P-2.58

Detecting Nano-scale Height Displacements of Single Cells Using Optically Trapped Nanomotors

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Nanometer-scale movements within living cells arise from essential biological processes such as cytoskeletal remodeling and organelle interactions, serving as key indicators of cellular viability and function. Traditional methods that assess nanoscale motions at the whole-cell level often reduce these complex movements to indistinct noise, obscuring their origins and dynamics. Here, we introduce a high-resolution, non-invasive method using light-driven, rotating gold nanorods (nanomotors) in a 2D optical trap to detect height fluctuations of the cell membrane. As the nanomotor is optically trapped against the cell surface, cellular nanoscale movements induce z-axis displacements, detected as changes in its rotation frequency. This allows us to track height fluctuations as small as 10 nanometers over targeted membrane regions, with temporal resolution down to 2.5 ms. Our technique reveals distinct motion patterns across sub-cellular regions of endothelial cells, offering a new approach for real-time, high-precision analysis of cellular mechanics in both physiological and pathological contexts.