Non-contact mechanics of soft and liquid interfaces by hydrodynamic confinement using a frequency-modulated AFM

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Measuring the mechanical response of liquid interfaces without direct contact remains a major experimental challenge, particularly in liquid-liquid systems where no solid reference exists. Here, we develop a frequency-modulation atomic force microscopy (FM-AFM) method that probes liquid interfaces through the hydrodynamic confinement of a viscous liquid film between an oscillating probe and the interface. This approach provides simultaneous access to the in-phase and dissipative components of the effective mechanical response under confinement.
Initially, the method is validated on a liquid-solid interface, where the measured confinement thickness and the evolution of the mechanical impedance are consistent with elastohydrodynamic theory over nearly one decade in elastic modulus. It is then applied to a liquid-liquid interface, which exhibits a predominantly viscous response with a finite in-phase contribution and a confinement thickness in the micrometric range. These results show that hydro-dynamic confinement provides a sensitive, non-contact approach to compare the mechanical response of soft and liquid interfaces, and opens perspectives for investigating complex and highly deformable systems such as polymer films, biological membranes, and rafts of nanoparticles.