Contents

1 Introduction 1
- 1.1 A brief history of Quantum Computing . . . 1
- 1.2 Ion trap quantum computing . . . 4
- 1.3 Magnetic field gradient proposal . . . 6

2 Interaction of ions with em-fields 11
- 2.1 Interaction with the RF trapping potential . . . 12
  - 2.1.1 Potential and stability diagram . . . 12
  - 2.1.2 Secular and *micro-motion* . . . 15
  - 2.1.3 Ion crystals . . . 17
- 2.2 Interaction with laser light . . . 19
  - 2.2.1 Laser cooling . . . 19
  - 2.2.2 Optical pumping . . . 25
- 2.3 RF radiation: incoherent measurements and coherent interaction . . . 28
  - 2.3.1 Possible qubits . . . 28
  - 2.3.2 Four-level dynamics: Bloch equations . . . 32
  - 2.3.3 Incoherent spectra: Lorentz profiles . . . 35
- 2.4 Interaction with the magnetic gradient field . . . 38
  - 2.4.1 Ion addressing . . . 38
  - 2.4.2 Coupling internal and external dynamics . . . 41

3 Trapping single Yb^+ ions 47
- 3.1 The linear trap . . . 48
  - 3.1.1 Design . . . 48
  - 3.1.2 Ovens . . . 50
  - 3.1.3 *Trap drives* . . . 53
  - 3.1.4 Secular frequencies . . . 56
  - 3.1.5 Micro-motion . . . 60
- 3.2 Lasers and optics . . . 63
  - 3.2.1 Diode lasers . . . 63

Bibliografische Informationen
http://d-nb.info/985065362

digitalisiert durch DEUTSCHE NATIONAL BIBLIOTHEK

3.2.2 Laser system at 369 nm . . . 66
3.2.3 Intensity level control and light field switching . . . 67
3.2.4 Laser optics . . . 69
3.3 Detection systems . . . 71
3.3.1 Photo-multiplier . . . 71
3.3.2 Intensified CCD-camera . . . 73
3.4 Static and dynamic magnetic fields . . . 78
3.4.1 Static magnetic field coils . . . 78
3.4.2 RF-excitation coil . . . 81
3.5 Experiment control . . . 83

4 Photo-Ionization **87**
4.1 Ionization processes . . . 89
4.2 Atomic excitation spectra . . . 92
4.3 Deterministic number loading of ions . . . 99

5 Addressing single Yb^+ ions **101**
5.1 RF-optical double-resonance spectroscopy of a Yb^+ ion . . . 102
5.1.1 Line-width . . . 103
5.1.2 Amplitude . . . 108
5.2 Static magnetic fields . . . 109
5.3 Dynamic magnetic fields . . . 116
5.3.1 Simulation . . . 120
5.3.2 Rabi oscillations . . . 122
5.4 Magnetic gradient field . . . 131
5.4.1 Simulation . . . 131
5.4.2 Gradient alignment . . . 133
5.4.3 Ion addressing . . . 135

6 Conclusion **147**

A Solution of the four level Bloch-equations **153**

B Fluorescence rate: a simple rate equation model **157**

C Ytterbium **161**

Bibliography **165**

Danksagung **175**