3P INSTRUMENTS

Characterization of
particles · powders · pores

BeNano Series

- Wide Measuring Range: 0.3 nm - 15 µm
- High-performance Hardware
- Research Level Software
- Versatile Accessories

Particle Size measured by DLS
Zeta Potential measured by ELS
Molecular Weight measured by SLS

BeNano Series Overview / Contents

BeNano Series

The BeNano series is the latest generation of nanoparticle size and zeta potential analyzers designed by Bettersize Instruments Ltd. Dynamic light scattering (DLS), electrophoretic light scattering (ELS) and static light scattering (SLS) are integrated in the system to provide accurate measurements on particle size, zeta potential and molecular weight. The BeNano series can be widely applied in academic and manufacturing processes of various fields including but not limited to: chemical engineering, pharmaceuticals, food and beverage, inks and pigments, and life science.

Table 1 *The different models of the BeNano series*

	BeNano 90	BeNano Zeta	BeNano 90 Zeta
Particle Size	■	–	■
Zeta Potential	–	■	■
Molecular Weight	■	–	■

Contents

Features and Benefits

High-Performance Hardware

- **He-Ne Laser**
  Top-class light quality that is narrow, monochromatic and coherent
- **Avalanche Photodiode Detector (APD)**
  High sensitivity for low concentration or weak scattering sample
- **Temperature Control System**
  Wide temperature range (-10~110°C) suitable for more applications
- **Rapid Measurement Capability**
  Fast operations and editable results
- **Intelligent Intensity Adjustment**
  Intelligent adjustment of the intensity according to the signal-noise ratio
- **Sensitive Optical Fiber Detection System**
  Effectively increase signal-noise ratios due to high sensitivity of the optical system
- **Highly Stable Optical Design**
  Provides highly repeatable results with no routine maintenance required

Research Level Software

- **Standard Operating Procedure (SOP)**
  Ensures the completeness and accuracy of parameters
- **Phase Analysis Light Scattering**
  Measurement of low electrophoretic mobility and zeta potential
- **Intelligent Algorithm of Result Evaluation**
  Intelligent evaluation and processing of signal quality to eliminate the effect of random events
- **Versatile Calculation Modes**
  Various built-in calculation modes to cover multiple scientific research and application fields

Versatile Accessories

- **Capillary Sizing Cell**
  Sample volume down to 3-5 μL and higher measurement accuracy for large particles
- **Disposable Folded Capillary Cell**
  Enables excellent repeatability of zeta potential measurements and avoids cross-contamination

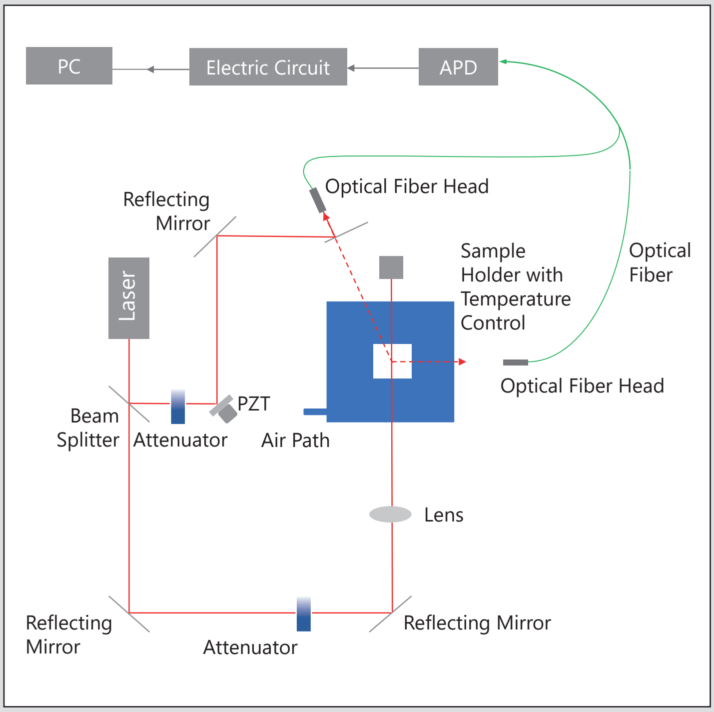


Figure 1 *Optical layout of the BeNano series*

Measurement Parameters

- Hydrodynamic diameter D_H
- Polydispersity index PdI
- Diffusion coefficient D
- Interaction parameter k_D
- Molecular weight
- Solution viscosity
- Intensity, volume, surface area and number distribution
- Zeta potential and its frequency distribution

Dynamic Light Scattering (DLS)

Dynamic light scattering (DLS), also known as photon correlation spectroscopy (PCS) or quasielastic light scattering (QELS), is a technology used to detect the fluctuations of the scattering intensities caused by the Brownian motion of particles. In the dispersant, smaller particles move faster, while larger particles move slower.

An Avalanche Photodiode (APD) Detector aligned at 90° collects the scattering intensities of the particles and records them with time. The time-dependent fluctuation is converted into a correlation function using the correlator. By applying a mathematic algorithm, the diffusion coefficient D is thereby obtained. The hydrodynamic diameter DH and its distribution arecalculated through the Stokes-Einstein equation:

