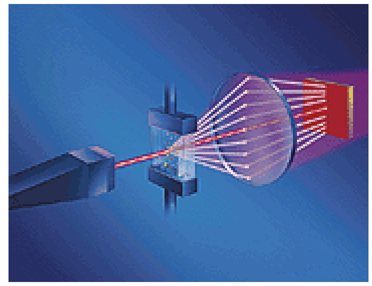
SATURN DIGISIZER II™
TECHNIQUE OVERVIEW

Light Scattering Analysis Technique



The size and shape of a particle affect the way light interacts with the it. Particle sizing techniques measure specific parameters affected by particle size rather than measuring particle size directly. Examples of these altered parameters include the particle's settling velocity, the volume of a medium that the particle displaces, and the pattern produced by light that has been scattered from a particle.

Static light scattering makes use of the **Mie theory** of light scattering by particles. Mie theory describes characteristics of the scattering pattern (light intensity versus scattering angle, among other things) produced by the interaction of a plane wavefront of monochromatic light with a spherical, isotropic particle suspended in a medium of known optical properties.

There is no single particle sizing technique that produces the best data for all sample types. However, often there may be found a single technique that consistently produces the best data for the size range, sample materials, and applications of concern to a particular laboratory. The light scattering technique is simply another way to view the size-related properties of the material.

Understanding what a technique actually measures, how it measures, and how the measurement relates to particle size are the first steps in determining if one technique should be used in place of another technique for a specific sample and application.

Saturn DigiSizer Analysis Technique

The high-definition CCD used in the Saturn DigiSizer measures light scattering patterns with exceptionally fine detail. The number of detector elements per degree of scattering angle is key to achieving high resolution size measurements.

As an example of resolution, the Saturn DigiSizer can produce baseline resolution for modes spaced as closely as 1.1 and 1.3 micrometers. This is made possible by the high-resolution digital imaging of the scattering pattern. The technique of particle sizing by static light scattering is based on Mie theory (which encompasses Fraunhofer theory). Mie theory predicts the intensity vs. angle relationship as a function of the size for spherical scattering particles provided that other system variables are known and held constant. These variables are the wavelength of incident light and the relative refractive index of the sample material and suspension fluid. Straightforward application of Mie theory, utilized by the Saturn DigiSizer, provides explicit particle size information.

Repeatability describes how closely the results of successive measurements agree. For validity, the measurements must be performed under the same conditions. Conditions include the sample material and its preparation, the analyst, the location, the measuring instrument, and the analytical procedure. Furthermore, the measurements should be performed over a short period so that reagglomeration cannot occur. The figure shown here is an overlay of eight consecutive analyses of a mixture of seven different polystyrene size references. Note the outstanding repeatability produced by the Saturn DigiSizer.

Where repeatability deals with successive measurements under the same conditions, ***reproducibility*** describes how closely measurements of the same parameter of the same sample agree when certain conditions are varied. For example, it may be required that the same measurement be obtained at a different site and by a different analyst using a different instrument (even if the same make and model). On the other hand, it may be as simple as reproducing the measurement of a reference material, all conditions being constant except there being a delay (hours, days, or weeks) between the measurements.

Mie Theory

Mie theory provides the fundamental light scattered by an individual particle is a function of the scattering pattern produced by spherical particles of a specific size. The intensity I is a function of the angle $\boldsymbol{\theta}$, wavelength $\boldsymbol{\lambda}$, the particle size x, the and the optical properties of the system (specifically, the index of refraction n of the particle relative to the suspension medium).

$$I = f(\theta, \lambda, x, n)$$

The wavelength of the incident light is a design constant, and relative index of refraction is an input parameter determined by the sample material and suspension medium. Therefore, the intensity of the scattered light **I** is a function of the remaining variables $\boldsymbol{\theta}$ and **x**, the scattering angle and particle size, respectively.

If particles of different sizes are illuminated, the resulting scattering pattern is the summation of all the contributions of intensity by each particle at each angle. Mie theory is applied to determine the theoretical particle quantity distribution by size that is required to best reproduce the experimentally measured scattering pattern.

Proprietary Modifications Used By Others

General Mie theory rigorously describes the scattering of monochromatic plane waves from an isotropic sphere. All conditions, particularly those of being an isotropic sphere, seldom are met in real situations. This causes a mismatch between the theoretical Mie scattering pattern and the experimentally measured scattering pattern for irregular particles of the same size. Some manufacturers elect to compensate to some extent for specific materials or in specific size ranges. In addition, parameters in Mie theory can be adjusted or new terms added to force compliance to certain recognized references.

Data reduction by the Saturn DigiSizer is based on scattering model sets, each calculated from general Mie theory for narrow distributions of isotropic spheres of a specific index of refraction and suspended in liquid of a specific index of refraction. Data reported by the Saturn DigiSizer relate directly to an equivalent Mie sphere.