NANOPHOX | PCCS

Particle Measurement | Laboratory
Size and Stability | 0.5 nm to 10,000 nm
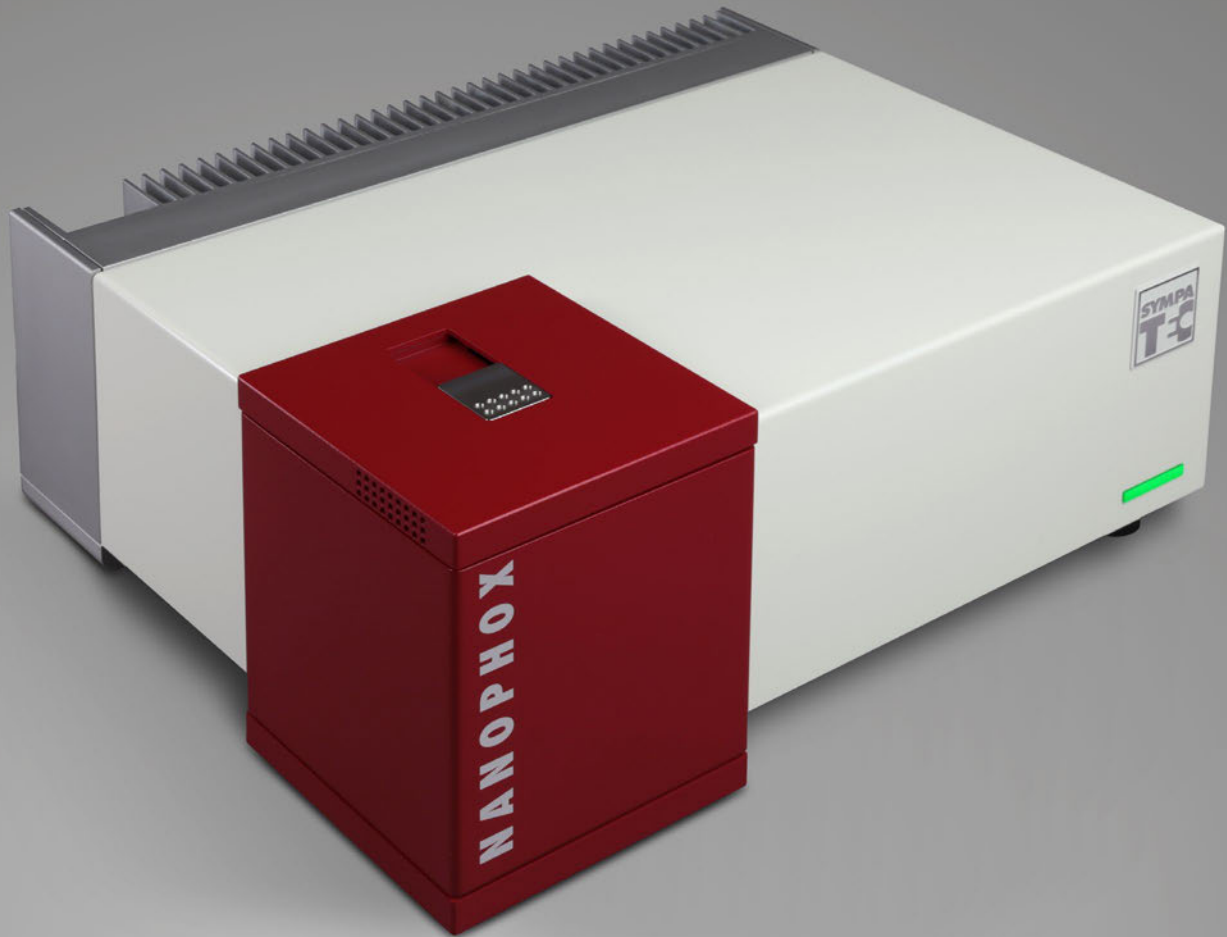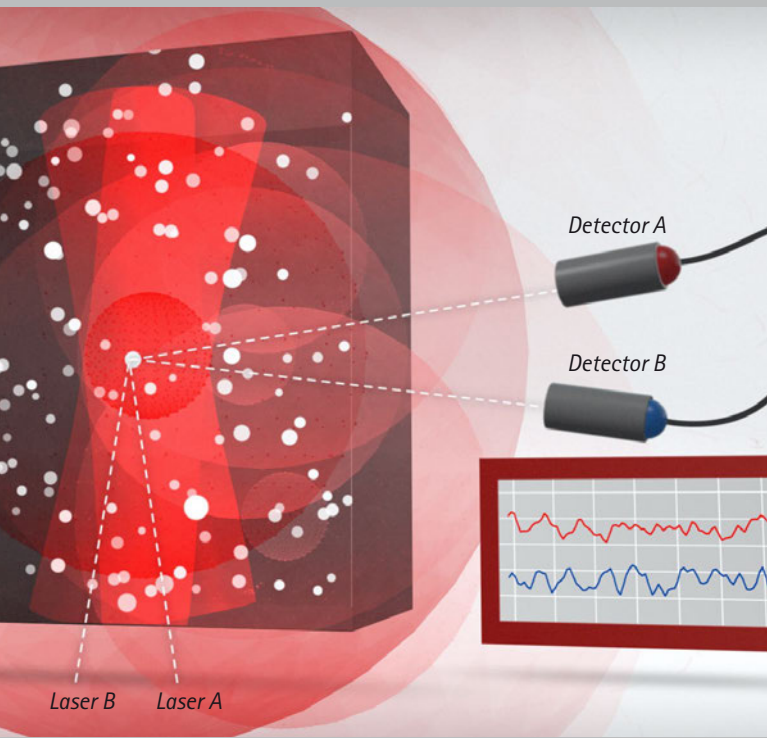
SYMPATEC

