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Report on the doctoral thesis"Interacting Rydberg Atoms : From Dense Clouds of Rydberg Atoms to Quantum Simulation with Circular Atoms" by Tigrane Cantat-Moltrecht

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The doctoral thesis presented by Tigrane Cantat-Moltrecht describes progress towards employing ultracold Rydberg atoms in circular states for quantum simulation. The final goal of the experiment is outermost ambitious and technologically extremely demanding. Therefore, it cannot be expected that all aspects of such a demanding endeavor can be covered by a single thesis. In fact, there is already an impressive series of outstanding thesis work being achieved in the direction to make circular Rydberg atoms accessible for quantum simulation (see Refs. [74-76] for the most recent theses). The thesis of Tigrane Cantat-Moltrecht now adds important new advances towards this exquisite goal.

The introduction and the first chapter contain a description of the broader and more specific field of research, respectively. Details of the experimental setup are contained in chapter 2, outlining the realization of a Bose-Einstein condensate in an atom chip and the Rydberg excitation from an ultracold gas trapped in the vicinity of the chip. Measurements of the coherence properties of Rydberg excitation close to an atom chip are published as Ref. [72] with Tigrane Cantat-Moltrecht as coauthor. A first important scientific result forms the basis of chapter 3, namely the interpretation of microwave Rydberg spectra for varying exposure times. The effects of Rydberg-Rydberg interactions are captured by three numerical models, based on which the excitation dynamics of the atom cloud under the interplay of Rydberg blockade, excitation facilitation and mechanical forces can be quantitatively described. These results are partially included in Ref. [73] coauthored by Tigrane Cantat-Moltrecht. Chapter 4 is then devoted to the development of a theoretical proposal for using chains of circular Rydberg atoms as a platform for quantum simulation. This chapter is essentially based on a recent paper posted as arXiv:1707.04397 with Tigrane Cantat-Moltrecht being on the author list. The creation of circular atoms close to an atom chip, a major advancement of the entire experiment, is reported in chapter 5. Through a detailed set of measurements, coherence times and life times for the circular states with principal quantum number 50 and 51 are mapped out. Suggestions for future improvement of these parameters are given. The final chapter summarizes the results of the thesis and provides an outlook into the mid- and long-term future perspectives of the experiment.

Overall, the thesis is very well written fulfilling all standards for a doctoral thesis. My only criticism, if any, is that it is not possible from the thesis to discern Tigrane Cantat-Moltrecht's original contributions to the results obtained within a large research team. It would have been helpful to clearly mark his contributions to the papers where is coauthor, but not first in the list of authors. Notwithstanding, the thesis contains an appealing mixture of theoretical, conceptual and experimental aspects including some truly novel advancements of science.

In conclusion, I recommend this well written thesis for defense.

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