

X-ray spectroscopy. x-ray lasers and high intensity x-ray sources 14

(H.-J. Kunze)

1. X-ray spectroscopy -line radiation 15

1.1 Introduction 15

1.2 Charge state distribution 15

1.3 Spectral line intensities 18

1.4 Hydrogenlike ions 20

1.5 Heliumlike ions 22

1.6 Line profiles 25

References 25

2. X-ray lasers 27

2.1 General considerations 27

2.2 Non-plasma systems 29

2.3 Plasma-based systems 30

2.3.1 Specific problems 30

2.3.2 Photoexcitation pumping 30

2.3.3 Collisional pumping 31

2.3.4 Recombination lasers 32

2.3.5 Pulsed capillary discharges 35

2.4 Multilayer x-ray mirrors 37

References 38

3. Point-like high-intensity x-ray sources 41

3.1 X-ray emission from hot dense plasmas 41

3.2 Plasma sources 43

3.3 Radiative collapse model 45

3.4 The low-inductance vacuum spark 48

References 51

Continuous emission of plasma in the soft X-ray region 53

(P. Bogen)

- 1.1 Introduction 54
- 1.2 Free-bound continuum 55
- 1.3 Free-free and free-bound continuum 57
- 1.4 Examples 58
- 1.5 Electron temperature measurement with absorption filters 59

- 2. Experimental set-up for soft X-rays 60
 - 2.1 Focussing of soft X-rays 60
 - 2.2 Spectrometer for soft X-rays 62
 - 2.3 X-Radiation detectors 66

- 3. Sliding sparks 70
 - 3.1 Introduction 70
 - 3.2 Sliding spark type 1 71
 - 3.3 Sliding spark type 2 71
 - 3.4 Experimental arrangement 72
 - 3.5 Evaluation of the measurements 72

Appendix 1: Sliding spark over solid xenon as light source for 85 production of plasma by photoionization of gases

Laser light scattering 89

(J. Uhlenbusch)

- 1. Introduction 90

- 2. Light scattering from a single electron 90
 - 2.1 Radiation field of an accelerated electron 90
 - 2.2 The radiated power 92
 - 2.3 Radiation from a single electron exposed to the field of an 93 electromagnetic wave

3. Light scattering from an electron ensemble	96
3.1 Introductory remarks	96
3.2 Scatter cross section for an electron ensemble	97
The dynamic form factor S	
3.3 Calculation of the dynamic form factor	98
3.4 Scattering from drifting electrons and ions	103
3.5 Scatter profiles from magnetized plasmas	104
3.6 Scatter profiles from contaminated plasmas	107
3.7 Relativistic effects	109
4. Various scatter experiments -a survey	111
4.1 General aspects for planning a scatter experiment	111
4.1.1 Scatter set-up and detection of scattered light	112
4.1.2 Optimalization of the signal to noise ratio	114
4.1.3 Calibration and interpretation of the scattered signals	115
4.2 Single-shot-experiments with a ruby laser	116
4.2.1 Introduction	116
4.2.2 Experimental set-up	116
4.2.3 Absolute calibration of the detection system by means of pure rotational Raman scattering of H ₂ and D ₂	119
4.2.4 Estimation of photon statistics and of the expected current signals	121
4.2.5 Evaluation of scattering signals and results	122
4.2.6 Addendum	124
4.3 Experiments with repetitively pulsed laser systems	125
4.4 Far-infrared-scattering experiment at thermal density fluctuations	130
4.4.1 General considerations	130
4.4.2 Detection optics	133
4.4.3 Signal to noise-ratio	135
4.5 Collective scattering from suprathreshold density fluctuations	137
5. Conclusion and perspectives	142
6. Acknowledgements	143

7. Literature 144

Laser-induced fluorescence 145

(H.F. Döbele)

1. Principles 146

2. Signal-to-noise ratios 157

3. Pump radiation sources 159

4. Applications of LiF 162

5. Multiphoton excitation 167

Microwave diagnostics 172

(H. Schlüter)

1. Introduction 173

2. Fundamentals of wave propagation in the absence of static 173
magnetic fields

3. Microwave interferometry 177

4. Resonator methods 188

5. Extension to the case $B_0 \perp O$ 189

6. Survey of complementary methods 191

Mass spectroscopy 194

(J. Winter)

1. The mass spectrometer 195

1.1 Ion formation 195

1.2 Mass separation 198

1.3 Ion detection 198

2. Residual gas analysis 199

2.1 Sensitivity, effects in the ion source 199

2.2 Application of residual gas analysis during conditioning of tokamak walls 202

2.3 Determination of the deposition rate during thin film formation 203

3. Measurements in "line of sight" geometry 204

4. Direct measurement of plasma ions 205

4.1 The problem of the aperture 205

4.2 Energy selective plasma mass spectroscopy 209

The DC cold cathode glow discharge 213

(E. Hintz)

