

DIFFUSING WAVE SPECTROSCOPY

OPTICAL MEASUREMENT OF PARTICLES MOBILITY



What is DWS ?

Diffusing Wave Spectroscopy is the dynamic Multiple Light Scattering measurement which records particles motion in a fluid. DWS is the Dynamic Light Scattering extended to opaque and concentrated media.



MS-DWS* Principle of Measurement

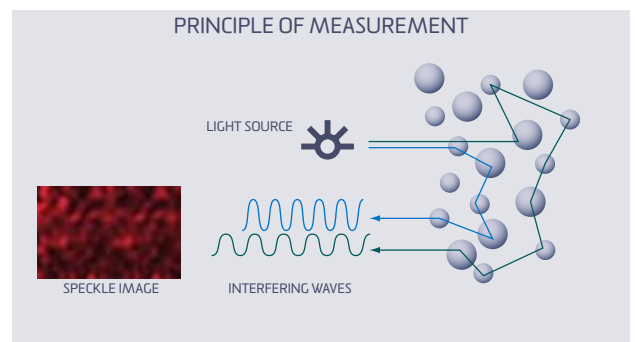
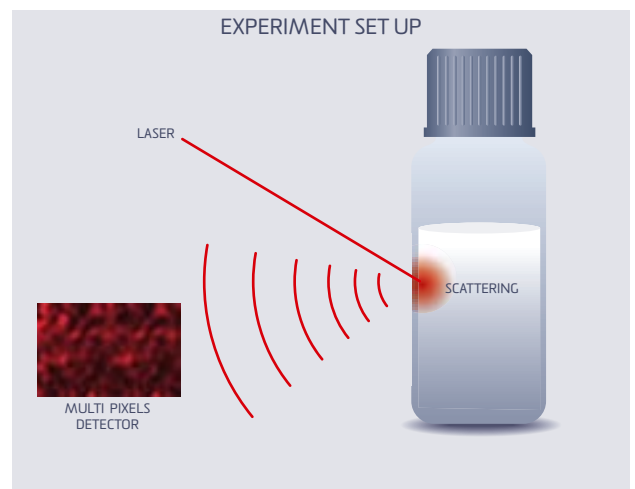
MS-DWS consists in sending a coherent laser light beam in a sample. The light is multi-scattered by the particles, which leads to interfering backscattered waves. An interference image called "Speckle image" is detected by a multi-pixels detector.

In a soft material, the thermal energy $k_B T$ leads to the motion of micron sized particles .

This Particle Brownian motion induces a deformation of the speckle image.

The multi pixel detector records the speckle pattern deformation to quantify the particle motion speed.

**Multi Speckle Diffusing Wave Spectroscopy*



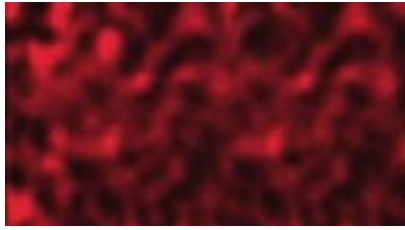
BENEFITS OF MS-DWS

- Works on opaque media
- Works on concentrated dispersions
- Sensitive to particle small displacement (from 1 to 100 nm)
- Access to micro-rheology parameters :
 - Viscosity
 - Elasticity
 - Relaxation time...



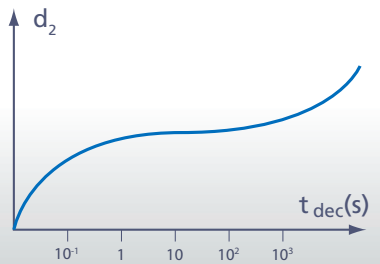
MS-DWS PROCESSING

SPECKLE IMAGE



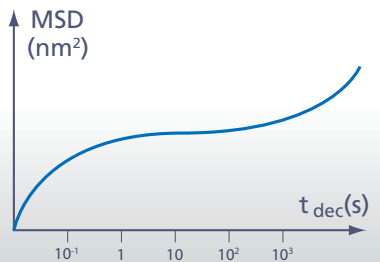
PATENTED ALGORITHM

DECORRELATION d_2
QUANTIFICATION OF PARTICLE SPEED



PATENTED ALGORITHM

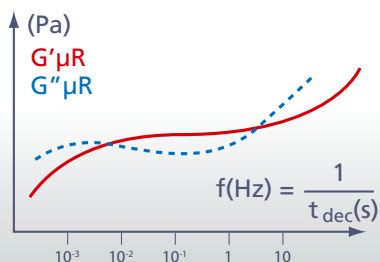
PARTICLE MEAN SQUARE
DISPLACEMENT
QUANTIFICATION OF PARTICLE
DISPLACEMENT



GENERALISED STOKES
EINSTEIN RELATION

$$\tilde{G}(s) = \frac{k_B T}{\pi a s \langle \Delta r^2(s) \rangle}$$

MICRO-RHEOLOGY
QUANTIFICATION OF VISCO-ELASTICITY



$\tilde{G}(s)$ = Shear modulus
 $k_B T$ = Thermal energy
 a = Particle radius
 s = Laplace frequency
 $\Delta r^2(s)$ = Laplace transform of MSD

$G' \mu R$ = Elastic modulus
 $G'' \mu R$ = Viscous modulus

...

MS-DWS AND MICRO-RHEOLOGY

Multi-speckle Diffusing Wave Spectroscopy microrheology (MS-DWS μ Rheology) is a recently introduced technique that greatly simplifies rheological measurements. No macroscopic deformation is applied to the sample. Instead, state-of-the-art optical techniques are used to measure the nanometer-scale motion of the sample constituents due to thermal energy. Rheological properties are deduced from this motion using a well-established formalism. Advantages of MS-DWS μ Rheology include:

- measurements in the linear regime
- no wall slip issues
- samples contained in standard glass vials
- no need to transfer the sample nor to clean the rheometer tools
- fast measurements that allow the sample evolution to be monitored

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PATENTED EXPERTISE

Formulation has developed innovative patented algorithms which enable to process the raw data decorrelation curve into sample end use properties like:

- Elasticity
- Viscosity
- Fluidity

MS-DWS APPLICATIONS

MS-DWS is a powerful multiple light scattering method to measure particle mobility. This technology is useful to analyse opaque and concentrated materials like concentrated emulsions, gels, polymers...

MS-DWS is used by:

- Rheolaser Lab to analyse the micro-rheology of soft materials
- Rheolaser Horus to characterise film forming products (coatings, varnishes, cosmetic films...)