Title:	Three-level laser heat engine at optimal performance with ecological function
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Abstract:	Although classical and quantum heat engines work on entirely different fundamental principles, there is an underlying similarity. For instance, the form of efficiency at optimal performance may be similar for both types of engines. In this work, we study a three-level laser quantum heat engine operating at maximum ecological function (EF) which represents a compromise between the power output and the loss of power due to entropy production. We present numerical as well as analytic results for the global and local optimization of our laser engine in different operational regimes. Particularly, we observe that in low-temperature regimes, the three-level laser heat engine can be mapped to Feynman's ratchet and pawl model, a steady-state classical heat engine. Then we derive analytic expressions for efficiency under the assumptions of strong matter-field coupling and high bath temperatures. Upper and lower bounds on the efficiency exist in case of extreme asymmetric dissipation when the ratio of system-bath coupling constants at the hot and the cold contacts respectively approaches zero or infinity. These bounds have been established previously for various classical models of Carnot-like engines. Further, for weak (or intermediate) matter-field coupling in the high-temperature limit, we derive some new bounds on the efficiency of the engine. We conclude that while the engine produces at least 75% of the power output as compared with the maximum power conditions, the fractional loss of power is appreciably low in case of the engine operating at maximum EF, thus making this objective function relevant from an environmental point of view.
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