NEAR-INFRARED LIGHT-DRIVEN NANOMOTORS
Toward Ballistic Transport of Medicaments Across the Cell Membrane

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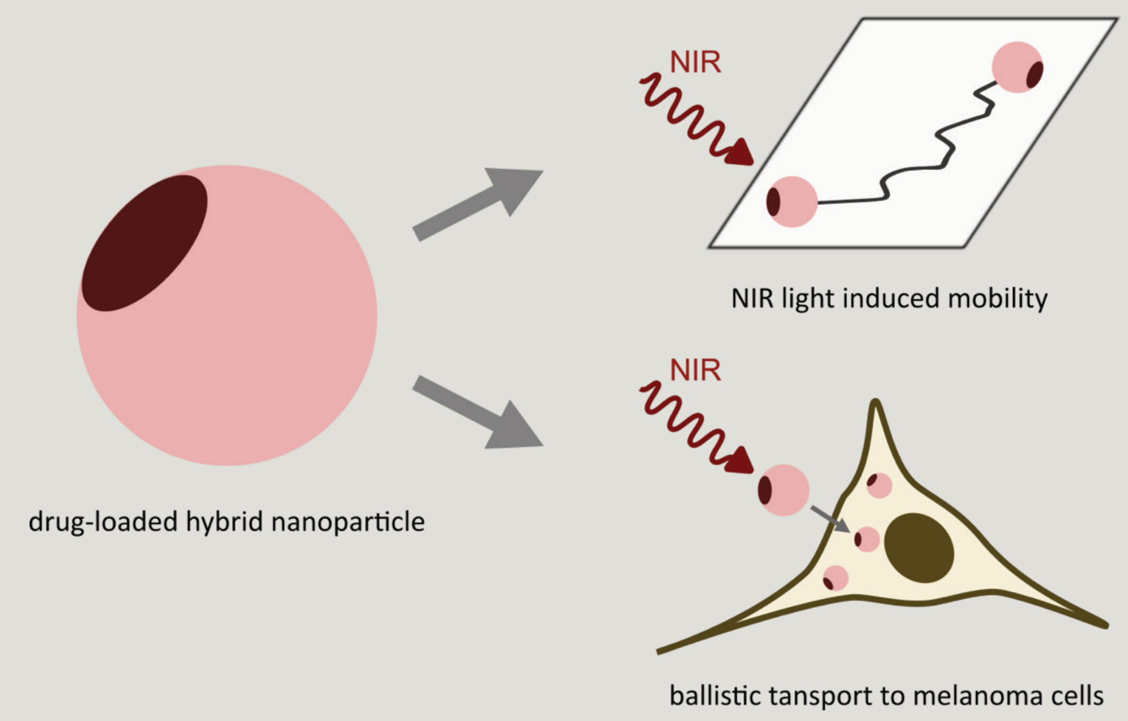
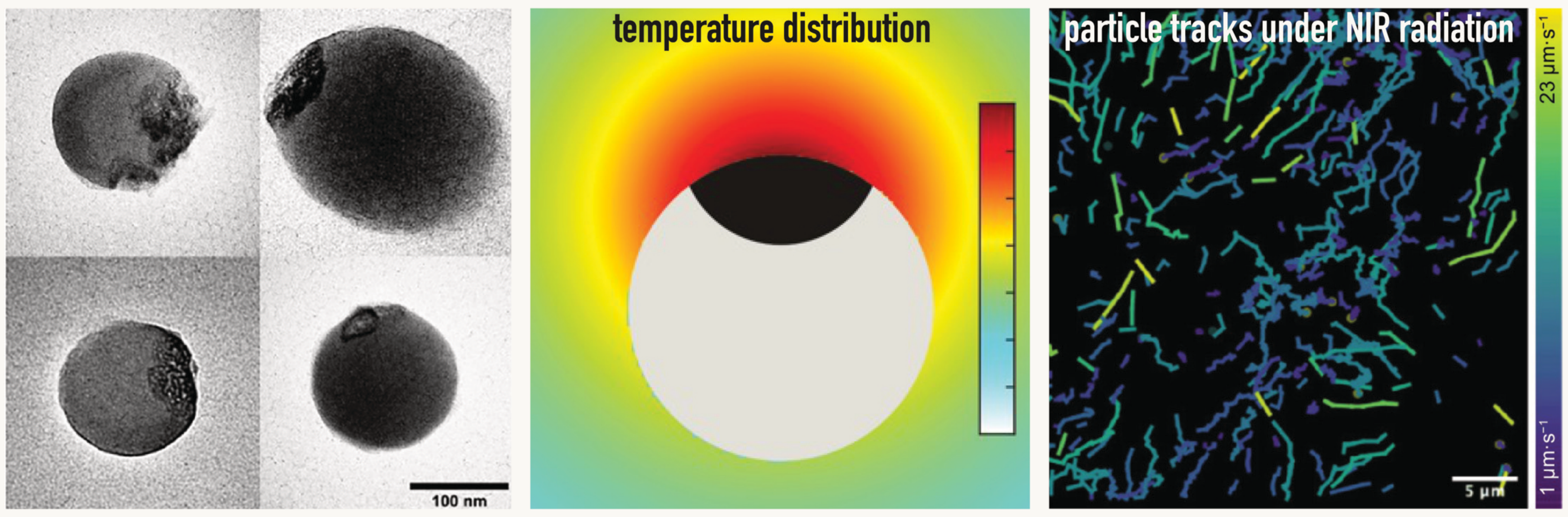
The roadmap