NANOPHOX | PCCS
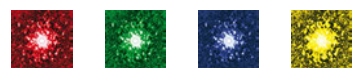
Clear Signals from Opaque Suspensions

Measuring Nanoparticles in Liquids

Detector A

Detector B

Laser B   Laser A

Trend Nanotechnology

The size reduction of materials plays a central role for the development of innovative products. Applications based on ➔ nanoparticles can lead to advances in the improvement of properties and functionalities of disperse systems.

In pharmacy and biochemistry nanoparticles serve as API carriers or can be charged with molecules for targeted drug delivery. Polymers applied for steric stabilisation or ions serving as electrostatic stabilisation modify the size of the nanoparticles. For fine tuning of their properties and to study the functionality in its natural environment, reliable and efficient technologies and appropriate measuring instruments are required.

Dynamic Light Scattering (DLS)

DLS is a robust, simple and non-contact method for the measurement of particle size and particle size distributions from the nanometre to the submicron range. With high sensitivity it is ideally suited for detection of size changes as a function of time. Process modifications occurring in seconds may be traced in real time.

Within a measuring time of just a few minutes a very high number of particles is captured guaranteeing representative results. Its independence of particle properties, which are difficult to assess or measure (e.g. refractive index, absorption coefficient and material density), constitutes additional advantages for DLS. In the nanometre range

these properties largely depend on size. In particular for coated, porous or alloyed particles they are difficult to determine.

For DLS analysis the hydrodynamic diameter is measured through optical detection of the ➔ Brownian molecular motion of particles in a liquid. The thermally agitated liquid molecules collide with the particles causing a random movement or diffusion.

According to the ➔ Stokes-Einstein equation the diffusion velocities are inversely proportional to the size of the particles.

$$D(x) = \frac{k_B \cdot T}{3 \cdot \pi \cdot \eta \cdot x}$$

PCS as conventional technology

The principle of DLS traditionally is realised with Photon Correlation Spectroscopy (PCS). A laser is transmitted through the sample. With the help of a photodetector the scattered light intensity is monitored over time and then ➔ autocorrelated. The particle size distribution can be calculated with the correlation function.
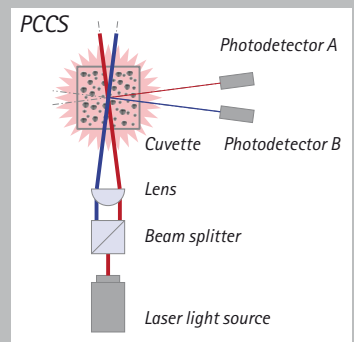
The size analysis with PCS is only valid for single scattered light. Samples of high solids concentration show a large proportion of ➔ multiple scattered light and the method reaches its limitations. To avoid incorrect data on particle distributions and to generate reliable measuring results, samples have to be diluted to a high ratio. In this way significant modifications of the particle properties are likely to occur.

