

DLS Data Interpretation

Nicomp® systems

OVERVIEW

The Entegris Nicomp® dynamic light scattering (DLS) system is an easy to use particle size and zeta potential analyzer. This technical note shows typical results from the Nicomp and explains how to interpret the data generated.

INTRODUCTION: DYNAMIC LIGHT SCATTERING

The DLS technique is an ideal method for measuring the particle size of suspensions from 1 nm to about 10 μm (depending on the particle density). A simplified optical diagram of the Nicomp system is shown in Figure 1.

The light scattering from the Brownian-motion of the particles causes photon count fluctuations on the detector. The time signature from the fluctuations is used to create the correlation function from which the translation diffusion coefficient D is determined. The particle size R is then calculated using the Stokes – Einstein equation:

$$D = kT / 6\pi\eta R$$

Where:
 k = Boltzmann's constant
 η = viscosity of solvent
 T = temperature (K)
 R = particle radius

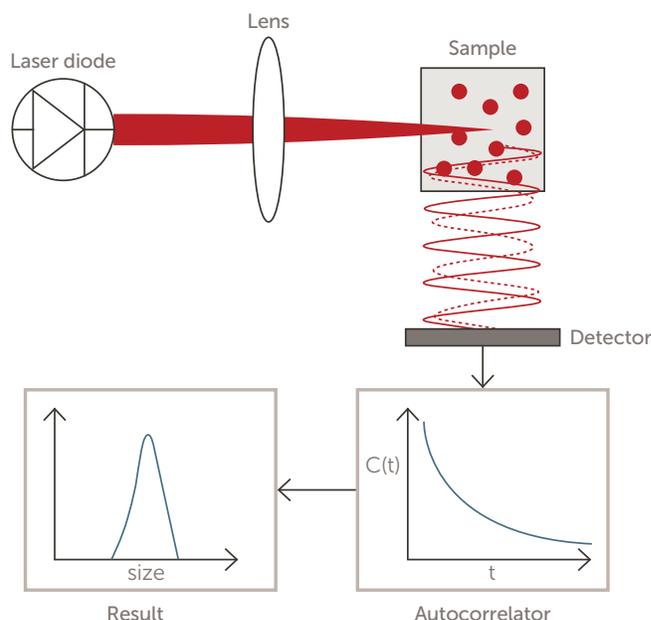


Figure 1. DLS optics

RESULT INTERPRETATION

A typical result for a narrow polystyrene latex standard (PSL) is shown in Figure 2.

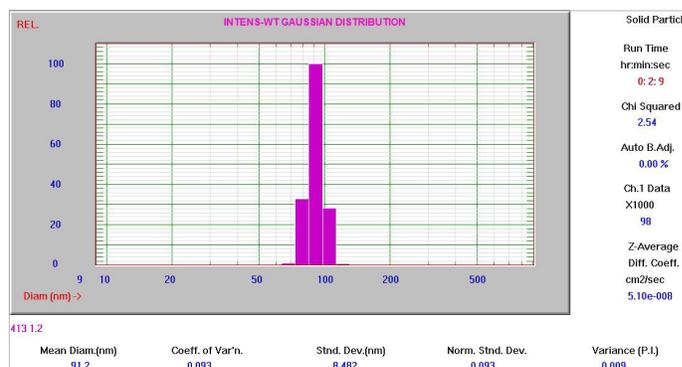


Figure 2. A Nicomp DLS result

This is an intensity weighted Gaussian distribution so the complete result can be defined by two numbers; the mean and standard deviation. But the ISO standard for DLS¹ suggests that the results should be reported using the mean and the polydispersity index, PI.

The nomenclature used in ISO 22412-2008 is technically accurate but seldom used in the real world. For example, the term used for the intensity weighted mean diameter is \bar{X}_{DLS} . In the Nicomp software this value is the Mean Diam. In other vendor's software this is sometimes called the Z average or Zave. Therefore, to report Nicomp results following the guidance in ISO 22412-2008, the two values to publish are the Mean Diam and Variance (PI).

A description of all reported values shown in Figure 2 from left to right, then top to bottom are provided below.

Mean Diam = Mean diameter from the intensity distribution, also \bar{X}_{DLS} and Zave.

