OPTIMIZING NUMBER OF DETECTORS FOR PARTICLE SIZE ANALYZERS

Claims are made by some manufacturers of particle size analyzers using the Static Light Scattering (SLS) technique (also know as Low-Angle Laser Light Scattering (LALLS) or laser diffraction), that a greater number of detectors will provide increased accuracy and resolution. This might seem logical at first glance, but a complete understanding of the subject will show that increasing the number of detectors is not the main variable in determining resolution. It can, in fact, lead to poorer accuracy, resolution and possibly also decreased sensitivity.

Overview

Static light scattering analysis is not a direct measurement of particle size. Rather, it is a measure of the interaction of light with a particulate material. This interaction is directly related to the size of the particles in the measurement zone.

There are a number of important variables that influence measurement and resolution in SLS particle size analysis including:

- Number and geometry of detector elements
- Detector's signal to noise ratio
- Smoothing and constructed condition in the inverse method

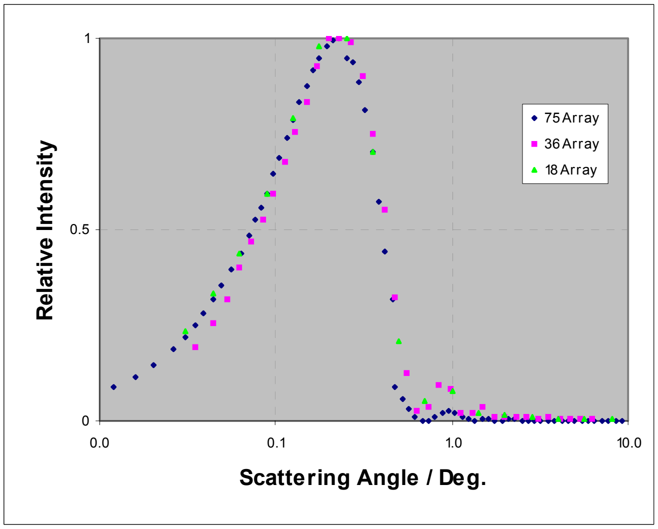
The basic principles and mathematics will not be covered in this document. Readers can refer to the ISO 13320-1 standard as a good overview of these subjects.

Requirements for Accuracy

The most important performance characteristic is accuracy. There are a number of particle size standards available with which to test an instrument's performance. For an accuracy test, mono-sized polystyrene latex beads provide an excellent test material.

To evaluate the response of different detector designs, Horiba conducted experiments using 18-, 36-, and 75-element detector arrays. The example below shows the results of measurements of a 50µm polystyrene latex standard. Other than the array and focusing lens, all other aspects of the optical system were constant.

As can be seen from the figure below, all three systems provide an accurate measurement of the intensity vs. angle relationship that is used to determine particle size. The important information is the position of the main peak, rather than the fine detail. With an appropriate mathematical process, each would return an essentially equivalent measurement of the particle size distribution.



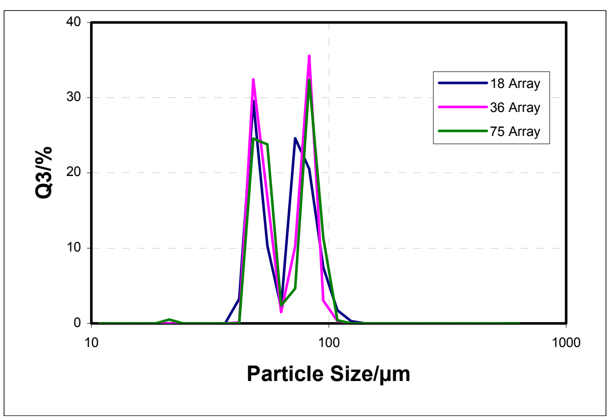
Requirements for Resolution

Resolution can be defined in different ways, but a good test of an instrument is a mixture of two closely spaced distributions of sizes.

The following test is for a mixture of mono-sized 50µm and 80µm polystyrene latex spheres.

Mie Theory allows us to calculate the light scatter patterns exactly for a given particle size distribution. This can then be entered into the calculation algorithm for particle size to show how the different measured data would turn out.

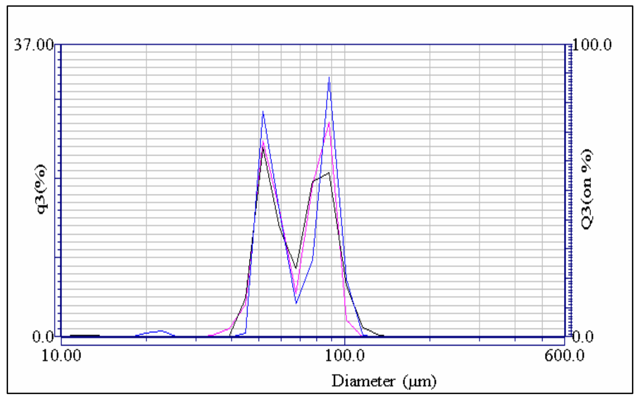
The data below shows simulated data for the mixture of 50µm and 80µm latex samples, measured with 18, 36, and 75 detector arrays. With this simulated signal, we can see that even the simple 18-detector array is able to resolve these two distributions.



