UNIVERSITEIT VAN AMSTERDAM

Interacting Rydberg Atoms on a Chip

J.J.M. de Hond

Summary of thesis (partially based on the "Popular summary" that can be found at the end):

In the area of quantum information there is currently a strong interest in systems with controllable interactions. Rydberg atoms are a prominent candidate for this; due to their extreme sizes (sometimes approaching the thickness of a human hair) their properties are what you would call extreme – compared to atoms in the ground state, that is. In our atom chip experiment we have investigated the strong interactions between Rydberg atoms in rubidium.

Using lasers we are able to excite these exotic states. A portion of this thesis is dedicated to the experimental setup that is required to control the lasers to a high degree, needed for good control over the atoms. After that, we describe our attempts at observing the effects of the strong Rydberg interaction. This is manifested, for instance, by the fact that it is not possible to excite more than one Rydberg atom within some volume (a second atom would interact with the first one, and hence would have a different energy which does not correspond to the energy of the excitation laser). This phenomenon, better known as 'Rydberg blockade,' was observed in our experiment. The blockade is interesting for applications within quantum optics, where it can for instance be used to create single-photon sources.

We have also investigated how the blockade comes into being; it takes some time, after all, before the cloud of atoms is completely saturated with Rydberg excitations. This we could observe reasonably well, and we were able to explain our observations using a model that described the coherence in our system. That this should work is not a given, since our system consists of tens of thousands of atoms that all behave quantum mechanically. Of course, we had to make some assumptions, because a full model would have been too complicated even for the largest supercomputers around today. This, then, is also one of the larger-scale goals that make this research so interesting: to investigate how quantum mechanics can be employed for complicated calculations and operations.