

Contents

| | | |
|----------|---|----------|
| 1 | Introduction and Overview | 1 |
| 2 | Gate Level Simulations | 3 |
| 2.1 | Ideal Quantum Computer Simulations | 3 |
| 2.1.1 | The Circuit Model of Quantum Computation | 3 |
| 2.1.2 | Quantum Algorithms | 8 |
| 2.1.2.1 | Shor's Algorithm for Prime Factorization | 8 |
| 2.1.2.2 | Grover's Search Algorithm | 14 |
| 2.1.3 | Massively Parallel Ideal Quantum Computer Simulator | 18 |
| 2.2 | Error-Prone Quantum Computer Simulations | 37 |
| 2.2.1 | Error Model | 37 |
| 2.2.2 | H^{2k} -Algorithm | 41 |
| 2.2.3 | Quantum Fourier Transform | 45 |
| 2.2.4 | Grover's Search Algorithm | 50 |
| 2.3 | Simulation of Quantum Error Correction | 56 |
| 2.3.1 | Quantum Error Correction Codes | 57 |
| 2.3.1.1 | Shor's 9-Qubit Quantum Error Correction Code | 58 |
| 2.3.1.2 | Steane's 7-Qubit Quantum Error Correction Code | 61 |
| 2.3.1.3 | 5-Qubit Quantum Error Correction Code | 65 |
| 2.3.2 | Ideal and Error-Prone Quantum Error Correction | 68 |
| 2.3.3 | Fault-Tolerant Quantum Error Correction | 71 |
| 2.3.3.1 | Theoretical Principles | 71 |
| 2.3.3.2 | Numerical Simulations | 81 |
| 2.3.3.3 | Conclusion | 102 |

CONTENTS

| | | |
|----------|---|------------|
| 3 | Dynamic Simulations of Ion Trap Quantum Computers | 105 |
| 3.1 | Theory of Ion Trap Quantum Computation | 105 |
| 3.2 | Dynamic Quantum Computer Simulator for Ion Traps | 120 |
| 4 | Summary and Outlook | 139 |
| | Acknowledgements | 143 |
| A | Quantum Circuit Symbols | 145 |
| B | Equivalence of Depolarizing Channel and Unitary Over-Rotations | 147 |
| C | Stabilizer Codes for Quantum Error Correction | 153 |
| D | Listings | 159 |