

Systems and Protocols for Quantum Metrology and Quantum Computation

A dissertation presented

by

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Systems and Protocols for Quantum Metrology and Quantum Computation

Abstract

Abstract about

- Quantum computation protocols
- and their use
- Quantum metrology protocols
- and their use
- systems capable of realizing them
- namely: optomechanical systems
- atomic systems

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Citations to Previously Published Work

Most of the chapters of this thesis have appeared in print elsewhere. By chapter number, they are:

- Chapter 2: “Single-photon nonlinearities in two-mode optomechanics,” P. Kómár, S. D. Bennett, K. Stannigel, S. J. M. Habraken, P. Rabl, P. Zoller, and M. D. Lukin, *Phys. Rev. A* **87**, 013839 (2013).
- Chapter 3: “Optomechanical quantum information processing with photons and phonons,” K. Stannigel, P. Kómár, S. J. M. Habraken, S. D. Bennett, M. D. Lukin, P. Zoller, and P. Rabl, *Phys. Rev. Lett.* **109**, 013603 (2012).
- Chapter 4: “Heralded Quantum Gates with Integrated Error Detection in Optical Cavities,” J. Borregaard, P. Kómár, E. M. Kessler, A. S. Sørensen, and M. D. Lukin, *Phys. Rev. Lett.* **114**, 110502 (2015).
- Chapter 5: “Long-distance entanglement distribution using individual atoms in optical cavities,” J. Borregaard, P. Kómár, E. M. Kessler, A. S. Sørensen, and M. D. Lukin, *Phys. Rev. A* **92**, 012307 (2015).
- Chapter 6: “Heisenberg-Limited Atom Clocks Based on Entangled Qubits,” E. M. Kessler, P. Kómár, M. Bishof, L. Jiang, A. S. Sørensen, J. Ye, and M. D. Lukin, *Phys. Rev. Lett.* **112**, 190403 (2014).
- Chapter 7: “A quantum network of clocks,” P. Kómár, E. M. Kessler, M. Bishof, L. Jiang, A. S. Sørensen, J. Ye, and M. D. Lukin, *Nature Physics* **10**, 582587 (2014).
- Chapter 8: “Quantum network of natural atom clocks,” P. Kómár, T. Topcu, E. M. Kessler, A. Derevianko, A. S. Sørensen, and M. D. Lukin, *?? ??, ??* (2015?).

Acknowledgments

*Dedicated to my parents Erzsébet and Antal,
my sister Anna,
and my fiancée Szilvia.*

Chapter 1

Introduction and Motivation

1.1 Overview and Structure

1.2 Optomechanical Systems

1.3 Atom-Cavity Systems

1.4 Rydberg Interactions

1.5 Quantum Repeaters

1.6 Atomic Clocks and Quantum Metrology

Chapter 2

Single-photon nonlinearities in two-mode optomechanics

2.1 Introduction

From [1]

Chapter 3

Optomechanical quantum information processing with photons and phonons

3.1 Introduction

From [2]

Chapter 4

Heralded Quantum Gates with Integrated Error Detection in Optical Cavities

4.1 Introduction

From [3]

Chapter 5

Long-distance entanglement distribution using individual atoms in optical cavities

5.1 Introduction

From [4]

Chapter 6

Heisenberg-Limited Atom Clocks Based on Entangled Qubits

6.1 Introduction

From [5]

Chapter 7

A quantum network of clocks

7.1 Introduction

From [6]

Chapter 8

Entangling collective Rydberg excitations of remote atomic ensembles

8.1 Introduction

From [1]

Bibliography

- [1] P. Kómár, S. D. Bennett, K. Stannigel, S. J M Habraken, P. Rabl, P. Zoller, and M. D. Lukin. Single-photon nonlinearities in two-mode optomechanics. *Phys. Rev. A*, 87:013839, 2013.
- [2] K. Stannigel, P. Komar, S. J M Habraken, S. D. Bennett, M. D. Lukin, P. Zoller, and P. Rabl. Optomechanical quantum information processing with photons and phonons. *Phys. Rev. Lett.*, 109:013603, 2012.
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