# Contents

1 Introduction

1.1 Precision tests and laser spectroscopy ........................................... 1
1.2 Generation and application of extreme ultraviolet frequency combs ......................... 2
1.3 Quantum-electro dynamics and the ground-state of helium 4
1.4 Motivation and outline of this thesis ........................................... 12

2 Theoretical background

2.1 Electromagnetic waves and wave packets ........................................... 15
2.2 Frequency-comb lasers ..................................................................... 27
2.3 Spectroscopy with frequency combs ............................................. 30
2.4 An analysis of the interaction of a two-level system with a phase-locked pulse-pair ........................................... 34
2.5 Theory of non-collinear optical parametric amplification ........... 40
2.6 High harmonic generation ......................................................... 44

3 Experimental realization of a frequency comb in the XUV

3.1 The frequency comb laser ........................................................... 55
3.2 Non-collinear optical double pulse parametric amplification 59
3.3 Phase measurement setup ........................................................... 63
3.4 Harmonic Generation and Excitation Setup ................................... 66

4 Phase stability of optical parametric amplification

4.1 Setup ................................................................. 73
4.2 Results and discussion ............................................................... 74
4.3 Conclusions ................................................................. 77
## Contents

5 Phase stability of a double-pulse OPA 79  
5.1 Amplification of pulse pairs 81  
5.2 Measurements of the amplifier phase shift 84  
5.3 Conclusions 94

6 XUV frequency comb metrology on the ground state of helium 95  
6.1 Overview and principle of XUV comb generation and excitation 99  
6.2 Experimental setup 103  
6.3 Frequency metrology on $1s^2 - 1s4p$ and $1s^2 - 1s5p$ transitions in helium 110  
6.4 Discussion 112  
6.5 Conclusions and outlook 131

7 Outlook 135  
7.1 Two-photon excitation of the $1s^2 1S_0 - 1s2s 1S_0$ transition in helium 135  
7.2 Programmable pulse delay for Fourier-transform spectroscopy of moderately complicated spectra 137

Bibliography 141

List of Publications 157

Summary 159

Samenvatting 163

Acknowledgements 167