$$D = \frac{k_B T}{3\pi\eta D_H}$$

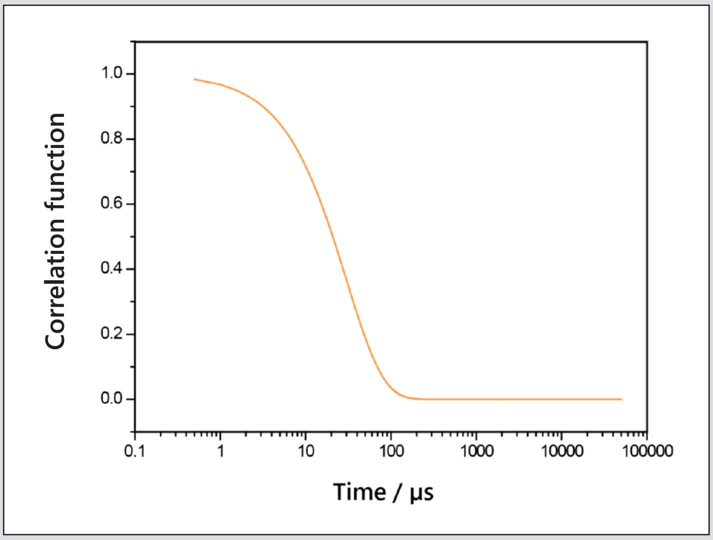


Figure 2a *The correlation function of small particles*

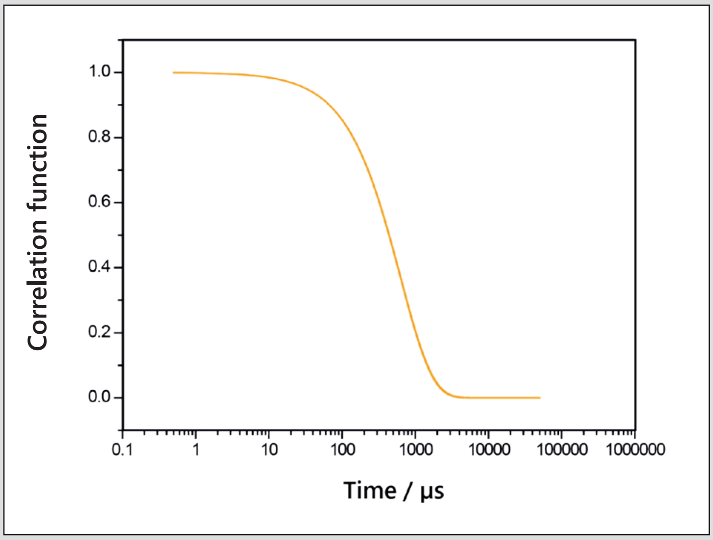


Figure 2b *The correlation function of large particles*

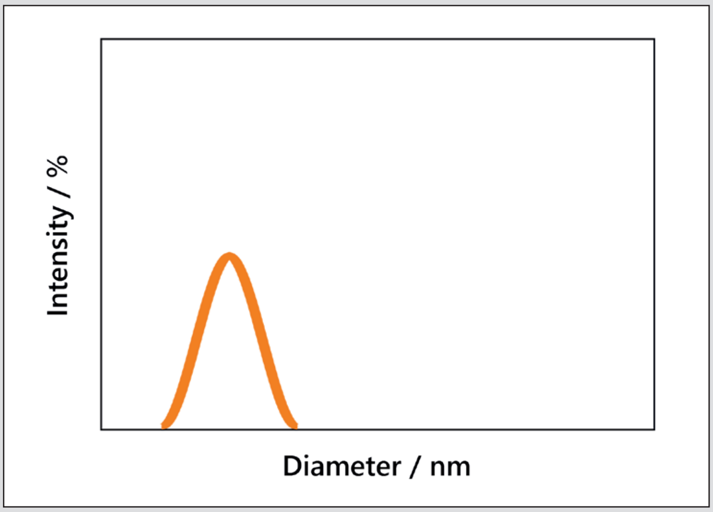


Figure 3a *Particle size distribution of small particles*

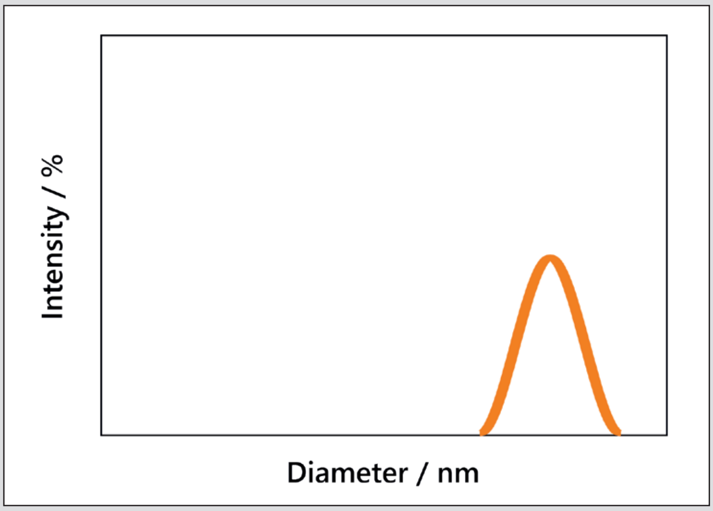
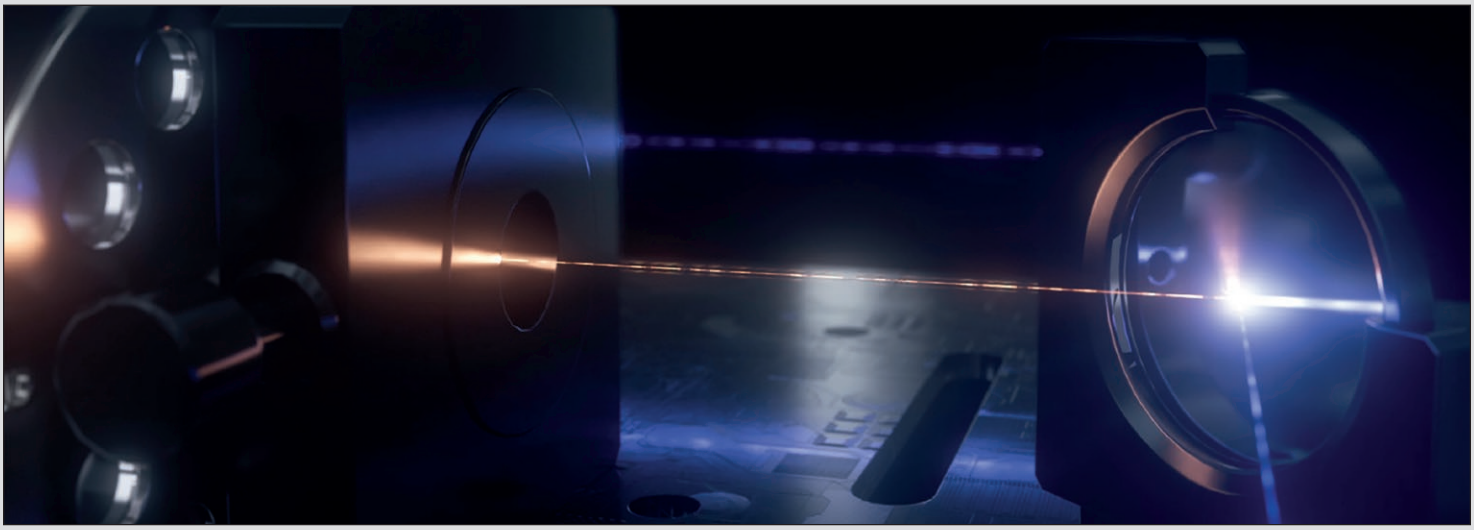


