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Optogalvanic Signal Optimization through the Coherent Control of Multiphoton Ionization

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Abstract: The optogalvanic signal, induced in a hollow cathode discharge in argon, is optimized by phase-shaping the pulses of an ultrashort Ti:Sa laser. Multiphoton transitions leading to ionization determine the efficiency of the electric signal generation.

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1. Introduction

This work presents and discusses the results on the optimization of the Optogalvanic Signal (OGS) induced by ultrafast shaped laser pulses in an electrical glow discharge in argon. The electrical glow is produced in a Hollow Cathode Discharge (HCD) generated in a cell containing a tube-shaped cathode coaxially aligned to the line joining the anode. The OGS generated in this discharge reflects the impedance change induced by the interaction of a resonant laser radiation with one or more atomic transitions in the gas. This gas is electrically excited within the HCD and operated in the subnormal regime, which corresponds to the region of the voltage versus current curve that exhibits a negative dynamic resistance. This electric behavior allows the amplification of the OGS by orders of magnitude [1].

2. Optogalvanic signal and control

The ability of controlling the generated OGS reveals the successful management of the quantum process dynamics designed by the interaction of the excited Ar atoms with a shaped coherent source. The OGS is connected to a multitude of physical mechanisms, like: excited atom collisions, excited atom-atom/ion collisions and photoionization [2]. The goal is to elucidate through this new insight these complex phenomena occurring in the discharge and also produce specific photoinduced effects.

The typical operating conditions of the HCD include: a potential between 250 to 500 V across the electrodes, a current through the discharge of 0.1 to 1.0 mA, and a gas pressure of 400 to 600 Pa. In this low-temperature plasma, the laser beam interacts with the argon-excited population inside the cathode glow region produced axially within the hollow space in the cathode.

In the analysis of the optimized OGS, the dependence on the optimized pulse is examined based on its spectral phase-shaping structure and the HCD operating conditions. The spectral region is chosen to be gated within the laser emission band between 750 and 850 nm. The laser used was a RAINBOW™ Femtolasers ($\Delta t < 7$ fs, $\Delta\lambda > 300$ nm @ 10%, $f_{rep} = 78$ MHz and average power of 300 mW), which was shaped by a DAZZLER™. Our acousto-optical shaping device was constituted of a 25 mm TeO_2 crystal, allowing a spectral resolution of a 2π phase change every 0.51 nm (corresponding to a total of 196 independent shaping elements, λ_i) [3]. A Pockels cell modulated the output beam in order to allow only phase-shaped pulses to interact with the HCD glow at a 1 kHz repetition rate.

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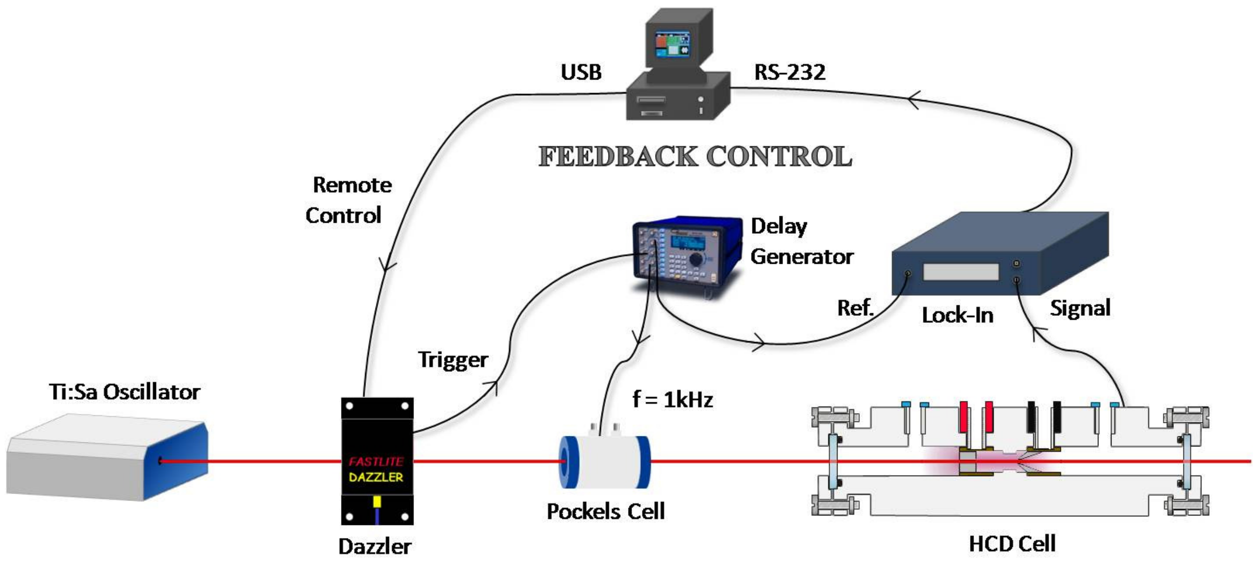

Fig.2 Experimental setup

3. Algorithm and results

An evolutionary algorithm was implemented in order to optimize the phase structure of individuals belonging to generations of pulses. The best-fit procedure developed here was based on selection, recombination and mutation of "phase-chromosomes" (pulse sets of $\varphi_i(\lambda_i)$), according to their corresponding OGS fitnesses [4]. An optimization parameter was defined based on the ratio between the best OGS among the individuals of a generation and the OGS generated by a Fourier Transform Limited (FTL) pulse.

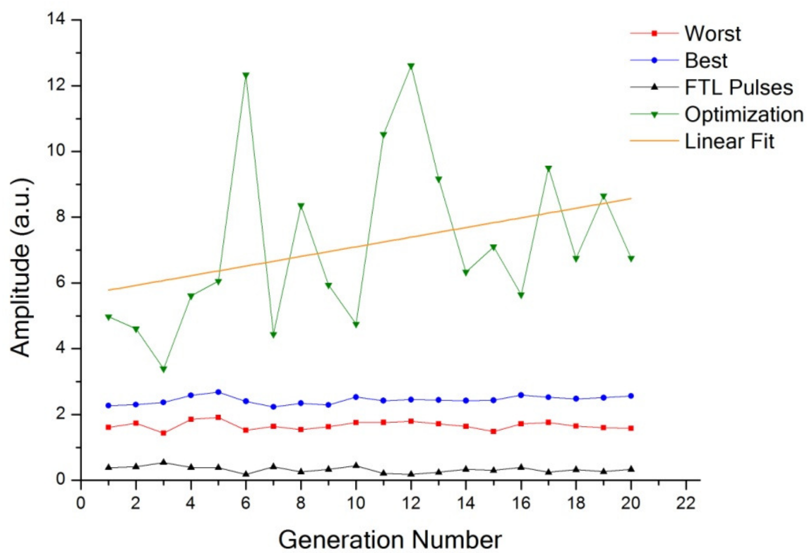

Fig.2 Evolution of fitness for pulses in different generations

Initial results (Fig.2) show an improvement of 600 – 850 % over the TFL results. For these, the phase structure of the best-shaped pulses favors phase jumps close to resonance of the first step of a multiphoton transition. This token indicates the population transfer to higher energy levels close to the ionization limit and also the direct photoionization process. The spectral gating procedure available in the amplitude modulation of the DAZZLER will be explored to investigate specific photoionization pathways.

4. References

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