

# DIFFUSING WAVE SPECTROSCOPY

## OPTICAL MEASUREMENT OF PARTICLES MOBILITY



### What is DWS ?

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



### MS-DWS\* Principle of Measurement

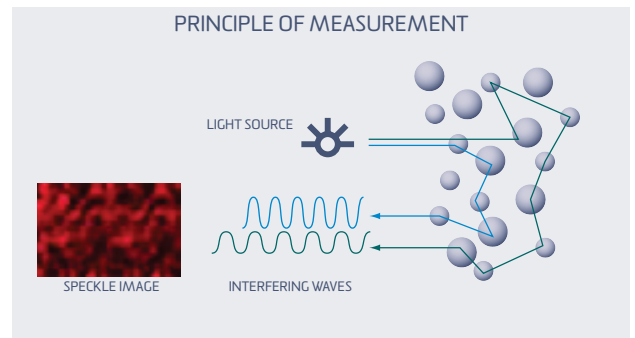
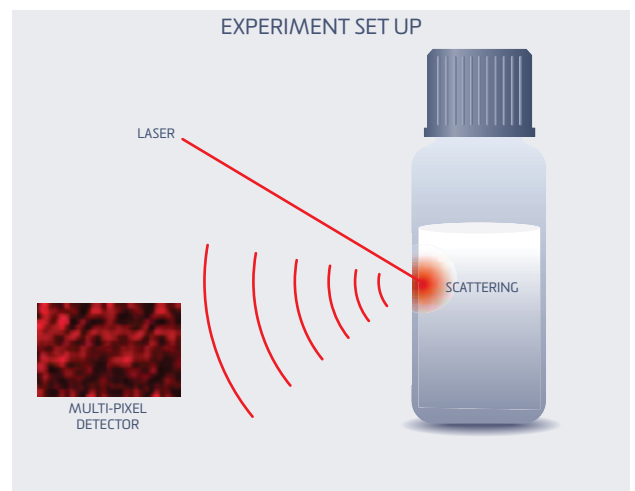
MS-DWS consists in sending a coherent laser light beam into a sample. The light is multi-scattered by the particles, which leads to interfering backscattered waves. An interference image called "Speckle image" is detected by a multi-pixel detector.

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

This Brownian motion induces a deformation of the speckle image.

The multi-pixel detector measures the speckle pattern deformation to quantify motion speed of the particle .

*\*Multi Speckle Diffusing Wave Spectroscopy*



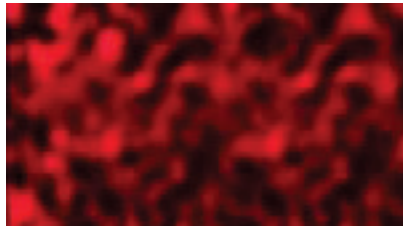
## BENEFITS OF MS-DWS

- Works on opaque and concentrated media
- Sensitive to small particle displacement (from 0,1 to 1000 nm)
- Access to microrheology parameters :
  - Viscosity
  - Elasticity
  - Relaxation time...



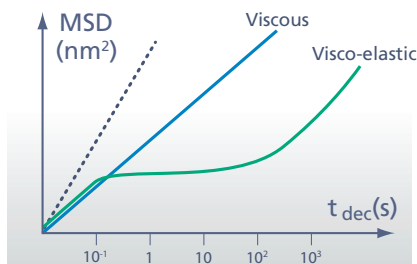
# MS-DWS PROCESSING

SPECKLE IMAGE



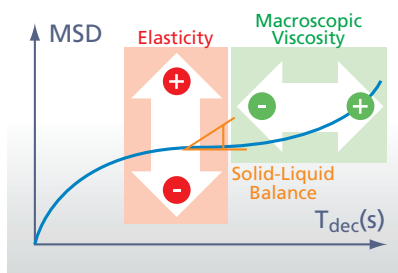
PATENTED ALGORITHM + CORRELATION FUNCTION

PARTICLE MEAN SQUARE DISPLACEMENT (MSD)



PATENTED ALGORITHM

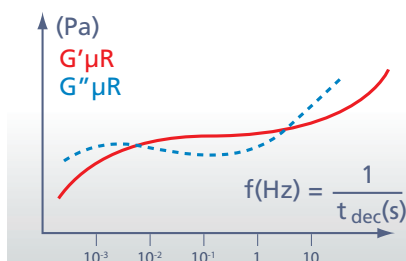
SLB, EI, MVI



GENERALISED STOKES EINSTEIN RELATION

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

MICRORHEOLOGY



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

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



## MS-DWS AND MICRORHEOLOGY

Multi-speckle Diffusing Wave Spectroscopy microrheology (MS-DWS  $\mu$ 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  $\mu$ Rheology include:

- measurements in the linear regime
- no wall slip issues
- samples contained in standard 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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## 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 microrheology of soft materials
- Rheolaser Horus to characterise film forming products (coatings, varnishes, cosmetic films...)