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6. AUTHORS
Cheng Chin

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14. ABSTRACT
Supported by ARO DURIP, we are constructing a new experimental platform to control individual atoms in an optical lattice to synthesize novel quantum matter and to explore the possibility to prepare a many-body system in an arbitrary quantum state. The grant offers 4 pieces of essential equipment for the quantum matter synthesizer, including the a solid state laser for the formation of optical lattices, a digital micromirror device to steer optical tweezers, 2 objectives for imaging and projection, as well as 2 scientific cameras.

15. SUBJECT TERMS
quantum matter synthesizer, ultracold atoms, optical lattices

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a. REPORT	b. ABSTRACT	c. THIS PAGE			Cheng Chin
UU	UU	UU	UU		19b. TELEPHONE NUMBER 773-702-7192

Report Title

Final Report: Construction of an Ultracold Quantum Matter Synthesizer

ABSTRACT

Supported by ARO DURIP, we are constructing a new experimental platform to control individual atoms in an optical lattice to synthesize novel quantum matter and to explore the possibility to prepare a many-body system in an arbitrary quantum state. The grant offers 4 pieces of essential equipment for the quantum matter synthesizer, including the a solid state laser for the formation of optical lattices, a digital micromirror device to steer optical tweezers, 2 objectives for imaging and projection, as well as 2 scientific cameras.

Except for the objectives which will be delivered in the next month, we have received other equipment and are currently in process to test and assemble the system. Experiments on the manipulation of atoms with the quantum matter synthesizer will soon start after we receive the objectives.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

Received Paper

TOTAL:

Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

Received Paper

TOTAL:

Number of Papers published in non peer-reviewed journals:

(c) Presentations

Number of Presentations: 0.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received Paper

TOTAL:

Number of Manuscripts:

Books

Received Book

TOTAL:

Received	Book Chapter

TOTAL:

Patents Submitted

Patents Awarded

Awards

Cheng Chin, APS DAMOP fellow

Graduate Students

NAME	PERCENT_SUPPORTED	Discipline
Gustaf Downs	0.00	
Jonathan Trisnadi	0.00	
FTE Equivalent:	**0.00**	
Total Number:	**2**	

Names of Post Doctorates

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Faculty Supported

NAME	PERCENT_SUPPORTED	National Academy Member
Cheng Chin	0.00	
FTE Equivalent:	**0.00**	
Total Number:	**1**	

Names of Under Graduate students supported

NAME	PERCENT_SUPPORTED	Discipline
Yunpeng Ji	0.00	
Paloma Ocola	0.00	
FTE Equivalent:	**0.00**	
Total Number:	**2**	

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period:	0.00
The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:	0.00
The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:	1.00
Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):	1.00
Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:	0.00
The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense	0.00
The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields:	1.00

Names of Personnel receiving masters degrees

NAME

Total Number:

Names of personnel receiving PHDs

NAME

Total Number:

Names of other research staff

NAME PERCENT_SUPPORTED

FTE Equivalent:
Total Number:

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

See Attachment.

Technology Transfer

ARO DURIP 66947PHRIP “Construction of an Ultracold Quantum Matter Synthesizer”

Scientific Progress and Accomplishments

The Quantum Matter Synthesizer (QMS) is a new experimental platform for quantum simulations and engineering new quantum phases. Once completed, the QMS will be able to load atoms into a far-detuned lattice projected through a high numerical aperture objective lens, image the atomic distribution and cool the atoms to the vibrational ground state, and then dynamically turn off and rearrange lattice sites to achieve the desired filling fraction and spin order. We will achieve this dynamically re-arrangeable lattice by forming our 2D optical potential with Digital Micromirror Devices (DMD).

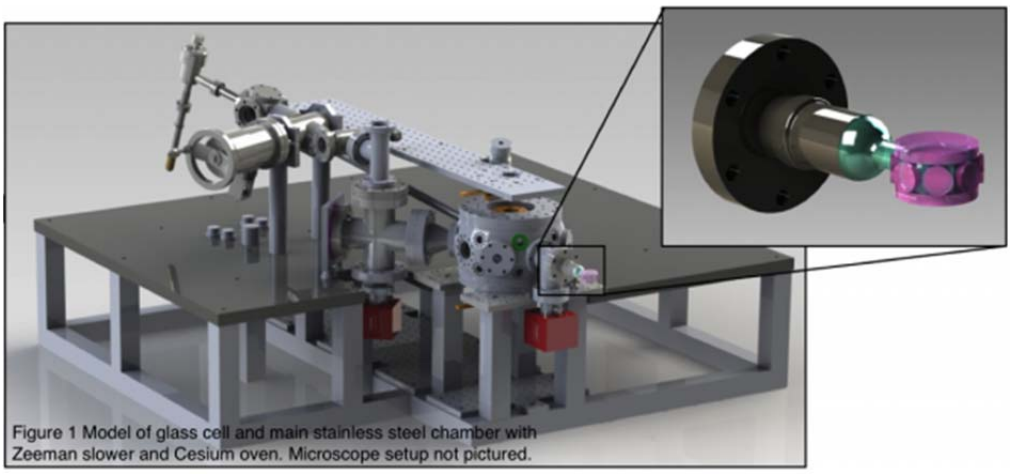

Figure 1 Model of glass cell and main stainless steel chamber with Zeeman slower and Cesium oven. Microscope setup not pictured.

