Coherences and correlations in an ultracold Bose gas

by

Heather Jean Lewandowski

B.S. Physics, Michigan Technological University, 1997

M.S. Physics, University of Colorado, 2001

A thesis submitted to the

Faculty of the Graduate School of the

University of Colorado in partial fulfillment

of the requirements for the degree of

Doctor of Philosophy

Department of Physics

2002

This thesis entitled:
Coherences and correlations in an ultracold Bose gas
written by Heather Jean Lewandowski
has been approved for the Department of Physics

Eric A. Cornell

Deborah S. Jin

Date

The final copy of this thesis has been examined by the signatories, and we find that both the content and the form meet acceptable presentation standards of scholarly work in the above mentioned discipline.

Lewandowski, Heather Jean (Ph. D. Physics)

Coherences and correlations in an ultracold Bose gas

Thesis directed by Dr. Eric A. Cornell

The development of a new and simplified system to create a Bose-Einstein condensate (BEC) is presented, as well as experimental studies of two spin-state condensed and non-condensed samples. The first part of this thesis describes in detail our apparatus and experiential procedure for creating a BEC. We designed a system to create a BEC that is simple and robust enough to be constructed by someone outside of the field of atom cooling and trapping. Our system includes several novel features that reduce the complexity of the apparatus, which include mechanical transfer of atoms and a hybrid magnetic trap.

The second part of this thesis describes studies of two spin-state clouds. We studied the correlations and coherences of non-condensed clouds using Ramsey spectroscopy to gain an understanding of interatomic interactions. We were able measure precisely the mean-field interactions between coherent particles, as well as determine mechanisms that preserve and destroy coherence. These experiments led us to the study of spin waves, in which scattering of indistinguishable particles gives rise to coherent spin oscillations. Using sensitive Ramsey spectroscopy, we were able to fully examine the spatio-temporal spin-state oscillations. Following the studies of normal cloud coherence, we went on to explore coherence effects in condensates.

Acknowledgements

First I would like to acknowledge my advisor Eric Cornell. He always amazes me with his physical insight and ability to be entranced by "shiny bits of physics," which led us to a lot of great science. He has the right balance of knowing when to give advice and when to let us direct the experiment. I am grateful to have worked with such an inspiring physicist. I would also like to acknowledge Carl Wieman who has offered guidance throughout my graduate career.

I have had the privilege to work with many talented people. During his postdoc, Dwight Whitaker helped to construct the apparatus and always kept us going even during the two months of vacuum hell. I could not have asked for a better graduate student to have in the lab than Dave Harber. His unquenchable enthusiasm combined with his laid back attitude made working long hours in the lab truly fun. Another postdoc I worked with, Jeff McGuirk, brought his training in precision measurement to our lab. He really made me think about the experiment in a new way. He was also a great friend who kept me at least partially sane during the writing of this thesis. It was great to have so many other graduate students and postdocs to talk to and learn from over the years including Paul Haljan, Kurt Miller, Brian DeMarco, Neil Claussen, Ian Coddington, Peter Schwindt, Ying-Ju Wang, John Goldwin, David Hall, Brian Anderson, Stephan Duerr, Peter Engles, Shin Inouye and Tetsuo Kisimoto.

The construction of the apparatus would not have gone so quickly and smoothly if not for the JILA instrument and electronics staff. Hans Rohner, Hans Green, Blain

Horner, James Fung-a-Fat, and Terry Brown were always willing to help figure out a solution to the many problems I presented them.

Lastly I would like to thank my family for all of their support. My husband Don put up with a lot of late nights and was always supportive. My parents Kathleen and Dennis have always encouraged me through the years. I would not be writing this thesis if not for them.

Contents

Chapter

Tables

Table

Figures

Figure