Coeff. Of Var'n. = Coefficient of variation from the intensity distribution

$$= \text{Std. Dev.}/\text{Mean}$$

Std. Dev. = Standard deviation from the intensity distribution, 68.2% of the total distribution lies within $\pm 1\sigma$

Norm. Std. Dev. = Std. Dev./Mean

Variance (PI) = Polydispersity index as defined below

$$PI = 2\bar{X}_{DLS}^2 \frac{\sum_{i=1}^N \Delta Q_{int,i} (1/x_i^2 - 1/\bar{X}_{DLS}^2)}{\sum_{i=1}^N \Delta Q_{int,i}}$$

Where:

$\Delta Q_{int,i}$: intensity-weighted amount of particles with size x_i , the size distributions may be obtained as a discrete set of diameters, x_i , and corresponding intensity-weighted amounts $\{\Delta Q_{int,i}, x_i, i = 1...N\}$

“Solid Particle” = There are two refractive index models used in the Nicomp software when converting from the intensity distribution to either the volume or number based distribution. The “Solid Particle” model assumes a high difference between the refractive index, RI, of the particle and the RI of the dispersing liquid. The “Vesicle” model assumes a closer ratio RI particle/RI liquid and is optimized for liposomes.

Note: these models do not affect the intensity results, only the volume and number results.

Run Time = Length of the measurement duration

Chi Squared = Goodness of fit calculation

Note: This value also indicates whether the Gaussian or multi-modal Nicomp result should be used. If the Chi Squared values is below 2-3, then the Gaussian result is suggested. For Chi Squared values greater than 3 consider using the Nicomp result.

Auto B. Adj. = Auto baseline adjustment. The baseline of the correlation function can destabilize when there are a few large particles present or with noisy raw data. A high Auto B. Adj. value indicates noisy data and better sample preparation may be required.

Ch 1. Data X1000 = contents of channel # 1 in the correlation function. A higher value indicates greater statistical accuracy in the function.

Z-Average Diff Coeff. = The diffusion coefficient D used in the Stokes - Einstein equation to convert from diffusion coefficient to particle size.

TYPES OF DISTRIBUTIONS

The result shown in Figure 2 is the Gaussian result; completely defined by the mean and standard deviation (or PI). Gaussian distributions have the characteristic that 68% of the total population lies within 1 standard deviation from the mean as shown in Figure 3.

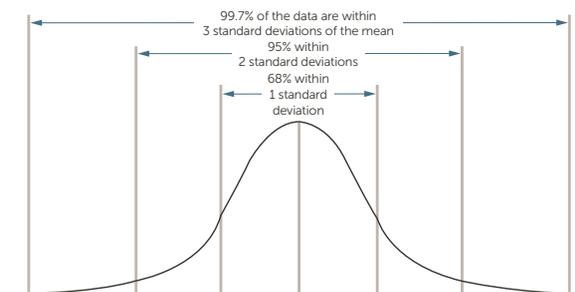


Figure 3. The Gaussian distribution

For samples that have more than one peak the unique Nicomp calculation is used to resolve the multiple peaks. A large Chi squared value indicates the simple Gaussian result is not a good representation of the raw data. The general mathematical procedure which is utilized in the proprietary Nicomp distribution analysis is referred to as inversion of the Laplace transform (“ILT”). This rather sophisticated technique has also been used to analyze a variety of problems in other scientific areas, unrelated to light scattering. The specific mathematical procedure is a more sophisticated version of the least-squares calculation used in the Gaussian (cumulants) analysis; it is referred to as non-negative least-squares (“NNLS”) analysis.

The result shown in Figure 4 has a high Chi squared value, implying that the Gaussian result is not the best fit to the raw data and the Nicomp result should be considered. The Nicomp result is shown in Figure 5.

