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THE SUMMARY OF Ph.D. DISSERTATION

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Title
Study of accurate pulse shaping of amplified femtosecond laser pulses for ultrafast coherent control

Abstract

The wave packets of excited state of matter can be manipulated by properly designing the electrical field of femtosecond laser pulses. When the interaction Hamiltonian is fully described, an optimal excitation waveform could be searched with a quantum chemical calculation. However, the calculated waveform shows complex structure; therefore, its amplitude and phase have to be manipulated accurately and unrestrained to revive the waveform in a laboratory. On the other hand, when the Hamiltonian is not fully described, an optimal excitation pulse is acquired by constructing a closed loop control in a laboratory, where the control cost is the response of matter with the laser pulse. Even in this case, the performance of the close loop control relies on the unrestrained performance and the accuracy of the pulse shaping system itself. In this study, a pulse shaper is installed before a femtosecond laser pulse amplifier, and the amplitude and phase of the intense optical pulses are accurately manipulated.

Chapter 1 summarizes previous studies, shows the background of this study. Then the objective of this study and the context of each chapter are shown.

In chapter 2, the characteristics of pulse shapers, especially, the spatio-temporal coupling effect are discussed in detail. In this chapter the spatio-temporal coupling effect was directly measured for the first time, and experimentally revealed that this effect seriously influences the light-matter interaction.

Chapter 3 describes the adaptive control algorithm, which is used in chapter 5 and chapter 7.

Chapter 4 describes the advantages of the pre-shaping scheme, such as the mitigation of the spatio-temporal coupling effect, and then the open loop control scheme is investigated. Experimental results in this chapter show that a closed loop control scheme must be constructed for accurate pulse shaping.

In chapter 5, a closed loop control scheme is demonstrated by referring spectrogram-like frequency resolved optical gating trace in pre-shaping amplifier system. The distinctive feature in this study is that both amplitude and phase were referred for the optimization and both of these were accurately manipulated. Hence the degree of system manipulation significantly increased.

In Chapter 6, TADPOLE (temporal analysis, by dispersion a pair of light) waveform characterization method is introduced to improve the accuracy of amplitude and phase characterization. The amplitude and the phase of a long pulse were measured with this measurement technique, and as a result, in addition to the high manipulation ability proved in chapter 5, the accuracy of the pulse shaping system was accomplished.

Chapter 7 describes the demonstration of the optical processing and ultra-fast coherent control experiments. Specific laser pulse parameter can be accurately and independently changed with the highly accurate pulse shaping system. This chapter describes that those capabilities of the pulse shaper are important to gain insight of a matter to obtain a simple physical model, through the experimental demonstrations of optical dissociation of ethanol and maximum enhancement of fluorescence from a dye.

Chapter 8 puts the results of all chapters together, and summarizes the results of this study.