Brownian particle moving in a back-and-forth traveling periodic potential subjected to a temporal external excitation

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The physical properties characterizing the directed ratchet transport of a driven overdamped particle subjected to a back-and-forth periodic potential [1] are explained theoretically from the degree-of-symmetry-breaking mechanism [2, 3] and confirmed by numerical experiments. We demonstrate that the universality scenario holds regardless of the waveform of the periodic vibratory excitations involved, while optimal directed ratchet transport occurs when their impulse transmitted (temporal integral over a half-period) is maximum.

Remarkably, we find that the present universality scenario remains effective even when the external periodic excitation is substituted by a chaotic signal having the same underlying main frequency in its Fourier spectrum. Specifically, we investigate the directed ratchet transport of a driven Brownian particle moving in a back-and-forth traveling periodic potential described by the overdamped model

$$\dot{x} + \sin\left[x - \gamma\eta f\left(t\right)\right] = \sqrt{\sigma}\xi\left(t\right) + \gamma\left(1-\eta\right) g\left(t\right), \quad (1)$$

where $f(t)$ is a $(2\pi/\omega)$-periodic function, $g(t)$ is a temporal signal having its main Fourier component at the frequency 2ω, γ is an amplitude factor, and the parameters $\eta \in [0,1]$ and φ account for the relative amplitude and initial phase difference of the two temporal signals, respectively, while $\xi\left(t\right)$ is a Gaussian white noise with zero mean and $\langle \xi\left(t\right)\xi\left(t+s\right)\rangle = \delta\left(s\right)$, and $\sigma = 2k_{\mathrm{B}}T$ with k_{B} and T being the Boltzmann constant and temperature, respectively. Figure 1 shows an illustrative example for the standard case where $f\left(t\right)$ and $g\left(t\right)$ are harmonic functions.

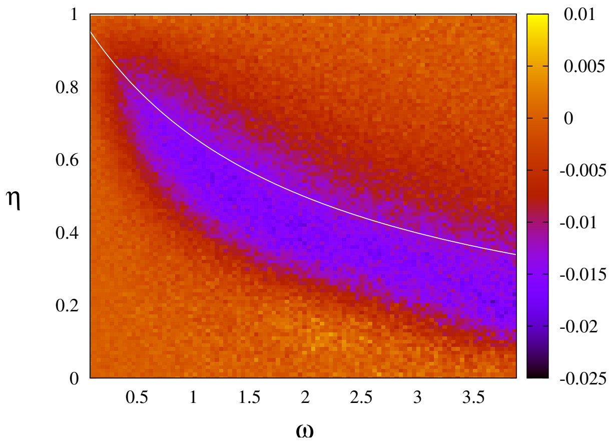

Fig. 1. Average velocity $\langle\langle \dot{x}\rangle\rangle$ *versus* relative amplitude η and frequency ω for the case $f\left(t\right) \equiv \cos\left(\omega t\right)$, $g\left(t\right) \equiv \cos\left(2\omega t+\varphi\right)$, and the parameters $\varphi = 0, \sigma = 10, \gamma = 15$. Also plotted is the theoretical prediction for the maximum average velocity (solid line).

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