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1. REPORT DATE (DD-MM-YYYY) 04-01-2023	2. REPORT TYPE Final Report	3. DATES COVERED (From - To) 1-Dec-2016 - 31-Aug-2017
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4. TITLE AND SUBTITLE Final Report: Research Area 11: ARO Special Programs/Short-Term Innovative Research (STIR) Program: Creating and controlling THz superradiance in an ultracold gas	5a. CONTRACT NUMBER W911NF-16-1-0583
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER 611102

6. AUTHORS	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAMES AND ADDRESSES University of South Alabama 307 N. University Blvd. AD 200 Mobile, AL 36688 -3053	8. PERFORMING ORGANIZATION REPORT NUMBER
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9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS (ES) U.S. Army Research Office P.O. Box 12211 Research Triangle Park, NC 27709-2211	10. SPONSOR/MONITOR'S ACRONYM(S) ARO
	11. SPONSOR/MONITOR'S REPORT NUMBER(S) 69829-PE-II.5

12. DISTRIBUTION AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision, unless so designated by other documentation.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT UU	15. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON Jianing Han
a. REPORT UU	b. ABSTRACT UU	c. THIS PAGE UU			19b. TELEPHONE NUMBER 251-460-6224

RPPR Final Report

as of 04-Jan-2023

Agency Code: 21XD

Proposal Number: 69829PEII

Agreement Number: W911NF-16-1-0583

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DUNS Number: 172750234

EIN: 630477348

Report Date: 30-Nov-2017

Date Received: 04-Jan-2023

Final Report for Period Beginning 01-Dec-2016 and Ending 31-Aug-2017

Title: Research Area 11: ARO Special Programs/Short-Term Innovative Research (STIR) Program: Creating and controlling THz superradiance in an ultracold gas

Begin Performance Period: 01-Dec-2016

End Performance Period: 31-Aug-2017

Report Term: 0-Other

Submitted By: Jianing Han

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Phone: (251) 460-6224

Distribution Statement: 1-Approved for public release; distribution is unlimited.

STEM Degrees:

STEM Participants:

Major Goals: The major goal of this project is to study the field suppression of THz superradiance. Specifically, we studied the electric field suppression of superradiance.

With ARO support, we studied the electric field suppression of superradiance in Rydberg atoms [4]. In order to do the Rydberg excitations, we studied the excitation lasers. We replaced the reflective grating in a standing-wave external cavity laser by a transmission grating, so that the laser output direction won't change if the frequency need to be changed [3]. This is essential for Rydberg excitations, in which case, the laser frequency need to be adjusted frequently. Moreover, we studied laser amplification to achieve high laser power [6]. We studied electric field suppression of superradiance [4]. Superradiance is caused macroscopic dipole composed by atomic dipoles. We discovered that the superradiance could be suppressed. In addition, as the atomic density increases, the superradiance is harder to suppress. We also did calculations about dipole-dipole interactions, and studied the dipole-dipole effects on the superradiance formation [1,2,5]. We have also tried to using the magnetic field to suppress superradiance. However, the challenge was to create and switch uniform magnetic field. We now able to create uniform field, and ready to carry out the magnetic field suppression experiment.

[1] "Five body interactions", J. Han, Phys. Rev. A Vol. 95, 062502 (2017).

[2] "Broadband Laser excitation of van der Waals polymers from a cold atomic gas" J. Han, Mol. Phys. Vol. 115, 2479 (2017).

[3] "A ring cavity diode laser", J. Han, Lindsay Hutcherson, Kaori Mune Kane, and Steven J. Shettlesworth, (Submitted).

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[5] "Van der Waals pentamers", J. Han, DAMOP 2017.

[6] "Laser amplification", Mengjie "Andy" Hu, Jianing Han, (to be presented in "Undergraduate Research Conference").

Accomplishments: With the support from ARO (Army Research Office) under contract: W911NF-16-1-0583, we got the first MOT (Magneto-Optical Trap) in the state of Alabama. In addition, we wrote four papers. Two of them [1, 2] were published, one of them [3] is under review, and one of them [4] is in preparation and submitted as one technical report to your agency. The published papers and submitted papers were uploaded as manuscripts. We prepared two posters [5,6], and both of them are attached. We developed one proposal, which has been submitted to your agency through grant.gov. In this recently submitted proposal, we focus on the magnetic field suppression. If time allows, we will try to induce the superradiance by a microwave field.

