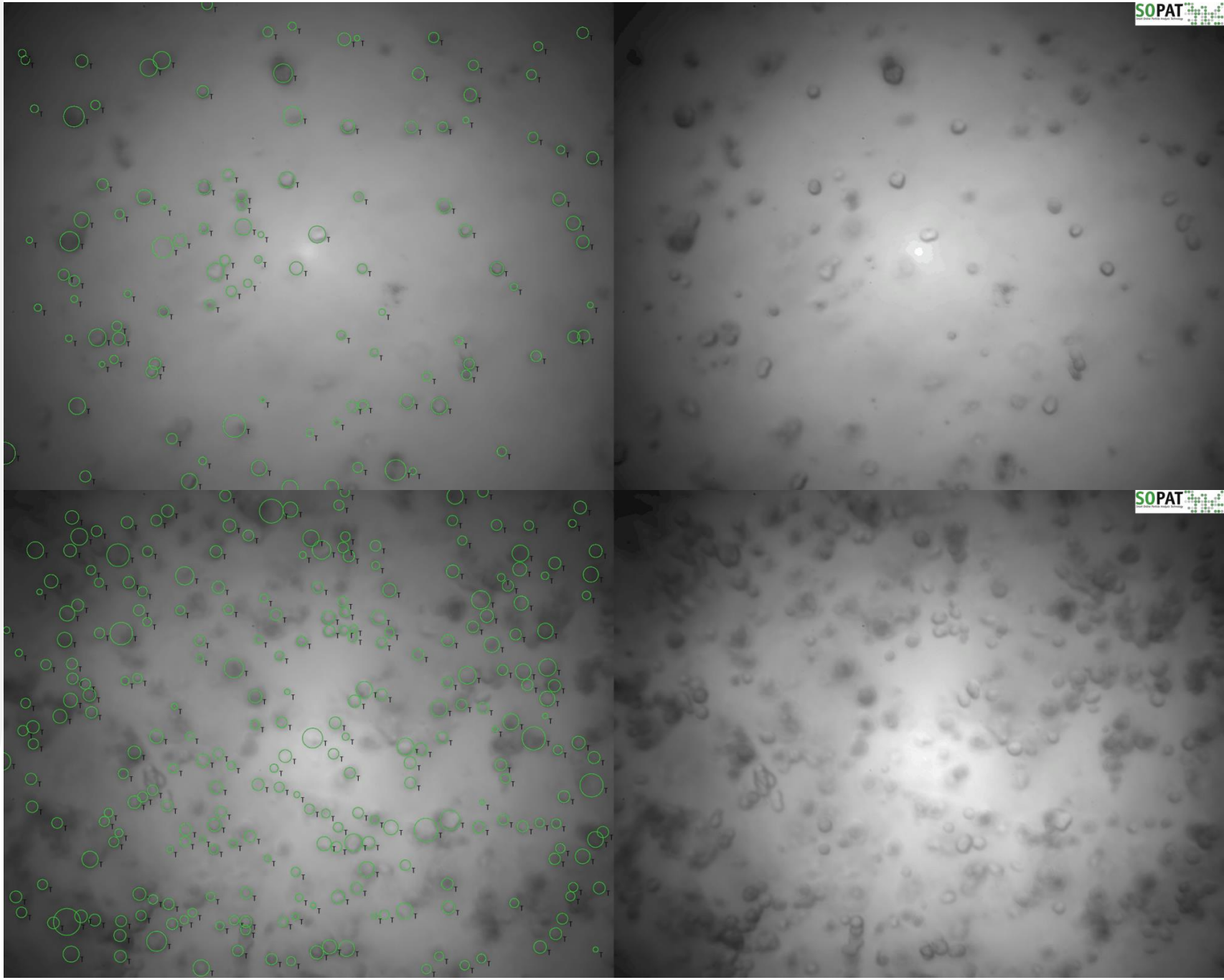
Monitoring

- Cell **Size**
- Cell **Concentration**
- Agglomerates
- Gas **Bubble** Sizes
- Gas **Bubble** Surface Area



