Chapter 8

Summary

This work, in the main part, was committed to simultaneous and independent phase, amplitude, and polarization shaping. In particular, constructing two setups capable of such manipulations of electromagnetic waves was described, and one of them was used to investigate the enhancement of the ionization process of sodium potassium molecules. Additionally, wavepacket dynamics of ultracold rubidium molecules was investigated by means of pump-probe spectroscopy.

8.1 Phase, amplitude, and polarization shaping

First, the concept of polarization was treated in Chapter 2 with focus on its mathematical description. It was shown how to generate states of polarization with desired ellipticities and orientations, by controlling the relative phase of orthogonal polarization components together with their amplitudes. In Chapter 3, the parallel setup was introduced. It is based on the superposition of two independent phase and amplitude shaped pulses having perpendicular polarizations. In addition, it allows for full control over the polarization, including rotation of the angle of the major axis of the polarization ellipse as well. The description of the setup was given with first tests of polarization manipulation and trial pulses resolved by a simple and intuitive polarization sensitive detection. Afterwards, in Chapter 4 an optical layout including a double layer modulator was developed that is also capable of polarization control together with phase and amplitude, but with a restriction regarding the orientation of the resulting polarization ellipse. This solution escapes the problem of interferometric stability required by the previous scheme on the cost of limited polarization control. Later, Chapter 5 considered the arrangements of crystals different from the $\pm 45°$ orientation. A new solution was introduced in a form of a four array modulator that could replace the previous double array modulators without any modification done to the classic 4f setup, and have the potential of full control over all the femtosecond pulse's parameters.

The developed and tested setups allow for independent and simultaneous control over the pulse characteristics in domains that were not accessible before. The introduced control over the polarization together with the phase and amplitude makes those tools extremely flexible and useful. The list of possible applications is not limited to coherent control experiments on molecules, but can also contribute to the fields of attosecond generation, information encoding, better understanding of a filament generation, and many more topics of physics, chemistry, and biology where light plays an important role.

8.2 Coherent control of sodium potassium

Coherent control of alkali dimers was the first performed experiment with the use of phase, amplitude, and polarization shaped pulses. The newly gained degree of freedom in pulse shaping takes advantage of perpendicular dipole moments of $\Sigma \rightarrow \Sigma$ and $\Sigma \rightarrow \Pi$ transitions present in the optimal ionization process. The evident rise in efficiency for the optimization including the polarization proved that the impact of polarization is relevant. This novel method provides new information about the investigated systems that can be acquired from the optimal pulse temporal and spectral features as well.

The coherent control experiments of simple diatomic molecules already shows the relevance of including the polarization in the set of manipulated parameters of the optimized pulses. The impact of this advance is expected to be higher with increased complexity of the investigated systems, therefore it would be perfectly suited for more complicated systems.

8.3 Investigation of ultracold Rb_2 molecules

The relatively new approach of binding molecules from atoms entrapped inside a MOT has been examined with the use of ultrafast pulses. The creation of molecules is based on excitation of colliding atoms by an IR pulse and thus creating a bond by photoassociation. Since short laser pulses are used instead of a narrow bandwidth CW laser, the excitation results in a propagation of wavepackets along the potential surfaces, which was used to shorten the intramolecular distance. At the proper intramolecular distances such molecules can be detected by ionization by the laser pulse originating from a Noncollinear Optical Parametric Amplifier built in the frame of this work. The obtained data suggest that a photoassociation process was might be responsible for the presence of the peaks in the pump-probe spectra. Further examination of the process including chirps of the IR pulses and closed loop experiments are required to confirm the presented interpretation of these findings.

The demonstrated experiment is meant to be a basis on which the production of cold molecules can be grounded. The successful creation of molecules has the potential to become the same for molecular physics what Bose Einstein Condensates are for atomic physics, namely it can lead to better understanding of molecular processes, bond formation and breaking, production of a molecular condensate, and fabrication of molecular lasers.