List of Suggested Reviewers or Reviewers Not To Include (optional)

SUGGESTED REVIEWERS:

Steven Kivelson: Stanford University.
email: (650) 723-4344,
phone: Kivelson@stanford.edu
strongly correlated systems, high temperature superconductivity, quantum Hall effect, stripeand nematic order
James Freericks: Georgetown University, Physics.
email: freericj@georgetown.edu,
phone: (202) 687-6159
Strongly-correlated electronic systems, computational methods, dynamics
Elbio Dagotto: University of Tennessee and Oak Ridge National Lab.
email: edagotto@utk.edu,
phone: (865)574-2592
theoretical studies of mechanical properties of metals and ceramics; numerical methods in quantum chemistry; approximate methods in quantum theory of solids, molecules and nanoparticles.
Herbert Fotso: SUNY at Albany, Physics.
email: hfotso@albany.ede,
phone: 518-442-4506
Strongly-correlated electronic systems, computational methods, quantum informtion science
Han Pu: Rice University.
email: hpu@rice.edu,
phone: (713) 348-3570
Theoretical amo; superfluid bosons and fermions, spin-orbit coupling, quantum optics, dft.
John Thomas: North Carolina State University.
email: jethoma7@ncsu.edu,
phone: (919) 515-5966
Experimental amo; superfluid fermions.
Vladimir Dobrosavljevic: Florida State University and National High Magnetic Field Lab.
email: vlad@magnet.fsu.edu,
phone: (850) 644-5693
dynamical mean field theory, high temperature superconductivity, disordered systems and Anderson localization
Hans-Gerd Evertz: Technical University, Graz, Austria.
email: evertz@tugraz.au,
phone: +43 316 873-8178
quantum simulations, matrix product states, real time dynamics, classical and quantum model Hamiltonians
Trey Porto: University of Maryland/Joint Quantum Institute.
email: porto@umd.edu,
phone: (301) 405-0854
ultra-cold atoms in optical lattices, simulations of many-body physics, quantum information processing; new laser cooling and trapping techniques.
Nathan Newman: Arizona State University.
email: Nathan.Newman@asu.edu,
phone: (480) 363-4940
growth, characterization and modeling of novel solid-state materials for microwave, photonic, and high-speed applications.
Bob Buhrman: Cornell University, College of engineering.

Suggested Reviewers contd...

**email: buhrman@cornell.edu,
phone: (607) 255-3732
Nanomagnetic materials and spintronics devices; spin torque and spin transfer effects; giant spin Hall effect; thin film materials.
Michael Santos: University of Oklahoma.
email: santos@nhn.ou.edu,
phone: (405) 210-2612
narrow-gap semiconductors and device applications, molecular beam epitaxy.
Shane Johnson: Arizona State University, Materials science.
email: Shane.Johnson@asu.edu,
phone: (480) 965-2565
Optoelectronic devices, epitaxial growth, compound semiconductors, device physics
Alan Seabaugh: University of Notre Dame, Electrical engineering.
email: aseabaug@nd.edu,
phone: 574 287-4032
tunnel field-effect transistors, atomically-thin transistors, ionic and ferroelectric memory, self-powered electronics.
Elanor Huntington: Australian National University, College of Engineering and Computer Science.
email: dean.cecs@anu.edu.au,
phone: +61 2 6125 8807
Quantum Cybernetics.
Ian Petersen: Australian National University.
email: ian.petersen@anu.edu.au,
phone: +61 2 61256059
Quantum Control.**

REVIEWERS NOT TO INCLUDE:

Pursuant to PAPPG Chapter II.C.1.e., each PI, co-PI, and other senior project personnel identified on a proposal must provide collaborator and other affiliations information to help NSF identify appropriate reviewers.(v.4/21/2017)

Please complete this template (e.g., Excel, Google Sheets, LibreOffice), save as .xlsx or .xls, and upload directly as a Fastlane Collaborators and Other Affiliations single copy doc.
Do not upload .pdf.

There are five tables:
A: Your Name & Affiliation(s);
B: PhD Advisors/Advisees (all);
C: Collaborators;
D: Co-Editors;
E: Relationships

List names as Last Name, First Name, Middle Initial. Additionally, provide email, organization, and department (optional) to disambiguate common names.

Fixed column widths keep this sheet one page wide; if you cut and paste text, set font size at 10pt or smaller, and abbreviate, where necessary, to make the data fit.

To insert *n* blank rows, select *n* row numbers to move down, right click, and choose Insert from the menu.
You may fill-down (crtl-D) to mark a sequence of collaborators, or copy affiliations. Excel has arrows that enable sorting.
"Last active" dates are optional, but will help NSF staff easily determine which information remains relevant for reviewer selection.

Table A: List your Last Name, First Name, Middle Initial, and organizational affiliation (including considered affiliation) in the last 12 months.

A	Your Name:	Your Organizational Affiliation(s), last 12 n	Last Active Date
	Richard Scalettar	University of California, Davis	Present

Table B: List names as Last Name, First Name, Middle Initial, and provide organizational affiliations, if known, for the following.

G: Your PhD Advisor(s)
T: All your PhD Thesis Advisees
P: Your Graduate Advisors

to disambiguate common names

B	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)
G	Prof. Douglas J. Scalapino	University of California Santa Barbara).	
G	Prof. Robert L. Sugar	University of California Santa Barbara).	
G	Prof. Peter G. Wolynes	at time of post-doc: University of Illinois Urbana-Champaign; presently at Rice University).	
T	Dr. Parhat Niyaz, Ph.D. 1996	Quickturn Designs	
T	Dr. John Kuei, Ph.D. 1997	Rockwell	
T	Dr. Carey Huscroft, Ph.D. 1998	Hewlett-Packard	
T	Dr. Matthew Enjalran, Ph.D. 2000	University of Southern Connecticut	
T	Dr. Dustin Froula, Ph.D. 2002	Lawrence Livermore National Laboratory	
T	Dr. Brian Maddox, Ph.D. 2006	Lawrence Livermore National Laboratory	
T	Dr. Amy Lazicki, Ph.D. 2007	Lawrence Livermore National Laboratory	
T	Dr. Alex Zujev, Ph.D. 2010	University of California Davis	
T	Dr. Norman Paris	Lewis and Clark College	
T	Dr. Michael Mikulis, Ph.D. 2007	Redstone Arsenal Huntsville	
T	Dr. Chris Varney, Ph.D. 2009	University of West Florida	

T	Dr. Mi Jiang, Ph.D. 2014	Swiss National Supercomputer Center	
T	Dr. Vlad Iglovikov, Ph.D. 2015	Bidgley	
T	WeiTing Chiu, Ph.D. 2018	expected	
T	Wenjian Hu, Ph.D. 2018	expected	
T	Tyler Cary, Ph.D. 2018	expected	
T	Bo Xiao, Ph.D. 2018	expected	
T	Ben Cohen-Stead, Ph.D. 2021	expected	
T	YuXi Zhang, Ph.D. 2021	expected	
T	Owen Bradley, Ph.D. 2023	expected	
T	Chunhan Feng, Ph.D. 2023	expected	
P	Dr. James Freericks, Professor	Georgetown University	
P	Dr. Tom Devereaux, Professor	Stanford University	
P	Dr. Marko Vekic,Deceased		
P	Dr. Karl Runge, Research Scientist	Lawrence Berkeley National Laboratory	
P	Dr. Martin Ulmke, Staff Scientist	FGAN Research Institute for Communication, Germany	
P	Dr. Ferenc Pazmandi, Patent Agent	Sidley Austin LLP	
P	Dr. Kyungsun Moon, Professor	Yonsei University	
P	Dr. Anne van Otterlo, Staff Scientist	Lucent Technologies, The Netherlands	
P	Dr. Charles Reichhardt, Staff Scient	Los Alamos National Laboratory	
P	Dr. Cynthia Olson, Staff Scientist	Los Alamos National Laboratory	
P	Dr. Thereza Paiva, Professor	Universidade Federale do Rio de Janeiro	
P	Dr. Helmut Katzgraber, Associate P	Texas A&M University	
P	Dr. Mahesh Chandran,Staff Scientis	General Electric Research, Bangalore, India	
P	Dr. Gokhan Esirgen, Laboratory Coo	University of Southern California	
P	Dr. Wei Ku, Professor	Shanghai Jiao Tong University	
P	Dr. Marcos Rigol, Professor	Penn State University	
P	Dr. Valeri G. Rousseau, Visiting pro	Loyola University New Orleans	
P	Dr. Karan Aryanpour, Postdoctoral	University of Arizona	
P	Dr. Wenbin Chen, Assistant Profess	Fudan University	
P	Dr. Nikolai Zarkevic, Researcher	Ames Laboratory	
P	Dr. Roger Lee, Assistant Professor	National Tsing Hua University	
P	Dr. Simone Chiesa,	Citibank	
P	Dr. Khan Mahmud, Postdoc	National Institute of Standards and Technology, Gaithersburg	
P	Dr. Chia-Chen Chang, Research Scie	University of California, Davis	
P	Dr. Ehsan Khatami, Assistant Profes	San Jose State University	

Table C: List names as Last Name, First Name, Middle Initial, and provide organizational affiliations, if known, for the following.

A: **Co-authors on any book, article, report, abstract or paper (with collaboration in last 48 months; publication date may be later).**

C: **Collaborators on projects, such as funded grants, graduate research or others (in last 48 months).**

C	Name:	Organizational Affiliation	Optional (email, Department) *to disambiguate common names*	Last Active
	Maykon Araujo	Univ Fed do Piaui		
	Zhaojun Bai	University of California Davis		
	Amin Barzegar	Texas A & M		
	George G. Batrouni	University of Nice		
	Ali Benali	University of Tunis		
	Thomas Blommel	University of Michigan		
	Tyler Cary	University of California Davis		
	Chia-Chen Chang	University of California Davis		
	Cheng Chien Chen	Argonne National Laboratory		
	Chuang Chen	Instof Phys, Chinese Acad of Science		
	WeiTing Chiu	University of California Davis		
	Natanael Costa	Universidade Federale Rio do Janeiro		
	Nicholas Curro	University of California Davis		

	Raimundo R. dos Santos	Universidade Federale Rio do Janeiro		
	Pedro Duarte	Rice University		
	Philipp Dumitrescu	University of Texas Austin		
	John Ferre	University of California Davis		
	Thibaud Flottat	Nice University		
	Richard M. Fye	Retired		
	Huaiming Guo	Beihang University		
	Russell A. Hart	Rice University		
	Nicole Hartman	Stanford University		
	Frederic H�ebert	University of Nice		
	Wenjian Hu	University of California Davis		
	Edwin W. Huang	Stanford University		
	Randall Hulet	Rice University		
	Hsin-Hsiang Hung	University of Texas		
	David Huse	Princeton University		
	Vladimir Iglovikov	Bidgley		
	Mark Jarrell	Louisiana State University		
	ChunJin Jia	Stanford University		
	ChengMing Jiang	University of California Davis		
	Steven Johnston	University of Tennessee		
	Helmut Katzgraber	Texas A & M		
	Ehsan Khatami	San Jose State University		
	Yvonne F. Kung	Stanford University		
	Jose P. Lima	Univ Fed do Piaui		
	Magnus Lipp	LLNL		
	Junwei Liu	Hong Kong Univ of Sci and Tech		
	Xinxing Liu	Rice University		
	YenLee Loh	University of North Dakota		
	Tianxing Ma	Beijing Normal Univ		
	Yang Meng	Instof Phys, Chinese Acad of Science		
	Tiago Mendes	Universidade Federale Rio do Janeiro		
	ZiYang Meng	Instof Phys, Chinese Acad of Science		
	Rubem Mondaini	Universidade Federale Rio do Janeiro		
	Juana Moreno	Lousiana State University		
	Brian Moritz	Stanford University		
	Devon Mortensen	University of Washington		
	Elizabeth A. Nowadnick	Cornell University		
	Thereza Paiva	Universidade Federale Rio do Janeiro		
	Warren E. Pickett	University of California Davis		
	Mohit Randeria	Ohio State University		
	Valerie Rousseau	Loyola University of New Orleans		
	Gerry Seidler	Univ Washington		
	Maksym Serbyn	University of California Berkeley		
	Rajiv R.P. Singh	University of California Davis		
	Nandini Trivedi	Ohio State University		
	Ashvin Vishwanath	University of California Berkeley		
	Lei Wang	Inst of Phys, Chinese Acad Sci		
	Yao Wang	Stanford University		
	Yao Wang	Stanford University		
	Bo Xiao	University of California Davis		
	Xiao-Yan Xu	Hong Kong Univ of Sci and Tech		
	Shuxiang Yang	Louisiana State University		
	Tsung Lin Yang	Rice University		
	LuFeng Zhang	Beijing Normal Univ		
	YuXi Zhang	University of California Davis		

Table D: List editorial board, editor-in-chief and co-editors with whom you interact. An editor-in-chief should list the entire editorial board.

B: Editorial board: Name(s) of editor-in-chief and journal (in past 24 months).

E: Other Co-Editors of journals or collections with whom you directly interacted (in past 24 months).

to disambiguate common names

D	Name:	Organizational Affiliation	Journal/Collection	Last Active

Table E: List persons for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.

R: Additional names for whom some relationship would otherwise preclude their service as a reviewer.

to disambiguate common names

D	Name:	Organizational Affiliation	Optional (email, Department)	Last Active

The following information regarding collaborators and other affiliations (COA) must be separately provided for each individual identified as senior project personnel. The COA information must be provided through use of this COA template.

Please complete this template (e.g., Excel, Google Sheets, LibreOffice), save as .xlsx or .xls, and upload directly as a Fastlane Collaborators and Other Affiliations single copy doc. Do not upload .pdf.

Please note that some information requested in prior versions of the PAPPG is no longer requested. THIS IS PURPOSEFUL AND WE NO LONGER REQUIRE THIS INFORMATION TO BE REPORTED. Certain relationships will be reported in other sections (i.e., the names of postdoctoral scholar sponsors should not be reported, however if the individual collaborated on research with their postdoctoral scholar sponsor, then they would be reported as a collaborator). The information in the tables is not required to be sorted, alphabetically or otherwise.

There are five separate categories of information which correspond to the five tables in the COA template:

COA template Table 1:
List the individual's last name, first name, middle initial, and organizational affiliation in the last 12 months.

COA template Table 2:
List names as last name, first name, middle initial, for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.

COA template Table 3:
List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following:
- **The individual's Ph.D. advisors; and**
- **All of the individual's Ph.D. thesis advisees.**

COA template Table 4:
List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following:
- **Co-authors on any book, article, report, abstract or paper with collaboration in the last 48 months (publication date may be later); and**
- **Collaborators on projects, such as funded grants, graduate research or others in the last 48 months.**

COA template Table 5:
List editorial board, editor-in chief and co-editors with whom the individual interacts. An editor-in-chief must list the entire editorial board.
- **Editorial Board: List name(s) of editor-in-chief and journal in the past 24 months; and**
- **Other co-Editors of journal or collections with whom the individual has directly interacted in the last 24 months.**

The template has been developed to be fillable, however, the content and format requirements must not be altered by the user. This template must be saved in .xlsx or .xls format, and directly uploaded into FastLane as a Collaborators and Other Affiliations Single Copy Document. Using the .xlsx or .xls format will enable preservation of searchable text that otherwise would be lost. It is therefore imperative that this document be uploaded in .xlsx or .xls only. Uploading a document in any format other than .xlsx or .xls may delay the timely processing and review of the proposal.

This information is used to manage reviewer selection. See Exhibit II-2 for additional information on potential reviewer conflicts.

1 Note that graduate advisors are no longer required to be reported.
2 Editorial Board does not include Editorial Advisory Board, International Advisory Board, Scientific Editorial Board, or any other subcategory of Editorial Board. It is limited to those individuals who perform editing duties or manage the editing process (i.e., editor in chief).

List names as Last Name, First Name, Middle Initial. Additionally, provide email, organization, and department
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For "Last Active Date" and "Last Active" columns dates are optional, but will help NSF staff easily determine which information remains relevant for reviewer selection.
“Last Active Date” and “Last Active” columns may be left blank for ongoing or current affiliations.

Table 1: **List the individual’s last name, first name, middle initial, and organizational affiliation in the last 12 months.**

1	Your Name:	Your Organizational Affiliation(s), last 12 r	Last Active Date
	Kirk, Wiley P.	University of Texas at Arlington	

Table 2: **List names as last name, first name, middle initial, for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.**

R: Additional names for whom some relationship would otherwise preclude their service as a reviewer.

to disambiguate common names

2	Name:	Type of Relationship	Optional (email, Department)	Last Active
R:				

Table 3: **List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following.**

G: The individual’s Ph.D. advisors; and

T: All of the individual’s Ph.D. thesis advisees.

to disambiguate common names

3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)

G:	Kao, Yi-Han	State University New York-Buffalo	yhk@buffalo.edu
T:	Olejniczak, Zbigniew	Jagiellonian University in Krakow	zbigniew.olejniczak@ifj.edu.pl
T:	Hahn, Kenneth	John Brown University	khahn@jbu.edu
T:	Palm, Eric, C.	National High Magnetic Field Laboratory	palm@magnet.fsu.edu
T:	Zhou, Tiecheng	Applied Materials Inc	tczhou@yahoo.com
T:	Andrews, Craig C.	TesSol, Inc	craig.andrews@tessol-inc.com
T:	Li, Feng	Parade Technologies, Inc.	fengli1986@gmail.com
T:	Gandhi, Jateen, S.	University of Houston	jateen.gandhi@mavs.uta.edu
T:	Sandu, Titus	National Institute for Research and Develo	titus.sandu@imt.ro
T:	Aubrey, Joysree, B.	Los Alamos National Laboratory	jba@lanl.gov
T:	Clark, Kevin, P.	Intelligent Epitaxy Technology, Inc.	kclark@intelliepi.com

Table 4: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following:

A: Co-authors on any book, article, report, abstract or paper with collaboration in the last 48 months (publication date may be later); and

C: Collaborators on projects, such as funded grants, graduate research or others in the last 48 months.

to disambiguate common names

4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active
A:	Randall, John, N.	Zyvex Labs	jrandall@zyvexlabs.com	
A:	Owen, James, H. G.	Zyvex Labs	jhgowen@zyvexlabs.com	
A:	Schmucker, Scott, W.	National Institute of Standards and Techno	scott.schmucker@nist.gov	
A:	Wyrick, Jonathan	National Institute of Standards and Techno	jonathan.wyrick@nist.gov	
A:	Misra, Shashank	Sandia National Laboratories	smisra@sandia.gov	
C:	Ballard, Joshua, B.	Indiana University	jbballar@iu.edu	2/1/18
C:	Erik Henriksen	Washington University, St. Louis	henriksen@wustl.edu	

must list the entire editorial board.

B: Editorial Board: List name(s) of editor-in-chief and journal in the past 24 months; and

E: Other co-Editors of journal or collections with whom the individual has directly interacted in the last 24 months.

to disambiguate common names

5	Name:	Organizational Affiliation	Journal/Collection	Last Active
B:	D. Gogova	Bulgarian Academy of Sciences, Sofia, Bulg	Superlattices and Microstructures	
B:	F. Medjdoub	Centre National de la Recherche Scientifiq	Superlattices and Microstructures	
B:	X. Wang	Peking University, Beijing, China	Superlattices and Microstructures	

The following information regarding collaborators and other affiliations (COA) must be separately provided for each individual identified as senior project personnel. The COA information must be provided through use of this COA template.

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COA template Table 2:
List names as last name, first name, middle initial, for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.