MicroBubbleScope

Dedicated to bubbles & foams

Some specs

- Length 220 mm
- 1.4404 (316L)
- 0.6 µm surface roughness
- Pressure range 0.01 – 10 bar
- Temperature range -10 – 130°C
- Monochrome
- IP 65 protection

Dedicated to

- Foam generators
- Microbubbles
- Polyurethane and non-food foams
- Beverages, coffee, crema, …

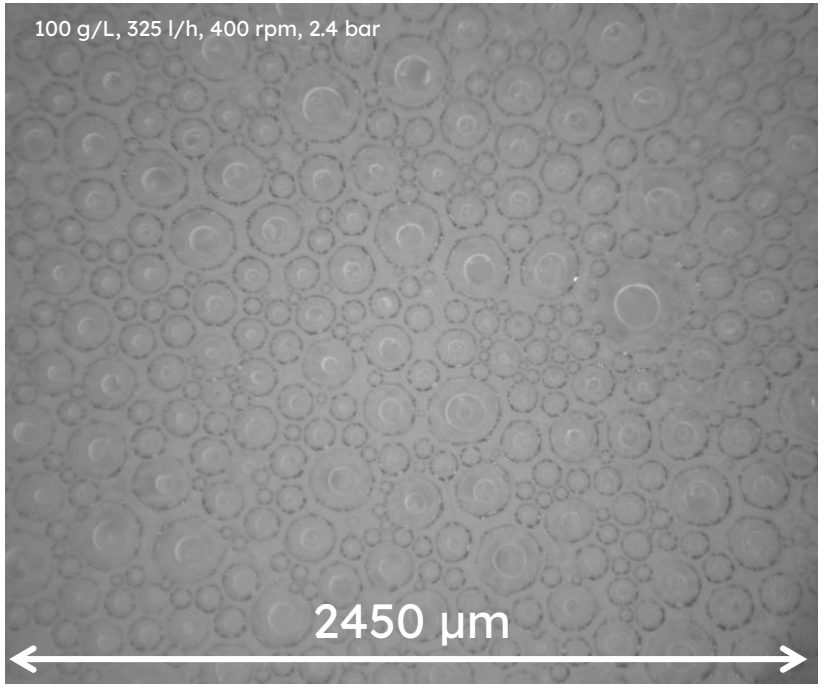

Beverage foaming, bottling processes etc.

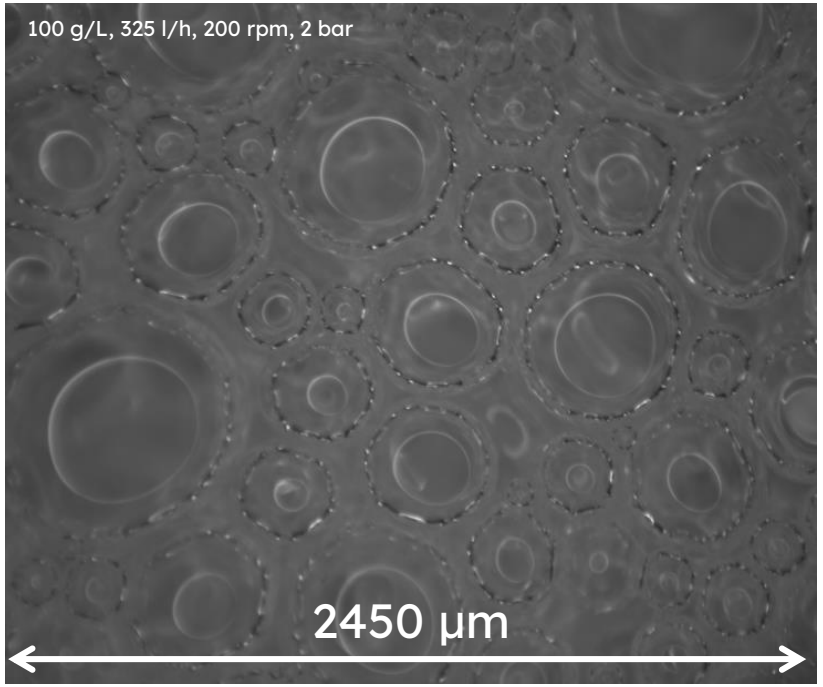

Sweets, dairy products, baked goods etc.


