Preface

One of the more delicate tasks in putting this book together was deciding what to include: where exactly are the boundaries of this new field? This problem has caused conference organizers enough headaches over the past decade or so, trying to find a common theme to embrace at least a dozen quite different research activities. Proceedings with curious titles like 'Ultrafast Phenomena VII', '3rd Fast Ignitor Workshop' and even 'Generation and Application of Short Wavelengths II' line the bookshelves of most researchers who have anything to do with high-power, femtosecond lasers. In spite of these schizophrenic tendencies, the global implications of future scientific endeavour using high-intensity lasers have been recently recognized by the OECD (Kato, 2001).

A science historian looking back 20 years from now may conclude that the field was at something of a crossroads at this point. Having grown out of an unlikely consortium of laser physicists, atomic physicists and hobbying plasma physicists from the laser fusion community, the research discipline of short pulse, high-intensity laser interactions with matter has matured to the point where several sub-fields can be clearly identified, such as 'high-harmonic generation', 'femtosecond x-ray diffractometry', or 'extreme-intensity physics'. The diversity of specialist input, together with a plasma-theory base augmented by contributions from established scientific fields such as astrophysics, nonlinear optics and computational physics, gives this topic an adventurous, pioneering feel, where speculative ideas compete for journal space with inexplicable experimental results.

For the graduate student just entering the fray, there is a bewildering variety of topics to choose from: atomic physics, laser physics, plasma physics and lately even particle physics; yet there are precious few defining criteria. One of the aims of this book then, is to supply just that: a cumulative definition of 'short pulse interactions' based on the physical phenomena which occur when a large number of laser-photons impinge on ordinary matter over a very short time.

In some respects it is easier to state what this book is *not* about, namely: quantum chemistry, spectroscopy, fusion or attosecond lasers; topics which crop up regularly enough, but as related fields or direct applications of the physics discussed in one of the earlier chapters. The recipe for its content instead comprises key-words such as: high (or ultra-high) intensity; femtosecond laser; relativistic; ultrafast; collective behavior; kinetic effects; extreme nonlinear, and so on. Most of the phenomena considered here involve laser field strengths way in excess of ionisation thresholds, so in Chapters 3–5, the core of the book, deals primarily with the interaction of light with free electrons or plasmas. By contrast, Chapter 2 begins with material on the borderline between its natural and ionized states, a regime which was the subject of many early studies with femtosecond lasers and which today constitutes an important scientific field in its own right. Together, these four chapters lay the foundations for the far-reaching practical applications reviewed in Chapter 7, which also takes a look at some of the more esoteric phenomena which are poised to form the basis of serious research programs in the future.

A large proportion of the illustrations in the book were created using numerical simulation codes developed by the author. Chapter 6 is therefore included to dispel some of the mystique surrounding this kind of theoretical calculation. Numerical schemes are given for these codes, together with a brief description of their use, and where to find them. Most of the programs are available from a dedicated web-site, the address of which can be found on page 215.

At the time of going to press, I am conscious of the fact that hundreds of new papers are appearing every month on topics directly related to those described herein. The rate of growth of this field — fuelled by seemingly unquenchable advances in laser technology — is such that in ten years' time each chapter will need a book of its own. Needless to say, a much more detailed account of atoms in intense fields can already be found, for example, in the work by Suter, *The Physics of Laser-Atom Interactions*; and a detailed treatment of nonlinear wave propagation in gases and underdense plasmas in *Laser Physics at Relativistic Intensities*, by Borovsky, Galkin, Shiryaev and Auguste. To counter these misgivings about impending outdatedness, I take heart from the fact that Kruer's book, *Laser Plasma Interactions* remains a must for people working in the femtosecond business, even though this book deals primarily with the long-pulse interactions typically found in inertial confinement fusion research. The present work should of course be seen as complementary to, and not competitive with Kruer's classic!

One could also argue that a textbook on this subject is premature: why not wait until the dust has settled and organize some collected monographs instead? Actually the material here has its origins in two review articles on femtosecond interactions penned by this author, but with a much more verbose approach in deriving and discussing important physical models. This will hopefully serve as an antidote to the increasingly concise style typical of the specialist journals (even for reviews), where the newcomer often comes to grief trying to figure out in which units the first equation is supposed to be written. The intention of this book, as the title suggests, is to introduce the reader — whether graduate student or non-specialist professional — to the wonders of high-intensity laser interactions with matter.

This mission could not have got underway without the positive intervention of Tony Bell when it was no more than a sketch on a sheet of A4; nor, for that matter, without the guiding hands of Malcolm Haines and Bucker Dangor, who set me on this trail in the Blackett Laboratory nearly 20 years ago. The valiant proof-reading efforts of former Jena colleagues Laszlo Veisz (who also checked many of the equations), Stefan Düsterer and Heiner Schwoerer (without whose help I could not have written a word on CPA) are gratefully acknowledged; as are my hosts at Jena University, Eckhart Förster and Roland Sauerbrey, who allowed me to inflict their students with large chunks of this material over the course of various lectures and computer practicals. Hearty thanks are also due to the following people who readily granted me permission to plunder their published and unpublished work: Elke Andersson, (Fig. 7.3); Thierry Auguste and Pascal Monot (Fig. 4.18); Marco Borghesi (Fig. 4.20); Christine Coverdale (Fig. 4.19); Eugene Clark (Fig. 5.20); Jacques Delettrez (Fig. 5.8); David Meyerhofer (Fig. 3.6); Patrick Mora (Fig. 4.16); Warren Mori (Fig. 4.17); Peter Norreys (Fig. 5.30); Heiner Schwoerer (Figs. 1.3, 1.4, 1.5); Donald Umstadter (Fig. 3.9) and Matt Zepf (Figs. 5.22, 5.30). I am also grateful to Lenore Betts at IC Press, whose enthusiasm and patience played a large part in rescuing this long-overdue project. Finally, a big thank-you is owed to my family, whose members have displayed extraordinary tolerance over the frequent disappearances of their spouse/father to the cellar during the past year.