Contents

Frequently used abbreviations i

1 Motivation 1

2 Introduction to Warm Dense Matter 3

2.1 High-energy density physics and fast ignitor scheme . . . 4
2.2 Short-pulse x-ray sources . . . 5
2.3 Astrophysical objects . . . 6

3 Relativistic optical-laser interaction with a solid metal 7

3.1 Introduction . . . 7
3.2 Plasma generation . . . 7
3.2.1 Ionization and electron acceleration . . . 8
3.2.2 Colissionless absorption . . . 9
3.3 Electron transport . . . 12
3.4 Strongly-coupled Plasmas . . . 14
3.4.1 K-shell ionization cross-sections . . . 14
3.4.2 Ti $K\alpha$ doublet and satellite lines . . . 15
3.5 X-ray spectroscopy of solid-density plasmas . . . 17
3.5.1 Diagnostics for solid-density plasma . . . 17
3.5.2 Crystal x-ray diffraction . . . 18
3.5.3 Properties of two-dimensional bent crystals . . . 19
3.5.4 A spectrometer for the Ti-$K\alpha$ doublet . . . 20
3.5.5 Absolutely calibrated film detector . . . 22
3.6 The LULI 100TW laser facility . . . 23
3.6.1 Layout of the laser amplifier system . . . 23
3.6.2 Temporal pulse shape - contrast and preplasma formation . . . 24
3.7 Radial bulk temperature and $K\alpha$ profiles . . . 25
3.7.1 Experimental setup . . . 25
3.7.2 Radial profiles . . . 29
3.7.3 Temperatures and spot sizes . . . 31
3.8 Summary . . . 37

4 Intense soft x-ray matter interaction **39**
4.1 Introduction 39
4.1.1 The FLASH-facility 40
4.2 XUV photo-absorption by Aluminum 41
4.2.1 XUV photo-absorption mechanisms 42
4.2.2 Conduction band of aluminum 43
4.2.3 Electron equilibration dynamics 43
4.2.4 Monte-Carlo simulations 44
4.3 Principles of XUV spectrometers 46
4.3.1 Challenges using XUV radiation 46
4.3.2 Focusing transmission-grating spectrograph after **Jasny** *et al.* . . 49
4.3.3 *HiTRaX* - a focusing reflection-grating spectrometer 52
4.3.4 Comparing different spectrometer designs 58
4.4 Bremsstrahlung and line spectroscopy 60
4.4.1 Experimental setup 60
4.4.2 Data analysis 62
4.5 Mapping the heated conduction band of aluminum 67
4.5.1 Radiative decay from the conduction band 67
4.5.2 Experimental setup 68
4.5.3 Integrated emission yield 68
4.5.4 Shape of the spectra 69
4.5.5 Results - Conduction band temperature 70
4.6 Turning solid aluminum transparent 71
4.6.1 Saturable absorption 71
4.6.2 Depletion of the L-shell 71
4.6.3 Experimental setup 72
4.6.4 Transmission data analysis 74
4.7 Summary 76

5 General Summary and Outlook **79**

6 Zusammenfassung **83**

Bibliography **85**

Acknowledgments **95**