Advances in technology at reduced length-scales has led to an increasing interest in designing and characterizing nanosystems with advantageous thermoelectric properties both for fundamental understanding and device applications. Thermoelectric transport through capacitively coupled quantum dots has received increasing attention, and has been studied in various contexts such as for refrigeration [1, 2] and energy harvesting [3, 4].

Whereas most theoretical studies have focused on the thermoelectric performance due to lowest-order single-electron tunneling processes, less attention has been given to higher-order multi-electron tunneling processes. To this end, we introduce a master equation approach with transition rates and heat transfer rates derived from the T-matrix formalism. Applying a regularization scheme we device a general numerical procedure for the evaluation of the multi-electron cotunneling rates.

We apply our approach to study thermoelectric effects in a system of two capacitively coupled quantum dots in a three-terminal configuration [3] illustrated in Fig. 1(a). Here, the Coulomb inter-dot coupling mediates a heat exchange between the active (biased) quantum dot system and the passive (unbiased) quantum dot system, whereby the active system is cooled when performing a cycle as illustrated in Fig. 1(b).

We find that cotunneling processes give rise to a significant correction to the cooling power in the region of large cooling power as illustrated in Fig. 1(c), and in some cases even quenches the cooling power. Our work highlights the necessity of including higher-order tunneling processes in calculations of thermoelectric quantities in coupled quantum-dot systems.

References

Figure 1: (a) Illustration of two capacitively coupled quantum dots (D and E) weakly connected to three reservoirs (A, B, and C). Tunneling is allowed between a quantum dot and its adjacent reservoirs, but not between the two quantum dots. (b) The operation cycle which cools down lead A and B and heats up lead C. (c) Maximum cooling power in lead A and B as function of temperature of the system for varying asymmetry of the coupling to the leads showing the sequential result (dashed curve) and the result including cotunneling processes (solid curve).