

**Direct Frequency Comb Spectroscopy for Optical
Frequency Metrology and Coherent Interactions**

by

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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.

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Direct Frequency Comb Spectroscopy for Optical Frequency Metrology and Coherent Interactions

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We take advantage of a phase-stable, wide-bandwidth femtosecond laser to bridge the fields of high-resolution spectroscopy and ultrafast science. This approach, which we call Direct Frequency Comb Spectroscopy (DFCS), involves using light from a comb of appropriate structure to directly interrogate atomic levels and to study time-dependent quantum coherence. In fact, DFCS may be effectively applied to determine absolute frequencies for atomic transitions anywhere within the comb bandwidth, obviating the need for broadly tunable and absolutely referenced continuous-wave (cw) lasers.

In this work, we apply DFCS to determine absolute atomic transition frequencies for one- and two-photon processes in laser-cooled ^{87}Rb atoms. In addition, DFCS enables studies of coherent pulse accumulation and multipulse interference, permitted by the relatively long-lived excited states. These effects are well modeled by our density matrix theory describing the interaction of the femtosecond comb with the cold atoms.

As in the case of precision spectroscopy performed with cw lasers, the use of the femtosecond comb as a probe requires a careful understanding of all systematic effects. We isolate and then mitigate the effects of the dominant sources of systematic errors, which include the mechanical effect of the optical comb on the atomic motion, Stark shifts by the probe laser, and Zeeman frequency shifts. The absolute frequency measurement results are comparable to the highest resolution measurements made with cw lasers. In addition, by determining the previously unmeasured absolute frequency of the 5S-7S two-photon transitions in ^{87}Rb , we show that prior knowledge of atomic transition frequencies is not essential for DFCS.

Dedication

To my family.

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