

CONTENTS

	Page
Acknowledgement	d
Abstract in Thai	e
Abstract in English	f
List of Figures	i
Chapter 1 Introduction	1
1.1 Motivation	1
1.2 Thesis outline	4
Chapter 2 Theoretical Background	5
2.1 Magneto-optical trap (MOT)	5
2.2 Optical dipole trap and optical lattice	8
2.3 Rydberg atoms	9
2.4 Rydberg-ground adiabatic interaction	12
2.5 Multi-level atom in light fields and two-photon transition	24
2.6 Light-assisted cold collision in blue-detuning regime	26
Chapter 3 Rydberg State Revisited for Deterministic Single-atom Source	28
3.1 Single-atom loading via light-assisted Rydberg-ground collision	28
3.2 Loading constraints	29
3.3 Analysis of single-atom loading probability	32
3.4 Summary	35
Chapter 4 Investigation of Repulsive Molecular Rydberg State	36
4.1 Experimental setup	36
4.2 One-dimensional optical lattice diagnosis	40
4.3 Trap loss due to blue-detuned two-photon excitation	45
4.4 Summary and outlook	47

References	51
Appendix	56
Appendix A Basis Wave Functions	56
Appendix B JJ-LS Transformation	58
Appendix C Quantum Dynamic of four-level system in magneto-optical trap	61
Curriculum Vitae	65



ลิขสิทธิ์มหาวิทยาลัยเชียงใหม่
Copyright© by Chiang Mai University
All rights reserved

LIST OF FIGURES

	Page
Figure 1.1 Optical lattice potentials (yellow) formed by superposition of orthogonal standing waves. The lattice can be approximated by array of harmonic oscillator potentials at each lattice site where an atom (red sphere) can be trapped.	2
Figure 2.1 Optical alignment of magneto-optical trap.	8
Figure 2.2 Principle of MOT	9
Figure 2.3 An one-dimensional optical lattice can be formed between two mirrors. Atoms are confined at anti-nodes (yellow pancake-like shape) of the standing wave. Any two adjacent sites are separated by the half of dipole laser wavelength, here 808 nm laser is used. The picture is not drawn with true scale.	10
Figure 2.4 Lifetime of Rydberg state $nS_{1/2}$ (blue), $nD_{3/2}$ (dashed Red) and $nD_{5/2}$ (dotted Green) as function of principle quantum number n .	12
Figure 2.5 Coordinate system used in this work. The position of atom B is chosen to be the origin. The internuclear \vec{R} is a vector directed from neutral atom B to the core C^+ of Rydberg atom. It is the quantization axis. \vec{r} is a position vector pointed from neutral atom B to the valence electron e . r_0 is the radius of the sphere enclosed by surface S_1 dividing space into two region where the closed surface S_2 extends to infinity.	14
Figure 3.1 Rydberg-Ground collision picture	29
Figure 3.2 Escape distance D_{es} is the minimum distance that the Rydberg atom needs to move for escaping the trap.	31
Figure 3.3 Approximated repulsive semi-molecular potential of $5S_{1/2} + 35D_{5/2}$.	33
Figure 3.4 Distribution of inter-particle distance	34

Figure 3.5 Occurrence strength of scattering processes as function of intermediate detuning. The gray shaded area covers the range of the detuning from 0 MHz to 80 MHz in order to indicate the safe range from one-body excitation that induces $D(1 1)$.	35
Figure 4.1 Optical schematic of MOT cooling laser. The phase locking technique is used to stabilize output frequency of ECDL1 with respect to ECDL0. The output power was amplified by the tapered amplifier. OI = optical isolator, HWP = half-wave plate, QWP = quarter-wave plate, APP = anamorphic prism pair, PBS = polarizing beam splitter	37
Figure 4.2 Optical schematic of MOT repumping laser.	37
Figure 4.3 Optical schematic of optical lattice laser.	38
Figure 4.4 Optical schematic of probe laser for Rydberg excitation.	39
Figure 4.5 Optical schematic of coupling laser for Rydberg excitation.	40
Figure 4.6 The configuration of laser beams used in the experiment: The red and blue arrows show propagation direction of 780nm probe beam and 480nm coupling beam respectively. The two double arrows on the right hand side represent linear polarization direction of 808nm dipole beam and the coupling beam respectively. MOT-repump beam propagates in $+y$ direction with circular polarization. The downward magnetic field B define quantization axis $+z$.	41
Figure 4.7 Experimental Parameters in Rydberg Experiments	42
Figure 4.8 Measured trap lifetime of rubidium atoms in the optical lattice. Trap lifetime of 588.3 ms was obtained by fitting the data with exponential decay function.	43
Figure 4.9 Temperature measurement by free-space ballistic expansion method. The data (red points) are fitted with Eq.(4.1).	44
Figure 4.10 Gaussian fitted profile represents how position of trapped atoms are distributed in the trap. The signal count data were obtained from converting the absorption image of atomic cloud Fig.(4.18)(right).	44

Figure 4.11	The distribution of number of trapped atom along cavity axis.	45
Figure 4.12	Experimental time sequence of Rydberg experiment	46
Figure 4.13	Excitation Scheme of Rydberg experiment: the energy levels presented here are bare states, no AC Stark shift.	47
Figure 4.14	Trap loss due to blue-detuning Rydberg excitation to $50^2S_{1/2}$	48
Figure 4.15	Radius as function of detuning to Rydberg state $50^2S_{1/2}$	49
Figure 4.16	Trap loss due to blue-detuning Rydberg excitation to $50^2S_{1/2}$	49
Figure 4.17	Radius as function of detuning to Rydberg state $50^2S_{1/2}$	50
Figure 4.18	In imaging process, the first image (left) is taken while trapped atom are released 1.5ms before taking image and expanding ballistically. The second image (center) is taken after waiting until there is no atoms in the area of imaging. These images are subtracted from each other for getting the cloud of atom in the lattice (right). The raw images have resolution of 2048x2048 pixels. Gaussian resampling method is used to reduce the resolution down to 512x512 pixels. The total number of trapped atom is 3 million.	50
Figure C.1	The D2 line energy levels of rubidium-85	62
Figure C.2	Dynamic of populations under the presence of the cooling field and the repumping field	63
Figure C.3	The real and imaginary parts of coherence term as function of time	64

Copyright© by Chiang Mai University
All rights reserved