COA template Table 3:
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COA template Table 4:
List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following:
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COA template Table 5:
List editorial board, editor-in chief and co-editors with whom the individual interacts. An editor-in-chief must list the entire editorial board.
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- **Other co-Editors of journal or collections with whom the individual has directly interacted in the last 24 months.**

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List names as Last Name, First Name, Middle Initial. Additionally, provide email, organization, and department (optional) to
Fixed column widths keep this sheet one page wide; if you cut and paste text, set font size at 10pt or smaller, and abbreviate,
To insert *n* blank rows, select *n* row numbers to move down, right click, and choose Insert from the menu.
You may fill-down (crtl-D) to mark a sequence of collaborators, or copy affiliations. Excel has arrows that enable sorting.
For "Last Active Date" and "Last Active" columns dates are optional, but will help NSF staff easily determine which information remains relevant for reviewer selection.
“Last Active Date” and “Last Active” columns may be left blank for ongoing or current affiliations.

Table 1: List the individual’s last name, first name, middle initial, and organizational affiliation in the last 12 months.

1	Your Name:	Your Organizational Affiliation(s), last 12 mo	Last Active Date
	Richard Silver	University of Maryland	

Table 2: List names as last name, first name, middle initial, for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.
R: Additional names for whom some relationship would otherwise preclude their service as a reviewer.

2	Name:	Type of Relationship	*to disambiguate common names* Optional (email, Department)	Last Active

Table 3: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following.
G: The individual’s Ph.D. advisors; and
T: All of the individual’s Ph.D. thesis advisees.

3	Advisor/Advisee Name:	Organizational Affiliation	*to disambiguate common names* Optional (email, Department)
G:	Xiqiao Wang (PhD Advisee)	University of Maryland	Physics
	Stephen Barbagallo (MS Ad	University of Maryland	Materials Science
	Kai Li (PhD Advisee)	University of Maryland	Chemical Physics
	Summanth Chikkamaranah	George Washington University	Mchanical Engineering
	Hui Zhou (PhD Advisee)	University of Maryland	Chemical Physics
	Stephen Fox (PhD Advisee)	University of Maryland	Electrical Engineering
	Vincient Tsai (PhD Advisee)	University of Maryland	Chemical Physics

Table 4: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following:
A: Co-authors on any book, article, report, abstract or paper with collaboration in the last 48 months (publication date may be later); and

C: Collaborators on projects, such as funded grants, graduate research or others in the last 48 months.

4	Name:	Organizational Affiliation	*to disambiguate common names* Optional (email, Department)	Last Active
A:	John Randall,	(Zyvex Labs)	Physics and Astronomy	current
A:	James H. G. Owen	(Zyvex Labs)		current
A:	Ezra Bussman	(Sandia)		current
A:	Shashank Misra	(Sandia)		current
A:	Tim Crimmins	(Intel)		7/10/05
A:	Garnett Bryant	(NIST)		current
A:	Neil Zimmerman	(NIST)		current
A:	Michael Stewart	(NIST)	Physics	current
A:	Josh Pomeroy	(NIST)	Physics	current
A:	Ranjit Kashid	(NIST)	Physics	current
A:	Joe Hagmann	(NIST)	Physics	current
A:	Curt Richter	(NIST)		current
A:	A. N. Ramanayaka	(Univ. Maryland)	JQI	current
A:	H.-S. Kim	(Univ. Maryland)		current
A:	K. Tang	(Univ. Maryland)	Physics	current
A:	Alexey Gorshkov	(U Maryland and NIST)	JQI	current
A:	Xiqiao Wang	(U Maryland)	JQI Physics	current
A:	Scott Schmucker	(Sandia)		
A:	M.Y. Sohn	(NIST)	Physics	1/1/18
A:	B.M. Barnes	(NIST)	Physics	current
A:	N. F. Zhang	(NIST)	Physics	current
A:	M. A. Henn	(NIST)	Physics	current
A:	M. T. Stocker	(NIST)	Physics	1/1/18
A:	George Stan	(NIST)	Physics	9/1/18
A:	Myers, A. F.	(NIST)	Physics	9/1/18
A:	Kai Li	(SEC)	Physics	3/1/18
A:	Roy Murray	Northrup Gruman		
A:	Xinbin Cheng	(Tongji Univ)	Physics	1/1/17
A:	Tongbao Li	(Tongji Univ)	Physics	1/1/17
A:	Xiao Deng	(Tongji Univ)	Physics	1/1/17
A:	Hui Zhou	(Argonne Natl Lab)	Physics	1/2019
A:	James Williams	(U Maryland)	Physics	9/1/18
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list the entire editorial board.

B: Editorial Board: List name(s) of editor-in-chief and journal in the past 24 months; and

E: Other co-Editors of journal or collections with whom the individual has directly interacted in the last 24 months.

5	**Name:**	**Organizational Affiliation**	*to disambiguate common names* **Journal/Collection**	**Last Active**

The following information regarding collaborators and other affiliations (COA) must be separately provided for each individual identified as senior project personnel. The COA information must be provided through use of this COA template.

Please complete this template (e.g., Excel, Google Sheets, LibreOffice), save as .xlsx or .xls, and upload directly as a Fastlane Collaborators and Other Affiliations single copy doc. Do not upload .pdf.

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COA template Table 1:
List the individual's last name, first name, middle initial, and organizational affiliation in the last 12 months.

COA template Table 2:
List names as last name, first name, middle initial, for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.

COA template Table 3:
List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following:
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- **All of the individual's Ph.D. thesis advisees.**

COA template Table 4:
List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following:
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List names as Last Name, First Name, Middle Initial. Additionally, provide email, organization, and department (optional)
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“Last Active Date” and “Last Active” columns may be left blank for ongoing or current affiliations.

Table 1: List the individual’s last name, first name, middle initial, and organizational affiliation in the last 12 months.

1	Your Name:	Your Organizational Affiliation(s), last 12 r	Last Active Date
	Gupta, Subhadeep	University of Washington, Seattle	current

Table 2: List names as last name, first name, middle initial, for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.

R: Additional names for whom some relationship would otherwise preclude their service as a reviewer.

to disambiguate common names

2	Name:	Type of Relationship	Optional (email, Department)	Last Active
R:				

Table 3: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following.

G: The individual’s Ph.D. advisors; and
T: All of the individual’s Ph.D. thesis advisees.

to disambiguate common names

3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)
G:	Pritchard, David	Massachusetts of Technology	Physics

G:	Ketterle, Wolfgang	Massachusetts of Technology	Physics
G:	Stamper-Kurn, Dan	University of California, Berkeley	Physics
T:	Hansen, Anders	PhD 2013, currently at Tomra, Norway	
T:	Khramov, Alexander	PhD 2013, currently postdoc at CERN	
T:	Jamison, Alan	PhD 2014, currently postdoc at MIT	Physics
T:	Dowd, William	PhD 2015, currently at Vertu Financial	
T:	Roy, Richard	PhD 2017, currently postdoc at NASA-JPL	
T:	Plotkin-Swing, Benjamin	PhD 2018, currently at Nion	
T:	McAlpine, Katherine	University of Washington, Seattle	Physics
T:	Green, Alaina	University of Washington, Seattle	Physics
T:	Gochnauer, Daniel	University of Washington, Seattle	Physics
T:	See Toh, Jun H.	University of Washington, Seattle	Physics
T:	Tang, Xinxin	University of Washington, Seattle	Physics
T:	Rahman, Tahiyat	University of Washington, Seattle	Physics

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A: Co-authors on any book, article, report, abstract or paper with collaboration in the last 48 months (publication date may be later); and

C: Collaborators on projects, such as funded grants, graduate research or others in the last 48 months.

to disambiguate common names

4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active
A:	Kotochigova, Svetlana	Temple University	Physics	
A:	Makrides, Constantinos	Temple University	Physics	
A:	Petrov, Alexander	Temple University	Physics	
A:	Li, Ming	Temple University	Physics	
A:	Li, Hui	Temple University	Physics	
A:	Yuen, Chi H.	Temple University	Physics	
A:	Hossain, Khalid	Washington State University	Physics	
A:	Forbes, Michael M.	Washington State University	Physics	
A:	Jayakumar, Anupriya	postdoc 2012-14		
A:	Shrestha, Rajendra	postdoc 2013-15, currently at SynRad		
A:	Bowler, Ryan	postdoc 2015-17, currently at EOSpace		
A:	Green, Alaina	University of Washington	Physics	
A:	Gochanauer, Daniel	University of Washington	Physics	
A:	McAlpine, Katherine	University of Washington	Physics	
A:	See Toh, Jun Hui	University of Washington	Physics	
A:	Tang, Xinxin	University of Washington	Physics	
A:	Cooper, Eric	Stanford University		
A:	Ton, Khang	BS 2017, currently at UC San Diego	Physics	
A:	Saxberg, Brendan	BS 2015, currently at U Chicago	Physics	
A:	Dowd, William	PhD 2015, currently at Vertu Financial		
A:	Jamison, Alan	PhD 2014, currently postdoc at MIT	Physics	
A:	Khramov, Alexander	PhD 2013, currently postdoc at CERN	Physics	
A:	Roy, Richard	PhD 2017, currently at NASA-JPL		
A:	Plotkin-Swing, Benjamin	PhD 2018, currently at Nion		
C:	DeMille, David	Yale University	Physics	
C:	Doyle, John	Harvard University	Physics	
C:	Ketterle, Wolfgang	Massachusetts Institute of Technology	Physics	
C:	Zwierlein, Martin	Massachusetts Institute of Technology	Physics	
C:	Ye, Jun	University of Colorado, Boulder	Physics	

C:	Bohn, John	University of Colorado, Boulder	Physics	
C:	Naduvalath, Balakrishnan	University of Nevada, Las Vegas	Physics	
C:	Zare, Richard	Stanford University	Physics	

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to disambiguate common names

5	Name:	Organizational Affiliation	Journal/Collection	Last Active

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1	Your Name:	Your Organizational Affiliation(s), last 12 r	Last Active Date
	Forbes, Michael, M	Washington State University	
		University of Washington (Affiliate)	

<u>Table 2:</u> List names as last name, first name, middle initial, for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.

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to disambiguate common names

2	Name:	Type of Relationship	Optional (email, Department)	Last Active

<u>Table 3:</u> List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following.

G: The individual's Ph.D. advisors; and

T: All of the individual's Ph.D. thesis advisees.

to disambiguate common names

3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)
G:	Wilczek, Frank	MIT	Department X
T:	Corbin, Ryan	Washington State University	
T:	Delikatny, Edward	Washington State University	
T:	Elsasser, Kyle	Washington State University	
T:	Hossain, Khalid	Washington State University	
T:	Huang, Chunde	Washington State University	
T:	Sarkar, Saptarshi	Washington State University	
T:	Tiwari, Praveer	Washington State University	

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C: Collaborators on projects, such as funded grants, graduate research or others in the last 48 months.

to disambiguate common names

4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active
A:	Arun, K G	Chennai Mathematical Institute, Siruseri		
A:	Bose, Sukanta	Washington State University		
A:	Bulgac, Aurel	University of Washington		
A:	Busch, Thomas	Okinawa Institute for Science and Techn.		
A:	De, Soumi	Syracuse University		

A:	Delikatny, Edward	Washington State University		
A:	Engels, Peter	Washington State University		
A:	Gupta, Subhadeep	University of Washington		
A:	Hossain, Khalid	Washington State University		
A:	Jin, Shi	University of Washington		
A:	Khamehchi, Amin	KLA-Tencor		
A:	Magierski, Piotr	University of Washington, Warsaw University of Technology		
A:	Mossman, Maren	Washington State University		
A:	Perez, Rodrigo N	UC San Diego		
A:	Reddy, Sanjay	University of Washington		
A:	Roche, Kenneth J	University of Washington, PNNL		
A:	Sarkar, Saptarshi	Washington State University		
A:	Schunck, Nicolas	LLNL		
A:	Sekizawa, Kazuyuki	Niigata University		
A:	Wlazłowski, Gabriel	University of Washington, Warsaw University of Technology		
A:	Zhang, Yongping	Shanghai University		
A:	Zhou, Dake	University of Washington		
C:	Brynmor Haskell	Nicolaus Copernicus Astronomical Centre, Polish Academy of Sciences		
C:	Duez, Matthew	University of Washington		
C:	Gandolfi, Stefano	LANL		
C:	Hergert, Heiko	MSU		
C:	Holt, Jeremy	Texas A&M University		
C:	Joaquín Drut	University of North Carolina		
C:	Mossman, Sean	Washington State University		
C:	Rodriguez, Tomás	Universidad Autónoma de Madrid		
C:	Sharma, Rishi	TIFR India		
C:	Zhang, Chuanwei	UT Dallas		

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If there are more than 10 individuals designated as senior project personnel on the proposal, or if there are print preview issues, each completed template must be saved as a .txt file [select the Text (Tab Delimited) option] rather than as an .xlsx or .xls file. This format will still enable preservation of searchable text and avoid delays in processing and review of the proposal.
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Table 1: List the individual's last name, first name, middle initial, and organizational affiliation (including considered affiliation) in the last 12 months.

1	Your Name:	Your Organizational Affiliation(s), last 12	Column1	ıst Active Date
	Steven R. White	UC Irvine		

Table 2: List names as last name, first name, middle initial, for whom a personal, family, or business relationship

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to disambiguate common names

2	Name:	Organizational Affiliation	Optional (email, Department)	Last Active

Table 3: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for

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3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)
	John Wilkins	Ohio State University	

Table 4: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following:

A: Co-authors on any book, article, report, abstract or paper with collaboration in the last 48 months (publication date

C: Collaborators on projects, such as funded grants, graduate research or others in the last 48 months.

to disambiguate common names

4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active
	Bo-Xiao Zheng	Cal Institute of Technology		
	Chia-Min Chung	UC Irvine		
	Philippe Corboz	University of Amsterdam		
	Georg Ehlers	Philipps-Universitat Marburg		
	Ming-Pu Qin	College of William and Mary		
	Reinhard M. Noack	Philipps-Universitat Marburg		
	Hao Shi	College of William and Mary		
	Shiwei Zhang	College of William and Mary		
	Garnet Kin-Lic Chan	Cal Institute of Technology		
	Anna Keselman	Weizmann Institute		
	Naoki Nakatani	Hokkaido University		
	Zhendong Li	Princeton University		
	Peizhi Mai	UC Santa Cruz		
	Sriram Shastry	UC Santa Cruz		
	J.P.F. LeBlanc	University of Michigan		
	Andrey E. Antipov	University of Michigan		
	Frederico Becca	CNR-10M-Domocritos National Simulation Centre and International School for Advanced Studies		

	Ireneusz W. Bulik	Rice University		
	Youjin Deng	Hefei National Lab for Phys Sci at Microscale & Dept of Modern Physics		
	Michel Ferrero	Ecole Polytechnique		
	Thomas M. Henderson	Rice University		
	Carlos A. Jimenenz-Hoyos	Rice University		
	E. Kozik	Kings College London		
	Xuan-Wen Liu	Hefei National Lab for Phys Sci at Microscale & Dept of Modern Physics		
	Andrew J. Millis	Columbia University		
	Nikolay V. Prokof'ev	University of Massachusetts, Kurchatov Institute		
	Gustavo E. Scuseria	Rice University		
	B.V. Svistunov	University of Massachusetts, Kurchatov Institute		
	Luca F. Tocchio	CNR-10M-Domocritos National Simulation Centre and International School for Advanced Studies		
	Igor S. Tupitsyn	University of Massachusetts		
	Zhenyue Zhu	UC Irvine		
	Emanuel Gull	University of Michigan		
	Mario Motta	College of William and Mary		
	David M. Ceperley	University of Illinois		
	John A. Gomez	Rice University		
	Sheng Guo	California Insitute of Technology		
	Tran Nguyen Lan	University of Michigan		
	Jia Li	University of Michigan		
	Fengjie Ma	Beijing Normal University		
	Ushnish Ray	California Insitute of Technology		
	Sandro Sorella	SISSA-International School for Advanced Studies		
	Edwin M. Stoudenmire	UC Irvine		
	Qiming Sun	California Insitute of Technology		
	Dominika Zgid	University of Michigan		
	Shiwei Zhang	College of William and Mary		
	Zhenyue Zhu	Private Company		
	David A. Huse	Princeton University		
	Thomas Baker	Sherbrooke		
	Glen Evenbly	Sherbrooke		
	Lucas O. Wagner	Amsterdam		
	Kieron Burke	UC Irvine		
	Douglas J. Scalpino	UC Santa Barbara		
	Steven A. Kivelson	Stanford		
	Matthew Fishman	CalTech		
	Michael P. Zaletel	Princeton University		
	Yuan-Ming Lu	Ohio State		
	Ashvin Vishwanath	Harvard		
	J. Lee	Maryland		
	Subir Sachdev	Harvard		
	Li Li	Google		
	Benedikt Bruognolo	Munich		
	A.L. Chernyshev	UC Irvine		
	Pavel Maksimov	UC Irvine		

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<u>Table 1:</u> List the individual's last name, first name, middle initial, and organizational affiliation (including considered affiliation) in the last 12 months.

1	Your Name:	Your Organizational Affiliation(s), last 12 r	Last Active Date
	Lyding, Joseph W	University of Illinois at Urbana-Champaign	current
	Lyding, Joseph W	Tiptek, LLC	current

<u>Table 2:</u> List names as last name, first name, middle initial, for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.

R: Additional names for whom some relationship would otherwise preclude their service as a reviewer.

to disambiguate common names

2	Name:	Organizational Affiliation	Optional (email, Department)	Last Active
R:	Lockledge, Scott	Tiptek, LLC		current
R:	Girolami, Gregory	Tiptek, LLC		current
R:	Lee, Jinju	Tiptek, LLC		current
R:	Harrison, Elijah	Tiptek, LLC		current

<u>Table 3:</u> List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following.

G: The individual's Ph.D. advisors; and

T: All of the individual's Ph.D. thesis advisees.

to disambiguate common names

3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)
G:	Kannewurf, Carl	Northwestern University	
G:	Marks, Tobin	Northwestern University	
T:	Abeln, Glenn	NXP Semiconductors	
T:	Albrecht, Peter	U.S. Patent Office	
T:	Arastu, Faraz	University of Illinois at Urbana-Champaign	
T:	Brockenbrough, Roger	Qualcomm	
T:	Chen, Yaofeng	University of Illinois at Urbana-Champaign	
T:	Chen, Zhi	University of Kentucky	
T:	Cheng, Kangguo	IBM	
T:	Do, Jae Won	ETRI, Korea	
T:	Foley, Edward T	Ochanomizu University, Japan	
T:	Grewal, Sartaj	University of Illinois at Urbana-Champaign	
T:	He, Kevin	Intel	
T:	Hersam, Mark	Northwestern University	
T:	Huang, Pin-Chiao	University of Illinois at Urbana-Champaign	
T:	Hubacek, Jerome	Lam	
T:	Koepke, Justin	Sandia National Laboratories	
T:	Liu, Lequn	Micron	
T:	Liu, Ximeng	University of Illinois at Urbana-Champaign	
T:	Olewizc, Tomas	Lam	
T:	Parsons, Kaitlyn	University of Illinois at Urbana-Champaign	
T:	Ritter, Kyle	Micron	
T:	Ruppalt, Laura	Naval Research Laboratory	

T:	Schmucker, Scott	NIST	
T:	Skala, Steve	SanDisk	
T:	Sun, Hongye	University of Illinois at Urbana-Champaign	
T:	Sztelle, Matthew	Intel	
T:	Tao, Meng	Arizona State University	
T:	Wood, Joshua	Northwestern University	
T:	Ye, Wei	KLA Tencor	
T:	Yu, Jixin	Micron	

Table 4: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following:

A: Co-authors on any book, article, report, abstract or paper with collaboration in the last 48 months (publication date may be later); and

C: Collaborators on projects, such as funded grants, graduate research or others in the last 48 months.