Cappuccino, coffee, dairy foams etc.


Pulp mixing, microbubbles, non-woven tissue production


Polyurethane foams, polyethylene foams, high quality foams, molded foams





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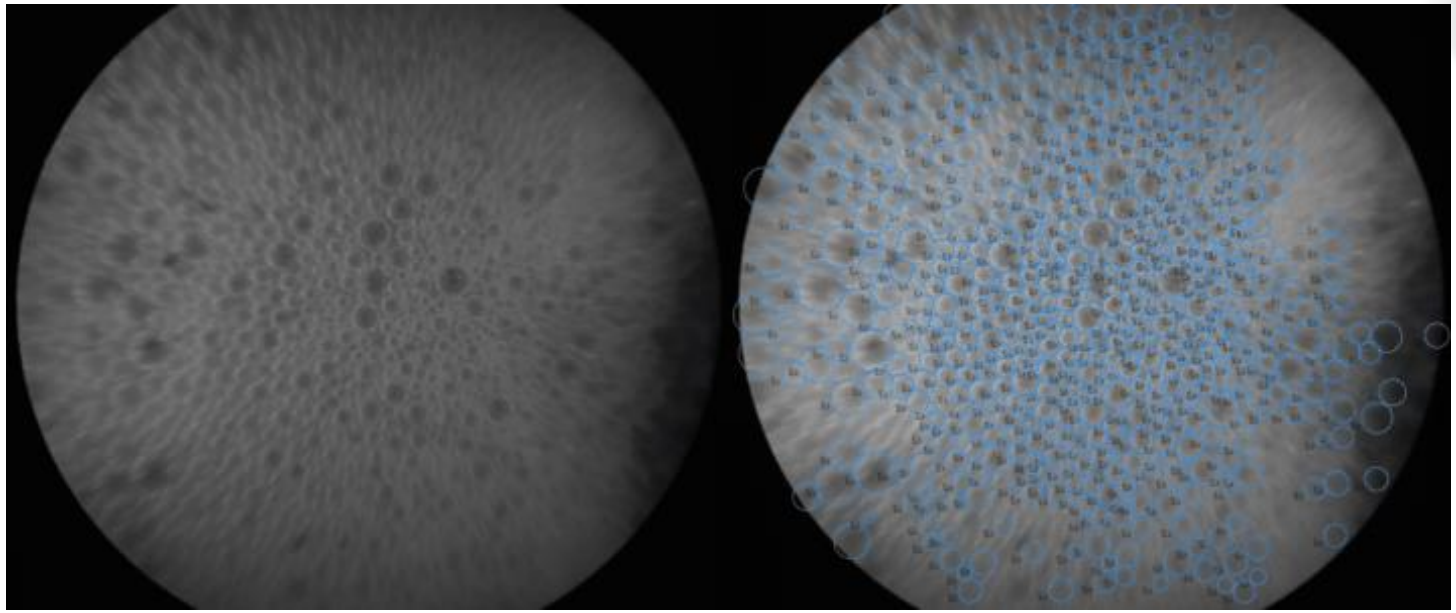
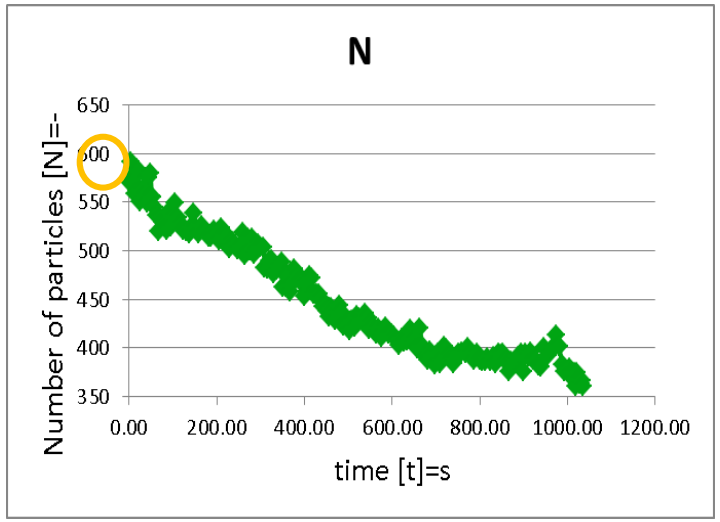
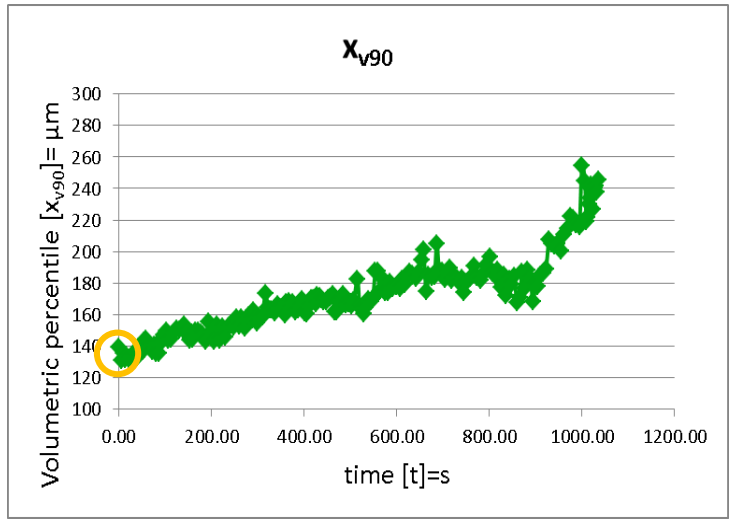