Figure 3b *Particle size distribution of large particles*



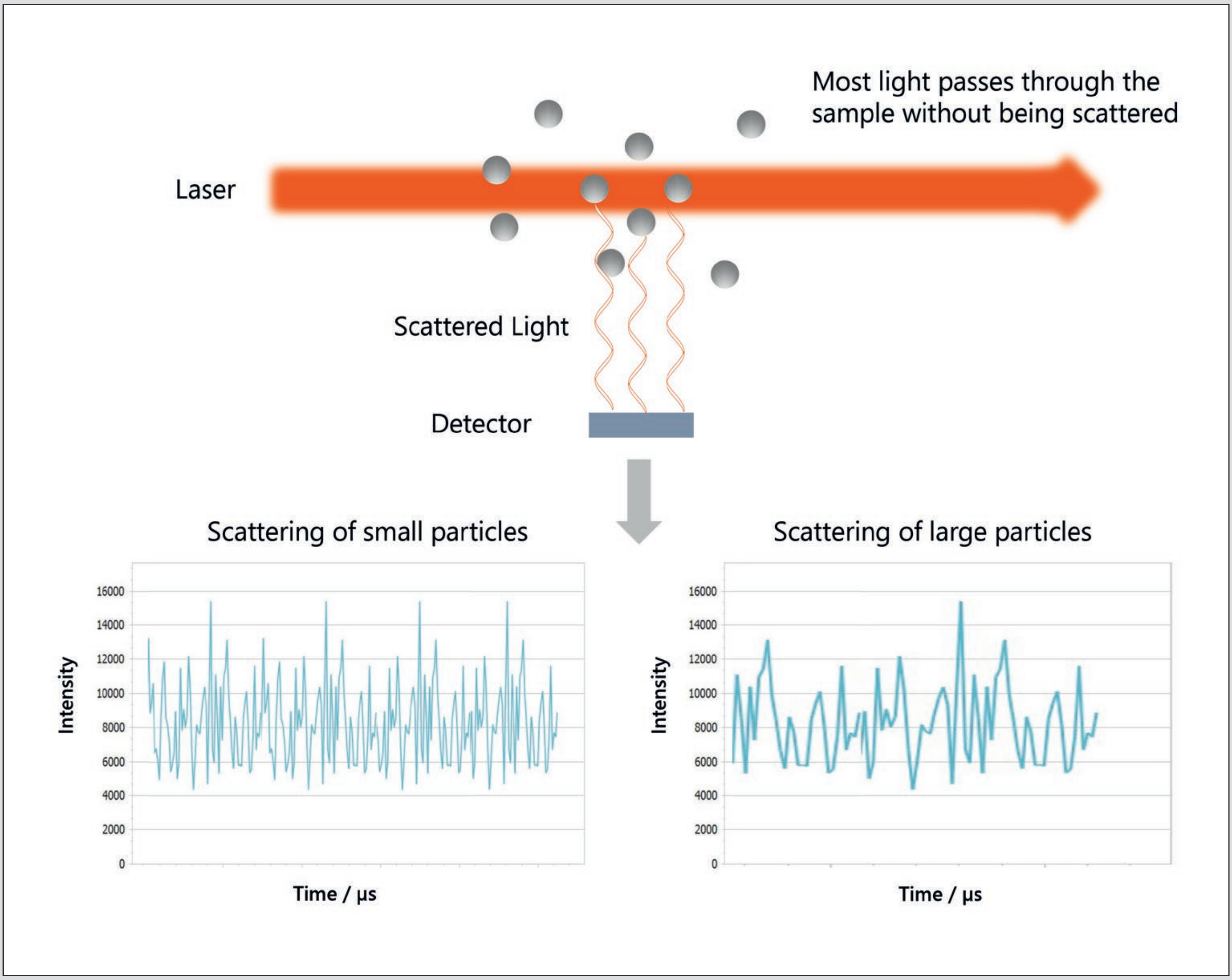


Figure 4 *Basic principle of DLS representing the differences in intensity fluctuation of small and large particles*

BeNano Series Features & Benefits DLS

High Resolution

The resolution of the DLS technology depends on the algorithm. Usually for two narrowly sized-distributed components with size difference of over 3:1, the algorithm discerns two individual peaks by adjusting the resolution to a higher level. The BeNano series provides several algorithms with different resolutions to meet the high-resolution requirements of different applications. Fig. 5 is the result of a 60 nm and a 200 nm latex mixture.

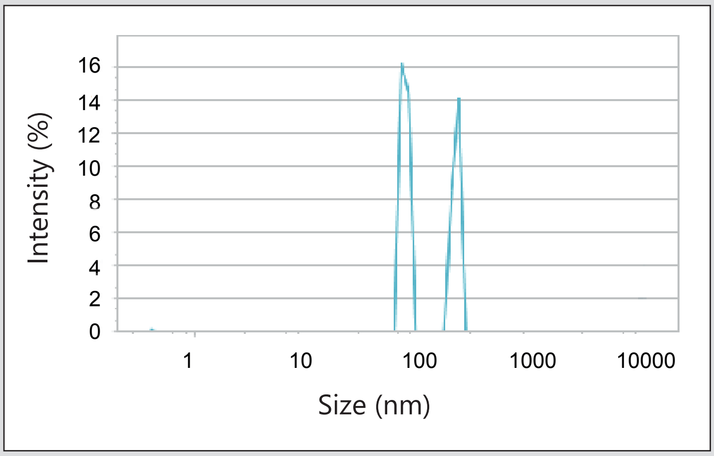


Figure 5 *Particle size distribution of a 60 nm and a 200 nm polystyrene latex mixture*

Repeatability

The optical system of the BeNano series is robust and stable. It has an automatic intensity adjustment and intelligent signal judgment system to ensure high stability and repeatability of the measurements. Fig. 6 shows the measurement repeatability of the 60 nm polystyrene latex. As demonstrated, the system provides excellent repeatability with a relative standard deviation less than 1 %.

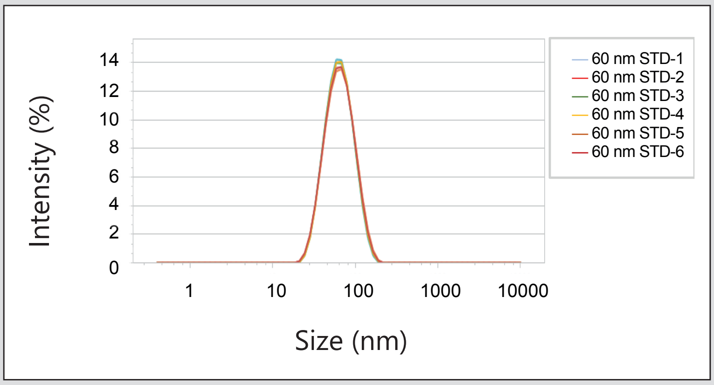


Figure 6 *Particle size distribution of a 60 nm polystyrene latex*

	Z-ave Size
Average	63.59
Standard Deviation	0.55
Relative Standard Deviation	0.86 %

Precision for small particles

The models of the BeNano series are equipped with a 10 mW He-Ne laser, a high-sensitivity APD detector and single-mode fibers, which provide unprecedented sensitivity and accurate measurement for extremely small particles with fast diffusion speeds.
Even for molecules smaller than 1 nm, such as vitamin B1 (as shown below) under very diluted conditions, the BeNano series can effectively detect its scattering intensity and fast decay signals to obtain the particle size and size distribution.

