Dynamic Light Scattering

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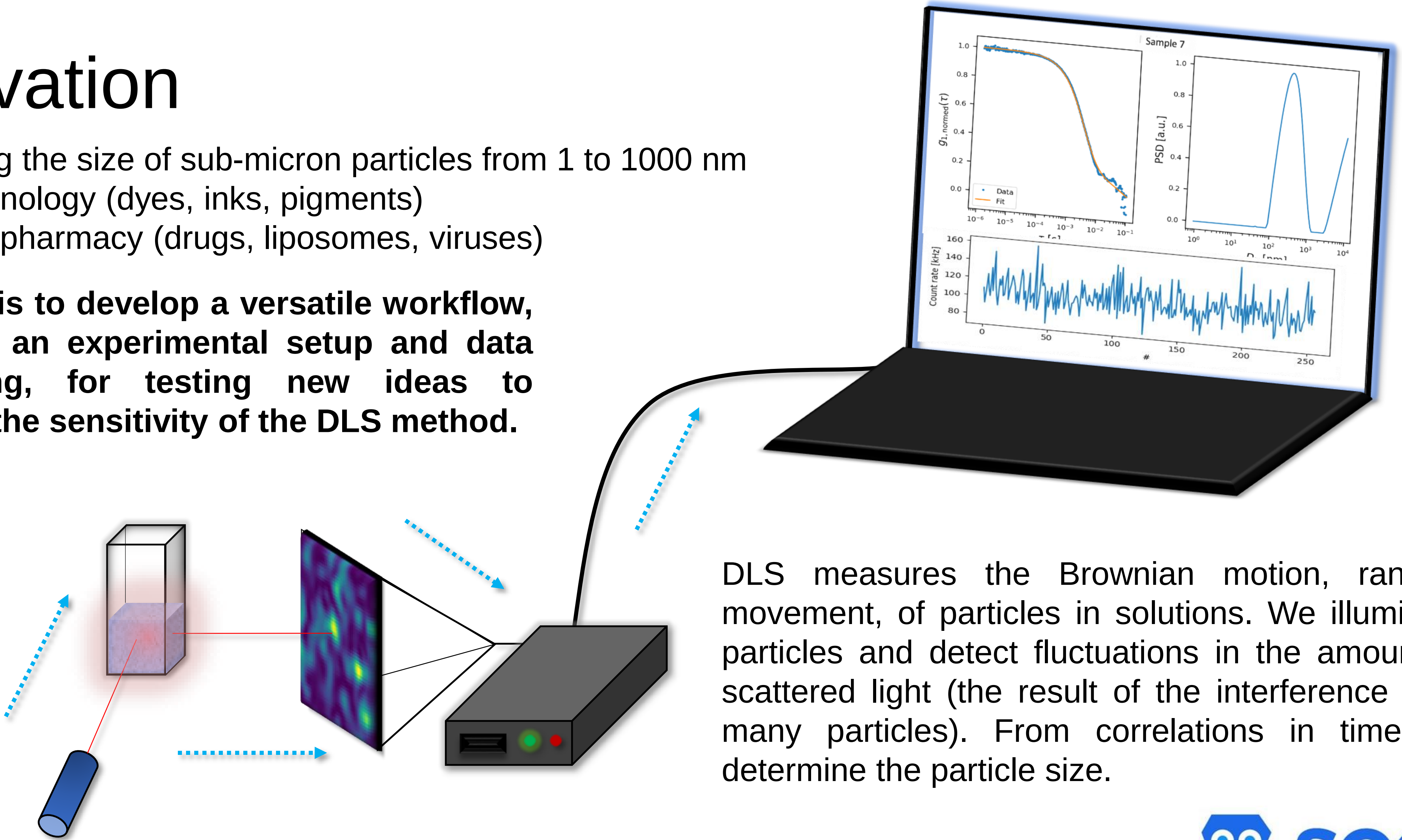
Abstract: We have developed an apparatus for analyzing nanoparticle size by the dynamic light scattering method (DLS). Unlike commercial devices, with our versatile apparatus, we can modify experimental and software workflow to improve functionality and increase the sensitivity of the method. The parameters reached in the current version of our apparatus are on par with a state-of-the-art commercially available DLS device.

Motivation

- Measuring the size of sub-micron particles from 1 to 1000 nm
- Nanotechnology (dyes, inks, pigments)
- Medicine/pharmacy (drugs, liposomes, viruses)

Our goal is to develop a versatile workflow, including an experimental setup and data processing, for testing new ideas to increase the sensitivity of the DLS method.



DLS measures the Brownian motion, random movement, of particles in solutions. We illuminate particles and detect fluctuations in the amount of scattered light (the result of the interference from many particles). From correlations in time we determine the particle size.