PCS

Photodetector

Cuvette

Laser light source
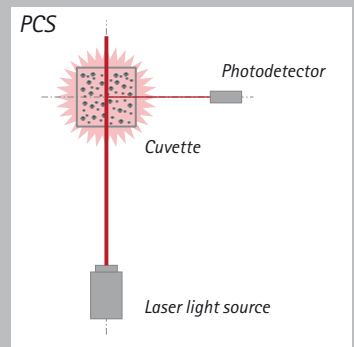
PCCS as key technology

By applying an innovative light scattering technique using Photon Cross-Correlation Spectroscopy (PCCS) we are able to provide concurrent measurements of particle size and stability in opaque suspensions and emulsions.

The outstanding technical features of 3D cross-correlation are the acquisition of two separately generated scattered light intensities and its cross-correlation. The single scattered light proportion is thus separated from the multiple scattered part. A single laser beam is split into two separate beams of identical intensity and superimposed in one sample. Two independent scattering waves are then recorded with one detector for each wave, thus ensuring the exact signal interpretation.

PCCS

Photodetector A

Cuvette   Photodetector B

Lens

Beam splitter

Laser light source

Nanoparticle Measurement in Primary Condition

NANOPHOX with PCCS

As a professional pioneer of PCCS we are offering the first table top instrument based on Photon Cross-Correlation Spectroscopy (PCCS). With this we consequently follow our strategy of developing innovative instruments which measure the sample as close as possible to its original state. PCCS opens possibilities for analysis of nanoparticles in suspensions and emulsions with hundreds of times higher solids concentrations than ever before.

The application of cross-correlation technology allows the calculation of the particle size distribution by eliminating the effect of multiple scattering. The amplitude of the cross-correlation function, which depends on the multiple scattering, provides direct measurement of changes in particle number and size. Differentiating measurements of agglomeration and sedimentation behaviour thus become feasible.

NANOPHOX is ideally suited for research and development as well as for industrial quality control.

Reliable results made simple
NANOPHOX helps to reach the target quickly. Elaborate sample preparation is not required as even samples of high concentrations often need no dilution. The results are less sensitive against potential contaminations which for strongly diluted samples tend to significantly influence the particle distribution. Automatic positioning of the cuvette and precise setting of the laser intensity for optimization of the measuring signal is straightfor-

ward and user-friendly, helping to make the measurement process fast and simple.

*» Small, smaller, nano …
with high sensitivity to
reproducible results! «*

Extended application range
NANOPHOX covers the vast particle size range of 0.5 nm to 10,000 nm. The size analysis is independent of concentration and masters high concentrations up to approximately 20 % by volume. Using a 30 mW semiconductor laser and Avalanche photo diodes minimum sample concentrations of just 0.0001 % by volume are measurable. This remarkably broad concentration range is possible due to the combination of PCS and PCCS in a single instrument.

With a precisely controlled temperature range from 0°C to 90°C the behaviour of nanodispersions can be observed or influenced, respectively. NANOPHOX proves its specific performance for stability analysis of steric or electrostatic stabilising in high-concentrated nanodispersions. No matter if the particles have been stabilised with electric charges, polymers or surfactants, NANOPHOX reliably provides information on aggregation or agglomeration behaviour. Thus new opportunities for characterization in previously uncharted fields, such as particle-particle interactions and changes in dynamic viscosity, are easily accessible.

