DYNAMIC LIGHT SCATTERING USING SILICON AVALANCHE PHOTODIODES

APPLICATION NOTE

MARCH 2010

ID Quantique's id100 series offers compact and affordable state-of-the-art single photon counting detectors based on silicon avalanche photodiode with best-in-class timing resolution and low dead time. This application note describes the use of the id100 single photon counting detector for the measurement of light scattered by particles. By analysing the fluctuation on the scattered intensity it is possible to evaluate the particle size.

Introduction

Dynamic Light Scattering (DLS), also known as Photon Correlation Spectroscopy (PCS) or Quasi-Elastic Light Scattering (QELS) is a technique commonly used to determine the size of small particles in a solution [1, 2].

Shining a monochromatic light beam onto a solution with particles causes a light scatter. When the particles are much smaller than the incoming wavelength, the light intensity is scattered uniformly in all directions (Rayleigh scattering), independent of the wavelength. However this scattered intensity fluctuates with time. The time-dependent fluctuation occurs because the particles undergo Brownian motion and the distance between them is constantly varying. Analysing the time dependence of the scattering intensity fluctuation and knowing the viscosity of the medium, yield to the diffusion coefficient of the particles from which the particle diameter can be calculated.

The measured diameter in DLS is called the hydrodynamic diameter and refers to how a particle diffuses within a fluid. The scattering intensity pattern is specific to the material being studied. The diameter obtained by this technique is that of a sphere that has the same translational diffusion coefficient as the particle being measured.

If a laser beam is applied to a solution with particles, the scattered light intensity can be measured at any time with the id100 single photon counting detector and the size of the particles can be evaluated, as described in the following sections.

Advantages of Dynamic Light Scattering

DLS is a non invasive technique and it is well-established for measuring the size of molecules and particles typically in the submicron region.

This method offers several advantages:

- Measures particle sizes of 1nm
- Typically ± 1% precision
- Short experiment duration (1-2min)
- Reliable and repeatable analysis
- No need for sample preparation
- Low sample volumes (200uL)
- Measures diluted samples
- Modest development costs

id100 Single Photon Counter

The id100 single photon counters are based on a reliable silicon avalanche photodiode (APD) sensitive in the visible spectral range. The modules are able to detect weak optical signals down to single photon level. With a timing resolution of only 40ps and a dead time of 45ns, the modules outperform existing commercial detectors in all applications requiring single photon detection with high timing accuracy.

The id100 is easy-to-use, self-contained and can be integrated in every optical set-up. Besides an extremely fast Instrument

Response Function (IRF) it has an excellent timing stability up to count rates of at least 10MHz. The id100 is available in the following executions:

- id100-20: free space coupling with 20mm active area
- id100-50: free space coupling with 50mm active area
- id100-MMF50: with 50/125 FC/PC Multi Mode Fibre coupling.

The id100 modules exit in two grades, depending on the dark count rate specifications. For the Ultra-Low Noise grade, the dark count rate is less than 2Hz for the id100-20 and less than 20Hz for the id100-50 and id100-MMF50. The key features are:

- Broad spectral range: 350 to 900 nm
- Best in class timing resolution of 40ps
- Low dark count rate of less than 2Hz
- Low dead time (45ns)
- Photon detection probability up to 35%
- Standard 50Ω output with BNC connector
- Fast active quenching circuit
- Low bias voltage +5V
- Not damaged by strong illumination

For the measurements mentioned below, the id100-MMF50 detector was used to compute the scattered light intensity.

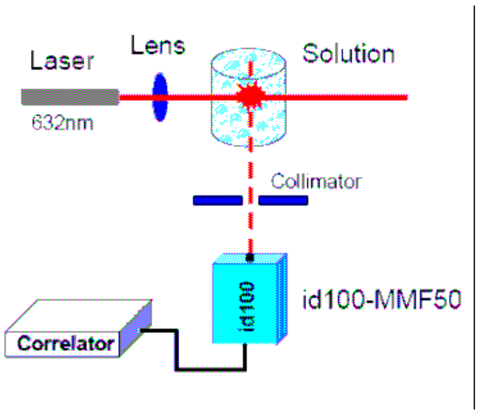

Figure 1: Dynamic Light Scattering experimental setup.

Auto-Correlation Measurements

The experimental setup is illustrated in figure 1. A 632nm HeNe laser is used for this measurement. The beam passes through collimation lenses, allowing the light to be focused onto the solution. The scattered light is then detected by the id100-MMF50 single photon detector.

The output signal from id100-MMF50 is sent to a correlator that computes the number of single photons detected as a function of time. The auto-correlation function is then calculated from the detected photon statistics.