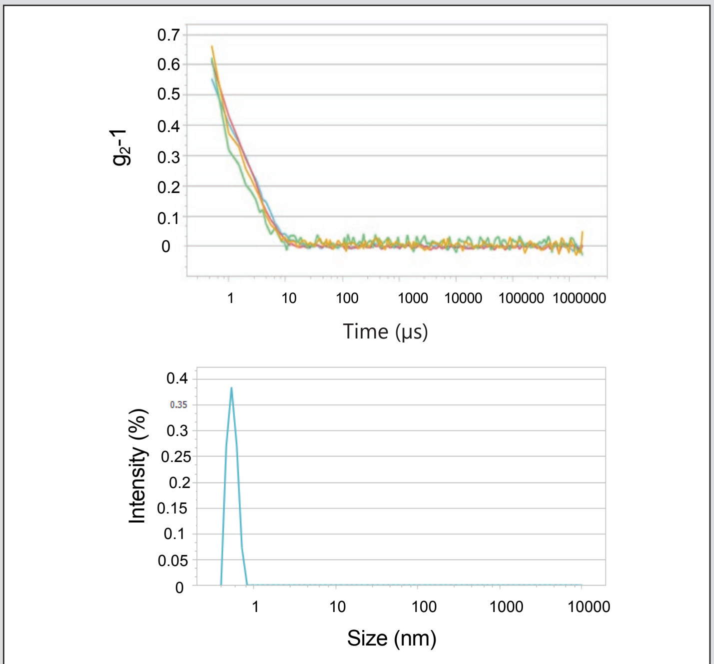


Figure 7 *Results for vitamin B1 under very diluted conditions*

Precision for large particles

Large particles diffuse slowly and are likely to sediment. Applying DLS technology for large particles requires the intelligent adjustment of the scattering intensity and ensures enough correlation time for the slow decay. The highly effective detection system of the BeNano series can offer sufficient correlation time providing accurate calculation of slow decay signals. Fig. 8 below is the measurement result of a 5 μm polystyrene latex.

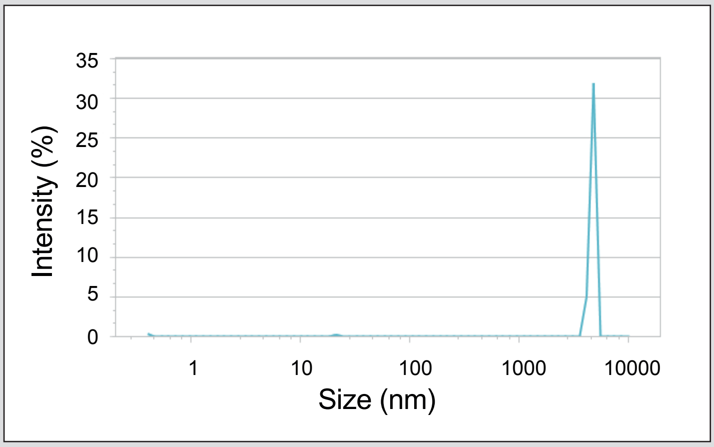


Figure 8 *Measurement result of a 5 μm polystyrene latex*

Electrophoretic Light Scattering (ELS)

Particles usually carry charges on the surface in aqueous systems, surrounded by counterions that form a firmly inner Stern layer and an outer shear layer. Zeta potential is the electrical potential at the interface of the shear layer. A suspension system with higher zeta potential tends to be more stable and less likely to form aggregates.

Traditional ELS technology

Electrophoretic light scattering (ELS) is a technology for measuring electrophoretic mobility via Doppler shifts of the scattered light. When an incident light illuminates dispersed particles that are subjected to an applied electric field, the frequency of the particles' scattered light will be different from the incident light due to the Doppler effect. The frequency shift is measured and converted to provide the electrophoretic mobility and hence the zeta potential of a sample by Henry's equation:

$$\mu = \frac{2\varepsilon_r \varepsilon_0 \zeta}{3\eta} f(\kappa\alpha)$$

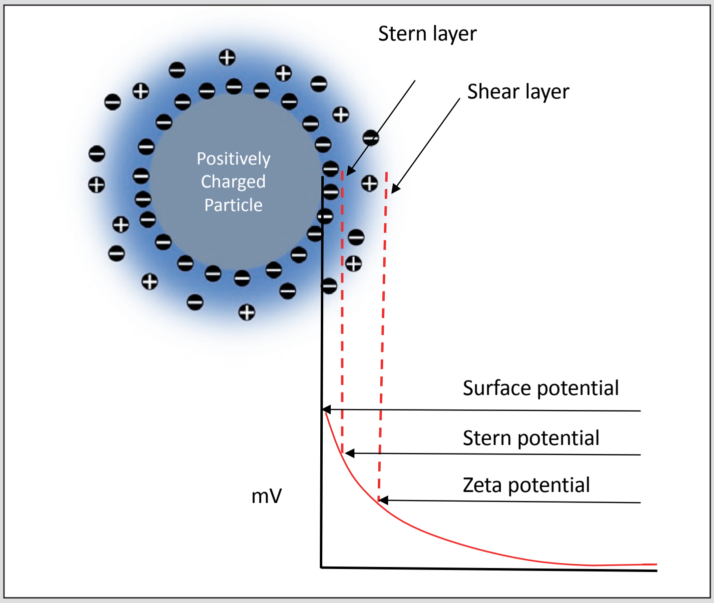


Figure 9 *Potential distribution at particle surface*

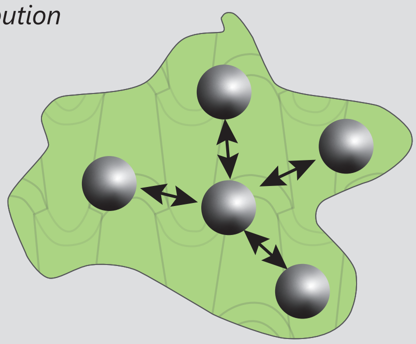


Figure 10 *Intermolecular forces between particles*

Phase Analysis Light Scattering (PALS)

The traditional ELS converts the correlated scattering signals into frequency distribution and then calculates the frequency shift Δf of the scattered light, compared with the reference light. Phase analysis light scattering (PALS), an advanced technology based on the traditional ELS technology, has been further developed by Bettersize Instruments Ltd. to measure zeta potential and its distribution of a sample.

By analyzing the phase information Φ of the original scattered signal, PALS obtains the frequency information of that light. The phase shift dΦ/dt with time is proportional to the frequency shift Δf.