4	Name:	Organizational Affiliation	Optional (email, Department) *to disambiguate common names*	Last Active
A:	Nguyen, Huy A	University of Illinois at Urbana-Champaign		current
A:	Banerjee, Progna	University of Illinois at Urbana-Champaign		current
A:	Nguyen, Duc	Northwestern University		current
A:	Gruebele, Martin	University of Illinois at Urbana-Champaign		current
A:	Jain, Prashant K	University of Illinois at Urbana-Champaign		current
A:	Zhang, Yingjie	University of Illinois at Urbana-Champaign		current
A:	Heiranian, Mohammad	University of Illinois at Urbana-Champaign		current
A:	Janicek, Blanka	University of Illinois at Urbana-Champaign		current
A:	Budrikis, Zoe	ISI Foundation, Torino, Italy		current
A:	Zappen, Stefano	ISI Foundation, Torino, Italy		current
A:	Huang, Pinshane Y	University of Illinois at Urbana-Champaign		current
A:	Johnson, Harley T	University of Illinois at Urbana-Champaign		current
A:	Aluru, Narayana R	University of Illinois at Urbana-Champaign		current
A:	Mason, Nadya	University of Illinois at Urbana-Champaign		current
A:	Goings, Joshua J	University of Washington, Seattle		current
A:	Pour, Mohammad Mehdi	University of Nebraska-Lincoln		current
A:	Lashkov, Andrey	Gargarin State Technical University of Saratov, Russia		current
A:	Radocea, Adrian	LAM Research, Freemont, California		6/1/17
A:	Liu, Ximeng	University of Illinois at Urbana-Champaign		7/1/18
A:	Sun, Tao	University of Illinois at Urbana-Champaign		10/1/17
A:	Lipatov, Alexey	University of Nebraska-Lincoln		current
A:	Korlacki, Rafal A	University of Nebraska-Lincoln		current
A:	Shekhirev, Mikhail	University of Nebraska-Lincoln		current
A:	Sysoev, Victor	Gargarin State Technical University of Saratov, Russia		current
A:	Sinitskii, Alexander	University of Nebraska-Lincoln		current
A:	Wiegold, Sarah	Technische Universität München		11/1/17
A:	Nienhaus, Lea	Massachusetts Institute of Technology		11/2/17
A:	Knoller, F L	Technische Universität München		11/3/17
A:	Schweinberger, F F	Technische Universität München		11/4/17
A:	Shepherd, J J	University of Iowa		11/5/17
A:	Heiz, U	Technische Universität München		11/6/17
A:	Esch, F	Technische Universität München		11/7/17
A:	Koepke, Justin	Sandia National Laboratory		6/1/17
A:	Gilbert, Matthew	University of Illinois at Urbana-Champaign		current
A:	Munukutla, Siddhanth	Intel		12/1/16
A:	Cheng, Noel	University of Illinois at Urbana-Champaign		6/1/16

A:	Carrion, Enrique	University of Illinois at Urbana-Champaign		6/1/16
A:	Hewaparakrama, Jayan	University of Illinois at Urbana-Champaign		6/1/16
A:	Rangarajan, Aniruddh	University of Illinois at Urbana-Champaign		6/1/16
A:	Datye, Isha	Stanford University		6/1/16
A:	Mehta, Rushabh	University of Illinois at Urbana-Champaign		6/1/16
A:	Haasch, Richard T	University of Illinois at Urbana-Champaign		6/1/16
A:	Girolami, Gregory S	University of Illinois at Urbana-Champaign		current
A:	Pop, Eric	Stanford University		6/1/16
A:	Vo, Timothy H	University of Nebraska-Lincoln		12/1/16
A:	Cress, Cory D	Naval Research Laboratory		3/1/16
A:	Friedman, Adam L	Naval Research Laboratory		3/1/16
A:	Dev, Pratibha	Naval Research Laboratory		3/1/16
A:	Culbertson, James C	Naval Research Laboratory		3/1/16
A:	Robinson, Jeremy T	Naval Research Laboratory		3/1/16
A:	Zhu, Zhi-Guang	Chinese Academy of Sciences		6/1/16
A:	Pringle, Brian	University of Illinois at Urbana-Champaign		6/1/16
A:	Wang, Wei-Hua	Chinese Academy of Sciences		6/1/16
A:	Li, Xiaosong	University of Washington, Seattle		11/1/15
A:	Scott, Gregory E	California Polytechnic University		current
A:	Hovarth, Cedric M	University of Arkansas		8/1/15
A:	Barraza-Lopez, Salvador	University of Arkansas		8/1/15
A:	Khatib, Omar	University of California, San Diego		7/1/15
A:	McLeod, Alexander S	University of California, San Diego		7/1/15
A:	Goldflam, Michael D	University of California, San Diego		7/1/15
A:	Wagner, Martin	University of California, San Diego		7/1/15
A:	Damhorst, Gregory L	University of Illinois at Urbana-Champaign		7/1/15
A:	Doidge, Gregory P	University of Illinois at Urbana-Champaign		7/1/15
A:	Bashir, Rashid	University of Illinois at Urbana-Champaign		7/1/15
A:	Thiemens, Mark H	University of California, San Diego		7/1/15
A:	Keilmann, Fritz	Ludwig-Maximilians-Universität, Munich		7/1/15
A:	Basov, D N	University of California, San Diego		7/1/15
A:	Martin, Pamela P	University of Illinois at Urbana-Champaign		12/1/17
A:	Rockett, Angus	Colorado School of Mines		6/1/16
A:	Estrada, David	Boise State University		4/1/15
A:	Lian, Feifei	University of Illinois at Urbana-Champaign		4/1/15
A:	Cha, Hyeongyun	University of Illinois at Urbana-Champaign		4/1/15
A:	Duan, Xiangyun J	University of Illinois at Urbana-Champaign		4/1/15
A:	Kaitz, Joshua A	University of Illinois at Urbana-Champaign		1/1/15
A:	Behnam, Ashkan	University of Illinois at Urbana-Champaign		1/1/15
A:	Aruin, Basil	Cymer-ASML		1/1/15

A:	Chen, Yaofeng	University of Illinois at Urbana-Champaign		current
A:	Dong, Hefei	University of Illinois at Urbana-Champaign		1/1/15
A:	Mallek, Justin	University of Illinois at Urbana-Champaign		11/1/14
A:	Cloud, Andrew N	University of Illinois at Urbana-Champaign		11/1/14
A:	Abelson, John R	University of Illinois at Urbana-Champaign		current
A:	Groose, Kyle L	University of Illinois at Urbana-Champaign		10/1/14
A:	Dorgan, Vincent E	University of Illinois at Urbana-Champaign		10/1/14
A:	Vlassiouk, Ivan	Oak Ridge National Laboratory		10/1/14
A:	Eres, Gyula	Oak Ridge National Laboratory		10/1/14
A:	King, William	University of Illinois at Urbana-Champaign		10/1/14
C:	Girolami, Gregory S	University of Illinois at Urbana-Champaign		current
C:	Aluru, Narayana R	University of Illinois at Urbana-Champaign		current
C:	Bezryadin, Alexey	University of Illinois at Urbana-Champaign		current
C:	Abelson, John R	University of Illinois at Urbana-Champaign		current
C:	Gruebele, Martin	University of Illinois at Urbana-Champaign		current
C:	Lockledge, Scott	Tiptek		current
C:	Randall, John	Zyvex Laboratories		current

Table 5: List editorial board, editor-in chief and co-editors with whom the individual interacts. An editor-in-chief

B: Editorial Board: List name(s) of editor-in-chief and journal in the past 24 months; and

E: Other co-Editors of journal or collections with whom the individual has directly interacted in the last 24 months.

to disambiguate common names

5	Name:	Organizational Affiliation	Journal/Collection	Last Active
B:	Lombardi, Fabrizio	Northeastern University	IEEE Transactions on Nanotechnology	current
E:				

The following information regarding collaborators and other affiliations (COA) must be separately provided for each individual identified as senior project personnel. The COA information must be provided through use of this COA template.

Please complete this template (e.g., Excel, Google Sheets, LibreOffice), save as .xlsx or .xls, and upload directly as a Fastlane Collaborators and Other Affiliations single copy doc. Do not upload .pdf.

If there are more than 10 individuals designated as senior project personnel on the proposal, or if there are print preview issues, each completed template must be saved as a .txt file [select the Text (Tab Delimited) option] rather than as an .xlsx or .xls file. This format will still enable preservation of searchable text and avoid delays in processing and review of the proposal. Please note that some information requested in prior versions of the PAPPG is no longer requested. THIS IS PURPOSEFUL AND WE NO LONGER REQUIRE THIS INFORMATION TO BE REPORTED. Certain relationships will be reported in other sections (i.e., the names of postdoctoral scholar sponsors should not be reported, however if the individual collaborated on research with their postdoctoral scholar sponsor, then they would be reported as a collaborator). The information in the tables is not required to be sorted, alphabetically or otherwise.

There are five separate categories of information which correspond to the five tables in the COA template:

COA template Table 1:
List the individual's last name, first name, middle initial, and organizational affiliation (including considered affiliation) in the last 12 months.

COA template Table 2:
List names as last name, first name, middle initial, for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.

COA template Table 3:
List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following:
- **The individual's Ph.D. advisors; and**
- **All of the individual's Ph.D. thesis advisees.**

COA template Table 4:
List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following:
- **Co-authors on any book, article, report, abstract or paper with collaboration in the last 48 months (publication date may be later); and**
- **Collaborators on projects, such as funded grants, graduate research or others in the last 48 months.**

COA template Table 5:
List editorial board, editor-in chief and co-editors with whom the individual interacts. An editor-in-chief must list the entire editorial board.
- **Editorial Board: List name(s) of editor-in-chief and journal in the past 24 months; and**
- **Other co-Editors of journal or collections with whom the individual has directly interacted in the last 24 months.**

The template has been developed to be fillable, however, the content and format requirements must not be altered by the user. This template must be saved in .xlsx or .xls format, and directly uploaded into FastLane as a Collaborators and Other Affiliations Single Copy Document. Using the .xlsx or .xls format will enable preservation of searchable text that otherwise would be lost. It is therefore imperative that this document be uploaded in .xlsx or .xls only. Uploading a document in any format other than .xlsx or .xls may delay the timely processing and review of the proposal.

This information is used to manage reviewer selection. See Exhibit II-2 for additional information on potential reviewer conflicts.

1 Note that graduate advisors are no longer required to be reported.
2 Editorial Board does not include Editorial Advisory Board, International Advisory Board, Scientific Editorial Board, or any other subcategory of Editorial Board. It is limited to those individuals who perform editing duties or manage the editing process (i.e., editor in chief).

List names as Last Name, First Name, Middle Initial. Additionally, provide email, organization, and department (optional)
Fixed column widths keep this sheet one page wide; if you cut and paste text, set font size at 10pt or smaller, and
To insert *n* blank rows, select *n* row numbers to move down, right click, and choose Insert from the menu.
You may fill-down (crtl-D) to mark a sequence of collaborators, or copy affiliations. Excel has arrows that enable sorting.
For "Last Active Date" and "Last Active" columns dates are optional, but will help NSF staff easily determine which information remains relevant for reviewer selection.
“Last Active Date” and “Last Active” columns may be left blank for ongoing or current affiliations.

Table 1: List the individual’s last name, first name, middle initial, and organizational affiliation (including considered affiliation) in the last 12 months.

1	Your Name:	Your Organizational Affiliation(s), last 12 r	Last Active Date
	Moheimani, S. O. Reza	University of Texas at Dallas	
		University of Newcastle, Australia	4/287/2015
		University of New South Wlaes, Australia	8/29/1997

Table 2: List names as last name, first name, middle initial, for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.

R: Additional names for whom some relationship would otherwise preclude their service as a reviewer.

to disambiguate common names

2	Name:	Organizational Affiliation	Optional (email, Department)	Last Active

Table 3: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following.

G: The individual’s Ph.D. advisors; and
T: All of the individual’s Ph.D. thesis advisees.

to disambiguate common names

3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)
G:	Petersen	Australian National University	

T:	Fleming, Andrew	University of Newcastle	
T:	Dunant Halim	University of Nottingham	
T:	Sam Behrens	CSIRO	
T:	Iskandar Mahood	IIU, Malaysia	
T:	Matthew Fairbairn	Hunter TAFE, Australia	
T:	Anthony Fowler	RMIT, Australia	
T:	Sachin Wadikhaye	India	
T:	Ali Mohammadi	University of Bath, UK	
T:	Busara Piryanont	University of Newcastle	
T:	Mohammad Maroufi	UT Dallas	
T:	Michael Ruppert	University of Newcastle	
T:	Steven Moore	University of Newcastle	
T:	Kai Karvinen	Leibniz Universität Hannover,	

Table 4: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following:

A: Co-authors on any book, article, report, abstract or paper with collaboration in the last 48 months (publication date may be later); and

C: Collaborators on projects, such as funded grants, graduate research or others in the last 48 months.

4	Name:	Organizational Affiliation	Optional (email, Department) *to disambiguate common names*	Last Active
A:	John Randall	Zyvex Labs		
A:	Farid Tajaddodianfar	UT Dallas		
A:	James Owen	Zyvex Labs		
A:	Ali Bazaei	University of Newcastle, Australia		
A:	Zhiyong Chen	University of Newcastle, Australia		
A:	Yuen Yong	University of Newcastle, Australia		
A:	Bukut Coskun	UT Dallas		
A:	Anthony Fowler	RMIT University		
A:	Mohammad Maroufi	UT Dallas		
A:	Hamed Alemansour	UT Dallas		
A:	Micahel Ruppert	University of Newcastle, Australia		
A:	David Haracombe	University of Newcastle, Australia		
A:	Michael Ragazzon	NIT, Norway		
A:	Ehud Fuchs	Zyvex Labs		
A:	Steven Moore	University of Newcastle, Australia		
A:	Sam Wiggins	University of Newcastle, Australia		
A:	Yong Zhu	Griffith University		
A:	Mehmet Yuce	Monash University		
A:	Bbusara Piriyanont	University of Newcastle, Australia		
A:	Adrian Neild	Monash University		
A:	Kai Karvinen	Leibniz Universität Hannover,		
A:	Bharath Bhikkaji	IIT-Mumbai		
A:	Sachin Wadikhaye	University of Aberdeen		
A:	Micky Rakotondrabe	FEMTO-Institute, France		
A:	Matthew Fairbairn	TAFE NSW		
A:	Tuncay Allan	Monash University		

Table 5: List editorial board, editor-in chief and co-editors with whom the individual interacts. An editor-in-chief

B: Editorial Board: List name(s) of editor-in-chief and journal in the past 24 months; and

E: Other co-Editors of journal or collections with whom the individual has directly interacted in the last 24 months.

5	Name:	Organizational Affiliation	Journal/Collection *to disambiguate common names*	Last Active
B:	T.H. Lee	NUS, Singapore	Mechatronics	

B:	D. Chao	SNU, Korea	Mechatronics	
B:	J. T. Gravdahl	NUST, Norway	Mechatronics	
B:	Christian Ott	DLR, Germany	Mechatronics	
B:	T-C. Tsao	UCLA	Mechatronics	
B:	Junmin Wang	OSU	Mechatronics	
B:	T. Yamaguchi	Ricoh, Japan	Mechatronics	
B:	N.A. Aspragathos	Univ Patras	Mechatronics	
B:	T. Atsumi	CIT, Japan	Mechatronics	
B:	J. Bae	UNIST, Korea	Mechatronics	
B:	K. Barton	Univ. Michigan	Mechatronics	
B:	R.D Ben-Mrad	Univ. Toronto	Mechatronics	
B:	M. Boudaoud	ISIR., France	Mechatronics	
B:	K. Bouazza-Marouf	Loughborough University, UK	Mechatronics	
B:	D. Bristow	MUST	Mechatronics	
B:	Y. Q. Chen	UC-Merced	Mechatronics	
B:	Z. Chen	Univ. Newcastle	Mechatronics	
B:	G. Cherubini	IBM-ZRL	Mechatronics	
B:	C. C. Chung	Hanyang Univ, Korea	Mechatronics	
B:	G. Clayton	Villanova Univ.	Mechatronics	
B:	R. Dixon	Loughborough University, UK	Mechatronics	
B:	C. Fantuzzi	Universit di Modena e Reggio Emilia, Italy	Mechatronics	
B:	V. Feliu	Escuela Técnica Superior de Ing. , Spain	Mechatronics	
B:	M. Gauthier	FEMTO-ST. France	Mechatronics	
B:	J. Gorman	NIST	Mechatronics	
B:	S. Haliyo	ISIR/UPMC, France	Mechatronics	
B:	M.F. Heertjes	indhoven Univ of Tech, Netherlands	Mechatronics	
B:	P. Hehenberger	Univ of Applied Sciences Upper Austria	Mechatronics	
B:	D. Hoelzle	OSU	Mechatronics	
B:	H.R. Karimi	Politecnico di Milano, Italy	Mechatronics	
B:	W. Kemmetmueller	Technische Universität Wien, Austria	Mechatronics	
B:	C. Knospe	University of Virginia, USA	Mechatronics	
B:	B. Koch	University of Alberta, Canada	Mechatronics	
B:	K. Kong	Sogang University, The Republic of Korea	Mechatronics	
B:	R.G. Landers	MUST	Mechatronics	
B:	K. Leang	The University of Utah, USA	Mechatronics	
B:	Y. Li	University of Macau, China	Mechatronics	
B:	Y. Li	University of Texas at Dallas, USA	Mechatronics	
B:	W.H. Liao	The Chinese University of Hong Kong	Mechatronics	
B:	L. Liu	Chinese Academy of Sciences	Mechatronics	
B:	S. Longo	Cranfield University, United Kingdom	Mechatronics	
B:	G. Magnani	Politecnico di Milano, Italy	Mechatronics	
B:	C. Manzie	University of Melbourne, Australia	Mechatronics	
B:	L. MASIA	Nanyang Technological Univ., Singapore	Mechatronics	
B:	C. Melchiorri	Università di Bologna, Italy	Mechatronics	
B:	M. Moallem	Simon Fraser University, Canada	Mechatronics	
B:	D. Oetomo	Melbourne University, Australia	Mechatronics	
B:	K. Oldham	University of Michigan, USA	Mechatronics	
B:	T.A.E Oomen	Eindhoven Univ of Tech, Netherlands	Mechatronics	
B:	R. Padhi	Indian Institute of Science, India	Mechatronics	
B:	M. Porfiri	New York University, USA	Mechatronics	
B:	M. Rakotondrabe	Université de Franche-Comté, France	Mechatronics	
B:	P. Rocco	Politecnico di Milano, Milano, Italy	Mechatronics	
B:	M. Ruderman	Universitetet i Agder, Norway	Mechatronics	
B:	J. Scruggs	University of Michigan, USA	Mechatronics	

B:	B. Shirinzadeh	Monash University, Australia	Mechatronics	
B:	K.-T. Song	National Chiao Tung Univ, Taiwan	Mechatronics	
B:	K.A. Stelson	Univ of Minnesota, Minneapolis, USA	Mechatronics	
B:	C. Su	Concordia University, Canada	Mechatronics	
B:	D. Sun	City Univ of Hong Kong, Hong Kong	Mechatronics	
B:	M. Takeshi	Saitama University, Saitama, Japan	Mechatronics	
B:	M. Tavokoli	University of Alberta, Edmonton, Canada	Mechatronics	
B:	J. Wu	S. Xie	Mechatronics	
B:	S. Xie	University of Leeds, Leeds, UK	Mechatronics	
B:	Q. Zou	Rutgers University, USA	Mechatronics	
B:	L. Zuo	Virginia Tech, USA	Mechatronics	

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Please note that some information requested in prior versions of the PAPPG is no longer requested. THIS IS PURPOSEFUL AND WE NO LONGER REQUIRE THIS INFORMATION TO BE REPORTED. Certain relationships will be reported in other sections (i.e., the names of postdoctoral scholar sponsors should not be reported, however if the individual collaborated on research with their postdoctoral scholar sponsor, then they would be reported as a collaborator). The information in the tables is not required to be sorted, alphabetically or otherwise.