Figure 2 shows the normalized intensity correlation function (ICF) fluctuation with time. For a detector with zero after pulsing probability, the normalized ICF curve should go from 1 to zero with the increase of lag time. The deviation from 1 observed at short lag times in figure2 is due to after pulsing rate of the id100-MMF50 that is below 2%.

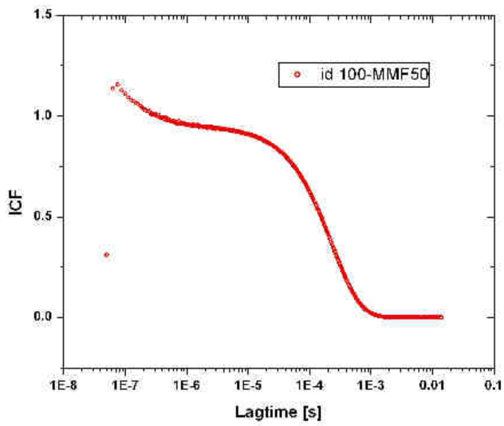

Figure 2: Intensity correlation function (ICF) dependence with time, in auto-correlation measurement. *Courtesy of LS Instruments.*

Cross-Correlation Measurements

The cross correlation measurement is performed with 2 single photon detectors (id100-MMF50), as shown in figure 3. This measurement consists in illuminating the sample with a laser beam at 632nm and measuring the coincidence of the scattered light at a fixed angle.

By performing a cross-correlation on the detected signal it is possible to eliminate the artefact created by the detectors' afterpulse rate.

The specific cross-correlation setup of LS Instruments (figure 3) also allows suppression of multiple scattered lights, which would usually ruin the signal in turbid samples.

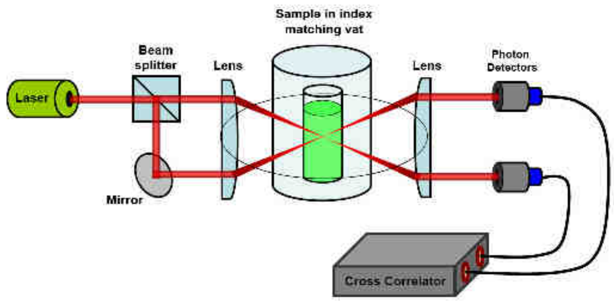

Figure 3: Cross-correlation experimental setup. *Courtesy of LS Instruments*[1].

Figure 4 shows a comparison of the normalized intensity correlation function between the auto-correlation and cross-correlation measurements. Since the influence of the after pulses is eliminated, the cross-correlation curve has a flat behaviour at short lag times. For longer lag times, both curves are similar.

As the after-pulsing effect is suppressed reliable particle sizing is now feasible

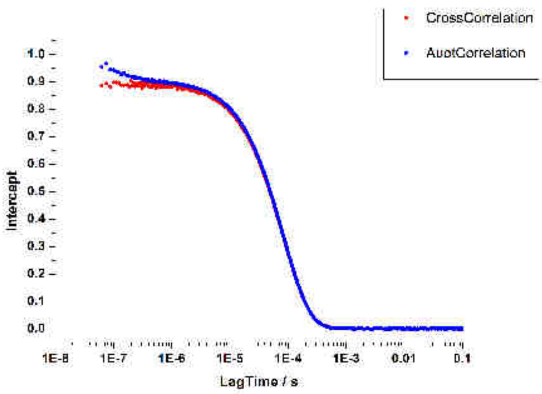

Figure 4: Comparison between cross-correlation and auto-correlation measurements. Courtesy of LS Instruments.

[1] *www.lsinstruments.ch*

Once the intensity correlation function is measured, the particle size can be calculated by fitting the data with mathematical models based on assumed particle size distributions [3].

Conclusion

ID Quantique's id100-MMF50 single photon detector is able to detect weak signals at the visible spectra with a time resolution of 40ps and 45ns dead time. The small influence of the after pulse rate is eliminated when performing cross-correlation dynamic light scattering (DLS) measurements.

The id100-MMF50 is an easy-to-use and self-contained detector that can be used for Dynamic Light Scattering (DLS) experiments and be implemented in commercial setups.

References

[1] P. Schurtenberger, and M. Newman, "Characterization of Biological and Environmental Particles using Static and Dynamic Light Scattering", In Environmental Particles, J. Buffle, H. van Leeuwen, Eds.; Lewis Publishers: Boca Raton, 1993, 37-115.

[2] T. G. Mason and D. A. Weitz, "Optical Measurements of Frequency-Dependent Linear Viscoelastic Moduli of Complex Fluids", Phys. Rev. Lett. 74 (1995), pp.1250-1253.

[3] F. Scheffold, "Particle Sizing with Diffusing Wave Spectroscopy", Journal of Dispersion Science and Technology, 23 (5) (2002), pp. 591–599.