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QUANTUM CHAOS, TRANSPORT, AND DECOHERENCE IN ATOM OPTICS

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QUANTUM CHAOS, TRANSPORT, AND DECOHERENCE IN ATOM OPTICS

by

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Acknowledgements

Experimental research is often a collaborative endeavor, and the work presented in this dissertation is certainly no exception. During the past six years I have had the pleasure of working with a number of bright and enthusiastic people that I would like to mention here.

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I have collaborated with Windell Oskay on all of the research in this dissertation. I cannot imagine having done the experiments in this dissertation without Windell's remarkable productivity and superior technical prowess. This is especially true of the chaos-assisted tunneling experiments in Chapter 6, where the two of us managed an enormously complicated experiment and took enough data to literally choke our computer. Windell's rock-solid and extensive LabVIEW code (which featured its own web page so that we could check on the status of the experiment from anywhere in the world) enabled the 12 and 33 day (running 24/7) data marathons that produced all of the CAT results. It was also great to work with someone that shares my ardor for doing things the "right" way, and I have appreciated his attention to detail. I should also note that Windell is responsible for nearly all of the 3D renderings in this dissertation, including the nice surface plots of the data in Chapter 6. It has been a pleasure knowing Windell both in and out of the lab, who has excellent taste in movies, art, italian cuisine, chocolate, and computers.

I worked with Bruce Klappauf from nearly the beginning of my graduate studies to build up the cesium experiment from scratch, and he worked on the early kicked-rotor experiments in Chapter 4. Bruce is not only laid back and very easy to work with, but also good at simply making

things work. His insight, creativity, and curiosity made him a great asset to the lab as well as a great guy to hang out with.

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QUANTUM CHAOS, TRANSPORT, AND DECOHERENCE IN ATOM OPTICS

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This dissertation details an experimental investigation of the center-of-mass motion of cesium atoms in a time-dependent lattice of light. The research described here proceeds along two general lines. The first group of experiments considers a realization of the quantum kicked rotor, where the optical lattice is applied in a series of short, periodic pulses. In the regime where the classical description of this system is strongly chaotic, the quantum and classical dynamics differ remarkably due to dynamical localization, which is a manifestation of the quantum suppression of classical chaos. Because this quantum localization is a coherent effect, it should be vulnerable to noise or coupling to the environment, providing a mechanism for restoring classical behavior at the macroscopic level. The experimental results confirm that dynamical localization can be destroyed by adding noise and dissipation in a controlled way, and furthermore they show that quantitative agreement between the experiment and a classical model can be reached with a sufficient level of applied noise.

The second line of research considers the weakly chaotic regime, where stable and chaotic regions coexist in phase space. The optical lattice is modulated sinusoidally in these experiments to realize the amplitude-modulated pendulum. Careful preparation of the initial atomic state, including stimulated Raman velocity selection, is necessary to resolve the phase-space features. Coherent tunneling oscillations are observed between two symmetry-related

islands of stability in phase space. Because the classical transport between the islands is forbidden by the system dynamics, as opposed to a potential barrier, the tunneling in this experiment is an example of dynamical tunneling. Additionally, the experimental data indicate through multiple signatures that the tunneling is enhanced by the presence of the chaotic region in phase space, an effect known as chaos-assisted tunneling.

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