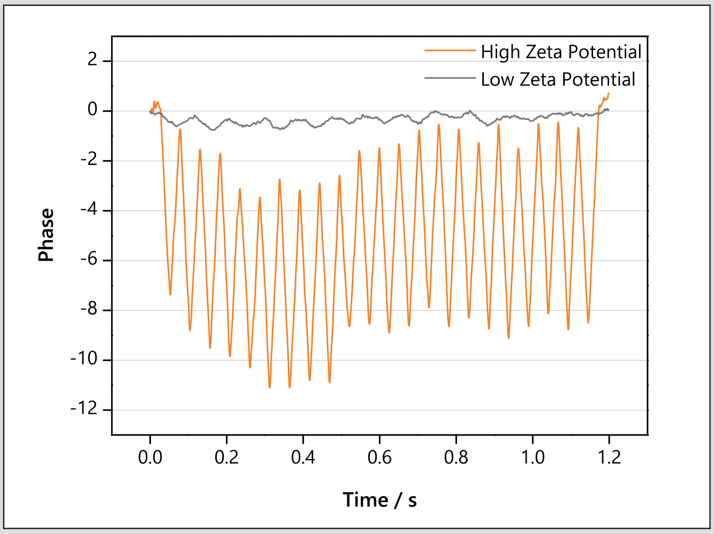


Figure 11 *Phase plot of PALS*

Static Light Scattering (SLS)

Static light scattering (SLS) is a technology that measures the scattering intensities, weightaverage molecular weight (M_W) and second virial coefficient (A_2) of the sample through Rayleigh equation:

$$\frac{KC}{R_\theta} = \frac{1}{M_w} + 2A_2C$$

where C is the sample concentration, θ is the detection angle, R_θ is the Rayleigh ratio used to characterize the intensity ratio between the scattered light and the incident light at the angle of θ, Mw is the sample's weight-average molecular weight, A_2 is the second virial coefficient, and K is a constant related to $(dn/dc)^2$.

During molecular weight measurements, scattering intensities of the sample at different concentrations are detected. By using the scattering intensity and Rayleigh ratio of a known standard (such as toluene), the Rayleigh ratios of samples at different concentrations are computed and plotted into a Debye plot. The molecular weight and the second virial coefficient are then obtained through the intercept and slope from the linear fitting of the Debye plot.

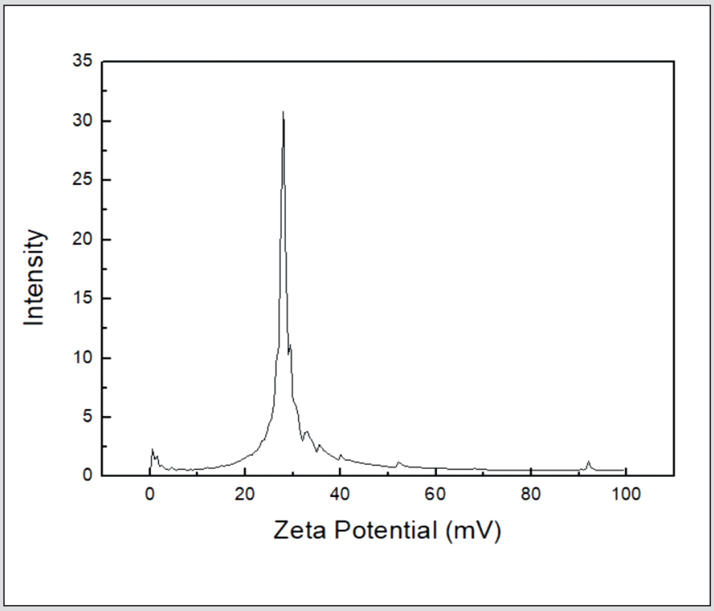


Figure 12 *Zeta potential distribution*

PALS technology can suppress the influence of the Brownian motion of particles on the results, thereby providing higher statistical accuracy. In various applications, PALS can effectively measure the zeta potential of particles whose charge approaches the isoelectric point, for instance, particles with very slow electrophoretic mobility at a high salt concentration.

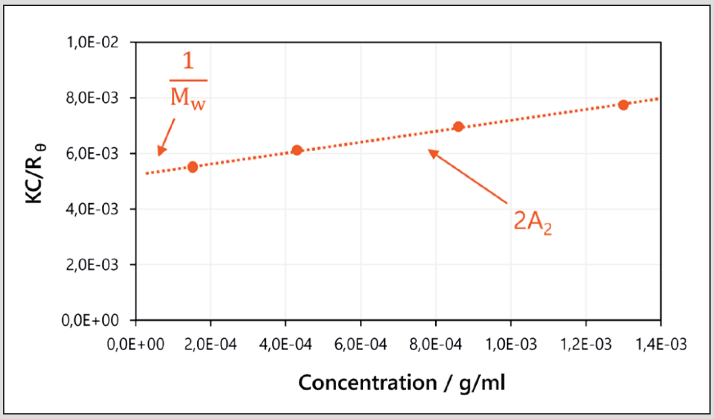


Figure 13 *Debye plot*

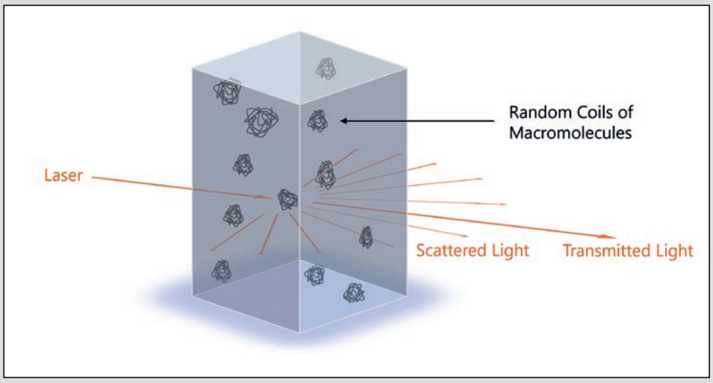


Figure 14 *Light scattering and transmission on macromolecules*

BeNano Series Software

A Research Level Software

The BeNano software comes with...

