

Contents

1. Introduction	1
2. Theoretical background	5
2.1. Magnetism in solids	5
2.2. Micromagnetic model and Landau-Lifshitz equation	7
2.2.1. Exchange energy	8
2.2.2. Zeeman energy	9
2.2.3. Demagnetization energy	10
2.2.4. Landau-Lifshitz-Gilbert equation and Thiele equation	12
2.2.5. Domain walls and magnetic vortices	15
2.2.6. Spin-transfer torque	16
2.3. X-ray magnetic circular dichroism	17
3. Methods	21
3.1. Numerical solution of ordinary differential equations	22
3.2. Micromagnetic simulations	23
3.3. Multiphysics simulation with the finite element method	28
3.4. Sample preparation	30
3.5. Magnetic force microscopy	32
3.6. Ferromagnetic absorption spectroscopy	33
3.7. Magnetic transmission x-ray microscopy	36
3.7.1. Static imaging	37
3.7.2. Time-resolved imaging	38
3.8. Generation of rotational currents	43
4. Results	47
4.1. Linear dynamics of magnetic vortices and antivortices	47
4.1.1. Thiele equation for vortices and antivortices	48
4.1.2. Free gyration in parabolic potentials	50
4.1.3. Zeeman energy in external magnetic fields	55
4.1.4. Deflection by a static magnetic field	57
4.1.5. Dynamics driven by homogeneous in-plane fields and currents .	59
4.1.6. Solution for rotational excitation	62
4.1.7. Time-resolved x-ray microscopy of rotational antivortex excitation	71
4.2. Nonlinear dynamics and polarization reversal	76
4.2.1. Experimental indications for nonlinear dynamics	77
4.2.2. Nonlinear extension of the Thiele model	80



Contents

4.2.3. Dependence on the amplitude of excitation	83
4.2.4. Dependence on the background field	92
5. Conclusion	97
A. Analytical calculations	99
B. Supplementary results	103
C. Process parameters	105
D. List of publications	107
D.1. Publications	109
D.2. Author contributions	111
Bibliography	113