Hydrodynamic ratchets: Feedback control of polymer motion in alternating Poiseuille flows inside microchannels

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In analogy to Brownian ratchets, hydrodynamic ratchets should be able to exploit fluctuating hydrodynamic flows and convert them into steady translational motions of microscopic objects. Here, we demonstrate this effect through numerical simulations of a model microfluidic system which consists of a polymer in a narrow fluid channel. Inside the channel, a Poiseuille flow with periodically alternating directions is externally created. In absence of control, the polymer in such a flow is periodically dragged in both directions and no translational motion is observed. In the considered model, the control is introduced by switching on and off a transverse force which acts on the polymer and, when present, brings it to the channel's bottom. The feedback is implemented by assuming that this force depends on the direction of polymer motion along the channel: when the polymer moves in the right direction, the force is absent, but once the direction of polymer motion is reversed, the force is switched on. The simulations are performed by using the multiple-particle collision dynamics for the fluid; they take into account hydrodynamic flow fluctuations. The polymer is modeled as a semi-flexible elastic chain. As we show, such model system can operate as a hydrodynamic ratchet, so that, on the average, the polymer proceeds to move along a definite flow direction selected by feedback control.