Abstract

In the present thesis, the interaction between atoms in superposition states and attosecond pulses is studied from the microscopic to the macroscopic regime. Using a semi-classical framework, three different models have been explored in order to investigate attosecond light–matter interaction processes.

The first model is a microscopic, single-atom model. Through using this model, the absorption and the radiation of an external attosecond pulse was studied for several atomic superposition states and pulse energies. The second model was composed by two coupled atoms, where the interaction was described by either dipole-dipole or radiation interaction. The model was validated by simulating the Förster resonant phenomena. In addition, this model was used to determine the behaviour of the interactions with respect to separation distance and the initial states of the atoms. It was found that dipole-dipole interaction is dominant in the near field, whilst radiation interaction is dominant in the far field. Additionally, it was found that superpositions with high principal quantum numbers increase the strength of the dipole-dipole interaction but not the radiation interaction. The simulated results have been validated, in the short-time regime, using perturbation theory.

The last model investigated in this thesis is a macroscopic many-atom model. It was implemented in order to simulate the propagation of an attosecond pulse through a large sample of atoms. Utilising this model, collective effects of many-atom systems were studied. It was found that a macroscopic sample emits collimated radiation and that dissipation of pulse energy in a macroscopic sample retains the behaviour of radiation produced by a single atom but that it is deformed by the propagation through the sample.

The models explored in this thesis can be used in the study of light-matter interaction on the attosecond timescale with inter-atomic interactions and collective effects. The work presented here can be built on further to investigate research areas such as the dipole-blockade effect in cold atom physics, ionisation due to inter-atomic interaction or collective coherent effects.