Laser passes cuvette inside NANOPHOX
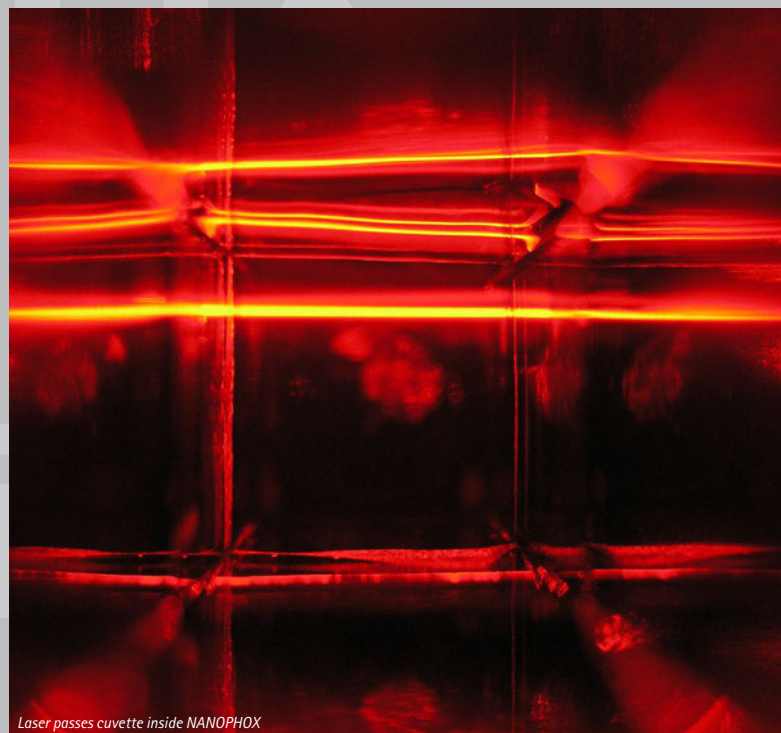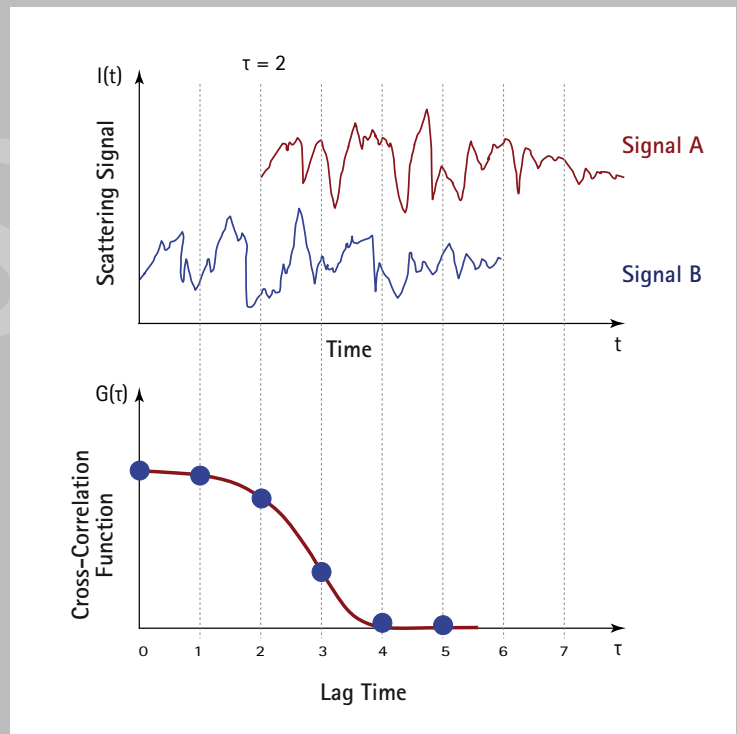
[3] *viscosity and temperature remain unchanged, fine particles move faster than coarse particles.*

⊕ **Autocorrelation:** *The scattered signal is correlated with itself at different points in time (a comparison of the time lagged and the original function).*

⊕ **Multiple scattered light** *occurs if the incident laser light is scattered more than once by particles and disturbs the scattering wave on its way to the detector.*
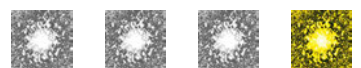
Nanoparticles in a Unique Concentration Range

