Light-Driven Aggregation of Microparticles via Negative Thermophoresis

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The coupling between electrokinetic phenomena and thermal gradients offers a largely unexplored route to control collective behavior in particle-based systems. When suspended particles strongly absorb light, localized heating at the particle level can generate self-induced temperature gradients in the surrounding electrolyte, giving rise to thermophoretic interactions that are absent under uniform thermal conditions.

Here we demonstrate a laser-driven aggregation process in aqueous suspensions of hybrid polystyrene–magnetite microparticles, governed by electrokinetically mediated uphill (negative) thermophoresis arising from particle-induced thermal gradients. Upon laser irradiation, light absorption by individual magnetic microparticles leads to localized heating of the electrolyte solution, producing temperature gradients that drive neighboring particles toward the irradiated region and result in the formation of a dense and dynamic aggregate.

The aggregation process is fully reversible and can be switched on and off by controlling the laser irradiation. By quantifying the cluster growth dynamics, we show that the strength of the effective attraction is strongly modulated by the electrolyte concentration. Increasing salt concentration progressively weakens the aggregation and eventually suppresses it, consistent with a reduction of the Soret coefficient at high ionic strength due to electrokinetic screening effects.

Beyond reversible aggregation, we identify a regime in which laser-induced thermophoretic forces drive the system toward a well-defined steady-state cluster size. These results highlight the central role of particle absorption and electrolyte-mediated thermophoresis in shaping nonequilibrium assembly pathways, and clearly distinguish the observed behavior from conventional optical trapping or equilibrium assembly mechanisms.

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Thermophoresis, aggregation, optofluidics

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