Parsum probe types

Measurement principle

Some specs

- Optical measurement with laser light source
- Designed especially for inline use
- Measures particle size and particle velocity
- Measuring range - Size: 50 (20) µm to 6mm
- Measuring range - Velocity up to 50 (100) m/s
- Up to 100°C process temperature
- No moving parts
- Wide range of accessories for process adjustment
- ATEX certified (zone 0/20)

The Basic Probe for general Purpose, ATEX-Option available, Length 280 mm

IPP 70-S/-Se

The Robust Industrial Probe for large process vessels, length 380 mm, longer version up to 1.2 m possible, Non-ATEX

IPP 75-S

The Food & Pharma Probe for the GMP area, length 280 mm, longer version up to 1.2 m possible, ATEX certified for Zone 0/20, self-monitoring functions,
Measuring range IPP 85: 20-600 µm / 50-6000 µm

IPP 80/85-P

All Parsum probes can use the full range of accessories e.g., dispersers as process interface. All probes work with the same basic software.

Particle Features

Following ISO Norm

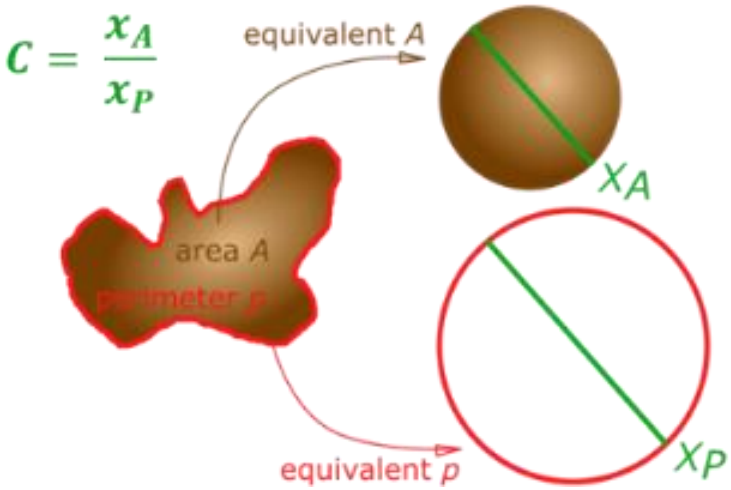
SOPAT uses ISO norm compliant analysis parameters to calculate the particle size. As images are 2D projections, SOPAT results are always based on the Feret diameter. The SOPAT software can extract the minimum, maximum and mean Feret diameter, $x_{F,min}$, $x_{F,max}$, $x_{F,mean}$.