COA template Table 2:
List names as last name, first name, middle initial, for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.

COA template Table 3:
List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following:
• The individual's Ph.D. advisors; and
• All of the individual's Ph.D. thesis advisees.

COA template Table 4:
List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following:
• Co-authors on any book, article, report, abstract or paper with collaboration in the last 48 months (publication date may be later); and
• Collaborators on projects, such as funded grants, graduate research or others in the last 48 months.

COA template Table 5:
List editorial board, editor-in chief and co-editors with whom the individual interacts. An editor-in-chief must list the entire editorial board.
• Editorial Board: List name(s) of editor-in-chief and journal in the past 24 months; and
• Other co-Editors of journal or collections with whom the individual has directly interacted in the last 24 months.

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This information is used to manage reviewer selection. See Exhibit II-2 for additional information on potential reviewer conflicts.

1 Note that graduate advisors are no longer required to be reported.
2 Editorial Board does not include Editorial Advisory Board, International Advisory Board, Scientific Editorial Board, or any other subcategory of Editorial Board. It is limited to those individuals who perform editing duties or manage the editing process (i.e., editor in chief).

List names as Last Name, First Name, Middle Initial. Additionally, provide email, organization, and department (optional)
Fixed column widths keep this sheet one page wide; if you cut and paste text, set font size at 10pt or smaller, and
To insert *n* blank rows, select *n* row numbers to move down, right click, and choose Insert from the menu.
You may fill-down (crtl-D) to mark a sequence of collaborators, or copy affiliations. Excel has arrows that enable sorting.
For "Last Active Date" and "Last Active" columns dates are optional, but will help NSF staff easily determine which information remains relevant for reviewer selection.
“Last Active Date” and “Last Active” columns may be left blank for ongoing or current affiliations.

Table 1: **List the individual’s last name, first name, middle initial, and organizational affiliation in the last 12 months.**

1	Your Name:	Your Organizational Affiliation(s), last 12 r	Last Active Date
	Kuljanishvili, Irma	Saint Louis University	

Table 2: **List names as last name, first name, middle initial, for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.**

R: Additional names for whom some relationship would otherwise preclude their service as a reviewer.

to disambiguate common names

2	Name:	Type of Relationship	Optional (email, Department)	Last Active
R:	NA			

Table 3: **List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following.**

G: The individual’s Ph.D. advisors; and
T: All of the individual’s Ph.D. thesis advisees.

to disambiguate common names

3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)
G:	Tessmer, Stuart	Michigan State University	Department of Physics

T:	NA		

Table 4: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following:

A: **Co-authors on any book, article, report, abstract or paper with collaboration in the last 48 months (publication date may be later); and**

C: **Collaborators on projects, such as funded grants, graduate research or others in the last 48 months.**

to disambiguate common names

4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active
A:	Das, Saptarshi	Pennsylvania State University		ongoing
A:	Divan, Ralu	Argonne National Laboratory	CNM	ongoing
	Ocola, Leonidas	Argonne natinal Laboratory	CNM	10/15/18
A:	Liu, Yuzi	Argonne National Laboratory	CNM	7/19/19
A:	Rui, Dong	Ningbo Institute of Industrial Technologies, China		6/30/17
A:	Moore, Logan	Burns & McDonnell, St. Louis		6/30/17
A:	Nasr, Joseph	Pennsylvania State University		ongoing
A:	Imaninezhad, Mozhdeh	Thermo Fisher Scientific		12/30/18
A:	Wang, Yang	Brown Univesrity		5/30/16
A:	Zustiak, Silviya	Saint Louis University		ongoing
A:	Karbach, Devon	Saint Louis University		5/30/19
A:	Brewster, Jacob	Saint Louis Univesrity		
A:	Wisbey, David	Saint Louis Universoty		ongoing
A:	Aripova, Nozima	University of Nebraska, in Omaha	Medical School , MD/PhD	5/30/18
A:	Alameri, Dheyaa	Saint Louis University		6/30/19
C:	Pantano, Maria	University of Trento, Italy		ongoing
C:	Kravchenko, Ivan	OakRidge Natinal Laboratory	CNMS	ongoing
C:	Lavrik, Nickolay	OakRidge Natinal Laboratory	CNMS	ongoing

Table 5: List editorial board, editor-in chief and co-editors with whom the individual interacts. An editor-in-chief

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E: **Other co-Editors of journal or collections with whom the individual has directly interacted in the last 24 months.**

to disambiguate common names

5	Name:	Organizational Affiliation	Journal/Collection	Last Active
E:	Gazzoli, Davide	University of Salento, Italy	Frontiers	ongoing
B:				

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Table 1: **List the individual's last name, first name, middle initial, and organizational affiliation in the last 12 months.**

1	Your Name:	Your Organizational Affiliation(s), last 12 r	Last Active Date
	Engels, Peter W	Washington State University (WSU)	

Table 2: **List names as last name, first name, middle initial, for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.**

R: Additional names for whom some relationship would otherwise preclude their service as a reviewer.

to disambiguate common names

2	Name:	Type of Relationship	Optional (email, Department)	Last Active
R:				

Table 3: **List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following.**

G: The individual's Ph.D. advisors; and

T: All of the individual's Ph.D. thesis advisees.

to disambiguate common names

3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)
G:	Ertmer, Wolfgang	University of Hannover, Germany	Institute for Quantum Optics

G:	Sengstock, Klaus	University of Hamburg, Germany	Institute for Laser Physics
T:	Hamner, Chris	Micro Encoder Inc, Kirkland, WA	
T:	Chang, JiaJia		
T:	Khamehchi, Amin	KLA-Tencor	
T:	Maren Mossman	Washington State University	
T:	Thomas Bersano	Washington State University	

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to disambiguate common names

4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active
A:	Blume, Doerte	University of Oklahoma		
A:	Busch, Thomas	Okinawa Institute for Science and Techn.		
C:	Cornell, Eric	JILA / CU Boulder		
A:	Davis, Matthew	University of Queensland, Australia		
C:	D'Incao, Jose	JILA / CU Boulder		
A:	Bersano, Thomas	Washington State University		
A:	Hou, Junpeng	University of Texas at Dallas		
A:	Mossman, Sean	Washington State University		
A:	Gokhroo, Vandna	Washington State University		
A:	Luo, Xi-Wang	University of Texas at Dallas		
A:	Sun, Kuei	University of Texas at Dallas		
A:	Zhang, Chuanwei	University of Texas at Dallas		
A:	Mossman, Maren	Washington State University		
A:	Hoefer, Mark	CU Boulder		
A:	Julien, Keith	CU Boulder		
A:	Kevrekidis, Panayotis	University of Massachusetts, Amhers		
A:	Khamehchi, Amin	KLA-Tencor		
A:	D'Ambroise, Jennie	SUNY Old Westbury		
A:	Frantzeskakis, Dimitris	University of Athens, Greece		
A:	Hossain, Khalid	Washington State University		
A:	Zhang, Yongping	Shanghai University, China		
A:	Forbes, Michael	Washington State University		
C:	Delikatny, Ted	Washington State University		
A:	Danaila, Ionut	Universite de Rouen Normandie, France		
A:	Qu, Chunlei	JILA / CU Boulder		
A:	Gong, Ming	Univ. of Science and Technology of China	USTC	
C:	Ho, Jason	Ohio State University		

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E:				

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1	Your Name:	Your Organizational Affiliation(s), last 12 mo	Last Active Date
	Khatami, Ehsan	San Jose State University	

Table 2: List names as last name, first name, middle initial, for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.

R: Additional names for whom some relationship would otherwise preclude their service as a reviewer.

2	Name:	Type of Relationship	*to disambiguate common names* Optional (email, Department)	Last Active

Table 3: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following.

G: The individual’s Ph.D. advisors; and
T: All of the individual’s Ph.D. thesis advisees.

3	Advisor/Advisee Name:	Organizational Affiliation	*to disambiguate common names* Optional (email, Department)
G:	Jarrell, Mark	Louisiana State Univeristy	Physics and Astronomy

Table 4: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following:

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to disambiguate common names

4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active
A:	McBrian, Kristopher	San Jose State University	Physics and Astronomy	
A:	Carleo, Giuseppe	Flatiron Institute	Center for Computational Quantum	3/2019
A:	Mulanix, Michael	Rice University	Physics	
A:	Bhattaram, Krishnakumar	San Jose State University	Physics and Astronomy	
A:	Almada, Demetrius	San Jose State University	Physics and Astronomy	
A:	Ch'ng, Kelvin	San Jose State University	Physics and Astronomy	8/2018
A:	Vazquez, Nick	San Jose State University	Physics and Astronomy	5/2018
A:	Zhang, Yi	Cornell University	Physics	
A:	Mesaros, Andrej	Cornell University	Physics	5/2019
A:	Edkins, S.D.	Stanford	Physics	5/2019
A:	Hamidian, M.H.	Harvard	Physics	5/2019
A:	Eisaki, H.	Tsukuba, Japan		5/2019
A:	Uchida, S	University of Tokyo	Physics	5/2019
A:	Davis, J.C. Séamus	Cornell University	Physics	5/2019
A:	Kim, Eun-Ah	Cornell University	Physics	5/2019
A:	Fujita, K.	Brookhaven National Laboratory		5/2019
A:	Bakr, Waseem S	Princeton	Physics	
A:	Brown, P T	Princeton	Physics	
A:	Guardado-Sanchez, E	Princeton	Physics	9/29/17
A:	Huse, David	Princeton	Physics	9/29/17
A:	Kondov, S S	Princeton	Physics	9/29/17
A:	Mitra, Debayan	Princeton	Physics	8/10/18
A:	Schauß, Peter	Princeton	Physics	8/10/18
A:	Devereaux, Thomas P	Stanford	Physics	4/10/18
A:	Wang, Yao	Stanford	Physics	4/10/18
A:	Guo, Huaiming	Beihang University, China	Physics	
A:	Carrasquilla, Juan F	Vector Institute		
A:	Cheuk, Lawrence W	Harvard	Physics	1/2019
A:	Lawrence, K R	MIT	Physics	1/2019
A:	Nichols, Matthew A	MIT	Physics	1/2019
A:	Mendez, Enrique	MIT	Physics	1/2019
A:	Hartke, Thomas R	MIT	Physics	1/2019
A:	Okan, Melih	MIT	Physics	1/2019
A:	Zhang, Hao	MIT	Physics	1/2019
A:	Senthil, Todari	MIT	Physics	1/2019
A:	Zwierlein, Martin W	MIT	Physics	1/2019
A:	Galatas, Andrew	UC Santa Cruz	Physics	12/5/16
A:	Shastry, B Sriram	UC Santa Cruz	Physics	12/5/16
A:	Perepelitsky, Edward	Collège de France		12/5/16
A:	Georges, Antoine	Collège de France		12/5/16
A:	Hart, Russell A	Rice University	Physics	2/14/15
A:	Hulet, Randy G	Rice University	Physics	2/16/15
A:	Iglovikov, Vladimir I	TrueAc- cord		9/1/14
A:	Jarrell, Mark S	Luoisiana State University	Physics and Astronomy	12/1/15
A:	Moreno, Juana	Luoisiana State University	Physics and Astronomy	12/1/2015
A:	Yang, Shuxiang	Luoisiana State University	Physics and Astronomy	12/1/2015
A:	Johnston, Steven	U Tennessee, Knoxville	Physics	
A:	Li, Shaozhi	U Tennessee, Knoxville	Physics	
A:	Melko, Roger G	U of Waterloo	Physics	3/2018
A:	Mravlje, Jernej	Jozef Stefan Institut		12/5/16
A:	Zitko, Rok	Jozef Stefan Institut		12/6/16
A:	Paiva, Thereza	UFRJ, Brazil		
A:	Scalettar, Richard T	UC Davis	Physics	

A:	Singh, Rajiv R P	UC Davis	Physics	
A:	Rigol, Marcos	The Pennsylvania State University	Physics	10/10/18
A:	Rousseau, Valery	Wooster College		12/2/15
A:	Trivedi, Nandini	Ohio State University	Physics	9/29/17
C:	Chiao, Sen	San Jose State University	Meteorology	
C:	Lustig, Brooke	San Jose State University	Chemistry	
C:	Turkoglu, Kamran	San Jose State University	Computer Engineering	
C:	Rey, Ana Maria	University of Colorado	JILA	
C:	Silver, Richard M	NIST/U of Maryland	Physics	
C:	Romanowsky, Aaron	San Jose State University	Physics and Astronomy	

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			to disambiguate common names	
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	Zhang, Chuanwei	The University of Texas at Dallas	

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R: Additional names for whom some relationship would otherwise preclude their service as a reviewer.

to disambiguate common names

2	Name:	Type of Relationship	Optional (email, Department)	Last Active

Table 3: **List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following.**

G: The individual’s Ph.D. advisors; and

T: All of the individual’s Ph.D. thesis advisees.

to disambiguate common names

3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)
G:	Niu, Qian	The University of Texas at Austin	

G:	Raizen, Mark	The University of Texas at Austin	
T:	Chunlei Qu	Stevens Institute of Technology	

Table 4: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following:

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4	Name:	Organizational Affiliation	Optional (email, Department) *to disambiguate common names*	Last Active
A:	Busch, Thomas	OJST		1/1/15
A:	Chen, Gang	Shanxi University		
A:	Chen, Shu	Chinese Academy of Science		
A:	Chen, Yong P.	Purdue University		
A:	Engels, Peter	Washington State University		
A:	Gartstein, Yuri	University of Texas at Dallas		8/15/15
A:	Gong, Ming	University of Science and Technology of China		11/13/17
A:	Greene, Chris	Purdue University		1/22/19
A:	Gu, Qing	University of Texas at Dallas		
A:	Guo, Guang-Can	University of Science and Technology of China		4/17/18
A:	Jia, Suotang	Shanxi University		
A:	Lyanda-Geller, Yuli	Purdue University		1/22/19
A:	Scarola, Vito	Virginia Tech		
A:	Stanescu, Tudor	University of West Virginia		
A:	Tewari, Sumanta	Clemson University		
A:	Xu, Yong	Tsinghua University		
A:	Zhang, Jing	Shanxi University		
A:	Zhang, Fan	University of Texas at Dallas		
A:	Zhang, Yongping	Shanghai University		3/17/17
A:	Zhou, Qi	Purdue University		1/22/19
A:	Zhou, Zheng-Wei	University of Science and Technology of China		4/17/18
A:	Zou, Xubo	University of Science and Technology of China		3/24/16
C:	Michael Forbes	Washington State University		
C:				

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B:	Richard White	Nature Journal	Scientific Reports	
E:				

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- **Editorial Board: List name(s) of editor-in-chief and journal in the past 24 months; and**
- **Other co-Editors of journal or collections with whom the individual has directly interacted in the last 24 months.**

The template has been developed to be fillable, however, the content and format requirements must not be altered by the user. This template must be saved in .xlsx or .xls format, and directly uploaded into FastLane as a Collaborators and Other Affiliations Single Copy Document. Using the .xlsx or .xls format will enable preservation of searchable text that otherwise would be lost. It is therefore imperative that this document be uploaded in .xlsx or .xls only. Uploading a document in any format other than .xlsx or .xls may delay the timely processing and review of the proposal.

This information is used to manage reviewer selection. See Exhibit II-2 for additional information on potential reviewer conflicts.

1 Note that graduate advisors are no longer required to be reported.
2 Editorial Board does not include Editorial Advisory Board, International Advisory Board, Scientific Editorial Board, or any other subcategory of Editorial Board. It is limited to those individuals who perform editing duties or manage the editing process (i.e., editor in chief).

List names as Last Name, First Name, Middle Initial. Additionally, provide email, organization, and department (optional)
Fixed column widths keep this sheet one page wide; if you cut and paste text, set font size at 10pt or smaller, and
To insert *n* blank rows, select *n* row numbers to move down, right click, and choose Insert from the menu.
You may fill-down (crtl-D) to mark a sequence of collaborators, or copy affiliations. Excel has arrows that enable sorting.
For "Last Active Date" and "Last Active" columns dates are optional, but will help NSF staff easily determine which information remains relevant for reviewer selection.
"Last Active Date" and "Last Active" columns may be left blank for ongoing or current affiliations.

Table 1: List the individual's last name, first name, middle initial, and organizational affiliation in the last 12 months.

1	Your Name:	Your Organizational Affiliation(s), last 12 r	Last Active Date
	Yang, Li	Washington University in St. Louis	

Table 2: List names as last name, first name, middle initial, for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.

R: Additional names for whom some relationship would otherwise preclude their service as a reviewer.

to disambiguate common names

2	Name:	Type of Relationship	Optional (email, Department)	Last Active
R:				

Table 3: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following.

G: The individual's Ph.D. advisors; and

T: All of the individual's Ph.D. thesis advisees.

to disambiguate common names

3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)
G:	Mei-Yin Chou	Georgia Institute of Technology (Emeritus)/	Physics

T:	Liang, Yufeng	Lawrence Berkeley Lab	
T:	Fei, Ruixiang	University of Pennsylvania	
T:	Soklaski, Ryan	MIT Lincoln Laboratory	
T:	shiyuan, Gao	California Institute of Technology	
T:			

Table 4: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following:

A: Co-authors on any book, article, report, abstract or paper with collaboration in the last 48 months (publication date may be later); and

C: Collaborators on projects, such as funded grants, graduate research or others in the last 48 months.

to disambiguate common names

4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active
A:	Kelton, Kenneth	Washington University in St. Louis		current
A:	Nussinov, Zohar	Washington University in St. Louis		4/1/16
A:	Yan, Jia-An	Towsen University		3/1/16
A:	Xia, Fengnian	Yale University		current
A:	Wang, Han	University of Southern California		current
A:	Banerjee, Parag	University of Central Florida		3/1/18
A:	Li, Xiaoqin	University of Texas		current
A:	Moody, Galan	NIST		10/1/18
A:	Li, Ju	MIT		6/1/16
A:	Park, Jiwoong	University of Chicago		7/1/16
C:	Kong, Jing	MIT		current
C:	Cha, Judy	Yale Univeristy		current
A:	Barraza-Lopez, Salvador	University of Arkansas		6/1/16
A:	Spataru, Catalin	Sandia National Laboratory		10/1/18
A:	Tomanek, David	Michigan State University		2/1/17
A:	Schuck, P. James	Lawrence Berkeley Laboratory		5/1/16
C:	Henriksen, Erik	Washington University in St. Louis		Current

Table 5: List editorial board, editor-in chief and co-editors with whom the individual interacts. An editor-in-chief

B: Editorial Board: List name(s) of editor-in-chief and journal in the past 24 months; and

E: Other co-Editors of journal or collections with whom the individual has directly interacted in the last 24 months.

to disambiguate common names

5	Name:	Organizational Affiliation	Journal/Collection	Last Active
B:				
E:				

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TITLE OF PROPOSED PROJECT **QLCI - CI: Center for the Simulation of Engineered Quantum Materials**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ 21,704,413	60 months	09/01/20	

THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW

☐ BEGINNING INVESTIGATOR
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☐ FUNDING OF INT'L BRANCH CAMPUS OF U.S IHE ☐ FUNDING OF FOREIGN ORG
☐ INTERNATIONAL ACTIVITIES: COUNTRY/COUNTRIES INVOLVED
☒ COLLABORATIVE STATUS
A collaborative proposal from one organization (PAPPG II.D.3.a)

PI/PD DEPARTMENT	PI/PD POSTAL ADDRESS
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PI/PD FAX NUMBER 530-752-4717	

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CO-PI/PD Richard Silver	PhD	1992	301-975-5609	rsilver3@umd.edu

CERTIFICATION PAGE

Certification for Authorized Organizational Representative (or Equivalent) or Individual Applicant

By electronically signing and submitting this proposal, the Authorized Organizational Representative (AOR) or Individual Applicant is: (1) certifying that statements made herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions if an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding conflict of interest (when applicable), drug-free workplace, debarment and suspension, lobbying activities (see below), nondiscrimination, flood hazard insurance (when applicable), responsible conduct of research, organizational support, Federal tax obligations, unpaid Federal tax liability, and criminal convictions as set forth in the NSF Proposal & Award Policies & Procedures Guide (PAPPG). Willful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U.S. Code, Title 18, Section 1001).

