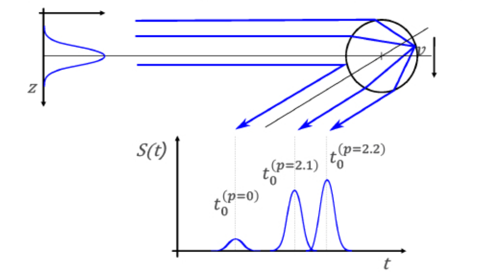
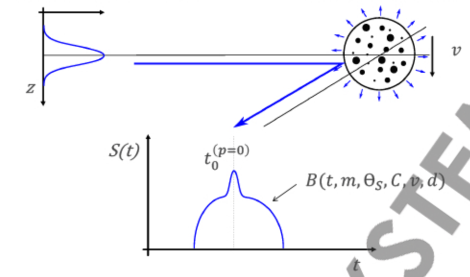
Time-Shift Technique Principles

AOM SYSTEMS
Advanced Optical Measurement Systems

Spray characteristics play an important role in a wide range of industrial applications, such as spray coating, spray drying and crop protection. Spray characterization methods are therefore essential tools for quality assurance, development and optimization of these processes.

Light scattering of a spherical drop passing through a focused laser beam





Scattering light from transparent particles can be interpreted as the superposition of all scattering orders present at the detector location:

$$S(t) = \sum_{\substack{p=0\\p=2.1\\p=2.2}} A_p(m,\Theta_S)\exp\left(-\frac{2\left(t-t_0^{(p)}\right)^2}{(w/v)^2}\right)$$

For suspensions, refracted light rays do not propagate undisturbed through the drop. The signal arising from this portion of scattered light is termed the baseline signal $B(t)$. The reflective signal remains unaltered:

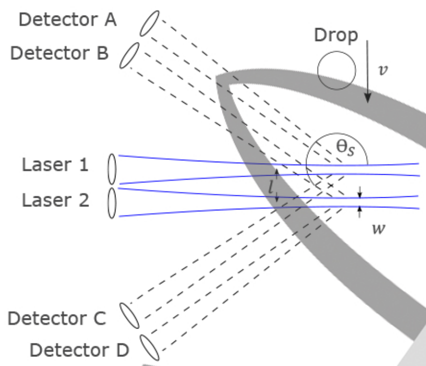
$$S(t) = A_{(p=0)}(m,\Theta_S)\exp\left(-\frac{2\left(t-t_0^{(p=0)}\right)^2}{(w/v)^2}\right) + B(t,m,\Theta_S,C,v,d)$$

Legend:

- $S(t)$ Time-shift signal
- $B(t)$ Baseline signal
- m Relative refractive index
- Θ_S Scattering angle
- Θ_i Incident angle
- A Amplitude
- p Scattering order
- w Laser beam width
- v Drop velocity
- d Drop size
- t Time
- t_0 Peak position
- C Concentration
- z Propagation direction

Principles of the Time-Shift technique

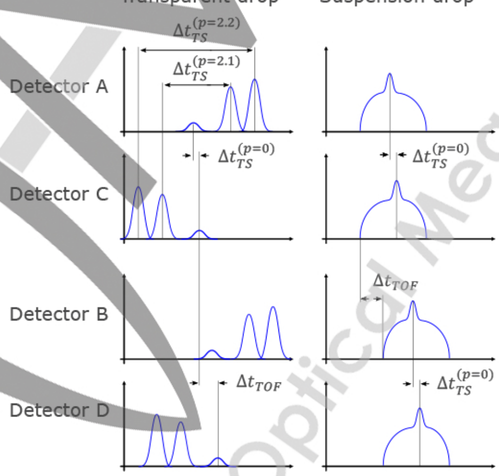
Schematic sensor setup, where the Time-of-Flight (*TOF*) and Time-Shift (*TS*) technique are combined:



TOF: Time difference between the signal at detector **A** and detector **B**. The same holds for detector **C** and detector **D**.

TS: Time difference between the signal at detector **A** and detector **C**. The same holds for detector **B** and detector **D**.

The scattered light is focused onto photo detectors. Each photo detector provides a time-shift signal:



Drop size and velocity are correlated with the time between individual scattering orders:

$$\Delta t_{TS}^{(p)} = \frac{d}{v} f\left(\Theta_i^{(p)}, \Theta_S, m\right)$$

$$\Delta t_{TOF} = \frac{l}{v}$$

Where the function f indicates the relative distance between incident points. The incident angle Θ_i is solved from:

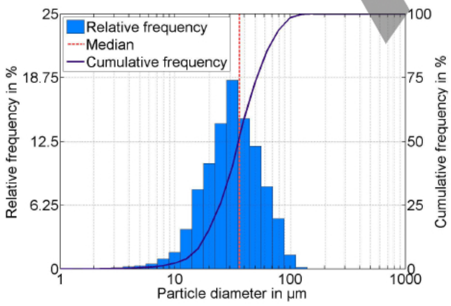
$$\sin\left(\Theta_i^{(p)}\right) = m \sin\left(\frac{\pi}{2p} - \frac{\Theta_S}{2p} + \frac{\Theta_i^{(p)}}{p}\right)$$

for $p \in [2, 4, 6, \dots]$

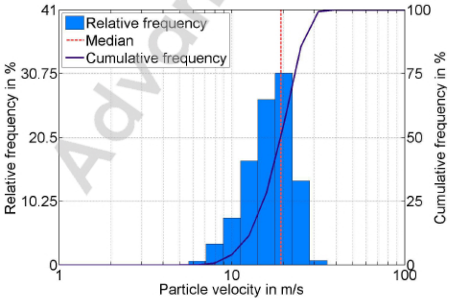
$$\sin\left(\Theta_i^{(p=0)}\right) = \cos\left(\frac{\Theta_S}{2}\right)$$

Measurement results

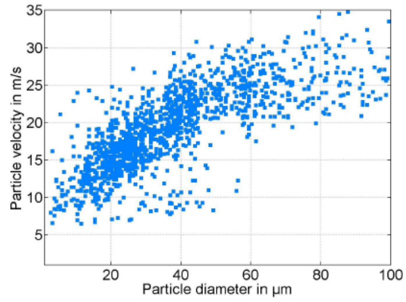
Particle diameter distribution



Particle velocity distribution



Diameter-velocity correlation



AOM-Systems GmbH
Benzstrasse 4

64646 Heppenheim
Germany

info@AOM-Systems.com
http://www.AOM-Systems.com

Tel: +49-(0)6252-98090-75
Fax: +49-(0)6252-69099-96