The ARO DURIP grant offers essential equipment for the construction of the QMS. The vacuum system is illustrated in Figure 1. Here a Zeeman slower and an oven provide a slowed beam of cesium atoms, which are further cooled by a magneto-optical trap at the center of the vacuum chamber. An optical lattice with precision phase control is loaded with optically cooled atoms and transfers the atoms into a small glass cell where the science experiment will be performed.

In the cell, the atoms will be controlled and imaged based on the quantum matter synthesizer, which consists of two microscope objectives, a pair of bitter magnetic coils, and an ultrastable plateform that over interferometric stability to visualize and manipulate single atoms. The cell is constructed based on new type of surface etching technology that offers superior transmission properties not achievable with conventional optical coating. Such surface treatment and performance is illustrated in the figure below:

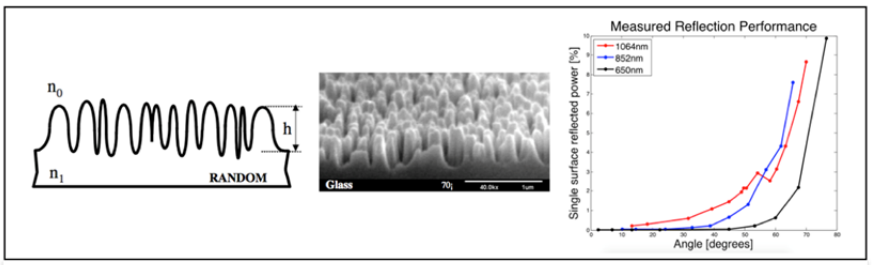

Figure 3 Surface etched windows on a glass cell provide high anti-reflection, even at large angles.

The essential components of the QMS is illustrated in the follow figure “Microscope/Glass cell setup”. Here atoms transferred from the main chamber will be located at the center of the glass cell (5). The glass cell offers excellent optical access to the atoms up to an incident angle of 60 degrees. Up to 16 beams can be steered to the atoms outside the high NA microscope objectives (3) through the mirror mount structure (4). The overall stability is offered by the stable mount to breadboards for Bitter electromagnet (2) and (6). In particular the relative stability of the objectives is provided by the stable mounts (7). Finally the full structure is supported by thick optical breadboard (1) that will support CCD, DMD and lattice optics.

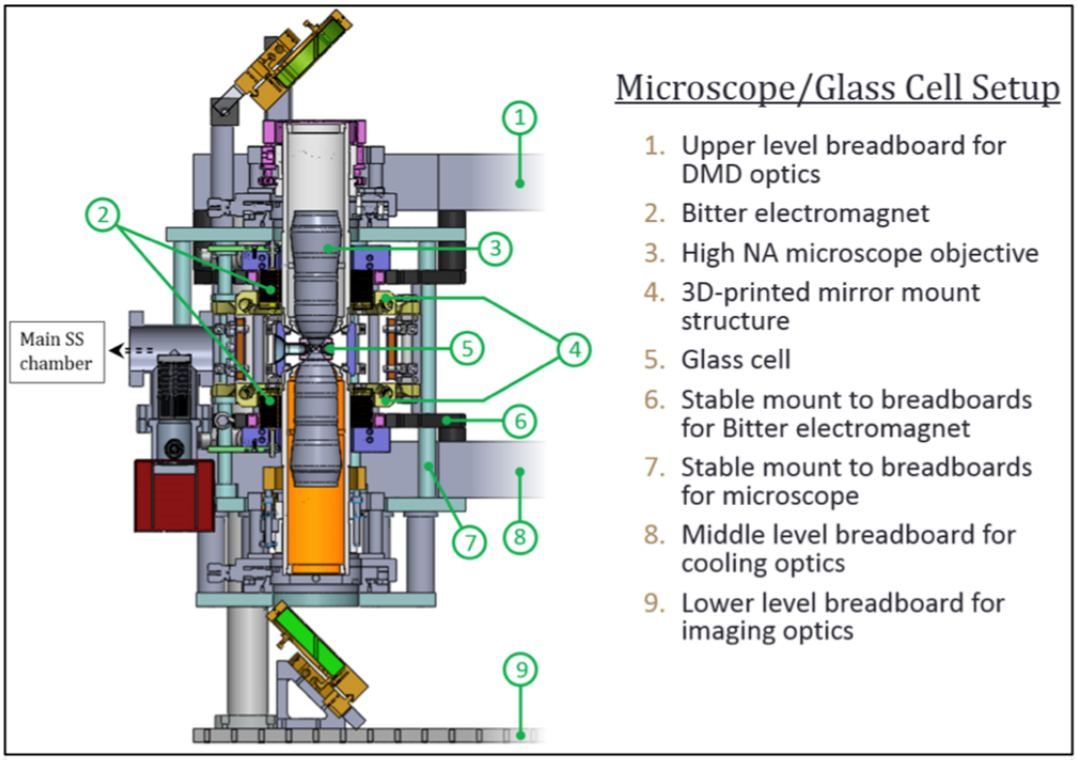

Figure 2 Two opposing custom microscope objectives (with high NA=0.8) allow for visualization and patterning of single atoms. Our objectives are secured to breadboards with a stability goal of 10nm in mind.

The system is current under construction and all pieces of equipment supported by ARO DURIP have been ordered and the objective tube lenses will be delivered at the end of the month (September 2016).