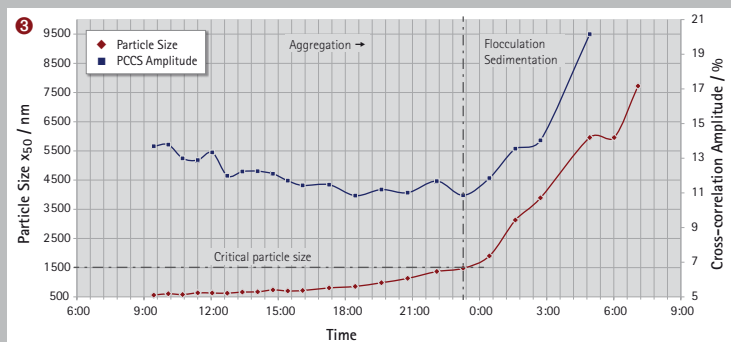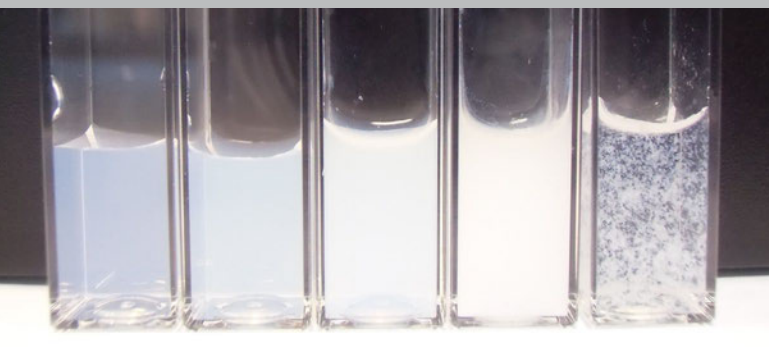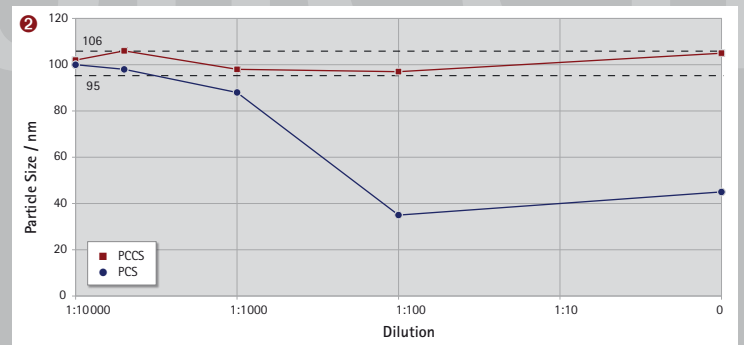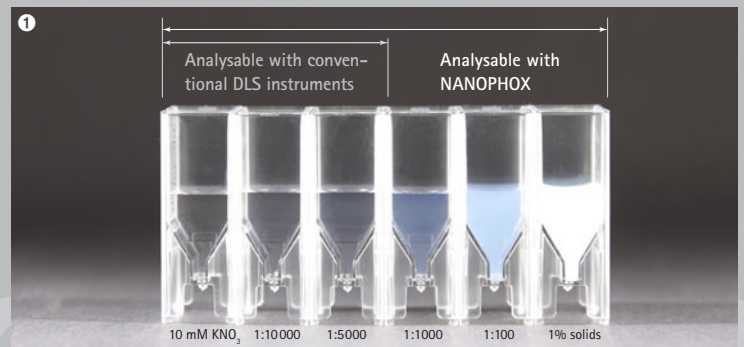## Who is Closer to the Original?
Dilution Series | Stability Analysis

Dilution series | PCS and PCCS

High solids concentrations induce ➔ photons to be scattered more than once. Distorted results and misinterpretations are the consequence. When measuring with PCS sample dilution reduces the multiple scattering. We have conducted tests with 100 nm DLS reference material over a wide concentration range showing the performance of PCCS. ❶ Five different latex samples illustrate a spectrum extending from the undiluted original suspension with 1 % solids content to a dilution ratio of 1:10,000.

❷ For measurements performed on the NANOPHOX in the PCCS mode the hydrodynamic diameter ranges within the specifications between

97 and 106 nm, independent of the dilution. Meanwhile the PCS results remarkably deviate from the specifications for dilution ratios of 1:1,000 and above. Particle size cannot be determined reliably without dilution.

For correct results no dilution of the latex sample is required when using PCCS. The application of cross-correlation significantly enhances the concentration range for samples which can be measured with dynamic light scattering. Unwanted sample dilution can be avoided and particle size measurements in the original concentration of the respective application are possible.

❶ Analysable with conventional DLS instruments — Analysable with NANOPHOX

10 mM KNO₃ — 1:10000 — 1:5000 — 1:1000 — 1:100 — 1% solids

❷ Particle Size / nm vs Dilution (PCCS, PCS)

Stability analysis

Stability is a vital factor for the production and storage of nano-dispersions. It provides information about the duration of use for a product under optimum storage conditions.

The stability of an emulsion or suspension is significantly affected by the chemical environment of the particles such as the pH-value, ionic strength, surfactant or polymer concentration.

❸ The time-dependent aggregation of a 500 nm latex suspension in a 0.15 molar NaCl solution is shown as an example. With progressing aggregation the sample becomes more turbid until it flocculates. The amount of coarse particles and its

➔ scattering efficiency increases. The cross-correlation amplitude decreases with increasing multiple scattering. Once the coarse particles reach a critical size so that sedimentation occurs, the particle concentration decreases and with this the fraction of multiple scattered light. The cross-correlation amplitude increases.

With the time dependent measurement of the cross-correlation amplitude and the mean particle diameter, PCCS captures aggregation and sedimentation kinetics. PCS cannot provide such information. The example impressively proves the interaction of two instable processes which NANOPHOX can measure directly, sensitively and reliably.

