

Table of contents

List of figures	xix
Nomenclature	xxvi
1 Introduction	1
1.1 Classical correlation	2
1.2 Quantum correlation	3
1.3 Temporal correlation	7
1.3.1 Time-ordered correlation	8
1.3.2 Out-of-time-order correlator	9
1.3.3 OTOC using position-dependent single spin observable	12
1.3.4 OTOC using block observables	14
1.4 Chaos	15
1.5 Chaotic Systems	15
1.5.1 Classical chaotic System	16
1.5.2 Quantum chaotic system	17
1.6 Spin-1/2	18
1.6.1 Spin-spin interaction	20
1.7 Heisenberg model	21
1.8 Ising Model	22

1.8.1	Boundary conditions	24
1.9	Transverse Ising model	25
1.10	Floquet transverse Ising model	25
1.10.1	Floquet map	26
1.10.2	Dzyaloshinskii–Moriya interaction (DMI)	28
1.10.3	2D square-lattice system with DMI interacation	29
1.11	Chaos in spin system	30
1.12	Magnons and spin wave	32
1.13	Magnonic crystal	33
1.13.1	Structure of magnonic crystal	33
1.14	Outline of the thesis	35
2	Out-of-time-order correlation and detection of phase structure in Floquet transverse Ising spin system	37
2.1	Introduction	37
2.2	Model	40
2.3	Out-of-time-order Correlation	40
2.4	Analytical calculation of TMOTOC	41
2.5	Speed for correlation propagation	43
2.6	Revival time	44
2.7	Phase Structure	46
2.7.1	Critical line with system size	50
2.8	Phase structure by frequencies of oscillations	51
2.9	Conclusion	52
3	Characteristic, dynamic and near saturation regions of Out-of-time-order correlation in Floquet Ising models	55

3.1	Introduction	55
3.2	Model	58
3.3	TMOTOC and LMOTOC	59
3.3.1	Analytical formula of TMOTOC	61
3.4	Results	62
3.4.1	TMOTOC in the integrable Floquet system	63
3.4.2	TMOTOC in the nonintegrable Floquet system	67
3.4.3	LMOTOC in the integrable Floquet system	69
3.4.4	LMOTOC in the nonintegrable Floquet system	71
3.5	Conclusion	73
4	Out-of-time-order correlation of the nonlocal block observables in Floquet Ising spin chain	75
4.1	Introduction	75
4.2	The spin model and background	78
4.2.1	The spin model	78
4.2.2	Out-of-time-order correlation and block operators	79
4.2.3	Average and asymptotic OTOC values	81
4.2.4	Nearest-neighbour spacing distribution	84
4.3	Constant field Floquet system	86
4.4	Special case	90
4.5	Conclusion	93
5	Quantum information diode based on the magnonic crystal	97
5.1	Introduction	97
5.2	Result	99
5.2.1	Proposed set-up for QID	99

5.2.2	Model	101
5.2.3	Out-of-time-order correlator	103
5.2.4	Rectification	106
5.3	Conclusions	107
6	Summary and Future Plans	109
6.1	Summary	109
6.2	Future plans	111
References		113
Appendix A Out-of-time-order correlation and detection of phase structure in Floquet transverse Ising spin system 129		
A-I	Calculation of transverse magnetization OTOC	129
A-II	Calculation of Longitudinal Magnetization OTOC	134
Appendix B Characteristic, dynamic, and near saturation regions of Out-of-time-order correlation in Floquet Ising models 135		
B-I	Calculation of TMOTOC in the non-integrable Floquet system using random state	135
B-II	Time evolution of TMOTOC	136
B-III	Time evolution of LMOTOC	140
Appendix C Out-of-time-order correlators of nonlocal block-spin and random observables in integrable and nonintegrable spin chains 143		
C-I	Calculation of post-scrambling OTOC using random unitary operator	143
C-I.1	Calculation of two-point correlation	144
C-I.2	Calculation of four point correlator	145

Appendix D Quantum information diode based on a magnonic crystal	147
D-I Diagonalization of Hamiltonian of 2D square lattice	147
D-II Calculation of left and right out-of-time ordered correlation functions . .	149