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Experimental Demonstration of Information-to-Energy Conversion in Small Fluctuating Systems

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What is the relation between information and thermodynamics has been a long standing question in science. In 1867, J.C. Maxwell proposed a Gedanken experiment to demonstrate violation of the second law of thermodynamics by assuming a small creature called Maxwell's demon which separates hot atoms from cold atoms. In 1929, L. Szilard formulated the idea of Maxwell for a more tractable setup in which a single particle is thermally moving in a box immersed in a heat bath. He succeeded to relate information entropy and the second law of thermodynamics in this Gedanken experiment. It had led to long and intense debates on the relation among thermodynamics, information, observation, and even computation until it was clarified recently. Nevertheless, experimental realization of information-energy-conversion has been elusive. Recently, we succeeded to demonstrate the information-energy-conversion by observing Brownian motion of colloidal particles and controlling them. We introduced a feedback control protocol based on the information of Brownian particle by electric fields and found that the particle rotates against the torque exerted by an external electric field and obtains free energy larger than the amount of work performed on it. By measuring detailed process, validity of a new nonequilibrium equality concerning the feedback control has been shown. Efficiency of information-energy conversion was evaluated in this feedback system. Moreover, I will discuss on possible generalization of this cocept to information processing in cell chemotaxis.

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