❸ Particle Size x₅₀ / nm and Cross-correlation Amplitude / % vs Time (Particle Size, PCCS Amplitude; Aggregation →; Flocculation Sedimentation; Critical particle size)

NANOPHOX Applications

Precise Results without Dilution | High Sensitivity for Size Change

Ophthalmic emulsion

In pharmaceutical applications particulate systems are applied as drug carriers. Its precise characterisation is a basic condition for the approval of the product. Pharmaceutical emulsions such as eye drops are subject to numerous quality characteristics, one of which is the droplet size of the disperse phase within the emulsion.

Droplets being too fine or too coarse may reduce the efficiency or may become a risk for the eye. The ophthalmic emulsion analysed in this example is a white, very turbid homogeneous liquid. With the PCCS technology the sample can be measured without dilution. ❶ The result shows the expected mono-modal size distribution with

a mean diameter of 120 nm. When measuring this sample in PCS mode the size distribution shows a mean diameter of just 68 nm and clearly remains below the expected specifications. The strong deviations can be explained by the influence of multiple scattering. Only after dilution to a ratio of 1:100 in pure water the size distribution of the droplets is correctly determined.

NANOPHOX measures the sample in its original condition, minimising the effect of sample contamination. Dilutions which might change the chemical properties can be discounted. Based on the robust and easy to use measuring method, the instrument is ideally suited for production and quality control of pharmaceutical emulsions.
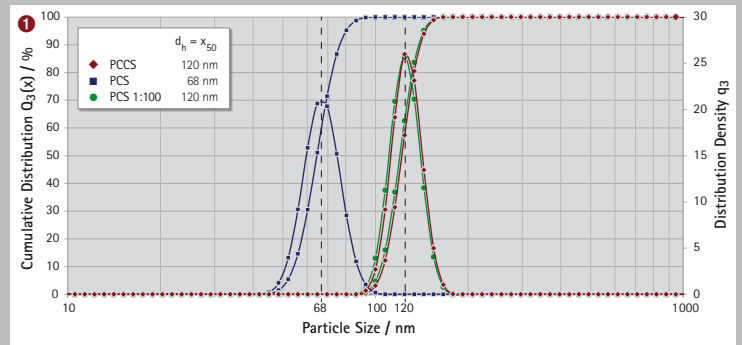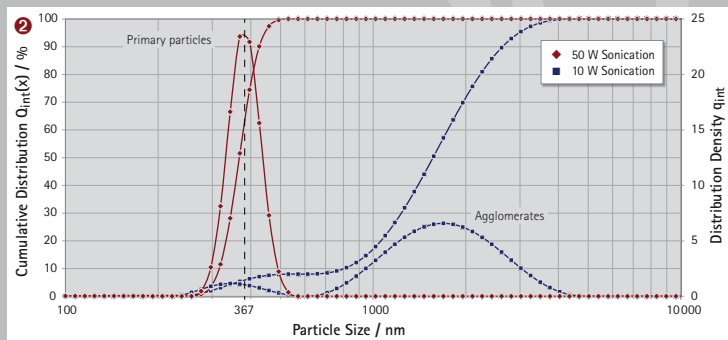
Alumina powder

A variety of nano and micro particles are synthesized by dry production processes. For numerous industrial applications of alumina powders the particles have to be prepared as suspensions before introducing them for efficient product improvements. This introduces the challenge of preparing stable dispersions. Agglomerates may affect the functionality of the product.

❷ For measurement of the dispersion quality a suspension was prepared of 0.05 % by weight alumina powder in water and treated with an ultrasonic probe. The energy input of 50 W yields a monomodal distribution with a diameter of 367 nm. Reducing

the ultrasonic power to 10 W provides a significantly worse dispersion quality. A remarkable portion of coarse agglomerates can be observed in the measured particle size distribution together with a reduced fraction of primary particles.

The strengths of NANOPHOX can be found in the broad concentration range and the sensitive resolution of bimodal particle distributions. It also very reliably indicates size changes.