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Training Opportunities: During the award period, we supported five undergraduate students by paying them salaries, purchasing equipment for them, and helping them to run experiments in the lab. In addition, we also did an outreach program. Seven high school students were exposed to this research. Five of them are from one of the nation's top high schools ASMS (Alabama School of Math and Science), and two of them are from Davison magnet high school in Mobile, Alabama.

Results Dissemination: This research was exposed to freshman physics majors as well as honor students at the University of South Alabama. In addition, this project was exposed to high school students who came to Tuesday Evening Physics, which is organized by the physics department at the University of South Alabama, and student researchers who worked in the PI's lab.

Honors and Awards: One of the undergraduate researcher, Mengjie "Andy" Hu received UCUR summer award from the University of South Alabama.

Protocol Activity Status:

Technology Transfer: Nothing to report.

PARTICIPANTS:

Participant Type: PD/PI

Participant: Jianing Han

Person Months Worked: 2.00

Project Contribution:

National Academy Member: N

Funding Support:

Participant Type: Undergraduate Student

Participant: Gayatri Deshmukh

Person Months Worked: 1.00

Project Contribution:

National Academy Member: N

Funding Support:

Participant Type: Undergraduate Student

Participant: Morgan Umstead

Person Months Worked: 1.00

Project Contribution:

National Academy Member: N

Funding Support:

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as of 04-Jan-2023

Partners

,

I certify that the information in the report is complete and accurate:

Signature: Jianing Han

Signature Date: 1/4/23 10:08AM

Final Progress Report

With the support from ARO (Army Research Office) under contract: W911NF-16-1-0583, we got the first MOT (Magneto-Optical Trap) in the state of Alabama. In addition, we wrote four papers. Two of them [1, 2] were published, one of them [3] is under review, and one of them [4] is in preparation and submitted as one technical report to your agency. The published papers and submitted papers were uploaded as manuscripts. We prepared two posters [5,6], and both of them are attached. We developed one proposal, which has been submitted to your agency through grant.gov. In this recently submitted proposal, we focus on the magnetic field suppression. If time allows, we will try to induce the superradiance by a microwave field.

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Abstract Submitted
for the DAMOP17 Meeting of
The American Physical Society

Van der Waals pentamers.¹ JIANING HAN, University of South Alabama — We report on the five-body repulsive van der Waals interactions in the strongly dipole-dipole coupled Rydberg states. Compared to three-body and four-body interactions, five-body van der Waals interactions show more energy levels and more potential wells caused by avoided crossings. This research bridges the few-body physics and many-body physics. Other disciplines, such as chemistry, biology, and medical field, will also benefit from better understanding van der Waals interactions.

¹The author would like to acknowledge the support from the Army Research Office (ARO) and the DOE Implementation Award.

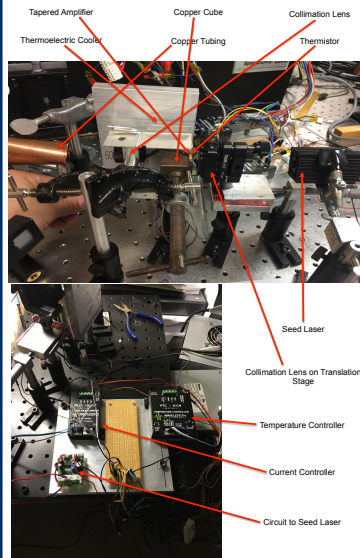
Jianing Han
University of South Alabama

Date submitted: 30 Jan 2017

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Introduction

What distance should atoms be pushed apart in order to maximize Van der Waals' repulsive forces? Building a laser amplification system can answer this question. Specifically, a low power laser beam will be sent to a high power laser diode. In other words, the low power laser will be used as a seed, which will be amplified through a high power laser diode. The beam comes out of the high power laser is similar to the incoming beam in polarization and frequency. There are many potential applications for this laser amplification system. For example, this can be used in laser trapping, based on the Stark effect, to trap both ground state atoms and excited state atoms. In addition, this can be also used for non-linear optics to generate other frequencies, such as frequency doubling, which can be used to excite ground state atoms to excited states. Atoms have to be in the excited states in order to exhibit the repulsive forces that will be studied. The high power laser will be the tool used to change the distance between the atoms through the Stark effect, which then changes the repulsive Van der Waals interaction strength. Ultimately, the repulsive forces will be utilized to push out an unneeded atom from a molecule. For example, this can be applied to cancer research, using visible laser light can push out certain atoms of cancer cells instead of ionizing the cells with high power rays.