Certification Regarding Conflict of Interest

The AOR is required to complete certifications stating that the organization has implemented and is enforcing a written policy on conflicts of interest (COI), consistent with the provisions of PAPPG Chapter IX.A.; that, to the best of his/her knowledge, all financial disclosures required by the conflict of interest policy were made; and that conflicts of interest, if any, were, or prior to the organization's expenditure of any funds under the award, will be, satisfactorily managed, reduced or eliminated in accordance with the organization's conflict of interest policy. Conflicts that cannot be satisfactorily managed, reduced or eliminated and research that proceeds without the imposition of conditions or restrictions when a conflict of interest exists, must be disclosed to NSF via use of the Notifications and Requests Module in FastLane.

Drug Free Work Place Certification

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent), is providing the Drug Free Work Place Certification contained in Exhibit II-3 of the Proposal & Award Policies & Procedures Guide.

Debarment and Suspension Certification

(If answer "yes", please provide explanation.)

Is the organization or its principals presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency? Yes ☐ No ☒

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) or Individual Applicant is providing the Debarment and Suspension Certification contained in Exhibit II-4 of the Proposal & Award Policies & Procedures Guide.

Certification Regarding Lobbying

This certification is required for an award of a Federal contract, grant, or cooperative agreement exceeding $100,000 and for an award of a Federal loan or a commitment providing for the United States to insure or guarantee a loan exceeding $150,000.

Certification for Contracts, Grants, Loans and Cooperative Agreements

The undersigned certifies, to the best of his or her knowledge and belief, that:

(1) No Federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any Federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, ''Disclosure of Lobbying Activities,'' in accordance with its instructions.

(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, Title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

Certification Regarding Nondiscrimination

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is providing the Certification Regarding Nondiscrimination contained in Exhibit II-6 of the Proposal & Award Policies & Procedures Guide.

Certification Regarding Flood Hazard Insurance

Two sections of the National Flood Insurance Act of 1968 (42 USC §4012a and §4106) bar Federal agencies from giving financial assistance for acquisition or construction purposes in any area identified by the Federal Emergency Management Agency (FEMA) as having special flood hazards unless the:

(1) community in which that area is located participates in the national flood insurance program; and

(2) building (and any related equipment) is covered by adequate flood insurance.

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) or Individual Applicant located in FEMA-designated special flood hazard areas is certifying that adequate flood insurance has been or will be obtained in the following situations:

(1) for NSF grants for the construction of a building or facility, regardless of the dollar amount of the grant; and

(2) for other NSF grants when more than $25,000 has been budgeted in the proposal for repair, alteration or improvement (construction) of a building or facility.

Certification Regarding Responsible Conduct of Research (RCR)
(This certification is not applicable to proposals for conferences, symposia, and workshops.)

By electronically signing the Certification Pages, the Authorized Organizational Representative is certifying that, in accordance with the NSF Proposal & Award Policies & Procedures Guide, Chapter IX.B. , the institution has a plan in place to provide appropriate training and oversight in the responsible and ethical conduct of research to undergraduates, graduate students and postdoctoral researchers who will be supported by NSF to conduct research. The AOR shall require that the language of this certification be included in any award documents for all subawards at all tiers.

CERTIFICATION PAGE - CONTINUED

Certification Regarding Organizational Support

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that there is organizational support for the proposal as required by Section 526 of the America COMPETES Reauthorization Act of 2010. This support extends to the portion of the proposal developed to satisfy the Broader Impacts Review Criterion as well as the Intellectual Merit Review Criterion, and any additional review criteria specified in the solicitation. Organizational support will be made available, as described in the proposal, in order to address the broader impacts and intellectual merit activities to be undertaken.

Certification Regarding Federal Tax Obligations

When the proposal exceeds $5,000,000, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Federal tax obligations. By electronically signing the Certification pages, the Authorized Organizational Representative is certifying that, to the best of their knowledge and belief, the proposing organization:
(1) has filed all Federal tax returns required during the three years preceding this certification;
(2) has not been convicted of a criminal offense under the Internal Revenue Code of 1986; and
(3) has not, more than 90 days prior to this certification, been notified of any unpaid Federal tax assessment for which the liability remains unsatisfied, unless the assessment is the subject of an installment agreement or offer in compromise that has been approved by the Internal Revenue Service and is not in default, or the assessment is the subject of a non-frivolous administrative or judicial proceeding.

Certification Regarding Unpaid Federal Tax Liability

When the proposing organization is a corporation, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Federal Tax Liability:

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that the corporation has no unpaid Federal tax liability that has been assessed, for which all judicial and administrative remedies have been exhausted or lapsed, and that is not being paid in a timely manner pursuant to an agreement with the authority responsible for collecting the tax liability.

Certification Regarding Criminal Convictions

When the proposing organization is a corporation, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Criminal Convictions:

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that the corporation has not been convicted of a felony criminal violation under any Federal law within the 24 months preceding the date on which the certification is signed.

Certification Dual Use Research of Concern

By electronically signing the certification pages, the Authorized Organizational Representative is certifying that the organization will be or is in compliance with all aspects of the United States Government Policy for Institutional Oversight of Life Sciences Dual Use Research of Concern.

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME **Kelly N Gilmore**	**Electronic Signature**	**Aug 1 2019 6:24PM**

TELEPHONE NUMBER	EMAIL ADDRESS	FAX NUMBER
530-754-7917	**kngilmore@ucdavis.edu**	

PROJECT SUMMARY

Overview:

The vision of this proposal is to establish an Institute that brings together expertise in atomic-resolution solid-state quantum devices and ultracold atomic gases with the express aim of developing a new generation of quantum simulation platforms. Over the last decade,
the field of quantum simulation using ultracold fermionic and bosonic gases has realized numerous novel quantum effects. More recently, the technology to place single or multiple dopant atoms at arbitrary lattice sites in silicon has made it possible to engineer solid-state
quantum simulators with much of the flexibility of atomic systems. The proposed Institute will take advantage of the complementary strengths of these two approaches, as well as the ability to cross-validate models between them, to enable synergistic progress far exceeding that possible with isolated efforts. The primary goals of this proposal are to achieve proof-of-concept quantum simulation of strongly correlated materials in engineered nanostructures, map these systems onto their atomic, molecular, and optical (amo) counterparts, and then explore new magnetic, topological, and superconducting states of matter, and quantum dynamics, with
both experimental platforms, in coordination with powerful computational tools.

Intellectual Merit:

Realizing the aims of the Institute will advance a number of fundamental topics in physics, including exotic superfluidity and superconductivity, d-wave pairing in the Fermi-Hubbard model, the emergence of topological states, quantum dynamics, and the effects
of geometry (including frustration) and disorder. It will also significantly advance a variety of technologies in scanning tunneling microscopy (stm), single-atom resolved nanostructure fabrication, synthetic spin-momentum lattices in ultracold atomic gases, and high-fidelity atomic qubit initialization using optical tweezer arrays.
Bringing the technology developed for ultracold gas applications to bear on questions which arise in solid state quantum simulators, this Institute will develop new and proven techniques for scalable quantum simulation. This effort will build from smaller arrays of quantum sites benchmarked against amo simulations and forefront numerical models including density functional theory, quantum Monte Carlo, the density matrix renormalization group, numerical linked cluster expansions, and many body perturbation theory, as well as their dynamic variants.

Broader Impacts:

It is no exaggeration to say that success in this endeavor could change the technological and industrial landscapes with both technical and social impact. In analogy with the semiconductor revolution, quantum simulation is currently at the stage of networking a few transistors. This Institute will enable scalable quantum simulations for nanotechnology and quantum computation applications: a cornerstone of the coming quantum revolution.
The combination of condensed matter and amo platforms also offers unique opportunities for workforce and infrastructure development. We envision cross-training of students in both technologies, and in theoretical and experimental foundations. Key features of our
proposal are (i) a two week annual workshop/summer school which will bring together all the team graduate students and postdoctoral researchers for pedagogic lectures and current research interactions; (ii) co-ordination of mentoring through a partnership with the UC
Davis Undergraduate Reserch Center; and (iii) a community outreach effort which includes public science presentations, primary and secondary school visitations, and a high school internship program which continues and extends an apprenticeship program organized by
one of the PIs over the last decade with funding from the Defense Advanced Research Project Administration and the Oak Ridge Institute for Science Education. This apprenticeship effort is currently partnered with River City High School in West Sacramento with a high proportion of underrepresented students. We will extend the program to include other high schools in Yolo County, and initiate a similar activity at another of our institutions.

TABLE OF CONTENTS

For font size and page formatting specifications, see PAPPG section II.B.2.

Appendix Items:

*Proposers may select any numbering mechanism for the proposal. The entire proposal however, must be paginated. Complete both columns only if the proposal is numbered consecutively.

2. Project Description

A. Team Description

Our team consists of PIs and Senior Personnel (SP) with complementary and synergistic expertise in condensed matter and atomic physics, and in theory and experiment:

- **Richard Scalettar (PI)**: University of California, Davis, Physics.
- **Peter Engels (SP)**: Washington State University, Physics and Astronomy.
- **Michael McNeil Forbes (Co-PI)**: Washington State University, Physics and Astronomy.
- **Subhadeep Gupta (Co-PI)**: The University of Washington, Physics.
- **Ehsan Khatami (SP)**: San José State University, Physics and Astronomy.
- **Wiley P. Kirk (Co-PI)**: University of Texas, Arlington, Materials Science and Engineering.
- **Irma Kuljanishvili (SP)**: St. Louis University, Physics.
- **Joseph Lyding (SP)**: Univ. of Illinois Urbana-Champaign, Electrical & Computer Engineering.
- **Reza Moheimani (SP)**: University of Texas, Dallas, Mechanical Engineering.
- **Rick Silver (Co-PI)**: University of Maryland, Physics and NIST, .
- **Steven White (SP)**: University of California, Irvine, Physics.
- **Li Yang (SP)**: Washington University, St. Louis, Physics.
- **Chuanwei Zhang (SP)**: University of Texas, Dallas, Physics.

We will also utilize the expertise provided by the following major partners in industry, National Labs, and international collaborators for fabrication, workforce development, and potential technology transfer:

- **James Owen, John Randall**: Zyvex Labs.
- **Shashank Misra, Andrew Baczewski**: Sandia National Lab
- **Kipton Barros, Ghanshyam Pilania**: Los Alamos National Lab
- **Neil Curson**: University College London (UCL) (*International collaborator*)

This team is well-suited to tackle the challenges described in this proposal. Concerning the new engineered silicon quantum simulation platform, devices will be fabricated and characterized by *Kirk*, *Kuljanishvili*, *Lyding*, *Misra*, *Owen*, *Randall*, and *Silver* – a group that has led the development of hydrogen depassivation lithography technique [1], and its improvements via higher STM tip currents to speed device fabrication, the use of multiple n- and p-type dopants in the same device, and improved methods of encapsulating the dopants with epitaxial Si overgrowth. This sub-team also has extensive capability to measure 2D quantum metamaterials, including transport, magneto-transport, spectroscopy, and thermodynamic techniques [2–12].

Moheimani, *Owen*, and *Randall* bring additional expertise [13–15] in developing technological device applications. *Moheimani* is the head of the Laboratory for Dynamics and Control of Nanosystems, dedicated to the development of methodologies and instrumentation for fast and accurate interrogation and manipulation of matter at the nanoscale. *Owen* and *Randall* lead Zyvex Labs, which develops atomically precise manufacturing with the goal of helping achieve Quantum Computers, Analog Quantum Simulators and Atomic Electronics.

The complementary atomic, molecular, and optical (AMO) platform is supported by *Engels*, *Forbes*, *Gupta*, and *Zhang* who have done pioneering work with quantum degenerate Fermi and Bose gases, including novel superconductivity (i.e. polarized superfluids [16, 17], Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) supersolids [18–20], p-wave pairing [21]), synthetic supersolidity [22], spin diode [23], Fermi-Bose mixtures [24, 25], radio-frequency spectroscopy [26], molecular Bose-Einstein condensates (BECs), atom interferometry [27], negative mass hydrodynamics [28], dispersion engineering using spin-orbit coupling (SOC) [29–31], artificial spin-momentum lattices [32], topological states [33–37], and high-density quantum chromodynamics (QCD) [38–40].

The approaches used by these two sub-groups offer many promising opportunities for synergism. The AMO community has extensive experience in dealing with the consequences of inhomogeneity induced by the confining potential or controlled disorder which can offer specific guidance to dealing with similar effects that need to be addressed within engineered silicon platforms. Single particle dynamics probed in AMO experiments on Bose-Einstein condensates make direct connections to the behavior of electrons in engineered silicon, tuned by gating to low densities. The ability to compare the behavior of independent quantum particles offers the most simple venue for cross-validating the behavior of the two platforms. Finally, the physics of small plaquette structures (2×2 dopant arrays and 2×2 momentum-spin artificial lattices) is central to the initial investigations of both groups, and serves as the starting point for going beyond single particle physics to understanding strong correlation phenomena inherent in, for example, exotic d-wave superconductivity [41–44].

A theory team – *Baczewski*, *Forbes*, *Khatami*, *Scalettar*, *White*, *Yang*, and *Zhang* – will act as a further condensed matter (CM)-AMO bridge. This group has complementary expertise in density matrix renormalization group (DMRG) (invented by *White* [45–47]), quantum Monte Carlo (QMC) [48] (*Khatami*, *Scalettar*), numerical linked cluster expansion (NLCE) [49, 50] (*Khatami*) and exact diagonalization (*Khatami*, *Zhang*) [51], quantum chemistry (*White*), density functional theory (DFT) and many body perturbation theory (MBPT) (*Forbes*, *Yang*, *Zhang*) [23, 31, 52–56], and non-equilibrium dynamics (*Forbes* and *Zhang*). Several of these approaches are especially effective for small clusters which provide some of the initial experimental targets. The theory team has a proven track record of high profile applications of these techniques to both CM [57–62] and AMO [23, 28, 51, 54, 63–67] systems.

Iterative agile techniques will be used to obtain convergence between theory and experiment, rapidly improving device fabrication through a closed-loop development cycle that will significantly improve our understanding of dopant lattices and their AMO counterparts. *Barros*, *Khatami*, *Pilania*, and *Scalettar* bring expertise in data-driven science discovery through machine learning (ML) [68–72], which accelerates and streamlines this process. Once this baseline is established, we will construct and explore larger 1D and 2D lattices to simulate strongly correlated quantum Hamiltonians like the Hubbard model.

B. Research Theme, Focus Areas, and Cross-Cutting Concepts

Overview: The organizing theme of our Challenge Institute is the development of algorithms, architectures and platforms for quantum simulators. Specifically, the first main objective is to demonstrate a new solid-state platform for quantum simulation that offers the advantage of scaling, similar to modern day semiconductor device technology. One of our first milestones is the fabrication and evaluation of an elementary plaquette quantum-simulator device, which is a basic engineered silicon 2×2 array. In parallel with the development of this new solid-state platform, we will achieve analogous lattices with the novel AMO approach of 'synthetic' spin-momentum lattices, benchmarking the CM work while simultaneously revealing interesting physical effects by contrasting the two platforms. In this first period, the AMO plaquettes, which are at present in a more advanced state of progress, will be used to study the dynamics of single particle BEC states, in preparation for later exploration of complex many body dynamics. We anticipate these efforts will encompass roughly the first half of the project period.

In the second half of the project, higher order plaquettes (5×5 to 10×10 arrays) of engineered silicon will be designed, fabricated, and characterized. At this stage the AMO capabilities will be extended to include single atom optical tweezer arrays initialized in the motional ground state with high fidelity, a promising candidate for scalable quantum simulation/computation. A powerful combination of computational and theoretical tools including

DMRG, QMC, large-scale exact diagonalization, NLCE, quantum chemistry, DFT, and MBPT, as well as data-centric approaches including ML, will enable realistic and accurate many-body characterization of these systems.

These three approaches, CM, AMO experiment, and many body simulations, will achieve pioneering advances in quantum simulation by incorporating controllable initialization and state evolution for the investigation of novel magnetism, superconductivity, and topological states. In combination, the experimental and theoretical work within these project segments will make meaningful progress toward the ultimate purpose of achieving a scalable solid-state quantum simulator.

The main science aim of this proposal is to extend the boundaries of both AMO and CM systems from the current lattice sizes and parameter ranges to the regime of scalable quantum simulation capable of studying single particle dynamics (including topological phases), disordered strongly correlated systems, and coherent quantum dynamics. This goal will be realized by using each framework to inform the other. Explicitly, fabrication limitations and disorder within CM systems produce effects that are difficult to systematically isolate, while AMO systems provide a pristine starting point into which one can add analogous effects. On the other hand, AMO systems are more transient and challenging to cool. By focusing initially on systems of a few coupled sites, we will benchmark these two frameworks for quantum simulation against each other within a relatively immediately achievable context. Characterizing and understanding these plaquettes will also form the starting point for the study of a number of interesting single particle dynamics and strong correlation phenomena.

We envision six focus research areas (FRAS), each exploiting synergies between CM and AMO, both experiment and theory:

¶ **Focus Research Area 1:** ***Synthesis, characterization, and modeling of small clusters.*** The focus here is to create small 2×2 clusters (plaquettes) in both CM and AMO platforms, fully characterizing these to high precision with theoretical techniques by iterating between experiment and theory until convergence is obtained. This will lay both theoretical and experimental foundations before attempting to scale the quantum simulations.

¶ **Focus Research Area 2:** ***High fidelity qubit initialization; optical tweezers.*** To extend the AMO capability in order to compare with larger CM clusters, we will develop the technology to realize a scalable, high-fidelity optical tweezer array. Neutral atoms trapped in optical tweezer arrays have recently emerged as a promising candidate because of attractive features such as identical qubits, scalability through atom-by-atom assemblers, and high precision control and measurement [73–80]. To use these for quantum simulation and computation, one needs high-fidelity initialization of each qubit. This requires deterministic preparation of single atoms in the vibrational ground state of the optical tweezers to achieve high-fidelity quantum gates and long coherence time. The focus here is design and implement schemes for achieving this high-fidelity qubit initialization.

