Quantum Fuels for Quantum Machines

Ceren B. Dağ[1], Wolfgang Niedenzu[2], Özgür E. Müstecaplıoğlu[3], and Gershon Kurizki[2]

[1] Physics Department, University of Michigan, 450 Church St., Ann Arbor, MI 48109-1040, USA;
[2] Department of Chemical Physics, Weizmann Institute of Science, Rehovot 7610001, Israel;
[3] Department of Physics, Koç University, Sariyer 34450, Istanbul, Turkey.

Introduction

Quantum machines powered by non-thermal (quantum coherent) resources can be classified into two kinds [1]:

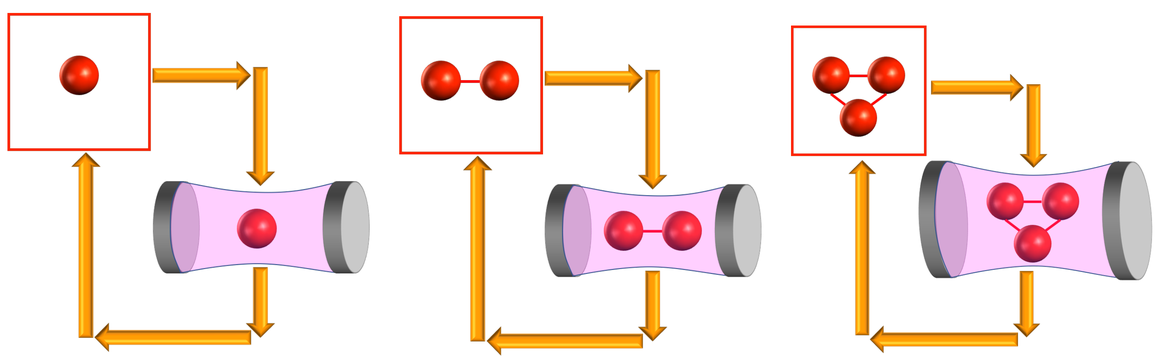
(i) Machines of the first kind, where the working substance of the machine receives both heat and work from the non-thermal bath (thermo-mechanical quantum machine).

(ii) Machines of the second kind, where the working substance of the machine can receive only heat from the non-thermal bath (quantum heat engine).

Can we identify a similar classification of quantum coherences in a resource that can be transferred to the working fluid of a quantum machine either as heat or as work?

1. Model System

We consider a generic micromaser setting in which a beam of atomic clusters pumps the cavity field. This beam constitutes a non-thermal bath for the cavity mode, which may be the working substance of photo-Carnot engine [2]. We investigate how the quantum coherences in the non-thermal atomic clusters determine the kind of the quantum machine and the performance limits.



Interaction of the pump atoms with the cavity field is described by the Tavis-Cummings model:

$$H_{TC} = H_a + H_c + H_{int},$$

where

$$H_a = \frac{\hbar\omega_a}{2}\sum_{k=1}^{N}\sigma_k^z, H_c = \hbar\omega_c a^\dagger a, H_{int} = \hbar g \sum_{k=1}^{N}\left(a\,\sigma_k^+ + a^\dagger\sigma_k^-\right),$$

are the atomic cluster, cavity field, and interaction Hamiltonians, respectively.

2. Results

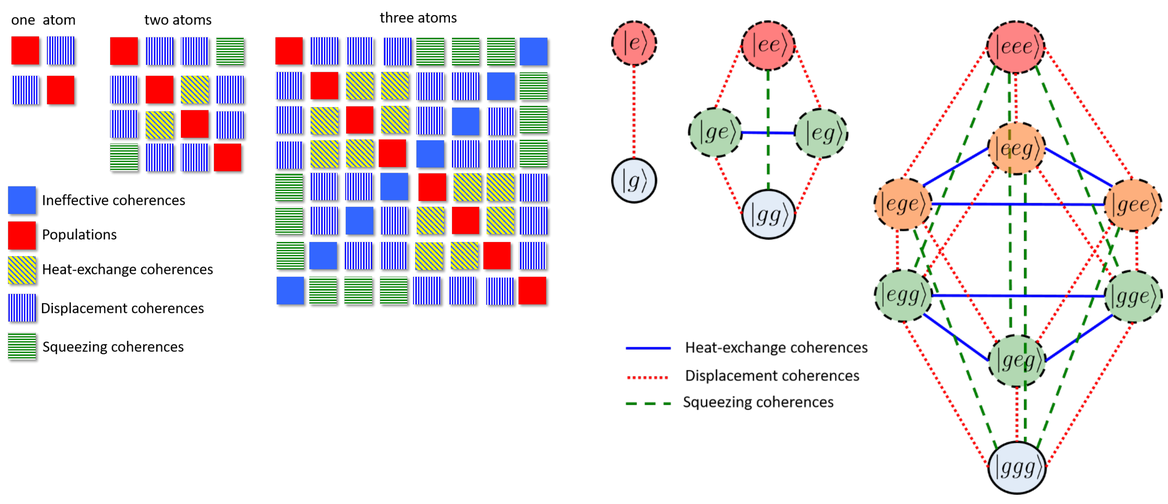
We derive the master equation in the following form [3]:

$$\dot{\rho} \sim -i\,[H_{\text{eff}}, \rho] + \mathcal{L}_s\rho + \mathcal{L}\rho$$

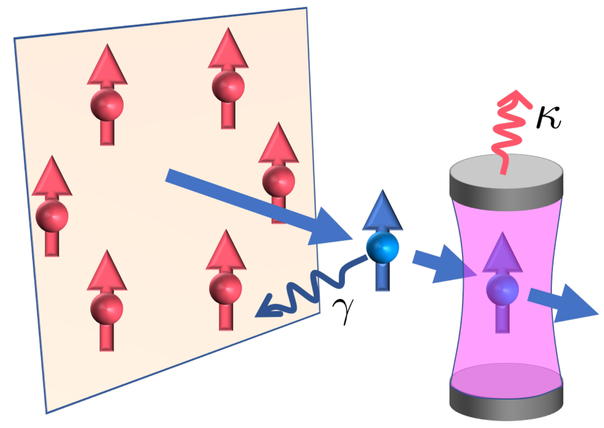
Effective coherent drive

Effective squeezed, thermal bath

The terms in the master equation are determined by disjoint contribution of the density matrix elements of the atomic cluster:



An alternative scheme to harvest coherences in larger atomic clusters: a quantum machine of the second kind powered by a Spin Star Network [4]



Conclusions

- Quantum coherences can be classified with respect to their heat and work equivalence as quantum resources.
- Heat exchange coherences power up quantum machines of the second kind. Squeezing and displacement coherences power up quantum machines of the first kind.
- Task dependent coherences can be large and hence yield more quantum enhancement in the machine efficiency.

Acknowledgments

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References

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