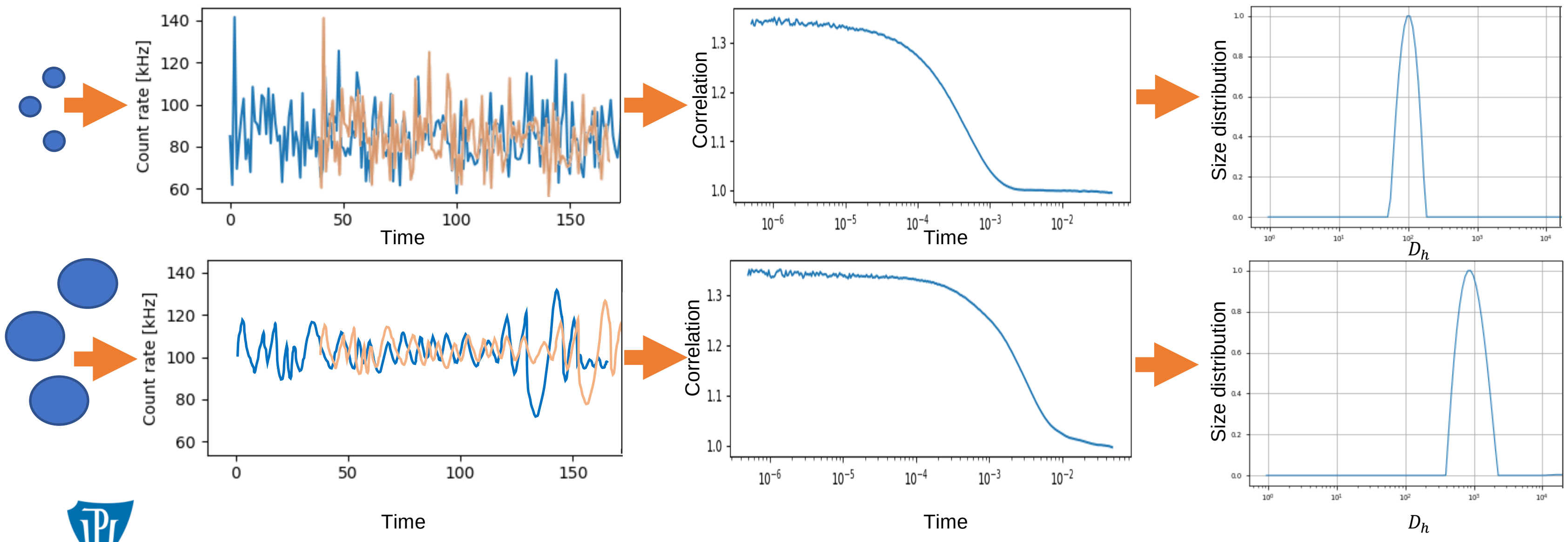
DLS Method

We compare scattered intensity after a variable time interval and create an autocorrelation function, which describes the similarity of compared signals decreasing in time (typically sum of negative exponentials).

Smaller particles diffuse quickly → more rapid fluctuations → compared signals decorrelates faster.

Bigger particles diffuse slowly → slower fluctuations → signals remain similar longer.

From the autocorrelation function, we extract diffusion coefficient D, which describes the movement of particles. With D, using the Stokes-Einstein equation, we determine hydrodynamic diameter (diameter of the sphere that diffuses at the same rate as the particle being measured), which relates to the particle size.



$$G_2(\tau) = \lim_{T\to\infty} \frac{1}{T}\int_0^T I(t)I(t+\tau)dt$$

Autocorrelation function

τ = *correlation time*

T = *measuring time*

$I(t)$ = *intensity at time* t

$I(t+\tau)$ = *intensity at time* $t+\tau$

$$D_h = \frac{kT}{3\pi\eta D}$$

Stokes-Einstein equation

D_h= *hydrodynamic diameter*

T = *absolute temperature*

k = *Boltzmann´s constant*

η = *viscosity*

D = *diffusion coefficient*

Results

Optimizations performed and discussed:

- Laser power and wavelength
- Collection aperture size
- Optical fiber core diameter and aperture

Comparison with ZetaSizer Nano ZS:

(9 samples with different particle size and concentration)

- 4 samples measured more accurately using our apparatus
- 3 samples on par
- 2 samples of high concentration measured less accurately using our apparatus, probably due to multiple scattering

Outlook:

- Multi-detector schemes
- Use of machine learning methods (neural networks)
- Analysis of complex samples with particles of different sizes
- Modulation of particles by ultrasonic waves or magnetic field → better sensitivity and selectivity

The developed experimental setup (scheme & photos).