Scientific report Exchange Grant #1203

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ESF activity: QUDEDIS

Title: Dynamics in Optical Lattices

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Applicant: Prof. dr. P. van der Straten, Utrecht University

Host Institute: Prof. dr. R. Grimm, TU Innsbruck

Purpose of the visit: Collaborate on the work of rubidium atoms in optical lattices.

Description of the work: In the field of cold molecules one of the main issues is the transfer of cold molecules, which are produced using a Feshbach resonance, from the highly vibrational excited state to the ground state. In Innsbruck the technique is pioneered to accomplish this task using stimulated Raman adiabatic passage (STIRAP). Although the technique has been applied successfully for atoms, it offers different challenges, when applied to cold molecules. It was shown as a prove-of-principle experiment, that cold molecules can be transferred from one molecular quantum state to another more strongly bound state with an efficiency of 87%. This result opens the way to transfer the molecules with a reasonable efficiency to the vibrational ground state by applying this technique in several steps.

Another part of the work deals with the use of radio-frequency radiation to directly transfer from one molecular state to another without exciting the molecules to an excited state. To research this possibility coupled-channels calculations were initiated using a program from NIST, Gaithersburg, to calculate bound, molecular states close to the dissociation level. Using the molecular wavefunctions the magnetic dipole transition rates between the states are calculated. One of the intriguing possibility is to couple the 'open' channel in the Feshbach problem directly to the 'closed' channel using RF-radition. This way

Feshbach resonances can be induced by using at a certain magnetic field the proper RF-frequency, thereby broadening the scope of Feshbach resonances.

In the first part I took part in the research in the lab to obtain the experimental data and the analysis of this data. The outcome of this work has been published in Physical Review Letters, about which one of the referees noticed, that 'This paper will reach high citation numbers'. In the second part I guided the calculational effort and the first experimental results in the lab.

Future collaborations: Although the collaboration has been very successful so far, there are still three experiments, that have started or are planned, which will take part in the next months to come. In one experiment we want to measure with interferometic precision the splitting between two molecular states, which would put severe restrictions on the parameters that determine the interatomic potentials. In a second experiment we want to induce Feshbach resonances by using RF-radiation, which will make it possible to induce these resonances at any magnetic field. In the third experiment we want to transfer molecules to more deeply bound states using magnetic dipole transitions with the ultimate goal to produce cold molecules in the vibrational ground state. This work will thus continue in the next few months and a new visit to Innsbruck will be planned soon.

Publications: There is already one publication published and three publications are planned.

- *Coherent Optical Transfer of Feshbach Molecules to a Lower Vibrational State*, K. Winkler, F. Lang, G. Thalhammer, P. v. d. Straten, R. Grimm, and J. Hecker Denschlag, Phys. Rev. Lett. 98, 043201 (2007)
- *Interferometric determination of level splittings for ultracold Rb_2 molecules*, F. Lang, B. Brandstätter, P. v. d. Straten, R. Grimm, and J. Hecker Denschlag, in preparation.
- *Inducing Feshbach resonances using RF-radiation*, F. Lang, B. Brandstätter, P. v. d. Straten, R. Grimm, and J. Hecker Denschlag, in preparation.

- *Producing ultracold molecules in the vibrational ground state using magnetic dipole transitions*, F. Lang, B. Brandstätter, P. v. d. Straten, R. Grimm, and J. Hecker Denschlag, in preparation.

Other comments: As can be seen from the report the exchange visit has been very successful. I would like the group of Rudy Grimm and especially Johannes Hecker Denschlag for the hospitality and the QUDEDIS-program for their support, without which it would not have been possible.

prof. dr. P. van der Straten
University of Utrecht
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