Nanotechnology-based drug or gene delivery relies on internalization of molecular cargo in cells via nanosized carriers. However, external material is typically taken up via clathrin- or caveolae-mediated endocytosis, leading to localization of nanoparticles within lysosomes upon internalization. This endo-lysosomal pathway typically results in degradation of molecular cargo, rendering delivery inefficient and inducing cell toxicity and death. We present a strategic framework to address this challenge by introducing an innovative method that utilizes near-infrared (NIR) light-driven nanomotors for the ballistic transport of molecular cargo across cellular membranes

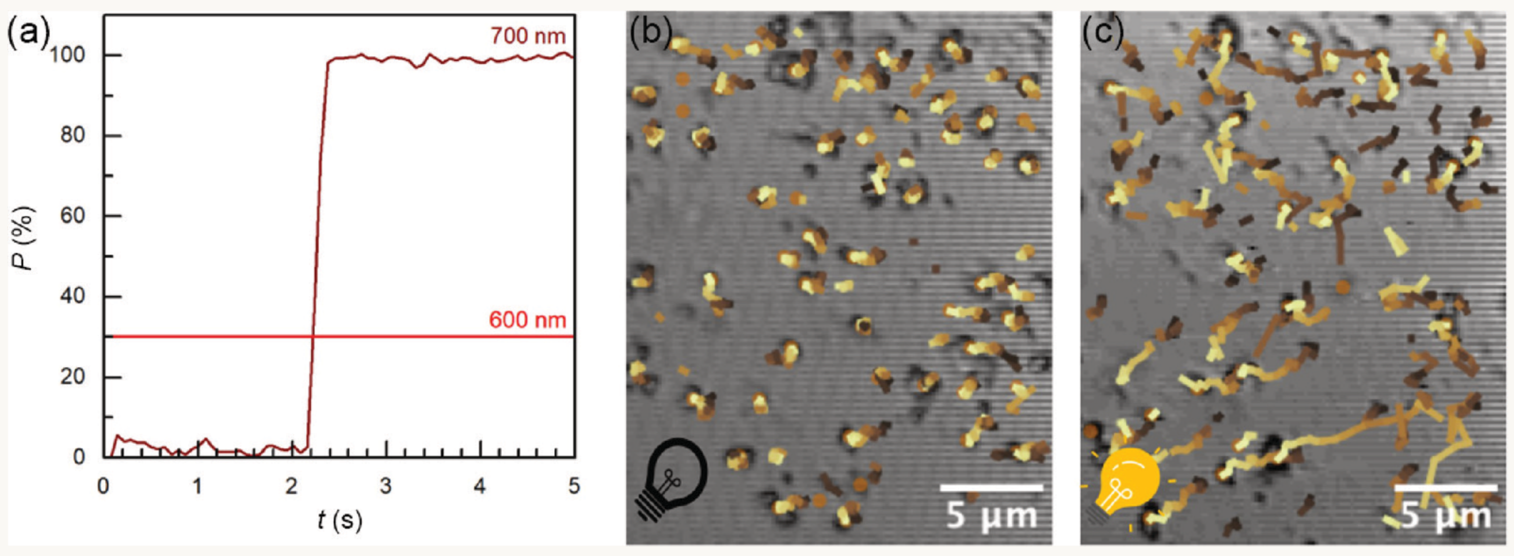


NIR LIGHT-DRIVEN PHOTOTHERMAL NANOMOTORS

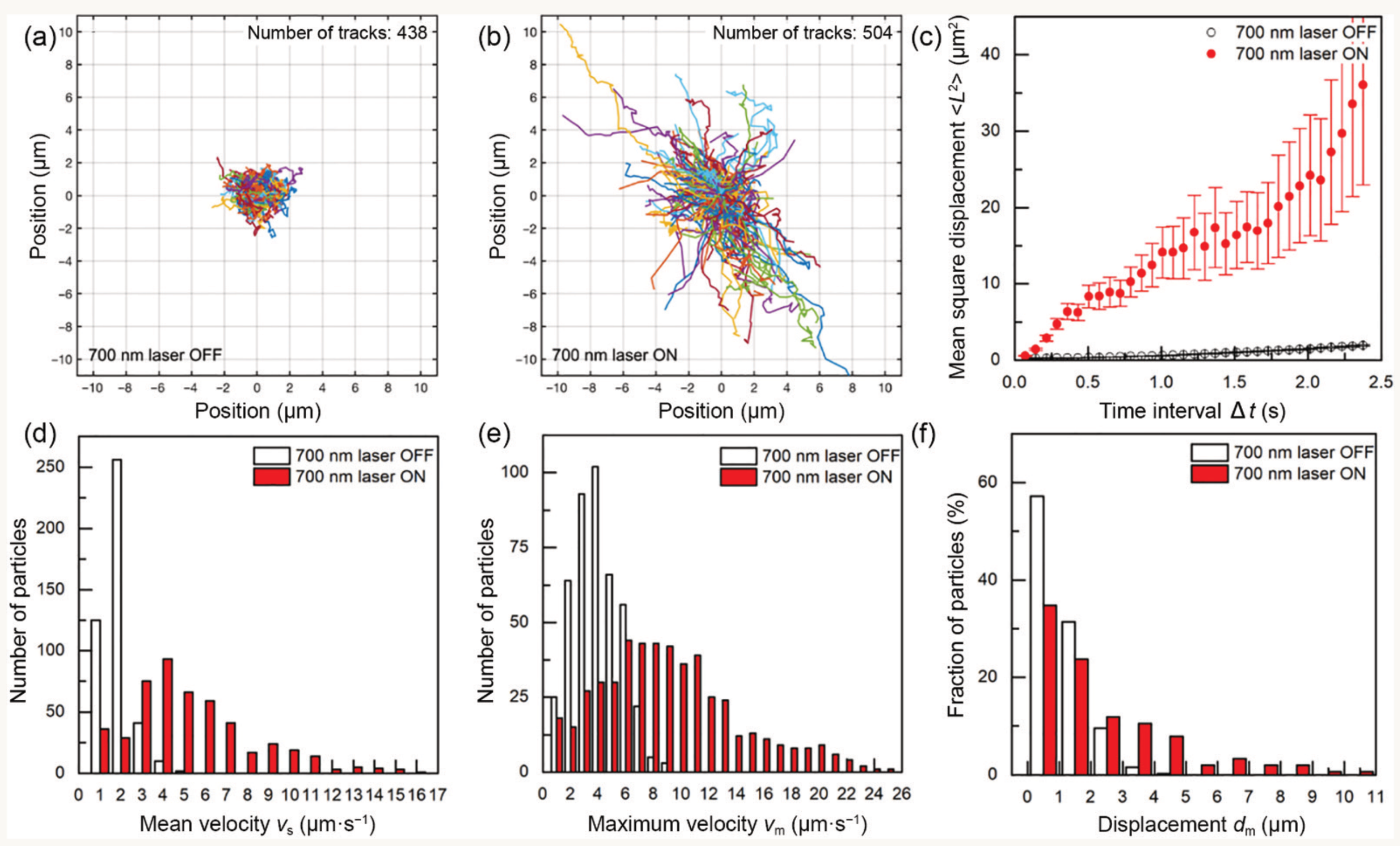
NIR light-driven nanomotors rely on the asymmetric photothermal heating of spatially anisotropic hybrid nanoparticle, composed of two spatially separated and structurally different components: photothermal component and functional component. In photothermal nanomotors the absorption cross section of the photothermal component is several orders of magnitude larger than of the functional component. This results in local increase in the ambient temperature on one side of the particle, which generates its propulsion due to thermophoretic forces. The functional component is a non-absorbing material which can be used to carry molecular cargo of biomedical interest, such as fluorescent dyes, drugs, genetic materials, or antibodies, without the risk of thermal degradation.



