

Contents

Acknowledgement	i
Abstract	ii
Publication List	vi
1 Introduction	1
1.1 Topological defects in magnets	1
1.2 Topological spin textures	7
1.2.1 Periodic arrays of topological defects	7
1.2.2 Emergent electromagnetic field	10
1.3 Experiments on topological spin textures	11
1.3.1 Skyrmion lattice	11
1.3.2 Hedgehog lattice	13
1.4 Stabilization mechanism	15
1.4.1 Dzyaloshinskii-Moriya interaction	15
1.4.2 Frustrated exchange interactions	16
1.4.3 Multiple-spin interactions	16
1.5 Purpose of this thesis	18
1.6 Organization of this thesis	19
2 Spin moiré picture	20
2.1 Moiré pattern	20
2.2 Spin moiré	21
3 Spin moiré engineering by spatial anisotropy	25
3.1 Model	26
3.2 Method	28
3.2.1 Variational calculation	28
3.2.2 Identification of the ground state	30
3.3 Results	32
3.3.1 Phase diagram	32

3.3.2	Phase transitions driven by anisotropy	33
3.3.3	Topological properties	37
3.4	Summary of this chapter	40
4	Spin moiré engineering by twist angle	42
4.1	Set up	43
4.2	Topological properties	46
4.2.1	Topological objects and emergent electromagnetic fields . .	46
4.2.2	Topological phase diagram	51
4.3	Variational calculation	54
4.3.1	Energy functional	55
4.3.2	Energy for each state	56
4.3.3	Results	58
4.4	Discussion	61
4.5	Summary of this chapter	62
5	Spin moiré engineering by phase shift	64
5.1	Phase degree of freedom and hyperspace representation	65
5.2	Hyperspace representation of skyrmion lattices	68
5.3	Chiral $3Q$ skyrmion lattice	70
5.3.1	Hedgehogs in hyperspace	71
5.3.2	Topological transition in hyperspace	74
5.3.3	Topological phase diagram	76
5.4	Nonchiral $3Q$ skyrmion lattice	79
5.4.1	Hedgehogs in hyperspace	80
5.4.2	Topological phase diagram	81
5.5	Summary of this chapter	84
6	Summary	86