Measurement of Ultrashort Electromagnetic Pulses

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INTRODUCTION

The electric field, rather than the intensity or pulse energy, is the fundamental entity in optics. This has two very important consequences: First, it is the field that contains the maximum information that it is possible to extract about the optical response of the source or scatter; and second, it is the field that dominates the precise character of the interaction of light and matter for all but the most intense optical interactions.

Our ability to understand and control the dynamics of light–matter interactions, however, is intimately connected to our ability to measure the electric field at optical frequencies and to determine the corresponding temporal, spectral, and spatial characteristics.

The field of ultrashort optical pulse measurement in the modern context can be dated back to the 1960's, with the development of techniques to measure short pulses taking place in parallel with the appearance of mode-locking techniques used to generate them. As lasers have produced shorter pulses, measurement techniques have become increasingly refined, and techniques such as frequency resolved optical gating (FROG) and spectral phase interferometry for direct electric field reconstruction (SPIDER) have become widely used tools that have revolutionized the way in which experiments in ultrafast optics are carried out [1–3]. For example, in laser physics, the pulse-shaping mechanisms in mode-locked lasers have been clarified, and new schemes for pulse compression both inside and outside the laser cavity have been developed. Ultrafast pulse metrology is now routinely used in day-to-day alignment of complicated chirped-pulse amplifier systems and, in nonlinear optics, pulse characterization has provided understanding of the details of spectral broadening processes and soliton dynamics in a range of novel photonic media such as microstructured glass fibers and gas-filled hollow-core waveguides.

These new applications, however, have brought new technological challenges. The fact that pulses from the latest generation of laser sources consist of only a few optical cycles means that the characterization methods used must be capable of accurately measuring very broad bandwidths. Pulses generated by nonlinear optical processes in waveguides are often far from transform-limited with complex substructure and spatiotemporal coupling, and this places additional demands on the measurement techniques that are used. In addition, the need for precision pulse measurement techniques has also extended from the ultrafast optics laboratory into the technological domain of telecommunications, and this has required the further development of techniques adapted specifically for very-low-pulse peak power. In yet another direction, measurement techniques are just beginning to have an impact in the attosecond domain. Here, the challenges are to find suitable nonlinear interactions and to develop robust ways of encoding the spectral phase of the very short wavelength pulses into detectable signals using these nonlinearities [4–13].

The past few years have seen dramatic advances in the field of ultrashort pulse measurement in response to these challenges, and this research has clarified both the strengths and limitations of the techniques used, and have led to a clearer picture of which particular methods are appropriate for particular measurement regimes. Contained in this Feature Issue, some papers address a selection of these issues, while other papers provide a broader cross-section through other international developments in this field. Overall, the papers here highlight the fact that the rapid development of new sources of pulsed radiation and new applications of broadband light continues to place demands on the pulse characterization tools used, and continues to stimulate exciting new questions.

Over many years, we have worked with many of the authors of the papers in this special issue, and we would like to extend both our thanks to them for their contributions and for their continuing efforts to advance the science of this field to new levels. We also extend our thanks to the referees and the journal production staff for their efficiency and assistance.

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