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Ultrafast pulse optimization using two-photon absorption induced thermal lens

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Abstract

We present a method that uses the two-photon induced thermal lens effect as feedback signal in an ultrafast pulse shaping technique for femtosecond pulse optimization in a closed-loop evolutionary algorithm. This approach presents robustness equivalent to those that employ other nonlinear processes but has the advantage that the sample does not need to be fluorescent neither harmonic generator. The method was demonstrated in the optimization of pulses from a Kerr-lens modelocked Ti:sapphire laser using fluorescent and non-fluorescent samples.

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Keywords: Nonlinear optics; Pulse shaping; Ultrafast pulse

1. Introduction

Owing to the technological evolution of laser manufacturing processes, femtosecond laser systems became commercially available recently, which spread out their use in several applications, such as multi-photon excited fluorescence microscopy [1–3], optical coherence tomography [4], optical metrology [5,6], time resolved spectroscopy and optical communications [7]. A consequential growth is also occurring in the coherent control of light–matter interaction using tailored femtosecond laser pulses. The capability of using light to control chemical reactions and nonlinear optical interactions has been sought by scientist for a long time [8]. Nowadays, due to the broadband spectral content of ultrafast femtosecond laser and to pulse shaping techniques, one can manipulate both phase and spectrum of ultrafast pulses, controlling the light–matter interaction or optimizing the laser pulse itself. In order to overcome the difficulties associated with the high number of parameters

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involved in these tasks, closed-loop learning algorithms have been employed [9]. For instance, selective photodissociation reaction [10] and chemical bond rearrangement [11] could be accomplished by using a genetic algorithm (GA). Several methods, which may employ acoustooptic modulators, deformable mirrors, liquid crystal modulators, or others, have been used to manipulate the pulse in time, spectrum or phase domains. These pulse shape techniques have also been extensively used to produce transform-limited pulses using nonlinear processes, such as second harmonic generation (SHG) or two-photon excited fluorescence (2PEF) as the feedback signal in a closed-loop learning algorithm [12]. Although these methods are now well established and work properly for the purpose of pulse optimization, it seems worthwhile to seek for alternative techniques that work even for samples that do not fluoresce nor generate the second harmonic. With this motivation, the present work proposes the use of the two-photon induced thermal lens (TL) effect as the feedback control signal for femtosecond pulses optimization. This new scheme was demonstrated in the pulse optimization of a Kerr-lens modelocked Ti:sapphire laser oscillator using fluorescent and non-fluorescent samples. Besides of being a versatile and sensitive alternative which does not require compound fluorescence or harmonic generation, this method can be the only solution when aiming to study the coherent control of nonlinear process in non-fluorescent samples. In fact, the TL method can be used with any type of sample, because there is no restrictions regarding, for instance, phase matching conditions or fluorescence spectral range. Additionally, due to the accumulative nature of the thermal process, the TL feedback control scheme proposed here can substantially improve the robustness of the optimization process, once the signal depends on the fluence and not on the pulse energy.

2. Experimental

The adaptive feedback control scheme proposed here, which basically consists of a pump–probe method, is shown in Fig. 1. The pump consists of ultrashort pulses produced by a Kerr-lens modelocked Ti:sapphire oscillator from KMLabs (≈20 fs, 5 nJ, center wavelength at about 800 nm and 80 MHz repetition rate), pumped by the second harmonic of a Nd:YVO_4 laser (Verdi-5, coherent). A micro-machined deformable mirror [13] is used to shape the phase of each spectral component of the pulses, in a zero-dispersion stretcher configuration [13–15]. The shaped pulses and a CW He–Ne probe laser are focused at the

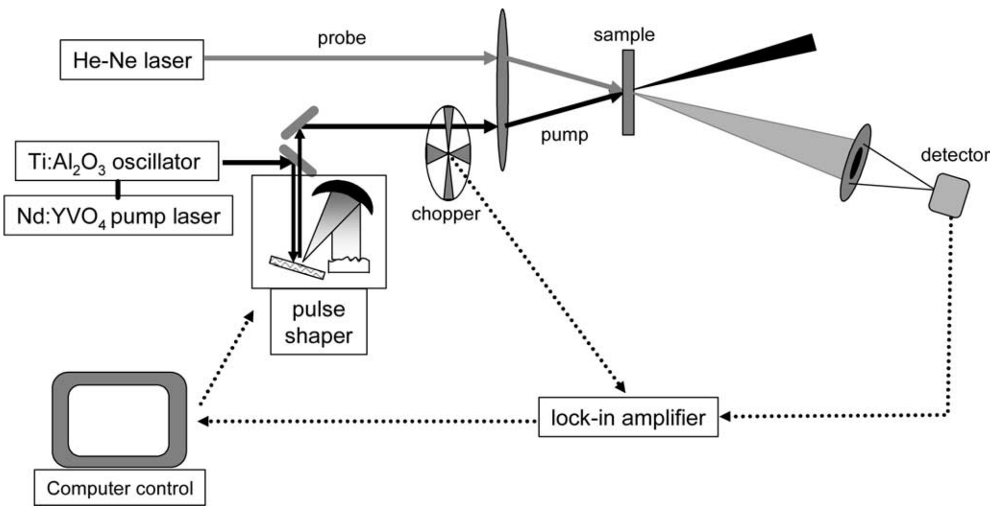

Fig. 1. Layout of the experimental setup using thermal lens as feedback for pulse shaping.