- a user-friendly interface
- various types of report pages
- Standard Operating Procedure (SOP)

File Measure Tools Help Test

Projects View | Records View | Intensity Distribution | Volume Distribution | Number Distribution | Cumulants Fitting | Multi-exponential Residues | Statistics Reports

Id	Sample	Z-ave (nm)	PDI	Operator	Test Time	Dispersant Viscosity (mpa.s)	Attenuator Number	Intensity Mode	Analysis Algorithm	Cumulant Threshold	Γ(1/s)	Average Intensity (kcps)
2	87878	65.58	0.002545		2020/4/3 15:37:39	0.8800	0	0	1	0.2	2347.708190	1230.78
2	87878	65.60	0.002299		2020/4/3 15:37:39	0.8800	0	0	1	0.2	2346.952481	1233.70
2	87878	65.51	0.002247		2020/4/3 15:37:39	0.8800	0	0	1	0.2	2350.210270	1252.54
5	S1	21.57	0.212261		2020/4/3 16:23:38	0.8800	0	0	1	0.2	7137.150225	158.82
5	S1	22.12	0.231187		2020/4/3 16:23:38	0.8800	0	0	1	0.2	6960.778734	159.69
5	S1	21.86	0.227739		2020/4/3 16:23:38	0.8800	0	0	1	0.2	7041.793876	159.71
6	S4	145.04	0.345431		2020/4/3 16:31:19	0.8800	0	0	1	0.2	1061.523908	445.34
6	S4	153.17	0.310902		2020/4/3 16:31:19	0.8800	0	0	1	0.2	1005.179439	450.71
6	S4	152.40	0.330934		2020/4/3 16:31:19	0.8800	0	0	1	0.2	1010.268756	458.29

Figure 15 *The BeNano software comes with user-friendly interface, results previews, and various types of report*

Features

- Standard Operating Procedure (SOP) ensures the completeness and accuracy of parameters
- Measurement interface shows real-time information and results of various types
- Results and statistics – automatic calculations of mean and standard deviation
- Statistics and overlay – compares results from multiple runs
- Over 100 parameters available, 100 % covering the needs for research, QA, QC, and production
- Life-long upgrades provided free of charge

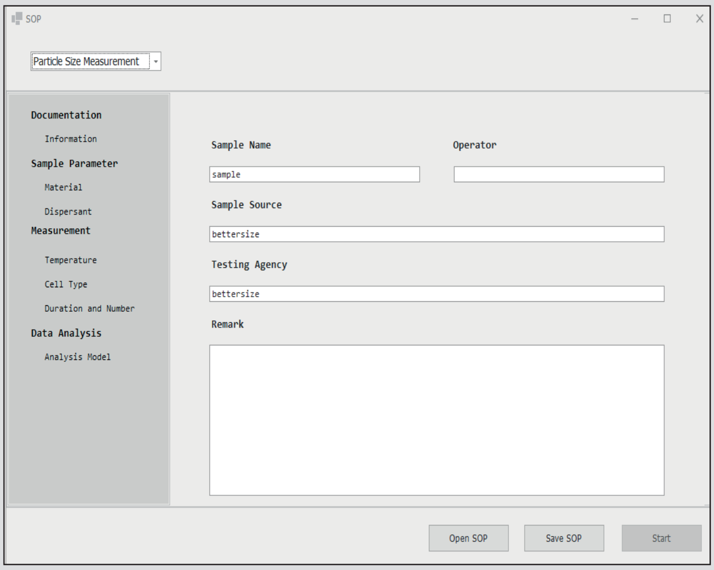


Figure 16 *Different settings for the SOP*

Electrophoretic Light Scattering

- Phase Analysis Light Scattering
- Zeta potential and its distribution
- Analysis models:
  - Smoluchowski
  - Hückel
  - Customized

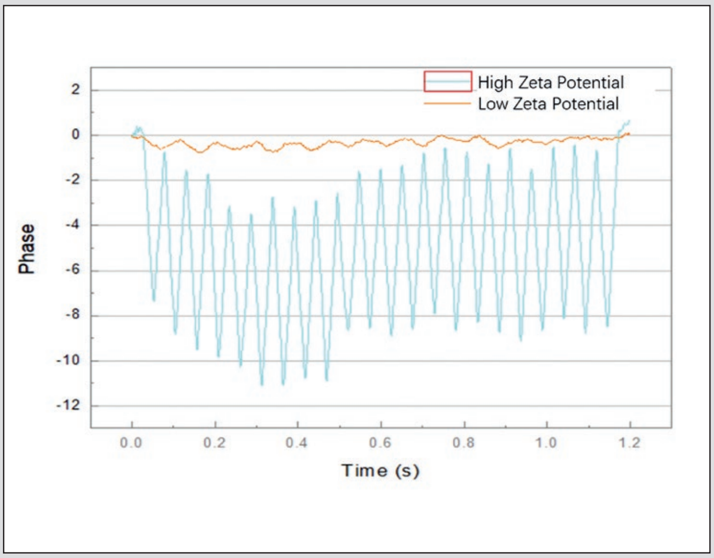


Figure 17 *Phase plot of PALS*

Powerful Statistics and Analyzing Tools

- Display the real-time results in the measurement page
- Mean, standard deviation, and relative standard deviation information available
- Able to reanalyze and re-edit historical data
- More detailed information displayed in the “Statistics and Overlay” page
- Capable of batch-processing multiple results

Dynamic Light Scattering

- Intelligent selection and deletion of poor-quality data
- Results of Z-ave particle size, PdI, particle size distribution, diffusion coefficient are available
- Analysis models:
  - Cumulants
  - Universal
  - CONTIN

