

Contents

Publications	v
Abstract	xi
1 Introduction	1
1.1 Scope and Organization of this Work	2
2 The Structure of the Sun	3
2.1 The Solar Interior	3
2.2 The Atmospheric Layers	5
3 Sunspots	7
3.1 Global Properties and Periodicity	8
3.2 The Umbra	12
3.3 The Penumbra	14
3.4 Formation and Decay of Sunspots	17
3.5 Penumbral Models	20
3.5.1 Siphon Flows and Turbulent Pumping	21
3.5.2 Buoyant Flux Tubes	23
3.5.3 Convection in Penumbral Gaps	26
3.5.4 Alternative Proposals	27
4 Spectropolarimetry	29
4.1 Description and Measurement of Polarized Light	29
4.2 Zeeman Effect	31
4.3 Radiative Transfer	35
4.4 Synthesis and Inversion of Stokes Profiles	40
5 Data Acquisition and Calibration	43
5.1 The HINODE Observatory	43
5.2 The Spectropolarimeter	47
5.3 Data Reduction and Image Reconstruction	48
5.4 Measurement of Doppler Velocity	51
5.5 Velocity Calibration	57
5.6 Summary	62

6	Observation of the Penumbral Velocity Field at Disk Center	63
6.1	Global Velocity Field	63
6.2	Morphology of Up- and Downflows	69
6.3	Search for Overturning Convection Within Penumbral Filaments	74
6.4	Flow Field in Bright and Dark Penumbral Filaments	74
6.5	Bright Penumbral Downflows	80
6.6	Correlations at Disk Center	82
6.7	Summary	83
7	Observation of the Horizontal Component of the Evershed Effect	85
7.1	The Evershed Outflow	85
7.2	Radial Dependency of Average Velocity	89
7.3	Morphology of Evershed Outflow	90
7.4	The Inclination of the Downflow Channels	92
7.5	Correlations at Large Heliocentric Angles	94
7.6	Summary	97
8	Asymmetries and Crossover Profiles	99
8.1	Height Dependency of Penumbral and Quiet Sun Velocity Fields	99
8.2	Crossover Profiles and Hidden Opposite Polarity	103
8.3	Properties of the Magnetic Flow	106
8.4	Inversion of Up- and Downflow Profiles	109
8.5	Summary	114
9	Net Circular Polarization	115
9.1	Penumbral Net Circular Polarization at Disk Center	115
9.2	Center to Limb Variation of Penumbral Net Circular Polarization	119
9.3	Polarity Reversal of Net Circular Polarization	122
9.4	Inversion	124
9.5	Summary	128
10	Conclusion	129
A	Estimation of Straylight in HINODE SP Data	133
B	Correlation Analysis	137
C	Calibrated HINODE SP Data	139
	Bibliography	141
	Abbreviations	155
	Curriculum Vitae	159
	Acknowledgment	161