Two-photon induced thermal lens as a feedback signal for ultrafast pulse optimization

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Abstract

We have achieved pulse optimization using an alternative approach, for us proposed, where the two-photon absorption induced thermal lens effect is used as the feedback signal for a closed-loop evolutionary algorithm. The results obtained by this technique are comparable to the ones achieved through the traditional two-photon excited fluorescence feedback signal approach, with the additional advantage that non fluorescent samples can be employed in coherent control methods.

Samples

The MEH-PPV and Disperse Orange 3 (DO3) solution concentrations were 0.21 mg/ml and 0.25 mg/ml, respectively. The absorption spectra in the UV-Vis region, obtained with a Cary 17 spectrophotometer, are presented in Fig.2. The MEH-PPV chromophore presents strong 2PEF when excited above linear absorption wavelength, at nonresonant region, with strong laser pulse. The DO3 dye is an azoaromatic compound, that presents a two-photon absorption process and subsequent nonfluorescent relaxation. On account of that, it is used in the two-photon induced thermal lens experiments.

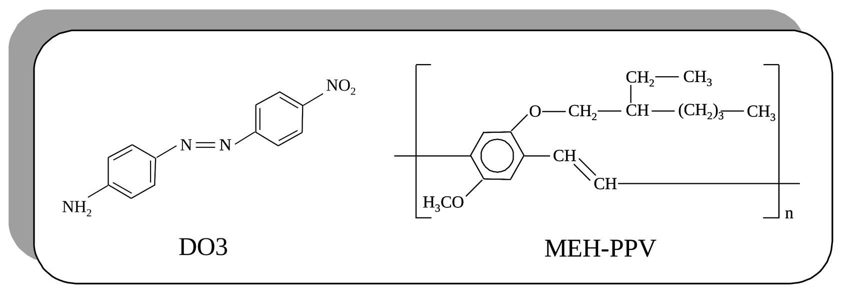

Figure 1: Molecular structures of the compounds employed.

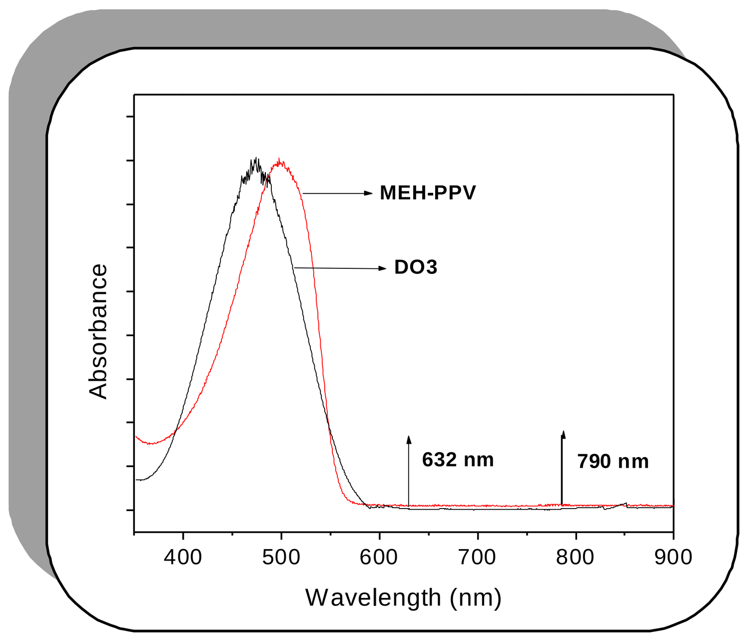

Figure 2: Absorbance spectra for the DO3 and MEH-PPV dissolved in DMSO and in chloroform, respectively.

Experimental setup

In this experiment we have used laser pulses with around 60 nm of bandwidth and duration of 15 fs, centered at 790 nm. The pulses were delivered by a commercial Ti:sapphire Kerr-lens modelocked (KLM) laser oscillator from K&M company, Fig. 3, operating with a repetition rate of approximately 80 MHz. The typical average power employed was 400 mW (~ 5 nJ per pulse).