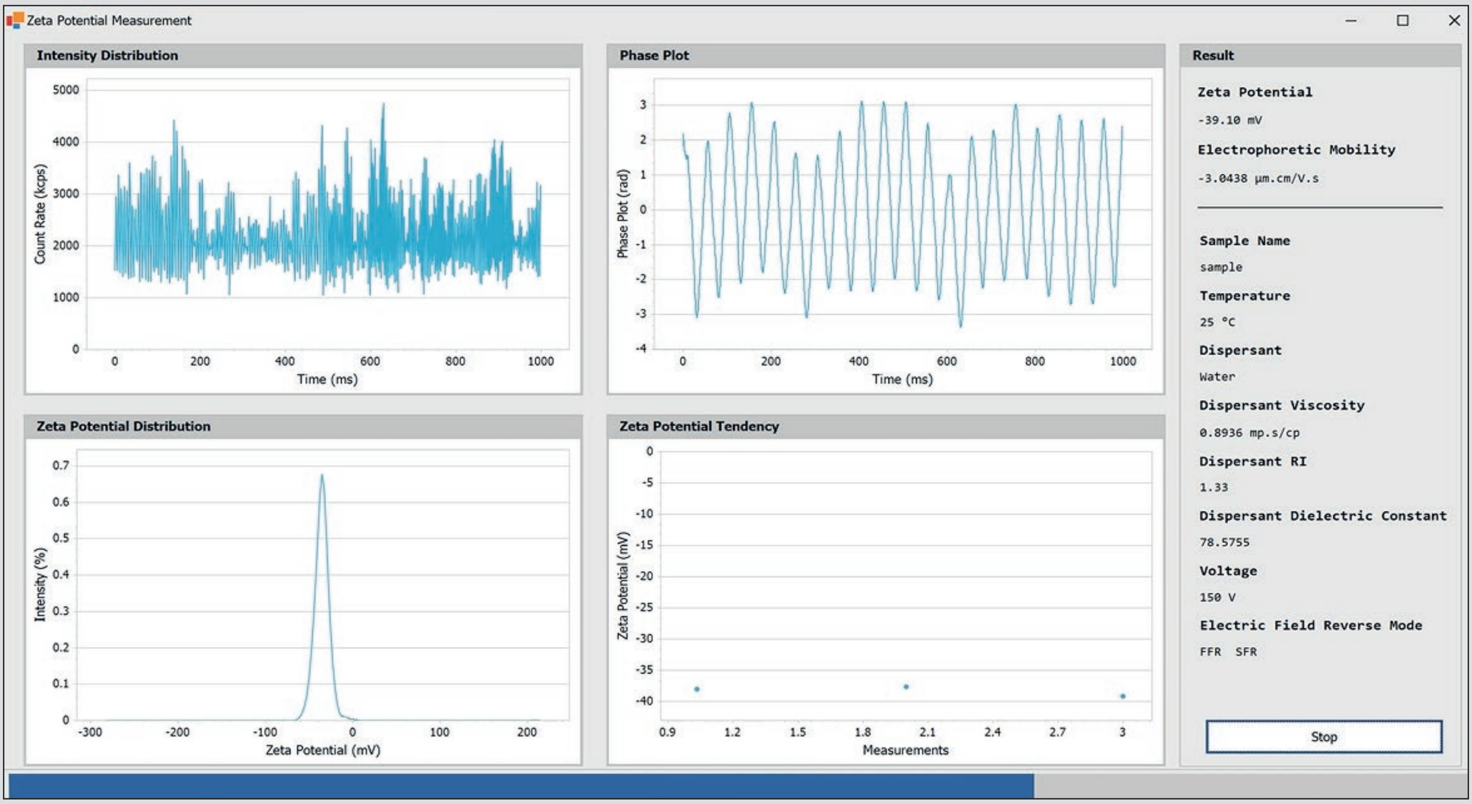


Figure 18 *Zeta potential measurement*

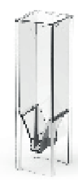
BeNano Series Accessories

Particle Size Measurement

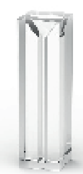
Type	Description	Material	Sample Volume	Temperature Range
Disposable PS Cuvette	Commonly used sample cell for aqueous samples	PS	1 – 1.5 mL	-10 – 70 °C
Glass Cuvette (square opening)	Commonly used sample cell for aqueous and organic samples	Glass	1 – 1.5 mL	-10 – 110 °C
Glass Cuvette (round opening)	Commonly used sample cell for aqueous and organic samples with better sealing performance	Glass	1 – 1.5 mL	-10 – 110 °C
Disposable Micro-volume Cuvette	Required for aqueous samples with micro volume	PMMA	40 – 70 μL	-10 – 70 °C
Micro-volume Glass Cuvette	Required for aqueous samples with micro volume	Glass	25 – 50 μL	-10 – 110 °C
Capillary Sizing Cell	Required for aqueous and organic samples with ultra-micro volume	Glass	3 – 5 μL	-10 – 70 °C

Disposable PS Cuvette (square opening)

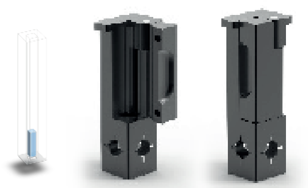
Glass Cuvette (round opening)



Disposable Micro-volume Cuvette



Micro-volume Glass Cuvette



Capillary Sizing Cell Kit

Zeta Potential Measurement

Type	Description	Material	Sample Volume	Temperature Range
Dip Cell	For aqueous and organic samples	PEEK, Platinum	1 – 1.5 mL	-10 – 100 °C
Folded Capillary Cell	For aqueous samples	PC	0.75 mL	-10 – 90 °C

Dip Cell Kit

Folded Capillary Cell

Capillary Sizing Cell

- Easy to use - just dip the sample and test!
- Low-cost and disposable compared to low volume quartz cell
- Extremely low sample volume required (3-5 μL)
- Avoids large particle sedimentation and allows for larger particle measurement up to 15 μm
- Smaller inner diameter of the capillary allows for a more uniform temperature field, avoiding the effect of turbulence or convection on the signal caused by the temperature field of the sample
- Shorter optical path (0.5 mm) - lower multiple light scattering effects

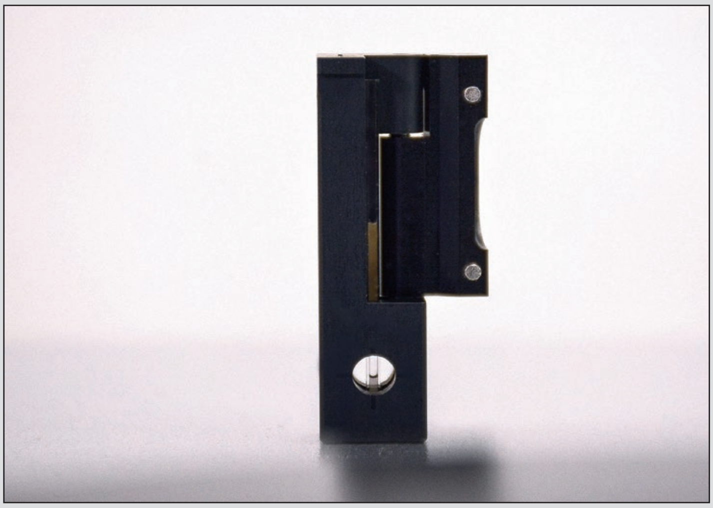
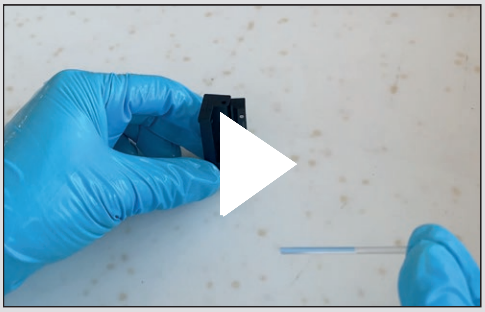


