Driven quantum harmonic oscillators: A working medium for thermal machines

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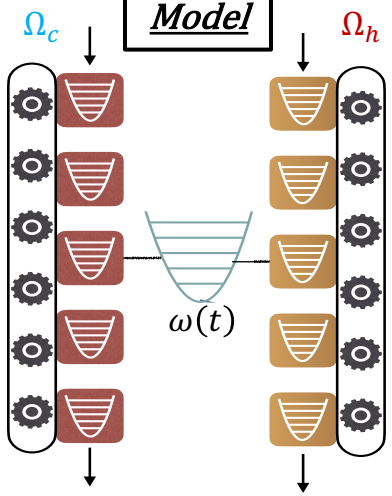
Model



Oscillating driving:
$\omega(t) = \omega_0 + \delta\omega \sin(\theta t)$

Thermodynamics

*For **SLOW** driving:*

$$\dot{Q}_c(t) = \Omega_c \bar{g}(n_c - n_h)$$
$$\dot{Q}_h(t) = \Omega_h \bar{g}(n_h - n_c)$$

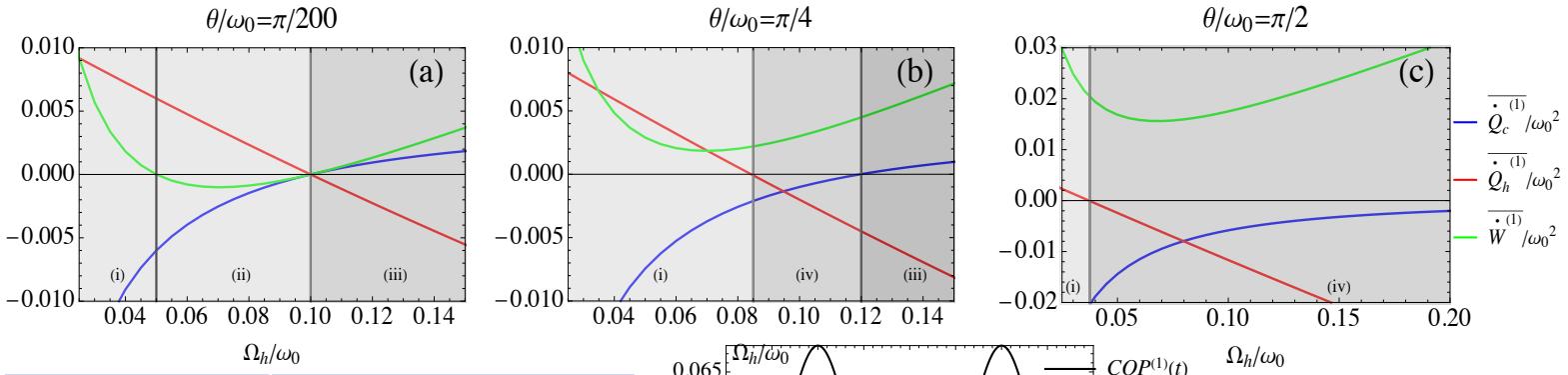
$$\dot{W} = \bar{g}(\Omega_c - \Omega_h)(n_h - n_c) + \frac{2n+1}{2}\dot{\omega}(t)$$

Dynamics

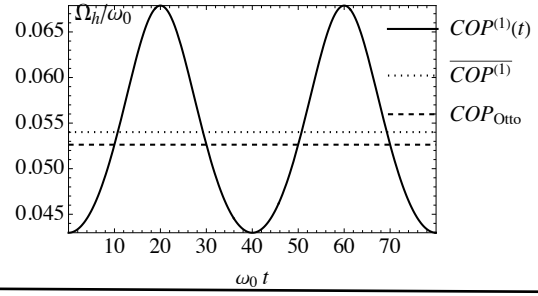
$$\dot{\rho}_S = -i[H_S(t), \rho_S(t)] + \gamma\bar{n}\left(a^\dagger \rho_S a - \frac{1}{2}\{aa^\dagger, \rho_S\}\right) + \gamma(\bar{n}+1)\left(a\rho_S a^\dagger - \frac{1}{2}\{a^\dagger a, \rho_S\}\right)$$

Result 1

Increasing driving speed θ ⇒ larger injection of power ⇒ heat flows from system into both baths (dissipator)

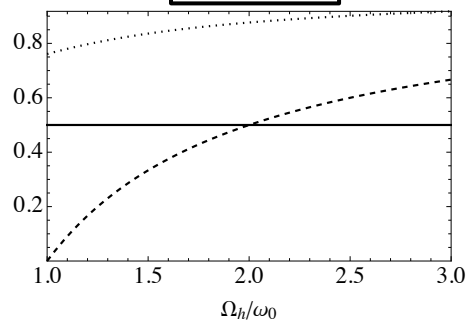


(i) Accelerator	$\dot{Q}_c < 0, \dot{Q}_h > 0, \dot{W} > 0$
(ii) Engine	$\dot{Q}_c < 0, \dot{Q}_h > 0, \dot{W} < 0$
(iii) Refrigerator	$\dot{Q}_c > 0, \dot{Q}_h < 0, \dot{W} > 0$
(iv) Dissipator	$\dot{Q}_c < 0, \dot{Q}_h < 0, \dot{W} > 0$



Oscillating power ⇒ average instantaneous COP over an oscillation higher than Otto value

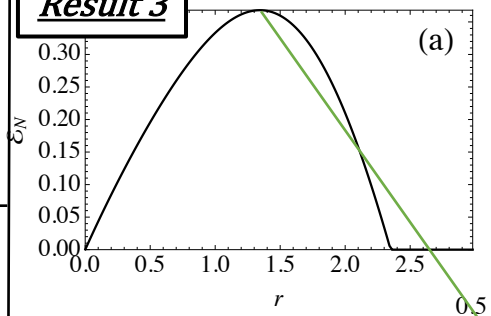
Result 2



*Applying a single-mode **squeezing** operator to the hot bath ⇒* $\beta_h^{(\text{eff})}$ *increases ⇒* $\eta_{Carnot}^{(\text{eff})}$ *increases*

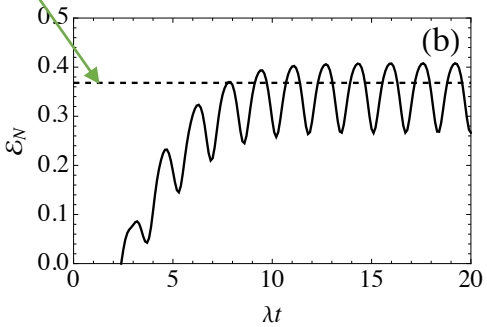
$$\eta_C^{(\text{eff})} = 1 - \frac{\beta_h^{(\text{eff})}}{\beta_c}$$

Result 3



*Squeezing is required for the generation of **entanglement** in a working medium made of **two QHO's***

Fast driving can lead to higher instantaneous values of the logarithmic negativity, $\mathcal{E}_N$



Conclusions

- *Increase in driving speed ⇒ increase in injected power ⇒ different operations*
- *Squeezing in hot bath ⇒ larger effective Carnot efficiency*
- *Squeezing necessary for entanglement in a two-oscillator system*
- *Driving system's oscillators can increase the degree of entanglement*

Reference:
https://doi.org/10.1116/5.0072067