With PCCS the result is independent of particle concentration and permits measurements of dispersion quality even in suspensions of high concentrations.
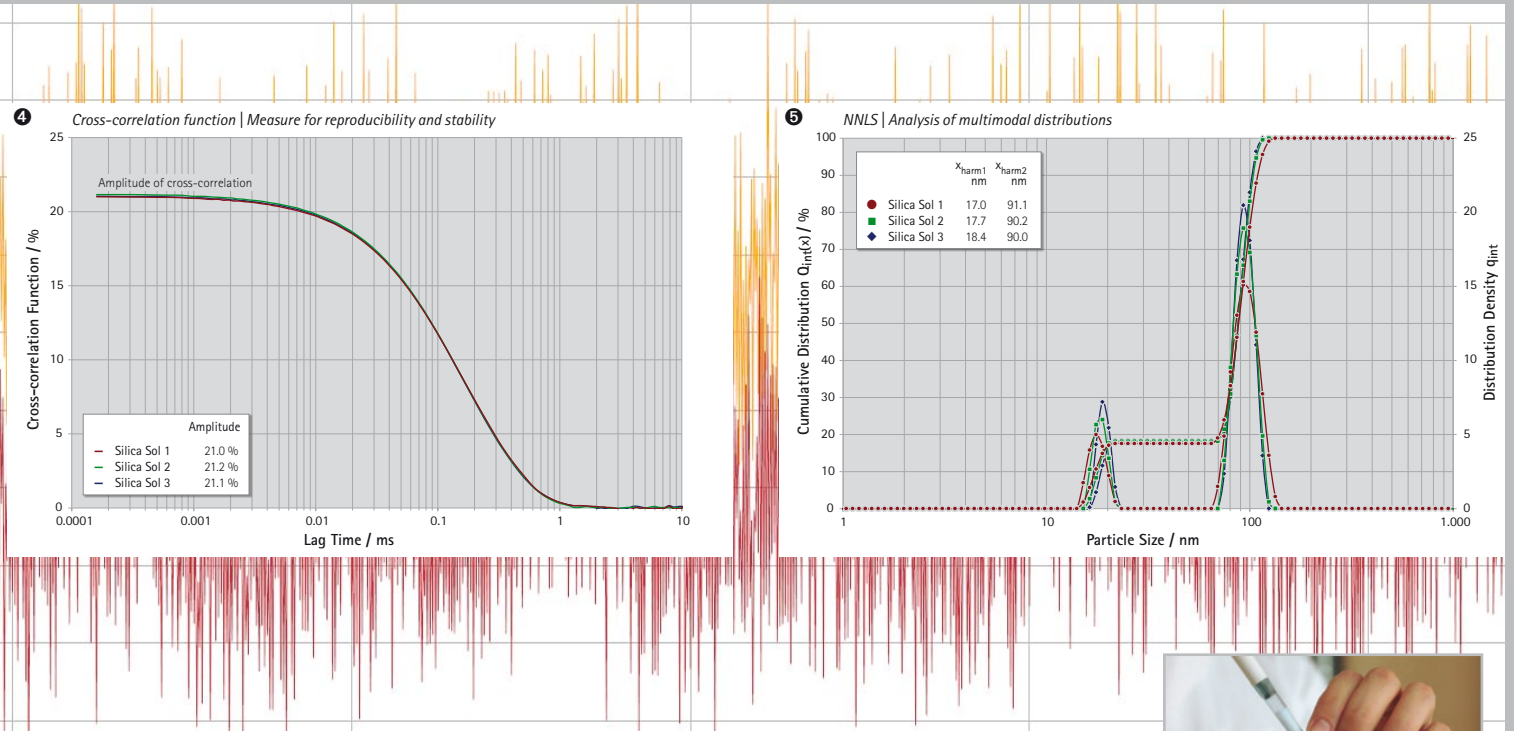
PAQXOS Software

Measuring Process and Results

Preparation | Measurement | Evaluation

❹ *Cross-correlation function | Measure for reproducibility and stability*

❺ *NNLS | Analysis of multimodal distributions*

	x_{harm1} nm	x_{harm2} nm
● Silica Sol 1	17.0	91.1
■ Silica Sol 2	17.7	90.2
♦ Silica Sol 3	18.4	90.0

PAQXOS combines our collective particle sizing expertise in a user-friendly application software which is realised as a network-ready 64-bit software for Windows® environments. A step-by-step wizard with built-in expert knowledge also leads the inexperienced user to successful measurements.

After ❶ filling the cuvette, the sample is ❷ loaded into the NANOPHOX single-handedly. A simple mouse click starts the measurement. The signal yield can be optimized fully automatically or manually. To guarantee a desired level of statistical accuracy and repeatability PAQXOS will make an educated decision for the measurement time, depending on the complexity of the sample. As the measuring signals are ❸ displayed in real time, changes in and quality of the measurement may be observed directly. After each run the raw data is stored in the database automatically. This allows for a later change of evaluation parameters and the re-evaluation of the sample without measuring again.