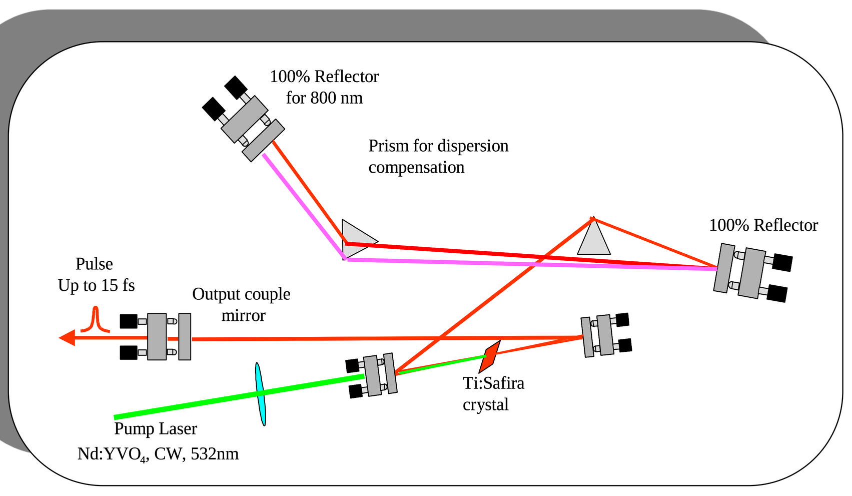

Figure 3: KLM Ti:sapphire femtosecond laser cavity.

In this work we have used a micromachined deformable mirror (MMDM) from OKO technologies to pulse shaping in the phase domain. The mirror in the MMDM is a 600 nm gold-coated silicon nitride membrane (8 mm x 30 mm) suspended over an array of 19 actuator electrodes on a printed circuit board. The maximum deflection is 4 μm with response of 1 ms. Potential applied to the actuator creates an electrostatic attraction between the membrane and the electrode, deforming the mirror surface. The total surface deflection of the mirror is a linear combination of the influence functions for all actuators. Deviation of the mirror surface causes the light to travel a different path, changing the phase of the spectral component in the area of the deformation. The MMDM is placed at the Fourier plane of a zero dispersion stretcher consisting of a 600 grove/mm ruled grating and a 25 cm focal-length mirror, Fig.4. In order to control the deformation of the MMDM we have used a GA program implemented in LabVIEW. Such program is very powerful in our case of multiple variable problems.

The pulse optimization is obtained using an evolutionary strategy which begins with a set of random pulse shapes whose associated thermal lens effect or fluorescence signal is measured. Those pulses that produce the most intense thermal lens effect or fluorescence are retained, duplicated, perturbed and reproduced, as the GA requires, Fig.5. This process is repeated until a desired number of interactions (generations). Basically, the GA is a search and optimization methodology inspired in the biological evolution, consequently, the biology concepts such as chromosome (father and children), reproduction, crossover, mutation, etc are applied in the computational GA code.

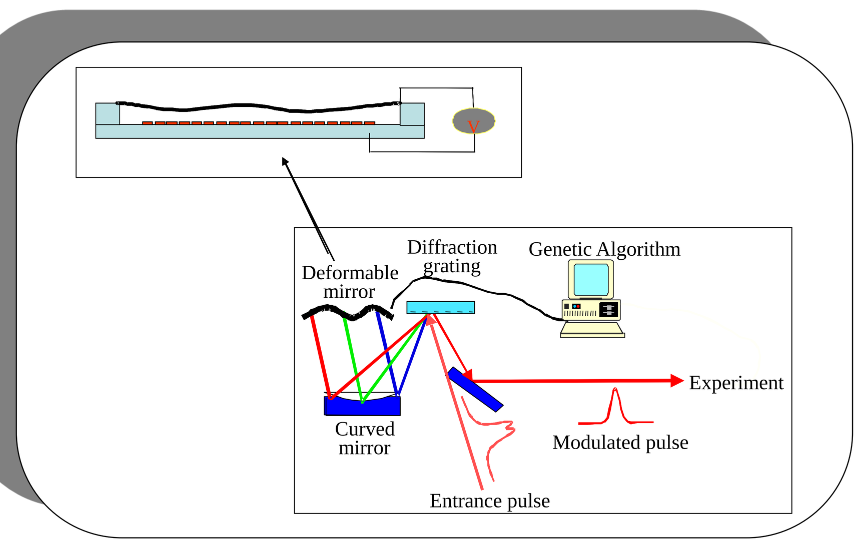

Figure 4: Experimental setup for pulse shaping.