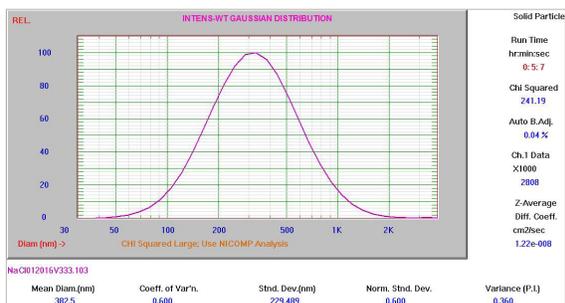


Figure 4. High Chi squared result, Gaussian result

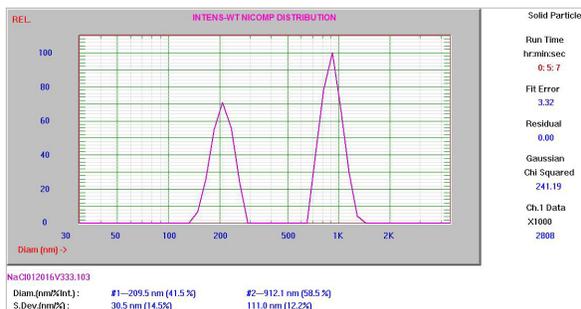


Figure 5. Nicomp result

The primary result from a DLS measurement is the intensity weighted distribution. The result can be converted to either a number or volume base distribution for the purposes of comparing to other techniques. For example, the number distribution will show a result closer in agreement to an SEM result since microscopy produces a number weighted distribution. The intensity distribution will be similar to the volume or number distribution for narrow, symmetric distributions. For broader distributions the results will diverge considerable in the general order of largest to smallest: intensity > volume > number. Comparisons of the intensity, volume, and number results for a sample is shown in Figure 6-8.

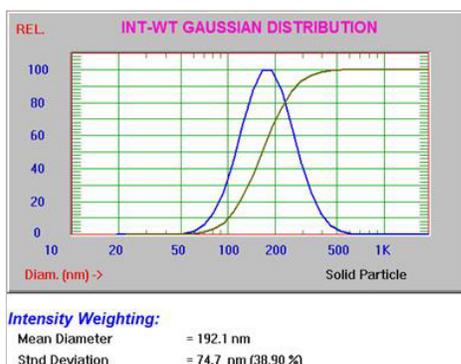


Figure 6. Intensity result

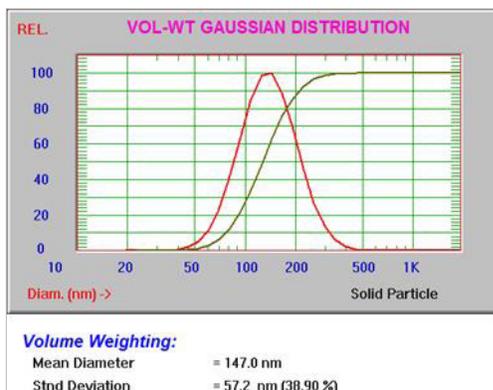
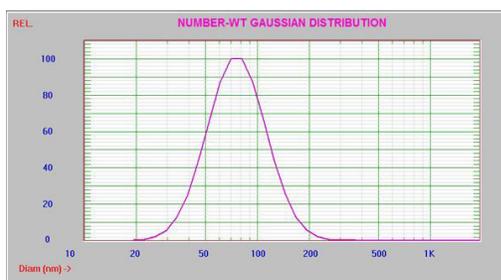


Figure 7. Volume result



Number weighting

Mean Diameter	81.5 nm
Std Deviation	31.699 nm (38.90%)

Figure 8. Number result

Data can also be displayed as a cumulative result below chosen percentages shown in Figure 9.

Cumulative result

25% of distribution	<85.2 nm
50% of distribution	<90.8 nm
75% of distribution	<96.6 nm
90% of distribution	<102.3 nm
99% of distribution	<112.7 nm
80% of distribution	<98.2 nm

Note: the last percentage (80% in this example) can be changed by the operator in the Control menu.

Figure 9. Cumulative result

21 CFR PART 11 SOFTWARE

A print out from a result from the Nicomp Net 21 CFR Part 11 software is shown in Figure 10.

92 nm PSL			
Recipe: PSL		Measurement Date 7/25/2016 12:17 PM UTC-07:00	
Sample Date	7/25/2016	Channel Width	12 µm (auto)
Refractive Index	1.333	Temperature	23 °C
Viscosity	0.933 cP	Intensity Set Point	300 kHz
Particle Type	Solid	First Channel Used	2
Cell Type	Square		
Analysis Results - Gaussian Distribution			
	Intensity	Volume	Number
Diameter	94.02	86.84	79.49
St.Dev.	15.98	14.76	13.51
CV %	17.00%	17.00%	17.00%
PI	0.03	0.03	0.03
Cumulative Results			
	Intensity	Volume	Number
25% of distribution <	82.55	76.25	69.00
50% of distribution <	92.61	85.54	78.30
75% of distribution <	103.09	95.96	87.04
80% of distribution <	106.09	98.73	90.38
90% of distribution <	115.21	106.41	97.41
99% of distribution <	137.64	127.13	116.38
Run Time	0:02:03		
Chi²	3.354		
Baseline Adj.	0.000		
Decay	2.463		
Fit Error	17.633		
Residual	0.000		
Minimum Diameter	10 nm		
Plot Size	45		
Smoother	3		
Plot Range	100		

Figure 10. Result from 21CFR11 compliant software

The results shown in this figure are mostly the same as the results shown earlier in this document, with the following differences:

In the "Analysis Results" shown in Figure 11 the "Diameter" result is actually the mean result based on the intensity, volume, and number distributions.

