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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 contrued as an official Department of the Army position, policy or decision, unless so designated by other documentation.

14. ABSTRACT

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a. REPORT	b. ABSTRACT	c. THIS PAGE			Mitchell Luskin
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RPPR Final Report
as of 13-Dec-2021

Agency Code: 21XD

Proposal Number: 75801MARIP **Agreement Number: W911NF-20-1-0114**

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Report Date: 19-Oct-2021 Date Received: 10-Dec-2021
Final Report for Period Beginning 20-Apr-2020 and Ending 19-Jul-2021
Title: Accelerated Search for Gate-tunable High Tc Superconductivity in Twisted Trilayer Graphe
Begin Performance Period: 20-Apr-2020 **End Performance Period:** 19-Jul-2021
Report Term: 0-Other
Submitted By: Mitchell Luskin Email: luskin@umn.edu
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Distribution Statement: 1-Approved for public release; distribution is unlimited.

STEM Degrees: 0 **STEM Participants:** 2

Major Goals: The major goal of the project is to acquire and construct a fast-turn-around cryogenic system with high magnetic field, to facilitate and expedite the search for correlated insulating and superconducting phenomena in twisted-trilayer graphene (tTLG) devices. In tTLG, the material parameter space is bigger compared to conventional twisted-bilayers due to the two consecutive twist angles and more complicated atomic relaxation. The cryogenic system acquired has a top-loading mechanism that facilitates fast thermal-cycle and sample exchange, allowing fast turn-around for searching the vast parameter space of tTLG devices.

Accomplishments: Despite the delay in the manufacturing and acquisition of the tool due to Covid, the cryogenic system and magnets have been successfully configured and tested at the Wang lab at the University of Minnesota in September 2021. Currently, electrical circuit with elaborate electrical filtering and thermal anchoring is being installed by graduate students in the Wang lab, and the system is expected to be ready for advanced electrical measurement by the end of the year.

Training Opportunities: Two graduate students (Xi Zhang, Wei Ren) have installed the dewar, magnet and cryogenic system. Xi Zhang has designed and is constructing a platform and manifold to assist top-loading of the samples, and has written code that allows efficient data-acquisition. Wei Ren has designed and constructed sample mounts, and is configuring advanced electrical wirings and filtering for transport measurement. The students acquired education and hands-on experience on electrical circuits, vacuum system, cryogenics and measurement setup designed for quantum device characterization at low temperature. Both students have also been trained in sample preparation and device fabrication.

Results Dissemination: Ke Wang and Mitchell Luskin have given several invited talks on correlated insulating and superconductivity in tTLG during year 2021. Since the equipment has just recently been installed, we have no papers yet citing this grant. We will have many papers during the next few years.

Honors and Awards: Ke Wang, International Union of Pure and Applied Physics Young Scientist Prize, 2020

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Protocol Activity Status:

Technology Transfer: Nothing to Report

PARTICIPANTS:

Participant Type: PD/PI
Participant: Mitchell Luskin
Person Months Worked: 1.00 **Funding Support:**
Project Contribution:
National Academy Member: N

Participant Type: Co PD/PI
Participant: Ke Wang
Person Months Worked: 1.00 **Funding Support:**
Project Contribution:
National Academy Member: N

Participant Type: Graduate Student (research assistant)
Participant: Xi Zhang
Person Months Worked: 3.00 **Funding Support:**
Project Contribution:
National Academy Member: N

Participant Type: Graduate Student (research assistant)
Participant: Wei Ren
Person Months Worked: 3.00 **Funding Support:**
Project Contribution:
National Academy Member: N

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Date Submitted: 7/25/20 12:00AM Date Published: 6/1/20 5:00AM
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Article Title: Modeling mechanical relaxation in incommensurate trilayer van der Waals heterostructures
Authors: Ziyan Zhu, Paul Cazeaux, Mitchell Luskin, Efthimios Kaxiras
Keywords: relaxation, trilayer
Abstract: The incommensurate stacking of multilayered two-dimensional materials is a challenging problem from a theoretical perspective and an intriguing avenue for manipulating their physical properties. Here we present a multiscale model to obtain the mechanical relaxation pattern of twisted trilayer van der Waals (vdW) heterostructures with two independent twist angles, a generally incommensurate system without a supercell description.We adopt the configuration space as a natural description of such incommensurate layered materials, based on the local environment of atomic positions, bypassing the need for commensurate approximations. To obtain the relaxation pattern, we perform energy minimization with respect to the relaxation displacement vectors. We use a continuum model in combination with the generalized stacking fault energy to describe the interlayer coupling, obtained from first-principles calculations based on density functional theory. We show that the relaxation patterns of twist
Distribution Statement: 2-Distribution Limited to U.S. Government agencies only; report contains proprietary info
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Partners

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I certify that the information in the report is complete and accurate:
Signature: Mitchell Luskin
Signature Date: 12/10/21 4:27PM

Please note that the equipment has only recently been installed. Thus, no papers have yet been published that cite this grant. We expect to publish several papers that cite this grant in the future.

Major Goals: The major goal of the project is to acquire and construct a fast-turn-around cryogenic system with high magnetic field, to facilitate and expedite the search for correlated insulating and superconducting phenomena in twisted-trilayer graphene (tTLG) devices. In tTLG, the material parameter space is bigger compared to conventional twisted-bilayers due to the two consecutive twist angles and more complicated atomic relaxation. The cryogenic system acquired has a top-loading mechanism that facilitates fast thermal-cycle and sample exchange, allowing fast turn-around for searching the vast parameter space of tTLG devices.

Accomplishments Under Goals: Despite the delay in the manufacturing and acquisition of the tool due to Covid, the cryogenic system and magnets have been successfully configured and tested at the Wang lab at the University of Minnesota in September 2021. Currently, electrical circuit with elaborate electrical filtering and thermal anchoring is being installed by graduate students in the Wang lab, and the system is expected to be ready for advanced electrical measurement by the end of the year.

Plans Next Period: Once the system is fully configured, 3 graduate students in the Wang lab will measure ~ 10 tTLG devices that have been fabricated and will continue to fabricate twisted bilayer and trilayer devices and search for novel quantum phenomena in moire and moire of moire superlattices.

Results Dissemination: Ke Wang and Mitchell Luskin have given several invited talks on correlated insulating and superconductivity in tTLG during year 2021.

Honors and Awards: Ke Wang, International Union of Pure and Applied Physics Young Scientist Prize, 2020

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