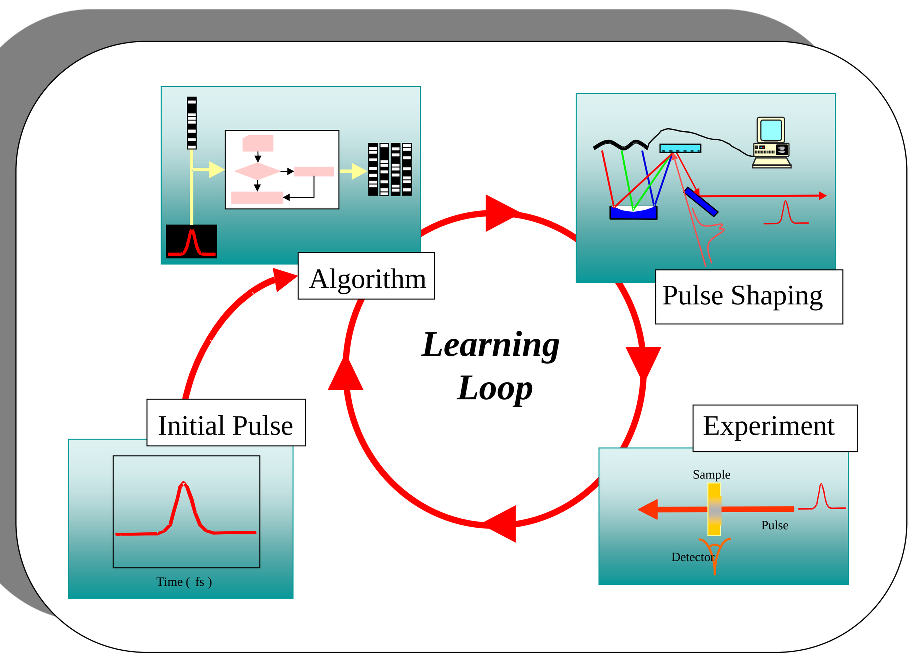

Figure 5: Experimental setup for pulse shaping optimization using GA..