Analysis Results – Gaussian Distribution

	INTENSITY	VOLUME	NUMBER
Diameter	94.02	86.84	79.49
St. Dev.	15.98	14.76	13.51
CV %	17.00%	17.00%	17.00%
PI	0.03	0.03	0.03

Figure 11. Mean diameter results from 21CFR11 software

In this example the intensity mean diameter (or Z average, or \bar{X}_{DLS}) is 94.02 nm.

ZETA POTENTIAL

The Nicomp system can also be used to measure the zeta potential of the sample. The zeta potential is the charge a short distance from the surface of the particle as shown in Figure 12.

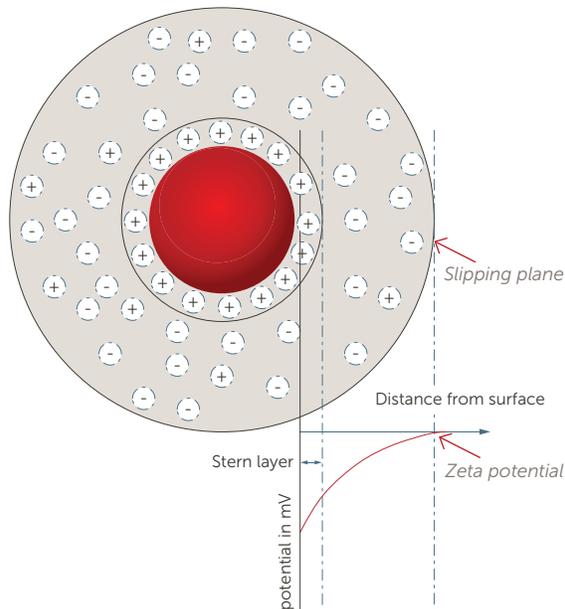


Figure 12. Zeta potential

Zeta potential is analyzed by applying an electric field to the suspension and measuring the speed and direction of the particle motion. The primary result from a zeta potential measurement is the electrophoretic mobility μ which is then used to calculate the zeta potential using the equation:

$$\xi = \eta\mu/\epsilon$$

Where:
 ξ = zeta potential
 η = viscosity of solvent
 μ = electrophoretic mobility
 ϵ = dielectric constant of solvent

The Nicomp can measure the particle motion either by detecting the frequency or phase shift. The preferred approach is measuring the phase shift using the technique phase analysis light scattering (PALS).

A typical zeta potential result from the Nicomp system is shown in Figure 11.

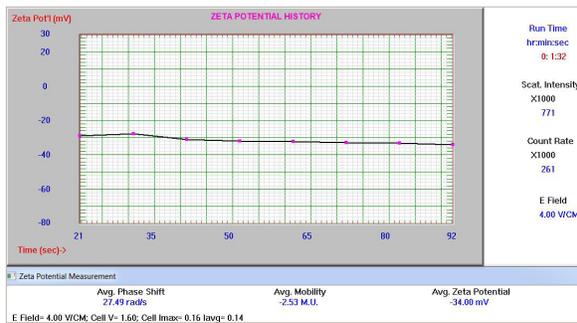


Figure 11. Zeta potential result

The result value to focus on from this measurement is the Avg. Zeta Potential, in this case the accumulated value after eight measurements. It is strongly advised to make multiple zeta potential measurements and use the averaged value.

Sometimes the best approach is to make multiple runs with several analysis per run - then take an average of the multiple runs. It is not unusual to not include outlier zeta potential results when making the final average calculation.

For this sample the user chose to apply an electric field strength of 4 V/cm. This induced the displayed Avg. Phase Shift of 27.9 rad/s – resulting in an average μ of -2.53 M.U. and zeta potential of -34.00 mV.

References

¹ ISO 22412 -2008 Particle size analysis – Dynamic light scattering (DLS)

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