PAQXOS provides graphical presentations, tables or paper reports that can be chosen from a variety of predefined and fully customisable formats. Fast and easy graphical display of results out of the measuring database as well as import of measurement parameters from existing measurements are realised by drag and drop. Data browser and filter functions allow the retrieval and presentation of extent analysis data. The intuitive graphical user interface supports the execution of reliable, meaningful measurements.

❹ The cross-correlation function, representing reproducibility and stability, is used to calculate the particle size distribution. In addition to the classic ⊕ 2nd Cumulant evaluation PAQXOS offers a distinctly more efficient ❺ Non Negative Least Square (NNLS) algorithm. The NNLS evaluation mode reliably presents polydisperse or ⊕ bimodal samples with up to 256 size classes directly as volume or intensity based distribution. Characteristic values such as the arithmetic or harmonic mean values (x_{harm}) of single modes are directly available.

Our ⊕ versatile PAQXOS software is ideally suited for demanding production and research applications. It also meets the requirements of FDA-regulated pharmaceutical industries and provides all safety functions,

❶

❷

❸
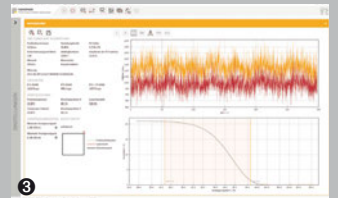
access controls and authentication methods stipulated in regulation 21 CFR Part 11 regarding electronic records and electronic signatures to ensure data integrity and prevent manipulation of records.

⊕ **2nd Cumulant evaluation** *provides a mean diameter and a polydispersity index (ref ISO 22412:2008). It cannot represent a particle size distribution.*

⊕ *A* **bimodal sample** *comprises two particle fractions (modes) of different size distributions.*

⊕ *An integrated* **scripting environment** *allows for the programming of elaborate routines to design repeat measurements in an efficient and reproducible manner.*

Furthermore, predefined measurement parameter settings may be implemented as binding **Standard Operation Procedures | SOPs.**

Pulverhaus

Brand Home of Sympatec's Premium Instruments

Development of Innovative Methods for Particulate Systems Characterization
Laser Diffraction | Image Analysis | Ultrasonic Extinction | PCCS

Perspective

"A classic is timeless and at the same time ahead of its time."

The variety of disperse products requires innovative and sustainable technologies to master the challenges in today's research, development, quality and production control.

With dry dispersion we have introduced product orientation and adaptation to laser diffraction.

The HELOS sensor family and a great range of dispersing units – spear-headed by RODOS – offer you premium performance. Our laser diffraction instruments allow for a significant extension of your particle knowledge concerning size and size distributions.

New questions and desires inevitably arise with unbowed progress. Power of innovation consequently remains key to future developments.

Today, if we encounter application limits of laser diffraction e.g., in suspensions of high optical concentration, we offer efficient solutions with ultrasonic extinction (NIMBUS).

If particle shape becomes of interest, we provide a great spectrum of powerful solutions with high-speed dynamic image analysis (QICPIC family). Now even sophisticated fibre analysis is amongst the range of multifaceted particle shape aspects.

And in case particles predominantly belong to the nanometre range, we have brought the unique Photon Cross-Correlation Spectroscopy (PCCS) to market with Sympatec's NANOPHOX.

By nature, we also keep an eye on the production of disperse systems when developing methods of particle characterisation. Hence, you may also trustfully address us in case process control becomes an issue. Laser diffraction with MYTOS, ultrasonic extinction with OPUS and dynamic image analysis with PICTOS are hundredfold approved process applications from Sympatec.

Designed with a consistent technological basis, our in-, on-, at-line systems reliably deliver results that are perfectly comparable to those of our laboratory instruments – most accurate, reproducible and at the shortest measuring times.

As "Particle People" we originate from the powder technology field. This is why we have a natural approach to process engineering and the production of disperse systems. The collective particle expertise of our physicists, mathematicians, computer scientists, engineers, electronic and mechanic technicians is built into our instruments.

Your particles in the best of hands with us.
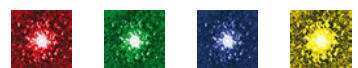
Particle Measurement and Know-how from Pulverhaus

Several Thousand Installations
At Particle Professionals Worldwide

SYMPA TEC

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❱ Sympatec

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❱ Partner

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