Rydberg atoms are coupled by long-range dipole-dipole interactions [1].

They attract a lot of attention for their important role in studying fundamental problems as well as potential applications in quantum control in few- and many-body systems, quantum information processing, quantum calculation, etc. [2-10].

The research discussed in this dissertation is focusing on the influence of the DD interactions on the electron dynamics of cold Rydberg atoms.

Three projects are presented in this dissertation, including both introduction of experimental setup and simulation results, respectively.

Common experimental setups and background knowledge are also provided.

One of my lab’s main efforts is to explore and manipulate quantum dynamics in atomic and molecular systems. A series of projects have been or are implemented to observe and control interactions between highly-excited Rydberg atoms. These projects help people to understand fundamental science in atomic physics. More than that, they may contribute to potential practical applications from designing many-body systems that simulate model condensed matter systems, to quantum information storage and processing, to the development of new radiation sources and detectors.

Work done by previous graduates Xiangdong Zhang and Mary Kutteruf has pushed the effort a big step. The project “Probing Time-Dependent Electron Interactions in Double Rydberg Wavepackets” done by Xiangdong Zhang helps us understand more about electron interactions within individual atoms. The project “Coherence in Rydberg Atoms: Measurement and Control” done by Mary Kutteruf extended the exploration to the interactions between electric fields and wavepackets in an ensemble of Rydberg atoms. My project is an extent of their work but also a relatively independent research which is to explore the interactions between Rydberg atoms within an ensemble. Another current graduate student Brian Richards is working on utilizing such interactions. Our projects are like puzzle chunks, working together to make the whole picture more complete.

My project to explore the influence of dipole-dipole interactions on wavepackets of Rydberg atoms has been divided into three sub-projects. First one is to explore the role of DD interactions in suppressing Dicke states (Chapter 5). The second one is to explore the influence on wavepackets’ evolution by DD interactions (Chapter 6). And the final one is to explore the coherence transfer via DD interactions (Chapter 7). Those three sub-projects help us understand better about what the DD interactions do in an ensemble of cold Rydber atoms.