Simulated results for PSL mixture

When the mixture is actually measured with the three detector array systems and analyzed with the same algorithm, we can see the close match with the simulated data and the essentially identical resolution capabilities.

It should be clear that the number of detectors used in measuring the light intensity distribution is not the main variable in determining resolution performance of an instrument.



Measured distribution for PSL mixture

Historical Approaches

There is a minimum number of detectors needed to provide a sufficiently detailed measure of the light intensity distribution. Early light scattering instruments used detectors with smaller numbers of detectors.

To measure different size ranges, the focusing lens could be moved to provide different focal lengths. This worked if all the particles of interest were in a relatively narrow size range. Any materials outside this size range would not be measured.

If an instrument manufacturer has not invested in a new detector array with more elements to cover a wider angular range, and therefore particle size range, the dynamic range of the instrument will be limited. Claims are made that the moveable lens allows the instrument to “focus” on one size range, but laser diffraction is not equivalent to a microscope, since all particles are fixed in the focal plane regardless of size.

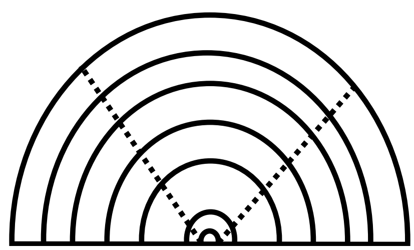
The data presented above shows that increasing the number of detectors covering a certain size range does not provide any greater resolution. The claim is spurious and only shows the limitation of the detector and optical design. A properly designed detector will cover the full angular range with sufficient resolution to provide complete results without requiring optical system changes.

Modern Detector Design

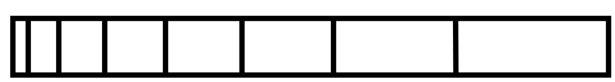
In designing a detector system, there are a number of factors that must be considered to provide optimum performance for use in a static light scattering particle size analyzer.

First, the behavior of light must be considered. As particle size decreases, the angle of scatter increases logarithmically and the intensity of the scattered light decreases. Taking this into account, the detector elements should be designed with a logarithmically increasing detector segment angular spacing and width.

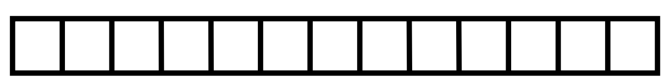
If the detector has linearly spaced detectors, as is seen with off-the-shelf detector arrays, little additional information is gained from the individual narrow, high-angle detectors. Instruments that use this detector type often add several detector signals together to get a corresponding angular range, at the expense of adding the noise from these multiple segments. The result is a decreased signal to noise ratio compared to a properly designed detector.



CONCENTRIC RING ARRAY



RECTANGULAR ARRAY: LOGARITHMIC



RECTANGULAR ARRAY: LINEAR

Historically, as companies attempted to increase the dynamic measurement range for an instrument design, the options were either to design a larger array, which is expensive, or to add additional detectors. A number of companies added a second detector array, usually the same part as the forward scatter array.

While this was an economical approach, the forward array with its narrow detector segments is less than ideal for measuring the higher-angle, low-intensity scattered light. An alternate approach is to use a second light source at an angle to the cell (or move the angle of incident light with a fiber optic), so that the scattered light collected on the main detector is from the higher angle scatter. Either approach has the same limitations of an inappropriate detector design for the task.

In Horiba's LA-series analyzers, the detector is a concentric ring array with logarithmically increasing segment spacing and a much larger surface area for the low intensity light scattered at higher angles. This helps compensate for the lower intensity light without having to boost the electronic gain and possibly electronic noise.
Once the light scatter information is collected at the detector, the algorithm has to deconvolute the contributions from different size populations. The increased noise from the larger number of detectors approach requires a lot of smoothing and leads to an ill-conditioned calculation. The net result is that the measurement may show a number of small peaks, which is claimed to be high-resolution, when, in fact, it is actually noise.

Summary

The high number of detectors of inappropriate design can thus be seen to actually decrease the performance of the analyzer. It should be clear that optimizing the detector system for the task precludes too large a number of detectors if the real intention is to provide improved resolution. A claim of superiority based solely on the number of detector elements is likely due to having an improperly designed system and trying to compete based solely on a single specification.

Horiba LA-930 Particle Size Analyzer with 87-element detector system

For further information on this document or our products, please contact:
Horiba Instruments, Inc.
17671 Armstrong Ave.
Irvine, CA 92614 USA
(949) 250-4811
www.horiba.com