Preface

Today, ultrafast lasers providing pulses with a duration of a several femtoseconds (1 fs = 10^{-15} s) up to a few picoseconds (1 ps = 10^{-12} s) are commercially available and are gaining more and more attention in the area of precise microstructuring. This is due to the fact that they enable completely new machining approaches impossible by applying conventional tools. The short interaction times result in strong non-equilibrium processes. Consequently, thermal and mechanical damage can be minimized and processing with practically no melt even in metal processing becomes possible resulting in sub-μm precision. The high intensities achievable when focusing ultrashort laser pulses even of moderate pulse energies allow for nonlinear interaction processes, which are the basis for processing transparent materials. Application examples are, e.g. the cutting of fragile glass structures for displays, the structuring of thin-films in photovoltaics to increase the solar cell efficiency, and the fabrication of LEDs or computer chips. Fantastic opportunities open up in the field of medicine. Here, for example highly precise cuts with minimal damage inside the human eye enable absolutely new therapy opportunities for cataract or presbyopia treatment. Thus, ultrashort laser pulse systems are universal tools with a plethora of applications in precise micro-manufacturing and medicine.

However, all these opportunities come along with a multitude of various challenges. On the one hand the system technology is rather complex and on the other hand the nonlinear effects during beam propagation and during the interaction process require fundamental understanding and precise control. Thus, although this technology is promising significant advantages, it is often termed not robust, not reliable, expensive, slow and inefficient and its implementation in real production processes is hindered. To overcome these obstacles and to explore the full potential of ultrashort laser pulses, the German Federal Ministry of Education and Research (BMBF) has launched a comprehensive research initiative on ultrashort pulse laser technology. This includes the development of innovative, inexpensive and powerful new ultrashort pulse laser systems as well as the appropriate system technology for beam control and steering. Apart from the research on laser sources a strong focus was on the development of the interaction processes itself, closely linked to specific application examples. This research effort has been pursued by 23 companies and 13 research institutions, which closely worked together within 9 joint research projects. The research was supported with more than 24 million Euros by the BMBF. A similar amount of money was spent in addition by the industrial partners involved. The major results of this research initiative are summarized in this book. In order to provide a coherent picture, the individual contributions are grouped thematically rather than by the original projects. Laser source development is covered in the first section, followed by a section describing fundamental interaction aspects, processing strategies as well as beam shaping, scanning and other relevant system technology. Finally, specific applications from surgery, THz generation to electron source generation for X-ray sources complete the overview.

The remarkable progress in ultrashort pulse technology and its applications as described here would not have been possible without the dedication of the companies and institutes, especially the researchers involved, but also the generous support by the German Federal Ministry of Education and Research. The editors and authors of this book express their sincere thanks to all of these.

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