Chapter 5

Summary and Outlook

I have described in this thesis the design, construction, and operation of an experimental apparatus we have built for producing and studying quantum degenerate ^{87}Rb -^{40}K Bose-Fermi mixtures. By evaporatively cooling the bosons and sympathetically cooling the fermions, we can produce a nearly pure Bose-Einstein condensate of ^{87}Rb atoms coexisting with a Fermi gas of ^{40}K atoms at about 0.2 times the Fermi temperature. The appearance of quantum degeneracy in the experiments has been characterized for each species and compared to theoretical predictions.

I have additionally presented measurements of the magnitude of the s-wave scattering length $|a_{\mathrm{RbK}}|$ between species. The scattering length is important in characterizing a variety of the equilibrium and dynamic properties of the mixture. I have discussed techniques for studying some elementary excitations of the system, and have analyzed the prospect for exploiting interactions with phonons in the condensate to create fermion pairs. It has been shown that current theory places this prospect within reach of current experiments.

Finally I have discussed our observation of Feshbach resonances between ^{87}Rb and ^{40}K atoms in non-degenerate mixtures. These important experiments open up the possibility of tuning a_{RbK} to any desired value in the experiment. Our experimental observations have been compared to theoretical calculations

and used to refine parameters describing the collisions between species.

The future of this experiment lies in exploiting these resonances in a variety of useful and exciting ways. After first measuring the elastic properties of the resonances, we can begin to utilize the resonant control of the interactions between species in a number of experiments. Possible studies include the controlled collapse of the mixture, the production of polar fermionic molecules, the generation of a boson-induced sound mode among spin-polarized fermions, generation of bright Bose-Fermi matter wave solitons, and the boson-induced pairing of fermions.

Relevant Publications

- J. Goldwin, S. B. Papp, B. DeMarco, and D. S. Jin, *Two-species magneto-optical trap with ^{40}K and ^{87}Rb*, Phys. Rev. A **65** 021402 (2002)

- J. Goldwin, S. Inouye, M. L. Olsen, B. Newman, B. D. DePaola, and D. S. Jin, *Measurement of the interaction strength in a Bose-Fermi mixture with ^{87}Rb and ^{40}K*, Phys. Rev. A **70**, 021601 (2004)

- S. Inouye, J. Goldwin, M. L. Olsen, C. Ticknor, J. L. Bohn, and D. S. Jin, *Observation of Heteronuclear Feshbach Resonances in a Mixture of Bosons and Fermions*, Phys. Rev. Lett. **93**, 183201 (2004)

- J. Goldwin, S. Inouye, M. L. Olsen, and D. S. Jin, *Cross-dimensional relaxation in Bose-Fermi mixtures*, Phys. Rev. A **71**, 043408 (2005)