¶ **Focus Research Area 3:** ***Novel superfluid and superconducting phases.*** The focus here will be to construct larger square lattices (up to 10×10) in CM platforms and coupled plaquette arrays in order to perform quantum simulations of novel phases of matter. Novel phases will be simulated directly using AMO systems. These experimental results will be compared with various many-body techniques to advance our understanding of exotic magnetic, superfluid, and superconducting states.

¶ **Focus Research Area 4:** ***Emergence of topological states with system size.*** Constructing longer clusters, we will investigate highly sought-after topological states within both AMO and CM systems. In the AMO context, these chains will be realized using synthetic spin-momentum lattices. The focus is to characterize the emergence of topological states as a function of system size, and to understand how these states are affected by atomic defects in the CM context.

¶ **Focus Research Area 5:** ***Quantum simulation of novel geometries and disorder.*** Here we will extend our technology to simulate quantum phenomena in novel geometries such as honeycomb, triangular, and Kagome lattices. In the AMO context, the focus will be on using different spin states to extend the synthetic lattices, while in the CM context, the focus will be on the effects of disorder naturally present in these systems,

¶ **Focus Research Area 6:** ***Dynamics of quantum states.*** To understand the complex dynamics associated with the coherent coupling of many quantum states, we will use the flexible AMO toolbox. Quantum dynamics will be studied both theoretically and experimentally, pushing the boundaries of both techniques to discover new quantum phenomena.

C. Challenge Institute Motivation

Strongly interacting quantum systems form the foundations of many existing and future technologies, such as magnetic materials and high temperature superconductors [81]. They also provide some of the most interesting targets of fundamental science, including quantum phase transitions [82], topological phases [83], non-Fermi liquid behavior [84], and exotic pairing symmetries [85, 86]. Understanding these materials and phenomena has been a long standing endeavor, often frustrated by the so-called fermion sign problem [87, 88] which implies exponential scaling of the QMC approach as also occurs for methods like exact diagonalization. This severely limits our ability to understand emergent quantum phenomena. For example, early numerical work found a ground state with d-wave symmetry in the Hubbard Hamiltonian on 2×2 plaquettes [89], suggesting that an on-site electron-electron interaction might play a role in novel superconducting materials. When combined via hopping to form an extended lattice of plaquettes, an interesting possibility exists of an 'optimal inhomogeneity' maximizing T_c [90–93] that may help explain high T_c superconductivity, but ab initio or experimental verification is needed. The *motivation for this Institute* is to provide the foundation for a scalable quantum simulation platform that can address such scientific questions.

Experimental attempts in the AMO context have achieved remarkable successes [94], and AMO systems have achieved high-fidelity neutral atom qubit initialization [95, 96], but significant barriers remain. Recasting these quantum systems in a CM context holds promise for crossing these barriers, allowing a synergistic and controlled investigation of strong correlation physics using a combination of state-of-the-art fabrication, experiment, and simulation. In recent years the technology enabling scanning tunneling microscopes to place individual dopant atoms at will on a silicon wafer with high fidelity has fully matured [97–99]. Although not as advanced as AMO technologies, the CM platform provides many experimental techniques, and has some advantages: In particular, CM devices are permanent, scalable, and one naturally has Coulomb interactions between particles, which are difficult to engineer with neutral atoms.

This proposal is timely as recent developments in both AMO and CM communities complement each other so that that the collaboration afforded by this Institute will improve quantum technology significantly faster than could be achieved by independent research paths. For example, current techniques in both AMO and CM will allow experimental access to small-scale lattices that capture many of the novel quantum effects described above. In this regime, one also has accurate theoretical control using techniques such as exact diagonalization and QMC. The Institute will thus allow a rapid closed-loop iteration between theory and both CM and AMO experiments to converge, providing precise benchmarks for the theoretical techniques, a proper characterization of imperfections in the CM experiments, and validation of synthetic dimensions and induced AMO interactions. From this baseline, the Institute will enable the rapid development of AMO technology to probe more complicated systems, and CM technology to scale the quantum lattices using well-known semiconductor fabrication technology.

The notion of using dopant lattices for quantum simulation has been broached before, but to our knowledge, no full-scale program of developing this technique has been undertaken. Recently Le et al. modeled Si dopant arrays and found "promising platforms for the quantum simulation of the Fermi-Hubbard model" [100]. Prati et al. studied transport through a disordered quasi-1D array of ion-implanted dopants and found conductance peaks ascribed to Hubbard bands [101]. The Simmons group concluded P donors in Si, "are suitable for simulating strongly correlated phenomena in larger arrays of dopants, establishing dopants as a platform for quantum simulation" [102]. These *prior and independent results* strongly support our proposal for a focused program developing Si dopant arrays for quantum simulation.

At the same time, the flexibility, turnaround time, and dynamic resolution available to AMO implementations will be integral to the success of this project. For example, the AMO framework allows for dynamical control and direct interrogation of quantum states [103–105], unlike in electronic devices. Atom interferometry can probe quantum phase differences [27, 106], and periodically driven lattice couplings lead to a variety of novel dispersion relations [107, 108] as well as topological phases [109–112]. Explicit control over s-wave interparticle interactions [113] has led to the realization of the BCS-BEC crossover [114], demonstrating the reach of AMO experiments for quantum simulation. These *successes in quantum simulation* strongly support our proposal to use AMO techniques to understand the quantum phenomena required to realize a scalable CM platform for quantum simulation.

This Challenge Institute will lay the foundation for two quantum simulation platforms capable of enabling significant scientific discovery. With their complementary advantages – AMO flexibility and control, versus CM scalability – the Institute will enable rapid progress to a scalable platform for quantum simulation difficult to achieve in isolation.

D. Major activities in the focus research areas

¶ **Focus Research Area 1:** ***Synthesis, characterization, and modeling of small clusters.*** The specific solid state system we will employ to create a scalable quantum simulator using the CM platform [115] consists of arrays of dopant atoms in silicon, placed with atomic precision and buried with an epitaxial overgrowth layer. Fig. 1 presents a schematic of the process, and Fig. 2 indicates an initial 3×3 success. Utilizing the technique of hydrogen depassivation lithography – invented by *Lyding* [4] – we will construct two-dimensional arrays of dopants beginning with 2×2 plaquettes.

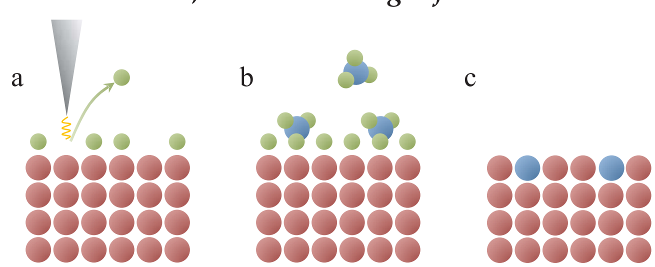

Figure 1: Dopant lithography: a) Current from an STM tip selectively desorbs H atoms from passivated silicon. b) Phosphine gas molecules, PH_3, attach to exposed Si dangling bonds. c) Heating desorbs much of the remaining hydrogen and P atoms replace surface Si atoms.

We will address the following challenges:
1) How do we overcome uncertainty of ± one dopant atom per given site? How do we achieve atomically perfect positioning in a reliable manner? 2) What is the best way to probe 1D and 2D

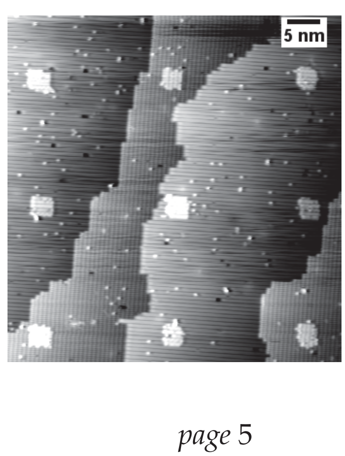

Figure 2: A 3×3 pixel lattice, with each pixel containing ≈ 50 Si dangling bonds produced by selectively as described in Fig 1. When followed by adsorption of phosphine molecules (PH_3), approximately 6-8 P atoms will be incorporated into each pixel after a heat treatment. (Image courtesy J. Lyding).

systems beyond charge transport measurements? What is the typical time evolution of the Hamiltonian that we want to monitor? 3) What is the role of disorder? How much atom-ic-scale disorder can we tolerate? 4) What is the physics for a 1D system where topological behavior or spin have been introduced?

Synthesis of Dopant Arrays with Atomic Precision: To achieve arrays with identical numbers of dopants at each site, we need to move beyond the stochastic incorporation process [116, 117] where the single P atom placement yield is 70% and the number and position of incorporated dopant atoms cannot be predicted precisely. We shall explore: 1) STM tip-assisted incorporation to block the desorption pathway [118], 2) alternative Group V dopants using AsH_3 in collaboration with Curson at UCL, 3) Sb, Bi (for increased spin-orbit coupling), 4) hole-based arrays using Group III dopants. The chemistry for acceptor dopant placement is relatively undeveloped. *Silver* and *Lyding* use diborane with STM lithography for B incorporation. For Al, *Kirk* is developing an *in-vacuo* alane source, while *Owen* at Zyvex Labs is exploring tri-alkyl Al precursors.

The perfect single-dimer patterns required have been demonstrated using low-temperature STM lithography [9, 119]. Reliable STM probes represent another important aspect of achieving atomically precise lithography. *Lyding* is working with Tiptek, LLC, to produce probes for long-term reproducible atomically precise lithography. Epitaxial silicon encapsulation without disturbing the dopant positions is achieved using a locking layer process followed by low-temperature epitaxy [7, 10, 11, 120]. However, as the dopant species changes from P to Bi, other methods such as a surfactant film [121, 122] may be more effective.

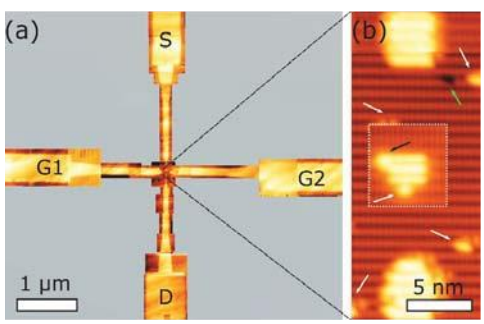

Figure 3: An STM image showing gates and leads for transport measurements of single/few atom devices. From Ref. [119].

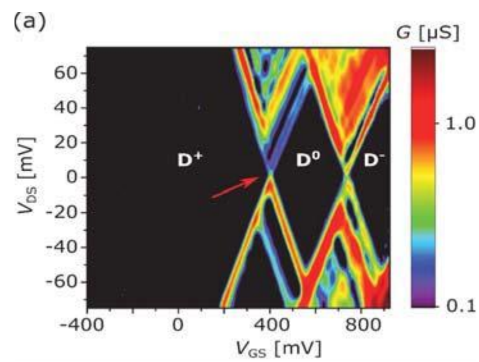

Figure 4: Low temperature measurements showing the energy level spectrum of a single dopant atom placed between 4 nm leads. From Ref. [119].

Measurement of designed arrays towards a quantum simulator: Even at this small scale we can realize non-trivial physics of the Hubbard model (moment formation, and short range antiferromagnetism (AF)), controlling the U and t parameters by placing one or more atoms at each lattice site, and by the choice of crystal structure and lattice spacing. Atomically aligned in-plane gates, similar to those shown in Fig. 3, allow control of individual site energy levels in a $1\times n$ or $2\times n$ atomic arrays. Atomic structures can be capacitatively and tunnel coupled to single electron transistors (single electron transitor (SET)), as shown in Fig. 3 and Fig. 9 below. Low temperature transport measurements can explicitly characterize energy level spectra and charging energies in single and few atom structures [119], as shown in Fig. 4. Additionally, scanning capacitance imaging of dopants buried up to 80 nm below the surface [123] may offer advantages over the traditionally known electrostatic imaging such as Kelvin Probe Microscopy and electrostatic force microscopy (EFM) because of the $1/r^2$ dependence on the distance between measuring probe and the location of the dopant, for capacitance (e.g. by *Kuljanishvili* [124] and using EFM [125] respectively). With scanning probe microscopy (SPM) methodology we shall explore different designs of probe sensors, capacitance change sensors, SET and resonant tunneling device (RTD) architectures; SPM probes can also be used as top gates. A second approach to measurement of the buried 1D or 2D systems is to introduce top gate arrays. For arrays of dopant patches, which are only a few nm apart, using SPM lithography we will fabricate aligned top gates, as it can locate the buried structures directly, and then fabricate aligned top gates, by various means [8] including direct writing of sub-5 nm wide metallic wires by STM [2] and atomic force microscopy (AFM)-based direct write techniques.

Convergence of detailed quantum calculation of lattice models with experimental outcomes: In analogy with the atomic resolution sites prepared in the CM context, we will, in parallel, use discrete atomic states in the AMO context that are independently measurable and addressable: namely spin and momentum. By controlling the coupling between states of different spin and momentum, one can study lattices in "synthetic" dimensions. As a benchmark, we will continue to evolve these advanced AMO research areas, while simultaneously matching parameters and geometries to aid in the more rapid realization of their CM counterparts.

First-principle DFT and MBPT calculations of single- and multiple-dopant pixels in silicon will provide accurate atomic structures of dopant arrays and many-electron correlation effects as input to sophisticated QMC treatments of full lattices, to be compared against experiments. Especially in the case of small lattices, an iterative loop of fabricate-measure-compare to calculation will form a solid underpinning toward understanding full-scale lattice simulations of the Hubbard model. This approach can also lend itself to data-centric techniques such as supervised ML to gain predictive power over model parameters given a set of experimentally measured properties, which will be explored through partnerships formed with Los Alamos National Laboratory (LANL). Similar processes have recently been adopted for tuning semiconductor quantum dot devices [126].

To benchmark against single particle dynamics, we will simulate small clusters at low temperatures using synthetic spin-momentum space lattices. These quantum simulators involve applying radio-frequency (RF) fields to resonantly couple hyperfine spin states while simultaneously illuminating atoms with a variety of optical lattice potentials. These potentials couple discrete momentum states, which can then act as a sites in a discrete synthetic lattice. The couplings between these spin and momentum states can be controlled via the intensity, detuning, and relative phase of the optical lattice and RF fields. Fig. 5 shows an example of dynamics in a 2×2 plaquette.

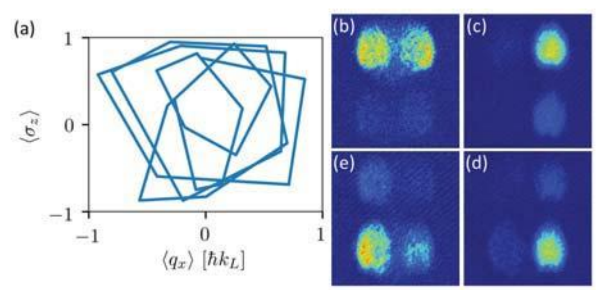

Figure 5: (a) A BEC under simultaneous spin and momentum coupling tracing out a circle in state space. (b)-(e) The time-of-flight images from $t = 0$ to 0.3 ms. The momentum populations are separated horizontally while the spin populations are separated vertically under a linear magnetic gradient as the cloud of atoms experiences free fall.

We will extend this concept by applying independent coupling to include additional spin and momentum state on the fermionic isotope ^{173}Yb, which has six spin states available, allowing for a $6 \times n$ plaquette within this framework. To determine the quantum phase, a quantity that is of key importance for quantum simulation, we will apply atom interferometry techniques.

¶ **Focus Research Area 2:** ***High fidelity qubit initialization; optical tweezers.*** We propose to investigate with theory, and experimentally realize, a scheme to prepare high-fidelity single atom ground states in an optical tweezer. This approach, inspired by particle and high-energy physics, uses the supersymmetric partner of the optical tweezer potential as an auxiliary tweezer to adiabatically extract excited atoms (Fig. 6), leaving a single atom in the ground state.

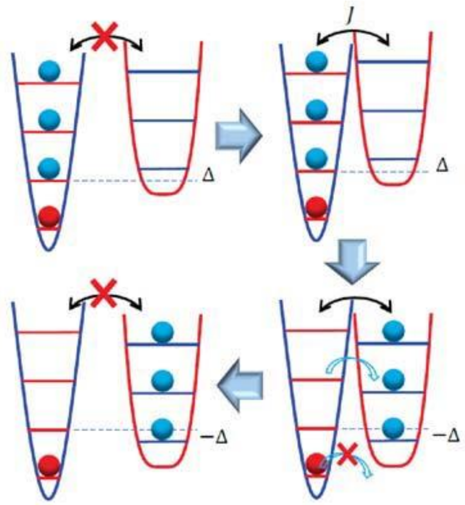

Figure 6: Adiabatic extraction of excited atoms from an optical tweezer using the supersymmetric partner potential as an auxiliary tweezer that has the same spectrum except for the ground state. J and Δ are the tunneling amplitude and detuning between two tweezers.

Our proposed high-fidelity qubit initialization, will overcome one fundamental roadblock that prevents the experimental realization of neutral atom quantum computation and quantum simulation [34, 37]. Beyond the ground state preparation, our proposed experimental work will mainly focus on quantum simulation. As an example, we will build a 4×4 small lattice using 16 optical tweezers and compare the quantum simulation results with those obtained in our corresponding solid-state platforms.

We will also explore the possibility of building up low entropy, large N systems by using auxiliary tweezer beams to bring in additional atoms into the tweezer trap by adiabatic merging. When added to particular eigenstates of the trap, in principle a sequential application of this approach can produce a low-entropy targeted many-body state built from the ground up. Clearly, interactions between the atoms will have to be carefully taken into account as they will perturb the eigenstates of the non-interacting system. We will first approach this question theoretically, building on current work by *Zhang*, before implementing experiments.

¶ **Focus Research Area 3:** ***Novel superfluid and superconducting phases.*** We will use engineered nanomaterials and ultracold atomic gases as platforms to study quantum simulations of exotic superconducting states, such as d-wave pairing, the supersolid FFLO state predicted to exist in the unitary Fermi gas [18], supersolid states [58] in systems with spin-orbit coupling, and coupled superfluids [25].

We will construct an array of 2×2 plaquette structures as shown in Fig. 7, beginning with smaller arrays and moving to larger arrays. We will investigate the d-wave ground state within the Hubbard Hamiltonian whose properties underpin superconducting cuprate pairing. After successfully making and characterizing high fidelity 2×2 plaquettes in both CM and AMO platforms (FRA-1), we will explore novel superfluid and superconducting phases that can occur in such coupled-plaquette systems [44, 90–92].

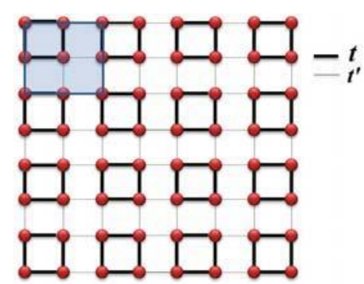

Figure 7: The plaquette Hubbard model consists of elemental 2×2 plaquettes.

With the AMO platform, we will explore a variety of exotic superfluid phases directly (homogeneous phases rather than lattice models) to understand their behavior and make connection with the continuum limit of the lattice models that will ultimately be simulated on the CM platform.