1. Introduction 214

1.1 General characterization of dc glow discharges 215

2. Collision processes and transport phenomena 218

2.1 Cross-sections 218

2.1.1 Elastic collisions 219

2.1.2 Inelastic collisions 221

2.2 Transport phenomena 222

2.2.1 Mobility of electrons and ions 222

2.2.2 Diffusion 223

- 2.2.3 The average energy of the electrons 224
- 2.2.4 The Townsend ionization coefficient 225

- 3. The dc-cold cathode glow discharge 226
 - 3.1 The Townsend discharge 226
 - 3.2 Similarity laws 229
 - 3.3 General characterization of the glow discharge 230
 - 3.4 Theoretical models and estimates 232
 - 3.4.1 A simplified model of the abnormal cathode fall 232
 - 3.4.2 Numerical models of the cathode fall 234
 - 3.5 The negative glow 237

Microwave discharges 252

(H. Schlüter)

- 1. Introduction 253

- 2. Breakdown 245

- 3. Steady-state discharges 256

- 4. Modelling of diffusion controlled discharges 257

- 5. Classification of arrangements for plasma generation 260

- 6. Surface wave discharges 264

High pressure glow discharges 267

(J. Salge)

- 1. Types of discharges and operation conditions 270
 - 1.1 Discharges between point and plane electrodes 270

1.2 Dielectric-barrier discharges 274

1.3 Preionized discharges 277

2. Applications 278

2.1 Ozone generation 278

2.2 UV-radiation 282

2.3 Surface treatment 284

2.4 Electrostatic precipitation 284

2.5 Gas laser 286

The pseudo spark-switch -a modern plasma application 292

(G. Ecker)

1. Plasma technology and switch gear 293

2. Typical discharges of gaseous electronics 294

3. Characteristica of the pseudo spark 296

4. Operation and data of the pseudo spark discharge 302

5. Advantages and bench marks 302

6. Analysis and interpretation of the PSS so far 309

7. Criticism and characterization of the predischage 316

8. Criticism and characterization of the main discharge 318

Laser-plasma-interaction 322

(J. Uhlenbusch)

1. Introduction 323

2. Ignition of an optical discharge 323
 - 2.1 Multiphoton ionization 324
 - 2.2 Cascade breakdown 324

3. Continuous optical discharges (COD) 327

4. Pulsed optical discharges (POD) 329
 - 4.1 Q-switched CO₂ laser system 329
 - 4.2 Spectroscopic set-up 329
 - 4.3 Asymmetry of H β 331
 - 4.4 Electron temperature and density 334

5. Laser-induced surface plasma 334
 - 5.1 Introductory remarks 334
 - 5.2 Experimental setup 336
 - 5.2.1 Q-switching with a mechanical chopper wheel 336
 - 5.2.2 Cutting and welding device 336
 - 5.2.3 Beam deflection technique 338
 - 5.3 Deflection angle and electron density distribution 339
 - 5.4 Experimental results 341
 - 5.4.1 Cutting 341
 - 5.4.2 Welding 343
 - 5.4.3 Electron density 343

6. References 347

Developments in plasma focus research 349

(J. Salge)

Introduction 350

1. Principle of operation 351

1.1 Ignition phase 352

1.2 Running down phase 353

1.3 Focus phase 355

2. Characteristic properties 356

2.1 Operation conditions 356

2.2 Plasma properties 357

2.3 Particle beams and radiation 357

2.4 Neutron emission 358

3. Possible applications 359

3.1 Neutron source 359

3.2 X-ray radiation 361

Ion sputtering of materials 367

(H.F. Döbele)

1. Phenomena 368

2. Applications of sputtering 368

3. Characteristic sputtering regimes 370

4. Detection techniques 383

**Plasma assisted deposition of thin films (discussed at the example of 388
a-C:H)**

(J. Winter)

1. Introduction 389

2. Deposition of hard amorphous carbon films a-C:H 391
 - 2.1 General review of the deposition processes 392
 - 2.2 RF discharges 394
 - 2.3 Large area deposition of a-C:H films in fusion devices by rf- 397
assisted dc glow discharges

3. Observations during film deposition 399

4. Properties of a-C:H 403
 - 4.1 Transparency. refractive index 403
 - 4.2 Film composition and thermal stability 404
 - 4.3 Physical structure 408
 - 4.4 Chemical bonding 409
 - 4.5 Hypothetical model of the a-C:H structure 411
 - 4.6 Adhesion to the substrate 413