Hence, the particle size distributions and their moments can be displayed as a function of each of the Feret diameters.

Normally, number-based and volume-based distributions are used. But length and area is also possible.

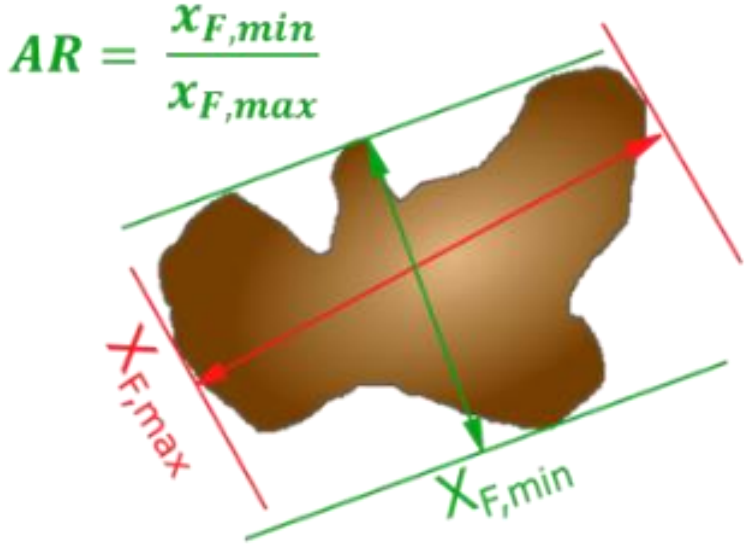
As for percentiles, SOPAT provides 1, 5, 10, 50, 90, 95, and 99 percentiles for each distribution type.

For non-spherical particles, SOPAT can also extract Aspect Ratio AR and Circularity C.