¶ **Focus Research Area 4:** ***Emergence of topological states with system size.*** We will implement the 1D Su-Schrieffer-Heeger (SSH) model in the CM framework, using the established AMO system as a benchmark. As we obtain control of our simulation platform, we will explore the boundary between few and many sites as topological states begin to take hold with special emphasis on band structure, transport, and surface states as a function of system size.

As with the studies in FRA-5 below, remnant disorder in synthesis can be turned to an advantage, since it is precisely the effects of randomness that are central to the topological insulators (TI) phase. We will explore topological edge states in higher dimensions and new geometries by coupling additional degrees of freedom, implementing a variety of extended SSH models. Our theory group has performed studies of a related Hamiltonian [127], and has implemented an efficient QMC code for the SSH physics in conventional CM systems. Applying this model to solid state arrangements of atomic defects is another open problem that we will explore.

QMC simulations and exact diagonalization suggest variation of the ground and excited state degeneracies with ribbon thickness plays a key role in superfluid transport down the ribbon. Our engineered nanostructures and optical lattices can both realize this geometry, providing a further context to investigate the size dependence of topological states. We will also explore the interesting connections between such domain walls and those found between AF regions of opposite sublattice occupation in cuprate superconductivity (SC) and the doped Hubbard model [43, 128–130].

¶ **Focus Research Area 5:** ***Quantum simulation of novel geometries and disorder.*** We plan to exploit the geometric freedom to move from investigations of square lattices (relevant to cuprate SC), to Dirac fermions in honeycomb lattices [131], and triangular or Kagome lattices, directly emulating models of frustrated quantum systems [132, 133]. Disorder will be a critical parameter to vary, enabling study of the dynamics of many-body localization [134]. We will conduct detailed numerical QMC calculations of the configurations of our dopant lattices with input provided by direct visualization and measurement of the fabricated lattices as well as ab initio DFT calculations.

A final research focus combines investigation of plaquette structures, novel SC and disorder: It has been shown [135] that in the plaquette Hubbard Hamiltonian of FRA-4, the effects of both chemical potential and hopping disorder on pair binding are reduced for unbalanced inter/intraplaquette coupling compared to the uniform case. With the understanding of disorder developed in the course of FRA-1, a succeeding research activity will be to study the deliberate introduction of randomness in the plaquette model and its effect on the stability of the paired state.

¶ **Focus Research Area 6:** ***Dynamics of quantum states.*** We will apply powerful numerical techniques including exact diagonalization, for smaller clusters, and time-dependent generalizations of DMRG to studying a variety of non-equilibrium dynamics. Within the DMRG framework, the leading obstacle is the growth of entanglement in time in a non-equilibrium system, such as after a quench. This is an area of exciting recent work [136] related to fundamental issues involving thermalization: how does a quantum system reach equilibrium, and how can we simulate such a system? Dynamical properties like the spectral function, spin susceptibility, and conductivity will also be investigated using QMC data [137, 138].

E. Major activities in training and workforce development

The PIs have comprehensive records of student training. Together, they have supervised close to 100 postdoctoral scholars, and several hundred undergraduate and graduate students. Most have gone on to productive technical careers in industry, national laboratories, and academia. Many remain actively involved in fields closely allied to quantum simulation. Joint mentoring arrangements between several PI's already exist. This Center has an opportunity to strengthen this record further, and enable students to capture the background and frontiers of CM and AMO, and of theory and experiment. *Scalettar* serves on the executive committee of the University of California, Davis (UCD) Undergraduate Research Center, which will coordinate undergraduate involvement in Center's activities. (See attached collaboration letter.)

We have established partnerships with researchers at Sandia National Laboratory (SNL) (*Misra* and *Baczewski*) who have expertise in engineered nanostructures, their modeling with DFT, and their applications to many-body physics and quantum computation. Similar partnerships exist with *Barros* and *Pilania* of LANL. Particularly intriguing is the possibility of expanding the interdisciplinary nature of our team's research and training of graduate students. *Barros* and *Pilania* are experts in advanced computer science methodologies in general and in ML in particular [71, 139, 140]. All these researchers have agreed to joint mentoring and extended student visits to their labs. Indeed, interactions have already begun with several graduate students that involve developing better QMC algorithms and applying ML to many-body quantum phenomena. The graduate and postdoctoral researchers we employ will be expected to routinely visit and confer with the scientific and technical staff at Zyvex, further strengthening our collaborative efforts and providing a pathway for young scientists with 'quantum skills' to directly enter and support the workforce, forming one pillar of the ongoing 'second quantum revolution' as well as providing a new employment opportunity for researchers from the home institutions of the PIs. The annual topical meeting and summer school will broaden the impact of our training efforts beyond students immediately in our groups to researchers in the general quantum simulation community.

Our outreach efforts will also help address workforce development at the beginning of the STEM pipeline. Public talks and community outreach will promote greater and more diverse participation in fields germane to quantum simulation among primary and secondary school students. Undergraduate research opportunities created in this project, especially at Primarily Undergraduate Institutions like San Jose State University with one of the most diverse population of students in the country, will offer students from minority groups insight into forefront science and encourage them to pursue advanced degrees. The PIs have records of promoting diversity in their workforce development, educating numerous students from underrepresented backgrounds, and playing leading roles in efforts like 'CalBridge' (*Scalettar* and *Khatami*) which seek to better inform undergraduate students from California's state colleges about graduate education.

F. Research Coordination and Community Engagement

There will be three centerpieces to our QLCI intragroup research coordination. The first are long-term (several week) visits between the Center's groups. Each student and postdoc will make several trips each year to ensure that efforts remain strongly coherent and complementary. Travel budgets have been constructed with this need in mind. Second, and closely aligned to these trips, each graduate student and postdoctoral researcher will select a secondary mentor, to broaden his/her career development. This pairing will emphasize either theory-experiment or else CM-AMO partnerships. Finally, an annual team meeting will allow all members to discuss achievements, and plans for the coming year. An initial meeting to organize the first year's effort will occur within a few months of the project start date.

Intergroup coordination/engagement will take place with other QLCI teams and with the larger quantum simulation community via a topical meeting (focusing on research) and a summer school (focusing on introductory-level expositions of the field) for graduate students and postdoctoral researchers. The goal will be a combination of cross-training students with detailed comparisons of quantum simulation technology, analysis, and physics of the two platforms. The topical meeting will also serve as an external networking opportunity where new experts can be recruited depending on the current interests and needs in the project. Funding has been requested to facilitate both these activities.

Concerning community engagement: The PIs will continue, and expand, their extensive and well-developed activities, which include public talks, secondary school visits, and student mentorship activities. Beyond these efforts, a very specific high school apprenticeship program will be organized at the University of California (UC) Davis. A similar, small scale (8-10 students/year) program has been run for the last decade by one of the PIs, funded by Defense Advanced Research Projects Agency (DARPA) and the Oak Ridge Institute for Science and Education (ORISE). The project brings River City High School (RCHS) students to the UC Davis campus for a one-month paid summer internship where they learn python for quantum simulation. Figure 8 shows apprentices recruited from the classes of computer science and robotics teacher Mr. Dubarrie Fagout at RCHS. RCHS has a diverse population including a pre-ponderance of students from under-represented groups. We will continue and expand this apprenticeship program in the Sacramento area to include Woodland High School, and also begin a second program at one of the other nodes of the Center. A primary goal of this apprenticeship program will be outreach to a community which does not otherwise have such opportunities.

Figure 8: Students in the DARPA high school apprenticeship program organized with RCHS.

G. Partnerships and Infrastructure Development

We have established partnerships with leading researchers in quantum simulators, engineered nanostructures, and ML at SNL Albuquerque (*Shashank Misra* and *Andrew Baczewski*) and LANL (*Kipton Barros* and *Ghanshyam Pilania*). As described in the Letters of Collaboration, these researchers will host extended visits by our team's graduate students which will involve exploiting computational expertise and resources as well as facilities for the CM experimental efforts. The participation of *Barros* and *Pilania*, who are experts in the application of advanced computer science techniques to problems in materials physics, will, in particular, bring significant additional interdisciplinary nature to the team.

University-based members of our team will work in close collaboration with our industrial partners *Owen* and *Randall* at Zyvex Labs, who have developed the foremost software suite for controlling scanning tunneling microscopes for patterning dopant lattices combined with epitaxial overgrowth capabilities. Indeed our partnership with Zyvex Labs will form a cornerstone of the broader impacts of this work. Zyvex Labs has been engaged for some years in the development, production, and refinement of software specifically intended to deliver precise control of STM tip motion for the purpose of fabricating dopant arrays in silicon.

A key mission of our partners at Zyvex labs is to achieve a sufficient level of accomplishment in the technology to produce precision dopant arrays, which is presently limited to a handful of dedicated laboratory operations, so as to make them more democratically available to the entire condensed matter research and industrial communities [141]. This entire business plan hinges upon the promise for dopant arrays to serve as a platform for simulating the most relevant physical models for technologically promising materials such as high-T_c superconductors. Our progress will inform and support this goal.

It is no exaggeration to say that success in this endeavor could change the technological and industrial landscapes. Opening the door to successful quantum simulation of realistic and technologically-relevant Hamiltonians could greatly accelerate the discovery of mechanisms underlying the most thorny condensed matter problems, notably including high-T_c superconductivity. Moreover, in the absence of large-scale algorithmic quantum computation, our approach of lattice-based quantum simulation promises to deliver results well beyond the reach of existing quantum calculation methods. A successful proof-of-concept demonstration of quantum simulation in even modestly sized 10×10 atom lattices would count as a profound success and pave a clear path for further development of this simulation technique.

To reach such a point, the present interdisciplinary team of engineering, physics, and computer modeling expertise will form the core of a small but tightly-coupled effort to solve the particular problem of demonstrating a working condensed matter quantum simulator. Our aim is to take this clearly promising platform and venture to leap beyond the minimal 1D arrays established so far [101, 102], to directly test the feasibility of quantum simulation.

H. Cross Disciplinary Engagement and Team Synergy

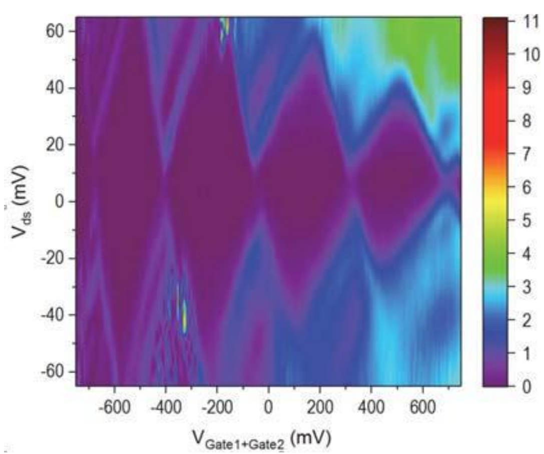

Figure 9: Low temperature differential conductance measurements of a few-atom transistor. [R. Silver, Unpublished]

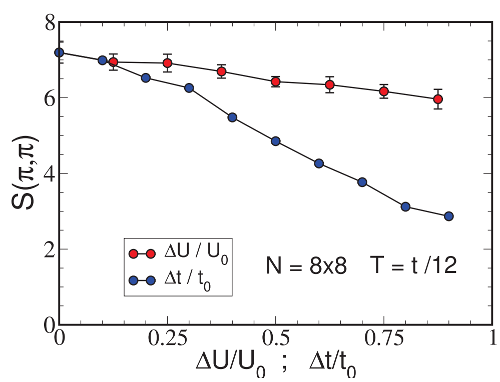

Figure 10: Comparison of relative effects of disorder in the inter-atom hopping Δt and intra-atom interaction strength ΔU on the degradation of the antiferromagnetic structure factor $S(\pi, \pi)$ for an 8×8 cluster at a temperature $T = t/12$.

Several collaborative projects demonstrate cross-disciplinary engagement and synergy: *Silver*, *Khatami*, *Owen*, *Randall*, *Kirk*, *Scalettar*: The CM experimental and theory teams have completed initial studies of energy level structures and the effect of disorder on transport in small nanomaterial arrays. To gain a better understanding of the energetics of a single doped site in Si with more than one dopant as the currently feasible building block for arrays of dopants, *Silver*'s groups have designed a few-atom transistor by attaching leads to and gating a doped site and have performed transport measurements. The results from Coulomb diamonds (see Fig. 9) and current traces are being analyzed by *Khatami* and *Scalettar* using

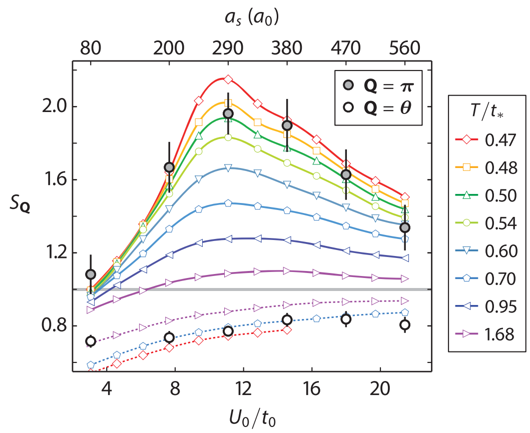

Figure 11: From Ref. [65]. Measured structure factor at the AF wave vector $S_{\vec{\pi}}$ (filled circles) and an incommensurate wave vector $S_{\vec{\theta}}$ (open circles) for various U_0/t_0 measured at the center of a three-dimensional trap. The values of the *s*-wave scattering length corresponding to U_0/t_0 are shown (top axis). QMC/NLCE calculations of $S_{\vec{\pi}}$ (open symbols, lines as guide to the eye) and $S_{\vec{\theta}}$ (open symbols, dashed lines as guide to the eye) for various T/t_0. The agreement validates a Hubbard model description of the AMO experiments, and provides an estimate of the temperature of the atomic cloud.

exact diagonalization of small Hubbard systems to estimate the number and whereabouts of the few dopants on the site. Ab initio calculations, in *Yang*'s group provide an efficient starting point for the Hubbard parameters explored in the quantum simulations.

The group has also investigated how randomness affects the fundamental many-body physics of larger arrays. Fig. 10 shows the evolution of the AF structure factor in an 8×8 array as the strength of disorder in the hopping amplitude or the interaction strength increases.

Numerous collaborations exist between team members. In particular, the AMO portion of the team has a strong regional connection in the Pacific Northwest: *Zhang* was previously at Washington State University (WSU), and *Forbes* maintains an affiliate appointment at the University of Washington (UW), interacting with *Gupta* and the nuclear theory community. Some examples of team synergy through collaborations are:

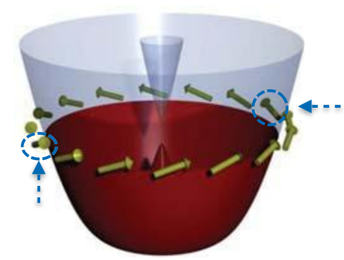

Figure 12: Illustration of the realization of chiral p-wave pairing from *s*-wave superfluid/superconductor using spin-orbit coupling and Zeeman field. The figure shows the band dispersion and spin orientation on the Fermi surface, where two spins with opposite momenta (circled in the figure) could have spin-triplet pairing through conventional *s*-wave interaction.

- *Engels*, *Zhang*: Joint theory and experiment work has explored the realization of Josephson effects in momentum space and their application to quantum circuits [34].
- *Forbes*, *Engels*: The dynamics of AMO systems with engineered dispersion relations has been examined in experiment and accompanying Gross-Pitaevskii simulations [142].
- *Forbes*, *Gupta*: Experiments for detecting superfluid entrainment using superfluid mixtures.
- *Khatami* and *Silver* have undertaken comparisons between theory calculations of transport and measurements on dopant arrays. These are at present within the context of model Hamiltonians. Combining these promising initial comparisons with the DFT, quantum chemistry and 'ab-initio' DMRG methods of *Yang* and *White* will enable the introduction of more realistic materials effects. *White* has already applied such approaches successfully to hydrogen chain systems. An interesting aspect of these investigations will be the promise of engineered nanostructures as a 'bridge' between the full complexity of a 'real material' and the oversimplifications of models.
- The theory PIs have been actively involved in modeling cold atom experiments with quantum simulations, including examining AF order (See Fig. 11) and more recently, charge and spin correlations and dynamics [51, 63–67]. Currently, they are exploring the possibility of observing non-Fermi liquid physics through a combination of AMO experimental and QMC/NLCE simulational data.

- The theory team also has considerable expertise [57, 58, 61, 62, 143] in novel superconducting phases of the sort accessible to our AMO experiments and ultimately to their CM counterparts. A recent example is our proposal to create a $p_x + ip_y$ superfluid directly from an s-wave superfluid utilizing spin-orbit coupling and Zeeman field (Fig. 12). The same idea was later applied to solid state s-wave superconductor/semiconductor heterostructures, now a major platform for exploring Majorana fermions in experiments.

I. Milestones and Evaluation Mechanism

¶ **Focus Research Area 1:** ***Synthesis, characterization, and modeling of 2×2 clusters.***
- Achievement of 2×2 and 1-d dopant arrays in Si with improved single dopant resolution and local gating/contacts. Theory modeling of disorder to guide these processes.
- Benchmarking with small AMO synthetic structures using momentum space manipulation.
- Development of new probes (scanning probe microscopy, scanning capacitance, spectroscopy).
- Intercomparison of 2×2 CM and AMO plaquette properties.
- QMC, exact diagonalization, and DMRG calculations of 2×2 properties; hopping, on-site potentials, orbital structure obtained by quantum chemistry and DFT studies.

¶ **Focus Research Area 2:** ***High fidelity qubit initialization; optical tweezers.***
- Preparation of single atoms in optical tweezers at lower temperatures and with reduced noise.
- Experimental studies and theory modeling of supersymmetric states with auxiliary tweezers.
- Construction of larger 4×4 lattices; comparison with quantum simulations.
- Development of adiabatic merging techniques to achieve low entropy atomic states, facilitating comparisons with targeted low temperatures of silicon dopant emulators.

¶ **Focus Research Area 3:** ***Novel superfluid and superconducting phases.***
- Synthesis of larger (5×5, 10×10) square lattice arrays. Quantum simulation of Fermi-Hubbard physics at low temperature, in combination with many-body theory calculations.
- Extension of 2×2 engineered silicon and cold atom plaquettes to arrays.
- Intercomparison of many body theory calculations of exotic magnetic and pairing states and their manifestation in both equilibrium and dynamic phenomena.

¶ **Focus Research Area 4:** ***Emergence of topological states with system size.***
- Demonstration of SSH topological edge states in synthetic momentum space lattices and comparison with extension of Langevin-based QMC codes to the SSH Hamiltonian.
- Theory-experiment studies of supersolid states in honeycomb nanoribbon geometries.

¶ **Focus Research Area 5:** ***Quantum simulation of novel geometries and disorder.***
- Synthesis of honeycomb, triangular, and Kagome dopant array geometries. Comparison with theoretical calculations of Dirac fermion and frustrated magnetism physics.
- Intercomparison of clean and disordered dopant arrays with theoretical calculations; systematic calculation of effects of randomness on transport, thermodynamic and SC properties.
- Investigation of higher order spin states in artificial spin-momentum lattices and computational techniques to understand possible spin-tensor generalization of spintronics.

¶ **Focus Research Area 6:** ***Dynamics of quantum States.***
- Comparison of dynamics of synthetic spin-momentum lattices with many-body calculations.
- Investigation of synthetic Hall tubes, topological states, and synthetic gauge fields.
- Extension of understanding of many-body localization using exact diagonalization and DMRG methodologies. Applications to artificial spin-momentum lattices.

