Contents

Abstract ix

Nomenclature x

Indices xi

Introduction xiii

1 The Basic Conceptions of Plasma Physics 1
- 1.1 Plasma Properties . . . 1
- 1.2 Quasi-neutrality of Plasma . . . 4
- 1.3 The Interaction of Electromagnetic Waves with Plasma . . . 9
- 1.4 Motion of Charged Particles in Plasma . . . 13
- 1.5 The State of Plasma . . . 18
  - 1.5.1 Equilibrium Plasma . . . 20
  - 1.5.2 Partially Non-equilibrium Plasma . . . 30
  - 1.5.3 Non-equilibrium Plasma . . . 39

2 Formation of Molecular Spectra in Plasma 43
- 2.1 Emission and Absorption of Spectra . . . 44
- 2.2 The Spectral Line Shapes . . . 48

3 Excitation of the Molecules in Non-equilibrium Plasma 55
- 3.1 Elastic Collisions . . . 55
- 3.2 Inelastic Collisions . . . 57
- 3.3 Excitation of Molecules by Electron Impact . . . 57

3.3.1 Excitation of Rotational States . . . 58
3.3.2 Excitation of Vibrational States . . . 60
3.3.3 Excitation of Electronic States . . . 66
3.3.4 Excitation of Vibronic States . . . 71
3.4 Excitation of Molecules During Collision with Heavy Particles 72
3.4.1 Excitation of Rotational States . . . 74
3.4.2 Excitation of Vibrational States . . . 76
3.4.3 Excitation of Electronic States . . . 79
3.4.4 Excitation of Vibronic States . . . 85

4 Technique and Methods of Spectroscopy 91
4.1 Spectroscopy Technique . . . 91
4.1.1 Monochromators and Spectrographs . . . 92
4.1.2 The Fabry-Pérot Interferometer . . . 96
4.1.3 Detection of Light . . . 103
4.2 Inversion Problems of Spectroscopy . . . 106
4.2.1 Algorithm of Regularization . . . 108
4.2.2 Algorithm of Differentiation . . . 113
4.2.3 Model Problems . . . 114

5 Diagnostics of Non-equilibrium Plasma 123
5.1 Elementary Processes in Non-equilibrium Molecular Plasma 126
5.1.1 Excitation of Rotational Levels of Molecular Electronically Excited States . . . 127
5.1.2 Velocity Distribution Functions of the Particles in Electronically Excited States . . . 131
5.2 Optical Actinometry of Plasma . . . 136
5.3 Investigation of Nonequilibrium Plasma Sources . . . 141
5.3.1 Experimental Methods . . . 142
5.3.2 Vacuum Arc Discharge for Hydrogen Ions Generation 144
5.3.3 Vacuum Arc Discharge for Deposition of Thin Coatings 146
5.3.4 Microwave Discharge for Carbon Dioxide Dissociation 156
5.3.5 Direct Current Glow Discharge as Active Medium of Waveguide CO_2 Lasers . . . 162

6 Modeling of Equilibrium Plasma 169
6.1 The Flows of Wall-Stabilized Arc Plasma . . . 170

6.2 Composition, Transport Coefficients and Thermodynamic Properties of Plasma . . . 175
6.3 Model of an Arc in the Channel . . . 178
6.4 The Calculation of Cylindrical Arc Characteristics . . . 182
6.5 Black and Volume Plasma Radiation . . . 188
6.6 Arc-Plasma Flows in the Approximation of the Boundary Layer 191
6.7 Determination of the Arc Plasma Properties on the Basis of MHD Equations . . . 198
6.8 The Optical Torch . . . 209
6.9 The Microwave Torch . . . 218

7 Modeling of Non-equilibrium Plasma 249
7.1 Physical Processes in Non-equilibrium Gas Discharges . . . 250
7.2 Partial Non-equilibrium Models of Plasma . . . 252
7.3 The Boundary Conditions . . . 254
7.4 Thermodynamic and Transport Coefficients . . . 256
7.5 Comparison of Equilibrium and Non-equilibrium Models of Plasma . . . 259
7.6 An Expanding Arc . . . 263
7.7 Short Electric Arc . . . 269
7.8 Non-equilibrium Microwave Discharge . . . 281
7.9 Non-equilibrium Induction RF Discharge . . . 300

8 Transport and Excitation in a Magnetized plasma 313
8.1 Parameter Range and Characteristic Collision Times . . . 314
8.1.1 Ionization and Excitation from the Ground State . . . 320
8.1.2 Plasma Transport Equations . . . 323
8.2 Diagnostic Methods . . . 328
8.2.1 Thomson Scattering . . . 328
8.2.2 Line Radiation . . . 332
8.2.3 VUV Emission Spectroscopy . . . 337
8.2.4 Continuum Emission Spectroscopy . . . 339
8.2.5 Laser-Induced Fluorescence . . . 341
8.2.6 Line Profile Analysis by Fabry-Pérot Interferometry . 348
8.2.7 Fluctuation Measurements . . . 354
8.3 Excitation and Radiation in the Argon I and II Systems . . . 367
8.3.1 Argon Neutral System . . . 368
8.3.2 The Argon II System . . . 374

8.4 Transport Properties of Magnetized Plasmas: Model and Experiments 375
8.4.1 Transverse Diffusion and Rotation 378
8.4.2 Longitudinal Ion Momentum Balance 390
8.4.3 Ion Energy Balance 394
8.4.4 Electron Energy Balance 397
8.5 Conclusions and Applications; a Summary 400

Conclusion **411**

Index **415**