Figure 19 *Capillary sizing cell*



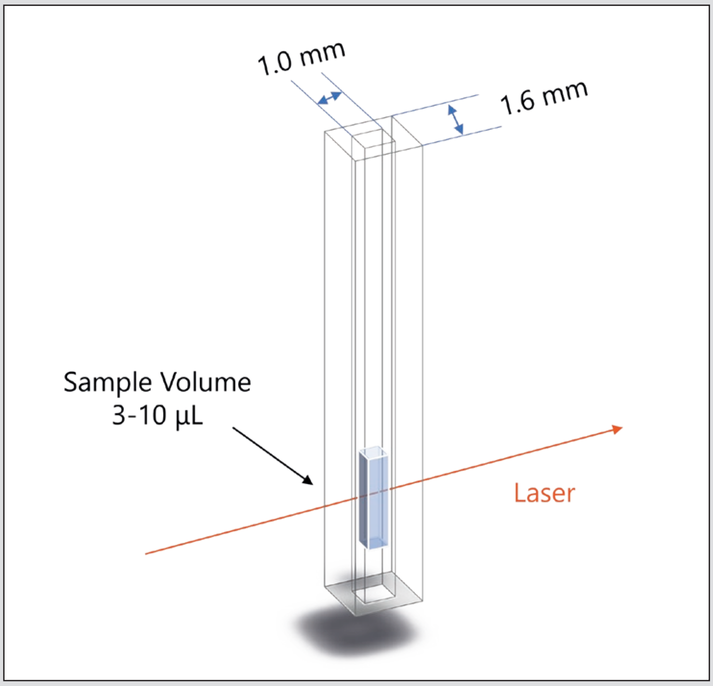


Figure 20 *Schematic structure of the capillary sizing cell*

Disposable Folded Capillary Cell

- 5 cm electrode distance to avoid heating of the sample, and to provide a more uniform electric field
- Avoids cross-contamination
- Suitable for high-polarity particle systems
- Optical path of 4 mm, capable of measuring samples with a maximum concentration of 40 % w/v
- High-tech but disposable item with low usage cost

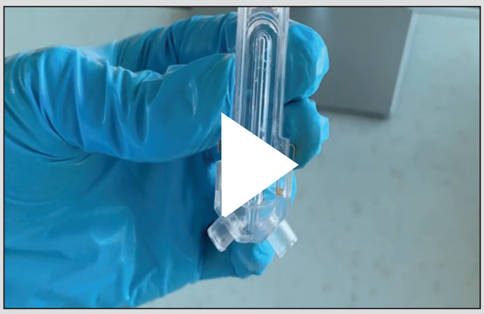


Figure 21 *Disposable folded capillary cell*

BeNano Series Specifications

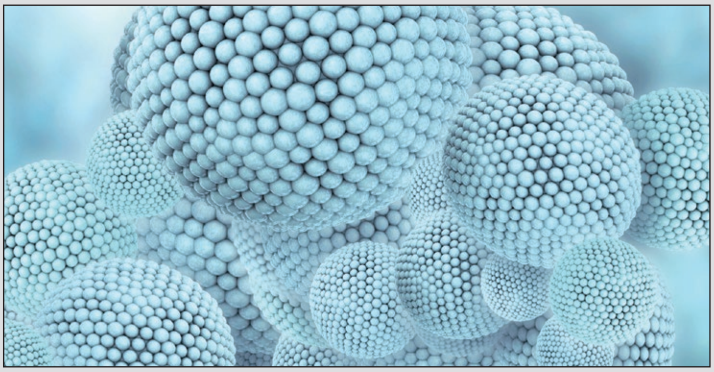
Functions	BeNano 90 Zeta	BeNano 90	BeNano Zeta
Measurement Principle	**DLS + ELS + SLS**	**DLS + SLS**	**ELS**
Particle Size Measurement			
Size Range (D_H)	0.3 nm – 15 μm*		
Minimum Sample Volume	3 μL*		
Detection Angle	90°		
Analysis Algorithm	Cumulants, Universal Mode, CONTIN		
Zeta Potential Measurement			
Detection Angle	12°		12°
Zeta Potential Range	No limit		No limit
Electrophoretic Mobility Range	> ±20 μm * cm / V * s		> ±20 μ.cm/V.s
Conductivity Range	260 mS/cm*		260 mS/cm*
Minimum Sample Volume	0.75 mL		0.75 mL
Molecular Weight Measurement			
Molecular Weight Range	342 Da – 2 x 10^7 Da*		
Others			
Viscosity Range	0.01 cp – 100 cp*		
Interaction Parameter k_D	No limit		
System Parameters			
Trend measurement mode	Time		
Temperature Control Range	-10 °C – 110 °C ± 0.1 °C		
Condensation Control	Dry air or nitrogen		
Laser Source	10 mW He-Ne laser, 633 nm		
Correlator	100 ns – 8000 s, up to 4000 channels		
Detector	APD (Avalanche Photodiode)		
Intensity Control	0.0001 % – 100 %, manual or automatic		
Dimensions (L x W x H)	62.5 x 40 x 24.5 cm (22 kg)		
Power Requirements	100 – 240 V, 50/60 Hz		

* Depending on samples and accessories

BeNano Series Application fields

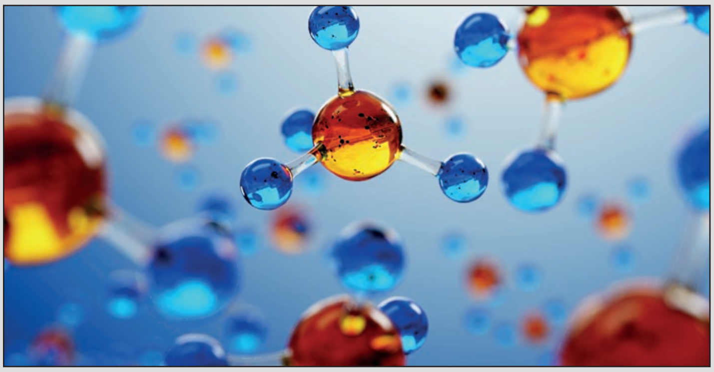
Bioscience and Biopharmaceuticals

Food and Beverage



Nanomaterials

Consumer Products



Chemicals

Paints, Inks and Coatings

Academia

Pharmaceuticals and Drug Delivery

Your partner in particle characterization

3P Instruments has over 30 years of profound expertise in the characterization of emulsions and dispersions, of particles and powders as well as surfaces and pores.

3P INSTRUMENTS

- Journal "Particle World" and biweekly news at www.3P-instruments.com
- LabSPA (Lab for Scientific Particle Analysis) for test and contract measurements
- Experienced service team with direct access to test instruments
- Friendly administration, optimized business processes, very short response times
- Instrument rental and leasing is possible
- Customer service and instruction briefing by highly qualified expert team
- R&D department working at scientific projects and solutions
- 3P Instruments analyzers with various options

Watch the BeNano video:

3P INSTRUMENTS

3P Instruments GmbH & Co. KG
Rudolf-Diesel-Str. 12
85235 Odelzhausen | Germany

Tel. +49 8134 9324 0
info@3P-instruments.com
www.3P-instruments.com

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