Probing Visco-elastic Properties of Biological Cells by Oscillatory Optical Tweezers
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Abstract:
Mechanical stresses on biological cells change not only the cell’s morphology, but also cell cycle, gene expression, and protein production in many biological systems; in general, the stress-strain relationship of biological cells depends on the mechanical integrity of the cells and the interaction of the cell with the extra-cellular matrix. For example, the mechanical influences are transmitted into biochemical signal pathway of Src proteins which correlate with the cytoskeleton on epithelial cells [1].

In this work, we probed the visco-elasticity of individual epithelial cells by optical trapping and optical forced oscillation of a submicron endogenous intracellular organelle. The experimental setup is shown in Fig. 1 (a). The storage and loss moduli (G' and G'') as a function of frequency, as shown in Fig. 1(b), were determined via the following two Eqs [2]:

\[
G'(\omega) = \frac{k(\omega)}{6\pi a} \frac{k_{OT}}{6\pi a} \left( \frac{A \cos \delta(\omega)}{D(\omega)} - 1 \right)
\]

\[
G''(\omega) = \frac{\omega \eta(\omega)}{6\pi a} \frac{k_{OT}}{D(\omega)} \left( \frac{A \sin \delta(\omega)}{D(\omega)} \right)
\]

where \(a\) is the particle radius, \(A\) is the amplitude of the oscillatory trapping beam, \(k_{OT}\) is the optical spring constant, \(D\) is the oscillating amplitude of the trapped particle, and \(\delta\) is phase shift of trapped particle relative to the phase of the oscillating tweezers. Optical trapping and oscillation of endogenous organelles allows us to probe both the steady-state and the dynamics of the intracellular mechanics.

![Fig. 1: (a) A schematic diagram of the experimental setup; (b) the storage and loss moduli G' (represented by “x”) and G'' (represented by “□”) as a function of frequency.](image)