Circularity C

Feret diameter x_F



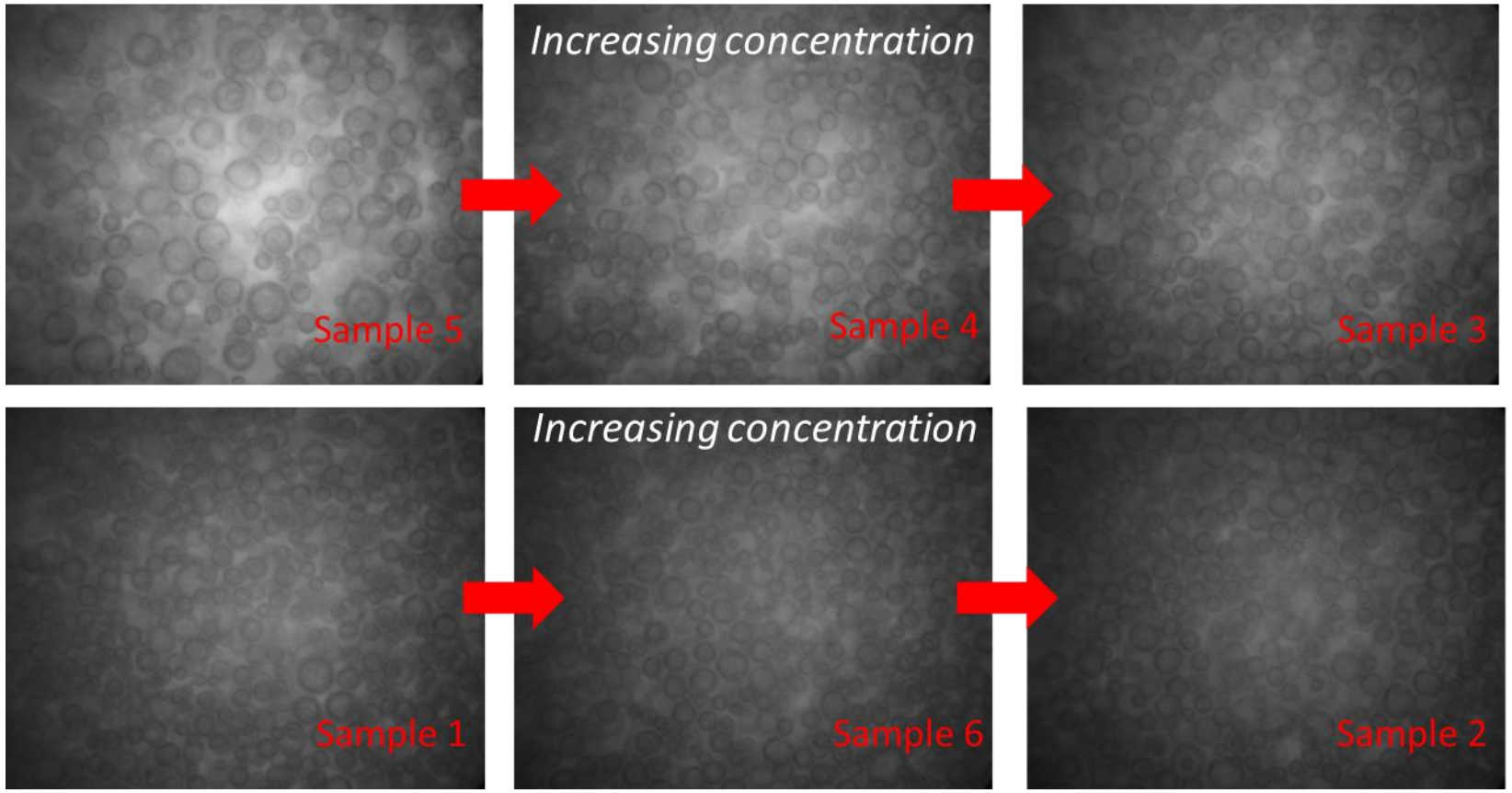
Aspect Ratio AR

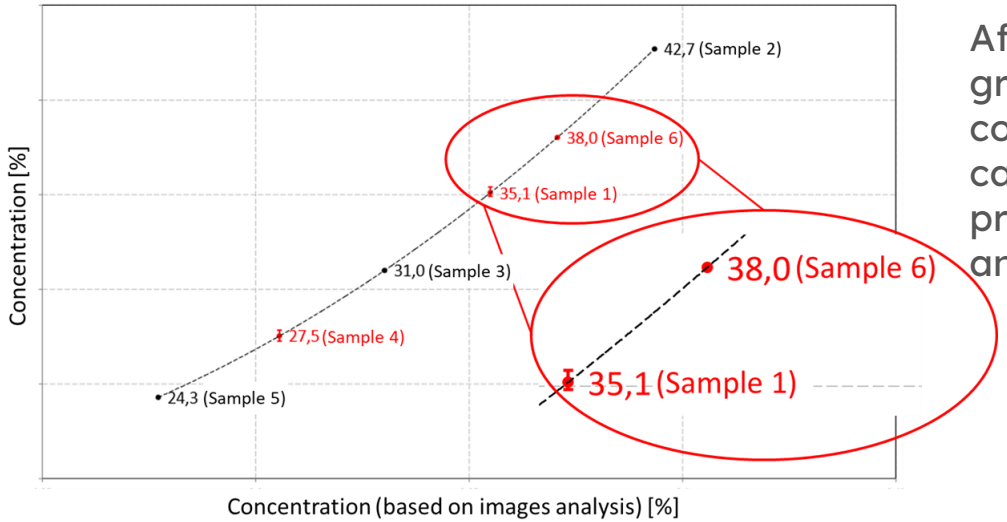
Feature Analysis

The SOPAT CoCa Tool

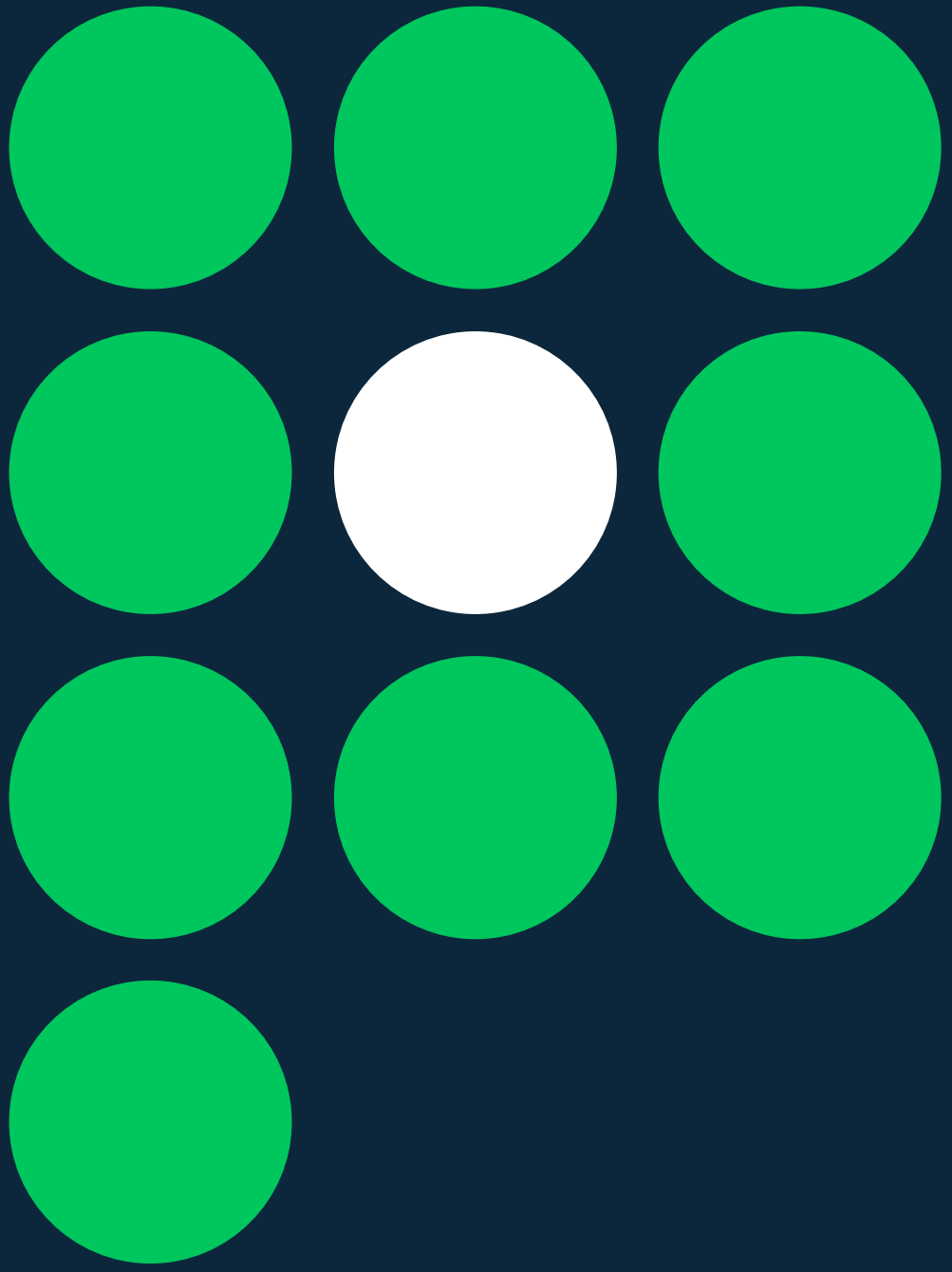
With SOPAT's CoCa-Tool (short for Concentration Calibration) it is possible to retrieve integral information from each image or each image series. Opposed to our particle size analysis, this is a pixel-wise analysis of information contained in the whole image. This can be used for multiple applications:

- Measurement of concentration, hold-up, and more
- Crystal formation and growth kinetics
- Turbidity measurement
- Dissolution measurement (e.g. powder)
- And many more….





After a calibration procedure (see graph on the left), the concentration of polymer capsules can be measured (hence: predicted) using the SOPAT feature analysis.



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sopat

Make every detail count