Nanoparticle Sizing: Dynamic Light Scattering Analysis in the Frequency Spectrum Mode

Instruments: Nanotrac series

Paul J. Freud, PhD

SL-AN-14 Rev. F

Abstract

Dynamic Light Scattering analysis is the basis of a common particle sizing measurement covering the range of nanometers to microns. At the nanometer end of the range, measurement becomes progressively more difficult as the particle optical scattering coefficients drop sharply, reducing the scattered light intensity. Two modes of optical measurement are commonly used, self-beating detection and controlled reference or heterodyne detection. With those two detection modes dynamic light scattering signals can be analyzed as either the autocorrelation function or the frequency shift power spectrum. This paper will discuss recent advances in signal processing in the controlled reference mode using the analysis of the frequency power spectrum. Issues of detectability, signal to noise, and size accuracy will be discussed with measurement examples in the size range down to nanometers.

Introduction

Particles in suspension are in constant random motion (Brownian motion) as the result of the interaction with the molecules of the suspending fluid. In the Stokes-Einstein (Furth 1956) theory of Brownian motion, particle motion is determined by the suspending fluid viscosity, the temperature and the size of the particle. From a measurement of the particle motion in a fluid of known temperature and viscosity, the particle size can be determined. The Dynamic Light Scattering (DLS) technique (Pecora 1967 and Dubin 1967) measures the motion optically. The suspended particles are illuminated with a coherent light source. The light scattered from the suspended particles has frequency shifts imparted to it from the time dependent position or velocity of the suspended particles. Measured over time, random particle motion forms a distribution of optical frequency shifts.

DLS Optical Detection

The use of a coherent optical reference allows, through optical wave interference, the conversion from optical frequencies to the difference between optical frequencies, the shift frequencies. For DLS the shift frequencies are on the scale of 1 Hz to 100KHz, readily detected by modest frequency electronics. Two methods of referencing are commonly used and are illustrated in Figure 1.

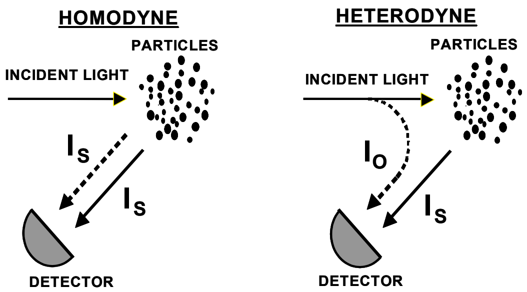

Fig. 1: *DLS detection modes*

Self-referencing, self-beating, or homodyne detection all refer to the left side of Figure 1. The mixing at the optical detector of all the collected scattered light provides the reference for difference frequency measurement. Controlled reference or heterodyne detection, shown on the right side of Figure 1, mixes the scattered light with a portion of the incident light. The un-shifted incident light provides the reference for the difference frequency measurement. The resulting detector output from either mode contains a distribution of frequencies representative of the particle size of the suspended particles.

The measured signal is generally processed by one of two modes, time-based autocorrelation or frequency-based power spectrum. One is the Fourier transform of the other. This paper deals with the frequency power spectrum mode and shows that through this mode a better-conditioned form of the particle size response matrix can be established. The forms of the power spectrum for heterodyne and homodyne detection are shown as equations (1) and (2).