The Build

- Tapered Amplifier: the TA (Tapered Amplifier) that will be used is a 980nm C-Mount diode (1cm width), which will be secured and enclosed to a copper block with the top exposed. This TA will be used as the high power laser ready to be seeded. The top of the TA will be exposed in order for the input facet of the TA to be seeded with the low power laser.
- Copper Cube: the copper cube (2in x 2in all around) was the selected material for this TA because it is such a good conductor of heat. Since the TA chip generates a large amount of heat during operation, the copper will be a good conductor to disperse the energy.
- Thermistor: a 0.5cm deep hole, the circumference of the thermistor, will be drilled near the Mounted TA in order for the Thermistor to be inserted. The thermistor is a resistor, whose resistance linearly depends on heating. This resistance can be converted to temperature in order to monitor the temperature that the TA operates at.
- Thermoelectric Cooler: when this plate is used with a temperature controller, it can cause the object that the TEC (Thermoelectric Cooler) is in contact with to either heat up or cool down. The TEC will be attached to the copper cube, in order to cool it down after it absorbs the energy of the TA.
- Temperature Controller: the temperature controller used in this system is one that is made by wavelength electronics. It will need to be used with a thermistor and a thermoelectric cooler. The thermistor will tell the temperature controller the temperature of the apparatus (the copper cube), and in turn, the temperature controller will tell the thermoelectric cooler to either cool down the cube or heat it up, accordingly to the temperature that it will be set at.
- Current Controller: similar to the temperature controller, the current controller will control the current that is being put out to the TA. The current controller used is also made by wavelength electronics and it has a limit that can be set so the current put out does not exceed this. This function will prevent the over powering of the TA.
- Seed Laser: the seed laser that will be used is a pre-made low power laser bought from laserland.com. This will allow up to amplify the laser system after it is collimated and shot through a lens at the high powered c-mount laser.
- Collimation Lenses: two collimation lenses will be utilized in this system. The first collimation lens will be on a homemade translation stage placed on the input side of the TA in order to focus the seed laser into the TA. The second collimation lens will be placed on the output side of the TA in order to collimate the rays outputted by the TA.
- Copper Tubing: a copper tube is obtained and clamped at the end. The inside of the tube is painted black since its emissivity is 1. It will be used as a beam dump for the laser.

Findings

Time (sec)	Voltage (V)
0	1.21
11	1.25
25	1.30
40	1.35
57	1.40
75	1.45
94	1.50
116	1.55
140	1.60
164	1.65
196	1.70
234	1.75
288	1.80
377	1.85

Table 1: this table shows the time vs. voltage it takes to reach 12-C (1.78V)

Time (sec)	Voltage (V)
0	1.80
30	1.77
60	1.74
90	1.71
120	1.70
150	1.68
180	1.66
210	1.64
240	1.63
270	1.62
300	1.60
330	1.59
360	1.58
390	1.57

Table 2: this table shows the time vs. voltage monitored after the TA is turned on once the block is initially cooled to 12-C.

Currently, the tapered amplifier and the seed laser are both working efficiently. The output power of the tapered amplifier as well as the seed laser can be individually adjusted precisely.

Future Uses

Currently, each component of the Laser Amplification system is working efficiently. The next step of this project is to actually seed the tapered amplifier properly in order for it to perform at maximum efficiency. Trials of seeding the tapered amplifier is currently unsuccessful, this may be explained by the fact the tapered amplifier is multimode and all of the ones used in the references that we used were single mode. Efforts are currently made to try to change the multimode tapered amplifier to single mode through the use of partial reflective mirrors, in order for it to be seeded by a single mode seed laser.

Once the proper seeding of the tapered amplifier is achieved, it will be used to run experiments on different atoms. The infrared ray produced by the seeded tapered amplifier will be focused on a single atom in hopes of exciting the electrons from the 1s orbital to the 2s orbital. Ultimately, this will be used to change the repulsive Van der Waals interaction strength in hopes of pushing out unwanted atoms from a cluster.

It is a pleasure to acknowledge the support from the Army Research Office (USA) under contract no. W91NF-16-1-0583. Andy Hu is supported by the UCUR (University Committee on Undergraduate Research) program at the University of South Alabama.

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