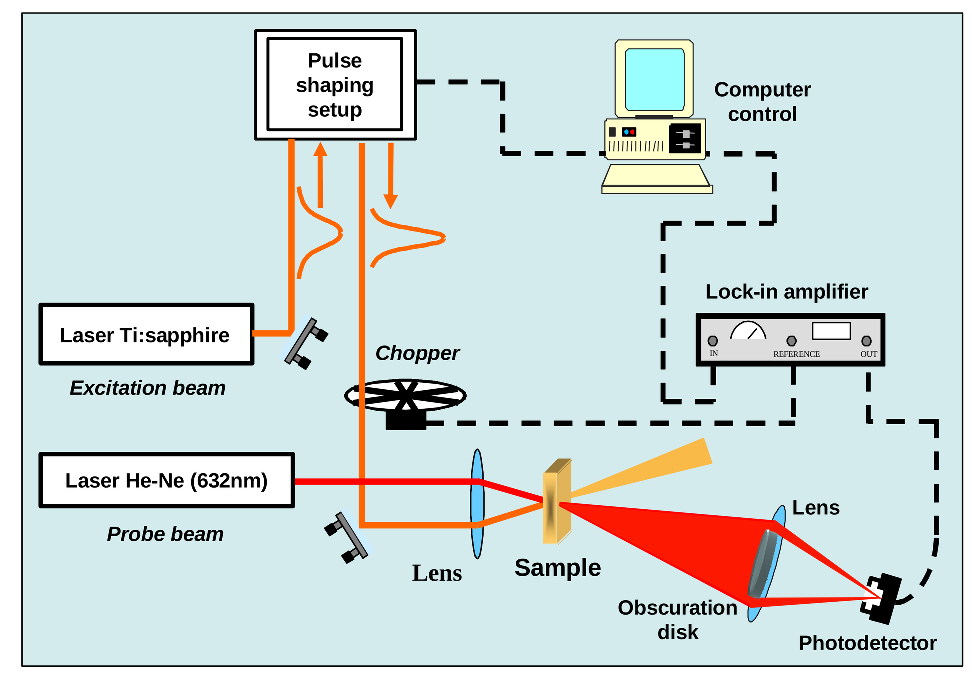

Figure 6: Experimental setup for pulse optimization via two-photon induced thermal lens.

The adaptive feedback control scheme proposed here, which basically consists of a pump-probe method, is shown in Fig. 6. As the excitation source it was employed the Kerr-Lens Modelocked (KLM) Ti:sapphire laser oscillator. The shaped pulses and a cw He-Ne laser (probe beam) were focused at the same spot in a nonlinear sample. In this way, due to the 2PA process a small thermal lens effect, which can be monitored by the probe beam, take place. Such thermal lens effect can be detected and used as the feedback signal in a closed-loop control using the GA.

The thermal lens effect is detected by monitoring the beam intensity pattern in the far field, by measuring the transmittance through an obscuration disk that blocks most of the beam (eclipsing configuration), enhancing the experimental sensitivity. This method is similar to the eclipsing Z-scan technique, however, here the sample is not scanned but positioned after the focal point of the first lens, once it corresponds to the point where a transmittance peak occurs in the eclipsing Z-can signature. This transmittance signal is used as the feedback signal in our evolutionary strategy.

Results

Using our pulse shaping setup we have optimized the ultrafast pulse via two-photon induced thermal lens (2PTL) and two-photon excited fluorescence (2PEF). The fluorescence and the transmitted light through obscuration disk were collected by a PIN photodetector with lock-in amplifier. In order to confirm the pulse optimization we have carried out FROG (Frequency-Resolved Optical Gating) measurements of the pulse before and after the optimization processes. Fig.7 illustrates the evolution of the fitness parameter (thermal lens magnitude) during the GA optimization process and the FROG measurements of the pulse before and after the optimization process via 2PTL in DO3 solution. Fig.8 illustrates the evolution of the fitness parameter (fluorescence intensity) during the GA optimization process and the FROG measurements of the pulse before and after the optimization process via 2PEF in MEH-PPV solution. The optimization processes takes about twenty minutes.

