From Light to Motion: IR-Driven Actuation in Adaptive Lanthanide MOF Crystals

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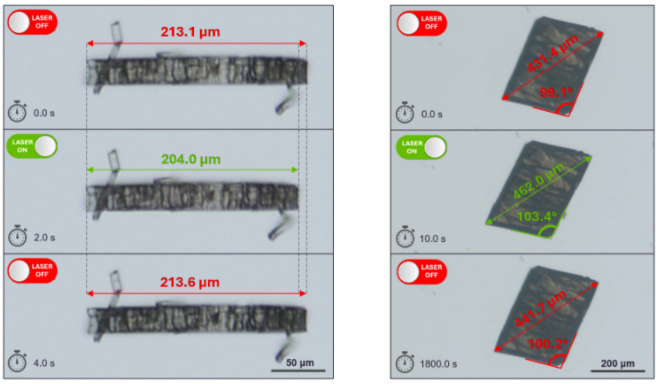
Dynamic crystalline materials represent a class of out-of-equilibrium systems capable of converting external stimuli into mechanical motion at the microscale. Such systems are of growing interest within active matter and soft materials communities due to their ability to couple energy dissipation with structural transformations and mechanical responses. [1,2]
Metal-Organic Frameworks (MOFs) are porous crystalline materials that have demonstrated structural and morphological flexibility. [3-7]
Here, we report light-driven actuation in a class of flexible metal–organic frameworks (MOFs) acting as stimuli-responsive crystalline micro-actuators. Upon irradiation with low-power infrared light (~100 mW) (Figure), these materials undergo reversible structural transformations that result in mechanical responses at the micrometer scale, including crystal contraction, morphology changes, and rotational or jumping motions.
The actuation is enabled by efficient photothermal conversion within the framework, arising from IR absorption at lanthanide-based coordination nodes. The resulting localized heating triggers a phase transition responsible for the observed mechanical motion. Importantly, incorporation of additional lanthanide dopants introduces upconversion-mediated energy transfer pathways, enhancing non-radiative relaxation processes and enabling actuation at reduced IR power densities.
These light-induced transformations are spatially addressable, reversible over multiple cycles, and stable over extended time scales. The coupling between optical excitation, local thermal gradients, and mechanical response is supported by in situ structural characterization under irradiation.
Overall, this work establishes MOF-based crystalline materials as a versatile platform for light-driven adaptive matter systems, bridging photothermal effects, phase transitions, and microscale mechanical actuation, with potential applications in soft microrobotics and remotely controlled adaptive materials.

Keywords:
Stimuli-responsive materials, Active matter, Light-driven actuation, Adaptive materials



Optical microscopy images of lanthanide-based Metal-Organic Frameworks with and without IR laser irradiation.

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