Master 2 Internship

Title: Opto-rheology : using mechanical effects of light for investigating the local rheology of complex fluids at and out of equilibrium in soft matter

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Project: Soft materials and complex liquids are present everywhere around us, and nevertheless we continue to miss their rheological properties, particularly at small scale (microdroplets, cells, ink and paint drying to just give three examples). Even if many types of reliable rheometers exist for large scale materials, most of them fail in characterizing small and/or confined and/or out of equilibrium samples and do not allow catching the liquid complexity at a local scale, in particular close to boundaries or inside small soft objects. One of the classical limitations is related to the mechanical contact used to shear soft materials, which promote pollution, modify the local structure or even break fragile materials. To overcome these difficulties, we propose to implement a radically new optical strategy with nanometric resolution and based on optical radiation pressure, which is local, active, non-invasive and contactless [1].

The principle is the following. A pump laser beam impinging the surface of a film or a drop exerts a normal stress called radiation pressure which deforms the liquid surface. The final shape results from the balance between radiation pressure ($\Delta nI/c$, Δn index contrast, $I=2P/(\pi w^2)$ laser intensity), Laplace pressure (γC, γ surface tension, C curvature ~ h/w^2), buoyancy ($\Delta\rho gh$ often negligible at small scale) and possibly elasticity; typically, with P=1W, $\Delta n=0.5$ and $\gamma=10\text{-}100$ mN/m, the height of the interface deformation is h=10-100 nm, and even smaller for more realistic index contrast Δn. The surface tension γ is deduced from the stationary amplitude of the interface deformation and the viscosity η from its dynamics (viscous velocity γ/η). We propose to probe the nanometer-scale deformation by interferometry (1 nm resolution) opening a new route for investigating any sort of confined Newtonian or viscoelastic fluid up to soft elastic materials (such as natural gels), textured or not as thin films or microdrops, even in presence of weak absorption and scattering, and possibly out of equilibrium.

Indeed, as a single measurement takes around 100 ms, the goal of the proposed M2 internship, is to demonstrate the efficiency of this optical approach to describe an almost uncovered situation, the out-of-equilibrium rheology of drying inks and paints, including visco-elasticity at very small scale, since rheology plays a major role in the quality of the covering and its properties. Considering the novelty of this contactless optical approach for investigating complex fluid properties at small scale and out-of -equilibrium, we plan developing this work within the frame of a PhD

[1] Verma, G., Chesneau, H., Chraïbi, H., Delabre, U., Wunenburger, R., & Delville, J. P. (2020). Contactless thin-film rheology unveiled by laser-induced nanoscale interface dynamics. Soft Matter, 2020, 16, 7904-7915; https://doi.org/10.1039/D0SM00978D