PARTICLE MOBILITY ANALYSES

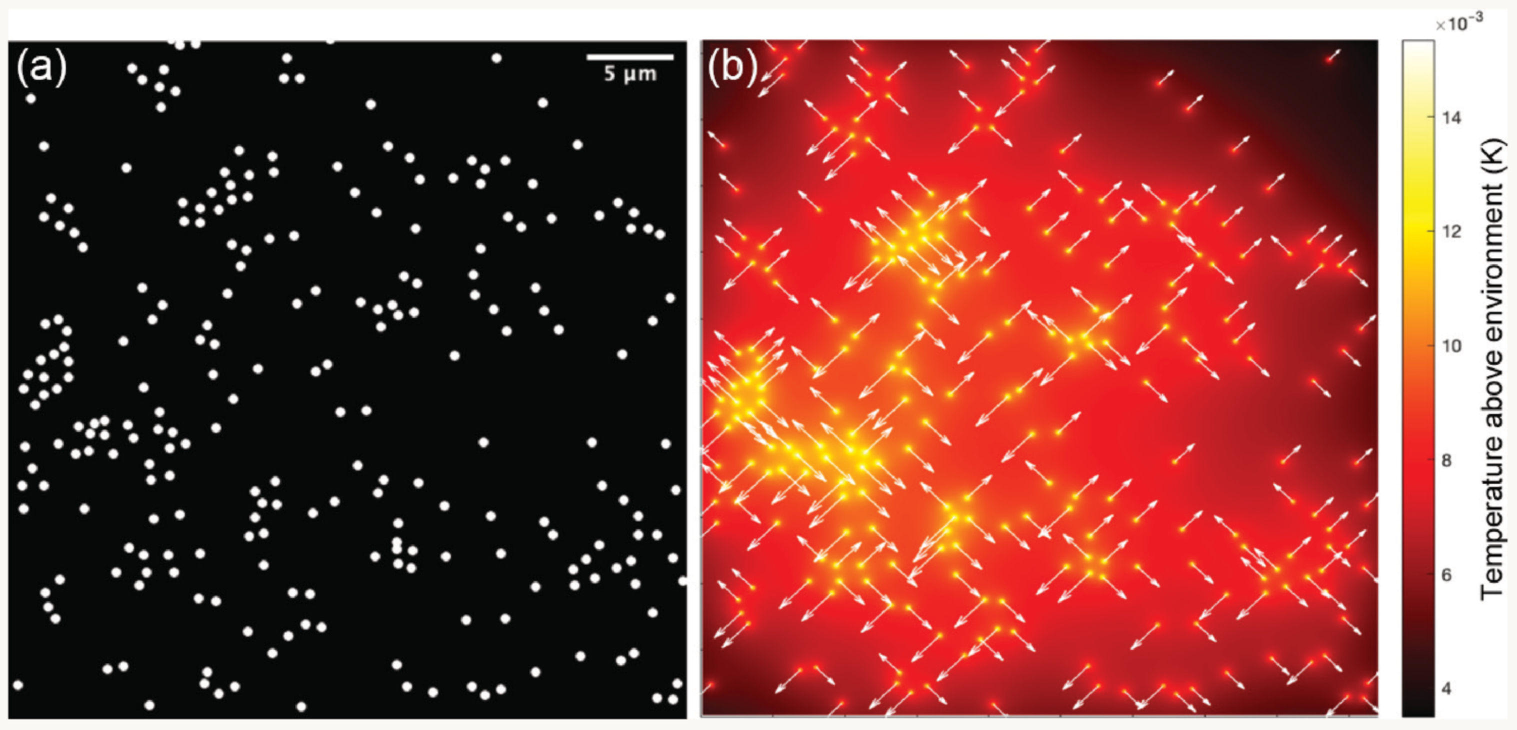


(a) Experimental conditions used in nanomotor motion studies. The trajectories of Ag-Ag_2S/TiO_2 nanomotors (b) before and (c) after application of 700 nm driving light.



Mobility analyses of Ag-Ag_2S/TiO_2 nanomotors upon continuous irradiation with 700 nm NIR laser light of 2.42 W·cm^{-2} power density.

In our recent study, we developed a novel type of NIR light-driven photothermal nanomotors composed of low-cost photothermal (Ag-Ag_2S) and functional (TiO_2) components. The mobility of the nanomotors was studied by CARS microscopy using dual light source. It is found that the nanomotors traverse distances up to 50 times their size. Motion analysis reveals that their maximum velocity reaches 20 μm·s^{-1}, or about 100 particle diameters per second. Our calculations indicate that the difference in absorption cross-sections at 700 nm between Ag-Ag_2S and TiO_2 components generates a temperature gradient along the nanomotor, which in turn drives its motion. The local temperature rise near the nanomotors is a result of both photothermal effects within individual nanoparticles and thermal interactions between them..



Simulation of collective photothermal effects in a system of Ag-Ag2S/Ti02 nanoparticles: (a) The observed spatial configuration of the nanoparticles just before 700 nm laser activation. (b) The map of local increase in the ambient temperature calculated for the Ag-Ag_2S component of the hybrid nanosystem. The arrows indicate calculated particle velocities.

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