PROPOSITION DE STAGE M2 Recherche

Titre: **Opto-Rheology : using mechanical effects of light for investigating the local rheology of complex fluids and soft matter**

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Résumé:

Soft materials and complex liquids are present everywhere around us: they compose our building blocks (from cells to tissues), they feed us (food texture) and they accompany us in our everyday life (hygiene products); and nevertheless we continue to miss their rheological properties, particularly at small scale (in presence of strong confinement or in cells, just to give two examples). How they flow or deform is often unclear while this remains essential for understanding transport at these scales. Even if many types of reliable rheometers exist for large scale rheology of materials, most of them fail in characterizing small and/or confined 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. In order 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, and allows for the first time in situ investigations of the rheology of Newtonian and non-Newtonian fluids from bulk to confined or enclosed micrometric volumes such as drops, thin soft films, shells and possibly cells.

The principle is the following. A pump 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 ($\sim \Delta n I/c$, Δn index contrast, $I=2P/(\pi w^2)$ laser intensity), Laplace pressure (γC, γ surface tension, C curvature $\sim h/w^2$), buoyancy ($\Delta\rho g h$ negligible at small scale) and possibly elasticity; typically, with P=1W, $\Delta n=0.5$ and γ=10-100 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 (velocity γ/η).

We propose in this project to probe the nanometer-scale deformation by interferometry (around 1 nm resolution) opening a new route for investigating any sort of confined Newtonian or viscoelastic fluid (except dark ones!) up to soft elastic materials (such as natural gels), textured or not as thin films or small drops (down to the beam size), even in presence of weak absorption.

The goal of the proposed M2 internship, is to extend preliminary works on thin Newtonian liquids films to viscoelastic and elastic soft materials such as gels (PAAM or natural one like alginate and agarose). Considering the novelty of this contactless optical approach, we plan developing this work within the frame of a PhD along three main directions: (i) the local characterization always difficult of thermal (heating, thermocapillarity) and concentration effects (solutal Marangoni) on interfaces, (ii) the investigation of turbid liquids and cell solutions for laser bioprinting, and (iii) the measurements of extremely low interfacial tensions ($\gamma \sim 10^{-6}$-10^{-9} N/m) for enhanced oil recovery.