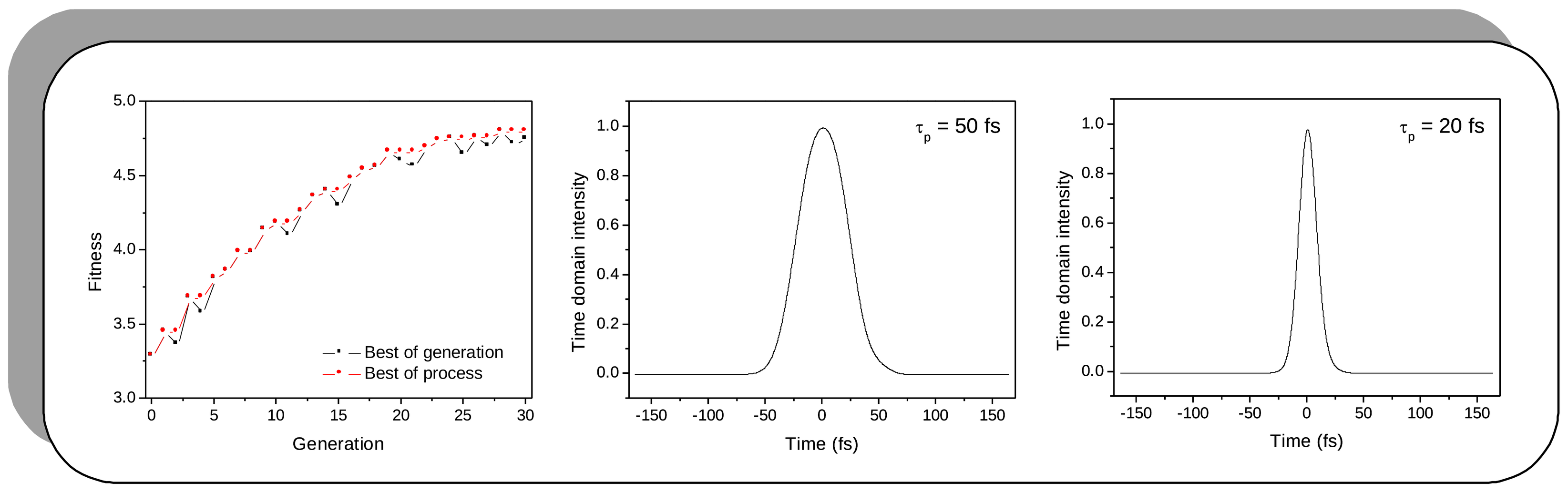

Figure 7: Evolution of the fitness parameter and the FROG measurements of the pulse before and after the optimization process via 2PTL..

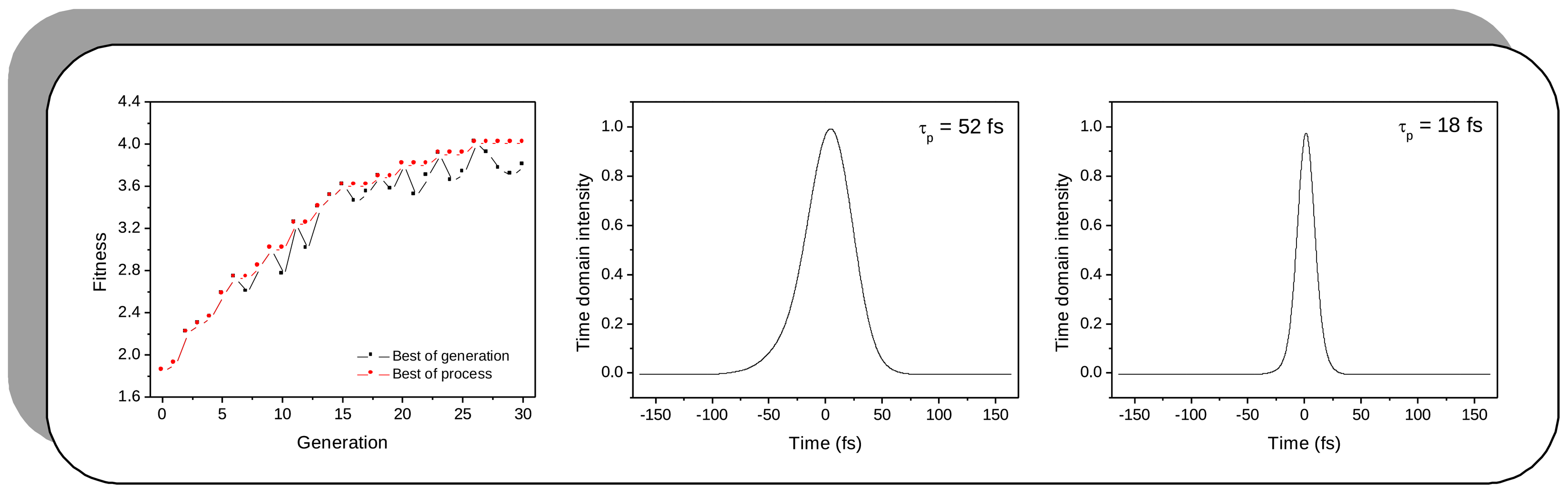

Figure 8: Evolution of the fitness parameter and the FROG measurements of the pulse before and after the optimization process via 2PEF.

Ours results has shown that approximately the same pulse optimization was achieved with both methods, 2PTL and 2PEF, thus confirming the feasibility of the proposed approach.

Conclusion

In summary, we have shown that 2PTL can be used as feedback for ultrafast pulse optimization using genetic algorithm in some cases where fluorescence is not present, thus being an alternative method for coherent control.

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