

# Annual Progress Summary

To: technicalreports@afosr.af.mil

Subject: Annual Progress Statement to Dr. Tatjana Curcic

Contract/Grant Title: (MURI 09) Production, Manipulation, and Applications of Ultracold Polar Molecules

Contract/Grant #: FA9550-09-1-0588

Reporting Period: 08/01/2009 to 07/31/2010

Annual accomplishments (200 words max):

*Production, Cooling, and Detection.* Buffergas cooling of large gaseous molecules was accomplished and molecular optical pumping into a magnetic trap was modeled. SrF 1D laser cooling and large optical forces from a cryogenic hydrodynamically enhanced molecular beam was accomplished. A new Stark deceleration technique promises large increase in molecular density. Experiments towards indirect cooling of KRb/Rb<sub>2</sub>, e.g. using FOPA was accomplished, as was LiNa magnetoassociation (as yet without surviving molecules).

*Structure and Chemistry.* KRb/RbCs collisions and potential surfaces of K<sub>2</sub>Rb and more have been calculated and ultracold chemical reactions were studied, also how to prepare KRb into single hyperfine states, using the effect of DC electric fields and optical lattices. This also leads to equal trapping potentials for different rotational sublevels. In KRb collisions trimers don't appear. The nature of anisotropic collisions was experimentally investigated and direct absorption imaging implemented.

*Quantum Information/Simulation.* Symmetry breaking/phase transitions in layered dipolar fermions were calculated, also regarding their experimental feasibility, as well as dipolar arrays for increasing single-photon nonlinearities and creating cluster states.

*Molecular Ions.* Redesigned traps improved the major problem of charging dielectrics due to laser ablation in traps significantly.

Archival publications (published) during reporting period:

1. *Cooling and Collisions of Large Gas Phase Molecules*, D. Patterson, E. Tsikita, and J. M. Doyle, Phys. Chem. Chem. Phys. in press.
2. *Theory and Spectroscopy for Ultracold KRb Molecules*, W. C. Stwalley, in Proceedings of the International Conference on Computational Methods in Sciences and Engineering (ICCMSE 2010), T. E. Simos and G. Maroulis, editors, in press.
3. *Structure and thermochemistry of K<sub>2</sub>Rb, KRb<sub>2</sub>, and K<sub>2</sub>Rb<sub>2</sub>* J. N. Byrd, J. A. Montgomery Jr., and R. Côté, Phys. Rev. A 82, 010502(R) (2010).

4. *Dispersion interactions and reactive collisions of ultracold polar molecules*, S. Kotochigova, New J. Phys. 12, 073041 (2010).
5. *Controlling the Hyperfine State of Ro-Vibronic Ground-State Polar Molecules*, S. Ospelkaus, K.-K. Ni, G. Quemener, B. Neyenhuis, D. Wang, M. H. G. de Miranda, J. L. Bohn, J. Ye, and D. S. Jin, Phys. Rev. Lett. 104, 030402 (2010).
6. *Direct absorption imaging of ultracold polar molecules*, D. Wang, B. Neyenhuis, M. H. G. de Miranda, K.-K. Ni, S. Ospelkaus, D. S. Jin, and J. Ye, Phys. Rev. A 81, 061404(R), (2010).
7. *Strong Dependence of Ultracold Chemical Reaction Rates on Electric Dipole Moments*, G. Quemener and J. L. Bohn, Phys. Rev. A 81, 022702 (2010).
8. *Quantum-State Controlled Chemical Reactions of Ultracold Potassium-Rubidium Molecules*, S. Ospelkaus, K.-K. Ni, D. Wang, M. H. G. de Miranda, B. Neyenhuis, G. Quemener, P. S. Julienne, J. L. Bohn, D. S. Jin, and J. Ye, Science 327, 853 (2010).
9. *Dipolar Collisions of Polar Molecules in the Quantum Regime*, K.-K. Ni, S. Ospelkaus, D. Wang, G. Quemener, B. Neyenhuis, M. H. G. de Miranda, J. L. Bohn, J. Ye, and D. S. Jin, Nature 464, 1324 (2010).
10. *Electric-Field Suppression of Ultracold Confined Chemical Rates*, G. Quemener and J. L. Bohn, Phys. Rev. A 81, 060701(R) (2010).
11. *Radiative Force from Optical Cycling on a Diatomic Molecule*, E.S. Shuman, J.F. Barry, D.R. Glenn, and D. DeMille, Phys. Rev. Lett. 103, 223001 (2009).

Changes in research objectives, if any: None

Change in AFOSR program manager, if any: None

Extensions granted or milestones slipped, if any: None

Include any new discoveries, inventions, or patent disclosures during this reporting period (if none, report none): None