REPORT DOCUMENTATION PAGE

Form Approved OMB NO. 0704-0188

1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE	3. DATES COVERED (From - To)
05-01-2021	Final Report	1-Sep-2019 - 30-Aug-2020

4. TITLE AND SUBTITLE
Final Report: STIR: Imaging nonlocal electronic transport with the SQCRAMscope

5a. CONTRACT NUMBER
W911NF-19-1-0392

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
Stanford University
3160 Porter Drive
Suite 100
Stanford, CA 94304 -8445

8. PERFORMING ORGANIZATION REPORT NUMBER

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)
75547-EL-II.3

12. DISTRIBUTION AVAILIBILITY 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 contrued 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	15. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Benjamin Lev
UU	UU	UU	UU		19b. TELEPHONE NUMBER 650-725-9199

RPPR Final Report
as of 06-Jan-2021

Agency Code:

Proposal Number: 75547ELII **Agreement Number: W911NF-19-1-0392**
INVESTIGATOR(S):

Name: Benjamin Lev
Email: benlev@stanford.edu
Phone Number: 6507259199
Principal: Y

Organization: **Stanford University**
Address: 3160 Porter Drive, Stanford, CA 943048445
Country: USA

DUNS Number: 009214214 EIN: 941156365
Report Date: 30-Nov-2020 Date Received: 05-Jan-2021
Final Report for Period Beginning 01-Sep-2019 and Ending 30-Aug-2020
Title: STIR: Imaging nonlocal electronic transport with the SQCRAMscope
Begin Performance Period: 01-Sep-2019 **End Performance Period:** 30-Aug-2020
Report Term: 0-Other

Submitted By: Benjamin Lev Email: benlev@stanford.edu
Phone: (650) 725-9199

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

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

Major Goals: The Scanning Quantum Cryogenic Atom Microscope (SQCRAMscope) is a quantum sensor in which a quasi-1D quantum gas images electromagnetic fields emitted from a nearby sample.

Project Goal of STIR: Our program seeks to apply the novel capabilities of our new quantum sensor, the SQCRAMscope, to the imaging of nonlocal transport in quantum materials.

Challenge: Use quantum gases to perform best imaging of magnetic fields near materials.

Our Approach: The SQCRAMscope, Scanning Quantum Cryogenic Atom Microscope, uses an atomic Bose-Einstein condensate (BEC) for cryogenic vector-resolved scanning probe microscopy of magnetic fields. It has the demonstrated capability of imaging transport in cryogenically cooled solid-state samples.

Accomplishments: We accomplished two main tasks. 1) We imaged the spatial distribution of nematic ordering versus temperature in an iron-based superconductor for the first time. This establishes the SQCRAMscope as a new method for characterizing technologically relevant materials. This work was published in Nature Physics in 2020. 2) We also improved the capabilities of the SQCRAMscope. Cryogen usage is reduced by replacing the liquid cryostat with a closed-cycle system and modified cold finger, and cryogenic cooling is enhanced by adding a radiation shield. The minimum accessible sample temperature is reduced from 35 K to 5.8 K while maintaining low sample vibrations. A new sample mount is easier to exchange, and quantum gas preparation is streamlined. This paper is under review in SciPost Physics.

Training Opportunities: This research program provides an exceptional training ground for graduate and undergraduate students in the formative scientific environment provided by Stanford University and our state-of-the-art laser lab. The research concerned physics and technical skills that find application in a variety of significant areas of technology, most notably lasers and photonics for telecommunications and advanced novel solid-state materials for electronic devices. The PI currently mentors ten graduate students and one undergrad. Tours of the lab to outside groups are regularly given to spark interest in modern physics ideas and techniques.

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Results Dissemination: • F. Yang, S. Taylor, S. Edkins, J. Palmstrom, I. Fisher, and B. L. Lev, Nematic Transitions in Iron-Pnictide Superconductors Imaged with a Quantum Gas, Nature Physics 16, 514 (2020).
News coverage:
- Nature Physics 16, 506 (2020): News & Views: Cooking with quantum gas, by James Analytis
- Phys.org article: “Imaging nematic transitions in iron pnictide superconductors”
- Physics World article: “Ultracold atoms put high-temperature superconductors under the microscope”

S. Taylor, F. Yang, B. Freudenstein, and B. L. Lev. A scanning quantum cryogenic atom microscope at 6 K, (2020). arxiv:2010.03559 under review at SciPost Physics.

Honors and Awards: Nothing to Report

Protocol Activity Status:

Technology Transfer: Nothing to Report

PARTICIPANTS:

Participant Type: Graduate Student (research assistant)
Participant: Jun Wang
Person Months Worked: 4.00 **Funding Support:**
Project Contribution:
International Collaboration:
International Travel:
National Academy Member: N
Other Collaborators:

Participant Type: Graduate Student (research assistant)
Participant: Kuan-Yu Li
Person Months Worked: 2.00 **Funding Support:**
Project Contribution:
International Collaboration:
International Travel:
National Academy Member: N
Other Collaborators:

Participant Type: PD/PI
Participant: Benjamin Leonard Lev
Person Months Worked: 3.00 **Funding Support:**
Project Contribution:
International Collaboration:
International Travel:
National Academy Member: N
Other Collaborators:

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as of 06-Jan-2021

Nothing to report in the uploaded pdf (see accomplishments)