

Contents

Acknowledgement	i
Abstract	ii
1 Introduction	1
1.1 Resonating valence bond state	2
1.1.1 Definition and fundamental properties	2
1.1.2 Mean-field description	4
1.1.3 Superconductivity by carrier doping	5
1.2 Kitaev spin liquid	7
1.2.1 Kitaev model and its exact solution	7
1.2.2 Kitaev-Heisenberg model	10
1.3 Superconductivity in the doped Kitaev-Heisenberg model	12
1.3.1 Mean-field theory	12
1.3.2 Numerical study	14
1.3.3 Experiments	15
1.4 Purpose of this thesis	15
1.5 Organization of this thesis	16
2 Model and Method	17
2.1 Model	17
2.2 Lanczos exact diagonalization	19
2.3 Density matrix renormalization group	21
2.4 Variational uniform matrix product state	22
3 Results for undoped Kitaev-Heisenberg ladder model	23
3.1 Global phase diagram	23
3.2 Phase boundaries around Kitaev spin liquid phases	26
3.3 Phase boundary between the spiral LL and zigzag phases	34
3.4 Discussion	35

4	Results for doped Kitaev-Heisenberg ladder model	37
4.1	Binding energy of doped holes	37
4.2	Superconducting correlations	41
4.3	Discussion	43
5	Summary	46
A	Detailed implementation of the VUMPS algorithm	49
A.1	Uniform MPS	49
A.2	Effective Hamiltonian	51
A.3	Optimization procedure	52
A.4	Algorithm	53
B	Supplementary materials for the undoped Kitaev-Heisenberg ladder model	55
B.1	Second derivatives of the ground state energy	55
B.2	Entanglement spectrum	55