Contents

Kurzfassung v

Abstract vii

Contents ix

1 Introduction 1

2 Physics Principles of Tokamak Transport and Rotation 7
2.1 The Tokamak . . . 7
2.1.1 Confinement . . . 8
Particle Drifts . . . 9
Magnetic Topolgy . . . 10
Safety Factor q . . . 11
2.1.2 Transport Regimes & Collisionality . . . 12
2.1.3 Energy and Particle Exhaust - Limiter vs. Divertor . . . 14
The Scrape-Off Layer . . . 15
2.2 Plasma Rotation and Radial Electric Field . . . 16
2.2.1 Background Rotation . . . 16
2.2.2 Impurity Rotation . . . 18
Poloidal Rotation . . . 19
2.2.3 Radial Electric Field . . . 19
The Radial Force Balance . . . 20
The E×B Shearing Rate $\Omega_{\tilde{\mathbf{E}}\times\tilde{\mathbf{B}}}$ . . . 21
Relevance for Plasma Confinement and Fusion Research . . . 21

3 TEXTOR and The Dynamic Ergodic Divertor (DED) 23
3.1 The Tokamak TEXTOR . . . 24
3.1.1 Setup and Operational Parameters . . . 24
3.1.2 Diagnostics & Heating . . . 25
3.2 The Dynamic Ergodic Divertor . . . 26
3.2.1 Setup and Parameters . . . 26
3.2.2 Magnetic Topology of TEXTOR-DED . . . 28
Visualization and Modeling . . . 29
Topological Structures and Layers . . . 31
3.3 Effects of Stochastization & Scenarios . . . 33
3.3.1 Edge Stochastization ($\vec{j} \times \vec{B}$ Force) . . . 34

3.3.2 Confinement Scenarios under the Influence of the DED 35

4 Spectroscopy & Diagnostics **37**
4.1 Active Charge Exchange Recombination Spectroscopy (CXRS) 37
4.1.1 Measured Quantities 38
Ion Velocity 38
Ion Temperature 39
Ion Density 40
4.1.2 Fine structure & Zeeman Effect 40
4.2 Diagnostic Setup 41
4.2.1 The RuDI Diagnostic Beam 43
4.2.2 Poloidal Observation System 44
Original Setup (2002-December 2007) 45
Upgraded Setup (since December 2007) 45
4.2.3 Toroidal Observation System 48
4.2.4 Spectrometers & Camera Systems 49
4.2.5 Theoretical Resolution of the Measurements 52
Poloidal Observation System 52
Toroidal Observation System 53
4.3 Calibration Methods 53
4.3.1 Radial Calibration 54
4.3.2 Finite Slit Height 55

5 Data Evaluation **57**
5.1 CXRS Measurements with the RuDi Hydrogen Beam 57
5.2 CIII Measurements 61
5.3 Accuracy 62

6 Results **67**
6.1 Rotation and Radial Electric Field without DED 67
6.1.1 Influence of Neutral Beam Injection - Toroidal Torque 68
Toroidal Rotation 68
Poloidal Rotation 71
The Total Radial Electric Field 72
6.1.2 Impurity Rotation in Scenarios with Negative field Line Helicity . . . 74
Neutral Beam Injection - Coordinates 75
Edge Rotation and SOL flow and Drifts 77
Poloidal Rotation Measurements vs. Neoclassical Theory 78
6.2 Rotation and Radial Electric Field under the Influence of the DED 80
6.2.1 Changes in the Radial Electric Field 80
6.2.2 DC DED - Stochastic Force 82
6.3 The Radial Electric Field during Confinement Changes with DED 85
6.3.1 Improved Particle Confinement with Resonant Magnetic Perturbations . 86
General Plasma Parameters and Discharge Conditions 87
Plasma Particle Confinement and Particle Balance 89
Correlation of Magnetic Topology and Particle Confinement 93

The Radial Electric Field and its Changes 99
IPC Scenarios with Negative Helicity 103
$\vec{E} \times \vec{B}$ shearing Rate $\Omega_{\vec{E}\times\vec{B}}$ 108
6.3.2 Pump Out Scenario with DED 110
6.3.3 Turbulent Transport and Plasma Fluctuations 115

7 Summary & Outlook **119**

Bibliography **I**

List of Figures **XVII**

List of Tables **XXV**

Acknowledgements **XXVII**