

Contents

1	Introduction	9
1.1	Quantum heat engines in theories	9
1.2	Quantum heat engines in experiments	14
1.3	Purpose of this thesis	16
1.4	Organization of the present thesis	16
2	Preliminaries	19
2.1	Second law and thermal efficiency	19
3	Results	25
3.1	Results for N -level systems	26
3.2	Results for two-level systems	29
3.2.1	Otto-like cycles and thermodynamic variables	30
4	Discussion	43
4.1	Condition of Markovian bath	43
4.2	Speed of quench process	44
4.3	Extension to general N -level systems	44
5	Conclusion	47
Appendix		49
A	Classification of quasi-static Otto cycle	49
B	Heat and work in quenching Otto-like cycles	51
C	Classification of quenching Otto-like cycle	54
D	Condition of exceeding the Otto limit	65
E	Analysis of the net concavity	67