Evaluation mechanisms include the standard criteria in the field- publication in high visibility refereed journals, invited talks at conferences, and successful placement of graduate students and postdoctoral scholars. An External Advisory Committee will provide short- and long-term feedback concerning our progress. Consultation with other QLEAP Institutes will provide further evaluation of our direction. Finally, our team and topical meetings provide opportunities for direct and immediate assessment of progress.

J. Prior NSF Support and Key Team Activities

The most central activity taken in preparation for this Challenge Institute submission was a two day Quantum Metamaterials Workshop organized by *Owen* and *Kirk* at NIST last year [115], focusing on the comparative strengths and weaknesses of CM and AMO approaches to strongly correlated quantum many-body systems, and the roads to developing effective synergy. Besides the organizers, a number of this team's PIs attended, including *Lyding*, *Silver*, *Khatami*, *Scalettar*, and *Randall*. The PIs recent NSF grants also lay the groundwork for this proposal:

- *Engels: NSF-PHY-1607495* (NSF-PHY-1607495) $586 630, 9/1/2016 to 8/31/2019. "Quantum phases and dynamics of Bose-Einstein condensates with artificial gauge fields"
- *Forbes: NSF-PHY-1707691* (NSF-PHY-1707691) $376 013, 9/1/2017 to 8/31/2020. "Quantum Dynamics with Cold Atoms"
- *Khatami: NSF-DMR-1609560* (NSF-DMR-1609560) $171 000, 3 years starting December 1, 2016. "RUI: Disorder in Strongly-Correlated Electrons on a Lattice" Explored disordered quantum lattice models in the thermodynamic limit at finite temperatures by implementing a new idea for the error-free treatment of randomness within numerical linked-cluster expansions.
- *Khatami: NSF-DMR-1918572* (NSF-DMR-1918572) $235 829, 3 years starting December 1, 2019. "RUI: Exact Dynamical Properties of Strongly Correlated Materials at Finite Temperatures"
- *Khatami: NSF-OAC-1626645 (co-PI)* (NSF-OAC-1626645 (co-PI)) $900 798, 3 years starting 8/1/2016.. "MRI: Acquisition of hybrid CPU/graphics processing unit (GPU) high-performance computing and storage for STEM research and education at San Jose State University"
- *Kirk: NSF-1563233)* (NSF-1563233)) $200 000, 3 years ending 8/31/2020.. "GOALI: Nanomanufacturing of acceptor dopants for atomically precise 2D bipolar devices"
- *Kirk: NSF-1747578)* (NSF-1747578)) $16 032, 1 year ending 8/31/2018.. "2D Designed Quantum Materials Workshop" [115]
- *Kuljanishvilli: NSF-DMR-1338021* (NSF-DMR-1338021) $157 094, 9/15/2014 to 9/15/2016. "MRI: Acquisition of Raman Spectrometer System for Research and Associated Educational Programs"
- *White: NSF-PHY-1812558* (NSF-PHY-1812558) $518 338, 9/01/2018 to 8/31/2021. "Strong Correlation DMRG and DFT"
- *Zhang: NSF-PHY-1806227* (NSF-PHY-1806227) $240 000, 8/01/2018 to 7/31/2021. "Spin Tensors in Ultracold Atomic Gases"
- *Zhang: NSF-PHY-1505496* (NSF-PHY-1505496) $240 000, 8/01/2015 to 7/31/2019. "Spin-orbital angular momentum coupled ultra-cold atomic gases"
- *Zhang: NSF-PHY-1104546* (NSF-PHY-1104546) $150 000, 8/16/2011 to 7/31/2015. "Collaborative Research: Topological States and Quantum Information in Semiconductors and Cold Atom Superfluids"

As described in the body of the proposal and references, significant collaborative research projects between team members are already underway: these form part of the foundation of this proposal.

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[142] M. A. Khamehchi, Khalid Hossain, M. E. Mossman, Yongping Zhang, Thomas Busch, Michael McNeil Forbes, and Peter Engels. "Negative mass hydrodynamics in a spin-orbit–coupled Bose-Einstein condensate". In: *Phys. Rev. Lett.* 118.15 (2017), p. 155301.

[143] Rajiv R. P. Singh and Richard T. Scalettar. "Exact demonstration of η pairing in the ground state of an attractive-U Hubbard model". In: *Phys. Rev. Lett.* 66 (24 1991), pp. 3203–3204.

BIOGRAPHICAL SKETCH
Richard T. Scalettar

Professional Preparation

- B.S. *summa cum laude* in Physics, UCI (1982)
- Ph.D. in Physics, UCSB (1986); advisors: Profs. D.J. Scalapino and R.L. Sugar
- Postdoctoral Fellow, Chemistry, UIUC (1987 – 1989)

Employment

- Distinguished Professor of Physics, UC Davis (since 2017)
- Vice Chairman, Physics Dept., UC Davis (2009 – 2011)
- Professor of Physics, UC Davis (1997 – 2017)
- Associate Professor of Physics, UC Davis (1993 – 1997)
- Assistant Professor of Physics, UC Davis (1989 – 1993)
- Vice Chairman, Physics Dept., UC Davis (1998 – 2003)

Visiting Positions

- Institut Non-Linéaire de Nice (2017)
- Universite Federale do Rio de Janeiro (2014 – 2017)
- University of Nice (1998, 2003)
- Argonne National Laboratory (1995)
- Lawrence Livermore National Laboratory (1989 – 1991)

Products

- Publications closely related to this project:

  [1] Y.X. Zhang, W.T. Chiu, N.C. Costa, G.G. Batrouni, and **R.T. Scalettar**, *Charge Order in the Holstein Model on a Honeycomb Lattice*, Phys. Rev. Lett. **122**, 077602 (2019).

  [2] N.C. Costa, T. Blommel, W.-T. Chiu, G.G. Batrouni, and **R.T. Scalettar**, *Phonon dispersion and the competition between pairing and charge order*, Phys. Rev. Lett. **120**, 187003 (2018).

  [3] T. Ma, L. Zhang, C-C. Chang, H-H. Hung, and **R.T. Scalettar**, *Localization of Interacting Dirac Fermions,* Phys. Rev. Lett. **120**, 116601 (2018).

  [4] R.A. Hart, P.M. Duarte, T. Yang, X. Liu, T. Paiva, E. Khatami, **R.T. Scalettar**, N. Trivedi, D.A. Huse and R.G. Hulet, "*Observation of antiferromagnetic correlations in the Hubbard model with ultracold atoms*", Nature **519**, 211 (2015).

  [5] T. Paiva, E. Khatami, S. Yang, V. Rousseau, M. Jarrell, J. Moreno, R.G. Hulet, and **R.T. Scalettar**, "*Cooling Atomic Gases With Disorder*", Phys. Rev. Lett. 115, 240402 (2015).

- Other significant work:

  [1] W.-T. Chiu, D.R. Mortensen, M.J. Lipp, C.J. Jia, B. Moritz, T.P. Devereaux, G.T. Seidler, and **R.T. Scalettar**, *Pressure Effects on the 4f Electronic Structure of Light Lanthanides,* Phys. Rev. Lett. **122**, 066401 (2019).

  [2] N.C. Costa, T. Blommel. W.T. Chiu, G.G. Batrouni, and **R.T. Scalettar**, *Phonon dispersion and the competition between pairing and charge order*, Phys. Rev. Lett. **120**, 187003 (2018).

  [3] *Pairing symmetry of interacting fermions on twisted bilayer graphene superlattice*, Huaiming Guo, Xingchuan Zhu, Shiping Feng, and **Richard T. Scalettar**, Phys. Rev. **B97**, 235453 (2018).

  [4] N.C. Costa, M.V.M. Araújo, J.P. Lima, T. Paiva, R.R. dos Santos, and **R.T. Scalettar**, *Compressible Ferrimagnetism in the depleted Periodic Anderson Model*, Phys. Rev. **B97**, 085123 (2018).

  [4] P.M. Duarte, R.A. Hart, T-L. Yang, X. Liu, T. Paiva, E. Khatami, **R.T. Scalettar**, N. Trivedi, and R.G. Hulet, "*Compressibility of a fermionic Mott insulator of ultracold atoms*", Phys. Rev. Lett. 114, 070403 (2015).

Synergistic Activities:

- CMSN and INCITE Allocation Committees, 2013–present.
- Chairman, Division of Computational Physics, American Physical Society, 2010.
- Editorial Board- Physical Review B, 2008-2012.
- Project Coordinator- Computational Materials Science Network, Computational Research Team: "Predictive Capability for Strongly Correlated Electron Materials", 2003–2010.
- Chair- UCD Minority Undergraduate Research Program, 2000–present; and Lead Instructor- COSMOS Summer High School Science Program, 2001–present.

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(a) Professional Preparation

UBC	Vancouver, Canada	Computer Science and Physics	B.Sc. 1999
UBC	Vancouver, Canada	Physics	M.Sc. 2001
MIT	Cambridge, MA	Physics	Ph.D. 2005
UW	Seattle, WA	Nuclear Theory Group	2005–2008
LANL	Los Alamos, NM	Theory Division	2008–2010
UW	Seattle, WA	Institute for Nuclear Theory	2010–2013

(b) Appointments

2014–now: Assistant Professor, Department of Physics and Astronomy, Washington State University.

2014–now: Affiliate Assistant Professor, Department of Physics, University of Washington.

2010–2013: Research Assistant Professor, Institute for Nuclear Theory, University of Washington.

2008–2010: Director's funded Postdoctoral Fellowship, Los Alamos National Laboratory.

2005–2008: Postdoctoral fellow, Nuclear Theory Group, University of Washington.

1998: NSERC Summer Research Fellowship at the Canadian Institute of Theoretical Astrophysics (CITA) with John Dubinski. Numerical analysis of large-scale galaxy formation simulations.

(c) Publications

(i) Most Related to Grant

1. M. A. Khamehchi, K. Hossain, M. E. Mossman, Y. Zhang, Th. Busch, M. M. Forbes, and P. Engels: *Negative mass hydrodynamics in a spin-orbit–coupled Bose-Einstein condensate.* Phys. Rev. Lett. 118 (2017) 155301
2. A. Bulgac, G. Wlazłowski, and M. M. Forbes: *Towards Quantum Turbulence in Cold Atomic Fermionic Superfluids.* J. Phys. B 50 (2017) 014001
3. G.Wlazłowski, K. Sekizawa, P. Magierski, A. Bulgac, and M. M. Forbes: *Vortex pinning and dynamics in the neutron star crust.* Phys. Rev. Lett. 117 (2016) 232701
4. A. Bulgac, and M. M. Forbes: *A Unitary Fermi Supersolid: The Larkin-Ovchinnikov Phase.* Phys. Rev. Lett. 101 (2008) 215301
5. A. Bulgac, M. M. Forbes, M. M. Kelley, K. J. Roche, and G. Wlazłowski: *Quantized Superfluid Vortex Rings in the Unitary Fermi Gas.* Phys. Rev. Lett. 112 (2014) 025301

(ii) Other Significant Publications

1. M. M. Forbes, S. Bose, S. Reddy, D. Zhou, A. Mukherjee, and S. De: *Constraining the neutron-matter equation of state with gravitational waves* arXiv:1904.04233 (2019). (Submitted to PRD.)
2. A. Bulgac, M. M. Forbes, and R. Sharma: *Strength of the Vortex-Pinning Interaction from Real-Time Dynamics.* Phys. Rev. Lett. 110 (2013) 241102
3. A. Bulgac, M. M. Forbes, S. Jin, Shi, R. N. Perez, and N. Schunck: *Minimal nuclear energy density functional* Phys. Rev. C. 97 (2018) 044313

4. M. M. Forbes, S. Gandolfi, and A. Gezerlis: *Resonantly Interacting Fermions In a Box.* Phys. Rev. Lett. 106 (2011) 235303
5. M. M. Forbes, E. Gubankova, W. V. Liu, and F. Wilczek, *Stability Criteria for Breached Pair Superfluidity*, Phys. Rev. Lett. **94** 017001 (2005)

(d) Synergistic Activities

- 2019: Principal organizer of the 5-week spring INT program: *Quantum Turbulence: Cold Atoms, Heavy Ions, and Neutron Stars*, bringing the ultracold atom and superfluid helium communities together with nuclear theory to use quantum simulation to advance nuclear astrophysics problems related to quantum turbulence.
- 2011: Principal organizer of the 4-month spring INT program: *From Cold-Atoms to Neutron Stars: Benchmarking the Fermion Many-Body Problem.*
- Training in Advanced Low Energy Nuclear Theory (TALENT) through seminars at various summer schools including the 2015 INT course on "Nuclear Physics of Neutron Stars and Supernovae" and the 2020 LBNL course on "Density Functional Theory and Self-Consistent Methods".
- Summer-2013: Supervised Michelle Kelley funded under the NSF REU program resulting in a high-profile PRL publication and "Outstanding Poster Presentation".

Subhadeep Gupta
Biographical Sketch

(a) Professional Preparation

Colgate University	Hamilton, NY	Physics	BA 1997
Massachusetts Institute of Technology	Cambridge, MA	Physics	Ph.D. 2003
University of California, Berkeley	Berkeley, CA	Physics	Postdoc 2003-2007

(b) Appointments

Professor of Physics University of Washington, Seattle	Sep 2018-present
Associate Professor of Physics University of Washington, Seattle	2013-2018
Assistant Professor of Physics University of Washington, Seattle	2007-2013
Miller Institute Postdoctoral Fellow University of California, Berkeley	2003-2006

Prizes, Fellowships and Awards

University of Washington Phys Dept Mentoring Award	2015
National Inst of Stds and Tech, PMG Award	2010-2013
National Science Foundation CAREER Award	2009-2014
Alfred P. Sloan Research Fellowship	2009-2011
University of Washington Royalty Research Fund Award	2008-09, 17-18
Miller Institute Postdoctoral Fellowship, UC Berkeley	2003-2006
Phi Beta Kappa	1996

(c) Publications

Most related to grant:

1. R. Roy, A. Green, R. Bowler, and S. Gupta, *Two-element mixture of Bose and Fermi superfluids,* Phys Rev Lett **118**, 055301 (2017).

2. B. Plotkin-Swing, D. Gochnauer, K. McAlpine, E. Cooper, A. Jamison, and S. Gupta, *Three-path Atom Interferometry with Large Momentum Separation,* Phys. Rev. Lett. **121**, 133201 (2018).

3. A.O. Jamison, B. Plotkin-Swing, and S. Gupta, *Advances in precision contrast interferometry with Yb Bose-Einstein condensates.* Phys Rev A **90**, 063606 (2014).

4. R. Roy, A. Green, R. Bowler, and S. Gupta, *Rapid cooling to quantum degeneracy in dynamically shaped atom traps,* Phys Rev A **93**, 043403 (2016).

5. A. Khramov, A. Hansen, W. Dowd, R. Roy, C. Makrides, A. Petrov, S. Kotochigova, and S. Gupta: *Ultracold heteronuclear mixture of ground and excited state atoms.* Phys. Rev. Lett. **112**, 033201 (2014).

Other significant publications:

1. S. Gupta, K.L. Moore, K.W. Murch, and D.M. Stamper-Kurn, *Cavity nonlinear optics at low photon numbers from collective atomic motion*, Phys. Rev. Lett. **99**, 213601 (2007).

2. A. Hansen, A. Khramov, W. Dowd, A. Jamison, V. Ivanov, and S. Gupta, *Quantum degenerate mixture of ytterbium and lithium atoms.* Phys. Rev. A. **84**, 011606R (2011).

3. K.W. Murch, K.L. Moore, S. Gupta, and D.M. Stamper-Kurn, *Observation of quantum-measurement backaction with an ultracold atomic gas*, Nature Phys. **4**, 561 (2008).

4. S. Gupta, K. Murch, K. Moore, T. Purdy, and D.M. Stamper-Kurn: *Bose-Einstein condensation in a circular waveguide.* Phys. Rev. Lett. **95**, 143201 (2005).

5. S. Gupta, Z. Hadzibabic, M.W. Zwierlein, C.A. Stan, K. Dieckmann, C.H. Schunck, E.G.M. van Kempen, B.J. Verhaar, and W. Ketterle: *Radio-Frequency Spectroscopy of Ultracold Fermions*. Science **300**, 1723 (2003).

(d) Synergistic Activities

- Director of the UW Physics NSF-REU program (since 2009)
- Organizing Committee Member of “Cold Atoms and Molecules” Section of the CLEO/IQEC conference (2013,15,17,19).
- Member of APS-DAMOP Program Committee (2017-19)
- Member of APS-DAMOP Executive Committee (2019-21)
- Member-at-Large of Executive Committee of APS Topical Group on Precision Measurement & Fundamental Constants (2016-18)

BIOGRAPHICAL SKETCH: WILEY P. KIRK

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PROFESSIONAL PREPARATION

Washington University, St. Louis		Physics	B. A.	1964
Stony Brook University (SUNY)		Physics	M. S.	1967
Stony Brook University (SUNY)		Physics	Ph.D.	1970
University of Florida	condensed matter	Physics	Postdoctoral	1970-1972

APPOINTMENTS

Research Professor of Materials Science and Engineering, University of Texas at Arlington, 2011-present
President & partner, 3D Epitaxial Technologies, LLC, Richardson, Texas, 2015-present
Visiting Professor of Materials Science and Engineering, University of Texas at Dallas, 2008-2011
Professor of Electrical Engineering, University of Texas at Arlington, 1999-2008
Director, Metroplex Research Consortium for Electronic Devices and Materials, 1998-2008
Director, Center for Nanostructure Materials and Quantum Device Fabrication, TEES, 1989-2002
Professor of Physics and Electrical Engineering, Texas A&M University, 1984-1999
Associate Professor of Physics, Texas A&M University, 1978-1983
Assistant Professor of Physics, Texas A&M University, 1975-1978
Director, Helium Liquefaction Facility, Texas A&M University, 1976-1997
Assistant Professor of Physics, University of Florida, 1973-1975
Visiting Scientist, Massachusetts Institute of Technology, summer 1973
Interim Assistant Professor of Physics, University of Florida, 1972-1973
Technical Collaborator, Brookhaven National Laboratories, 1969-1970
Instructor in Physics, State University of New York at Stony Brook, 1969-1970

FIVE PRODUCTS CLOSELY RELATED TO PROJECT

1. *2D Quantum Metamaterials*, W. P. Kirk, J. N. Randall, and J. H. G. Owen, Accepted for publication in International Journal of Modern Physics: Conference series (World Scientific, 2019).
2. *Si_2H_6 Dissociative Chemisorption and Dissociation on Si(100)-(2×1) and Ge(100)-(2×1),* J.-F. Veyan, H. Choi, M. Huang, R. C. Longo, J. B. Ballard, S. McDonnell, M. P. Nadesalingam, H. Dong, I. S. Chopra, J. H. G. Owen, W. P. Kirk, J. N. Randall, R. M. Wallace, K. Cho and Y. J. Chabal, The Journal of Physical Chemistry **C 115** (50), 24534-24548 (2011).
3. *High Rate Gas Dosing for Tip Based Nanofabrication Processes*, M. P. Kanouff, J. N. Randall, M. Nadesalingam, W. P. Kirk, and R. M. Wallace, J. Vac. Sci. Technol. **B 27**, 2769 (2009).
4. *Misfit Management for Reduced Dislocation Formation in Epitaxial Quantum-Dot-Based Devices,* Jateen S. Gandhi, Choong-Un Kim, and Wiley P. Kirk, J. Crystal Growth **364**, 169-177 (2013).
5. *Off-center Electron Transport in Resonant Tunneling Diodes Due to Incoherent Scattering*, Titus Sandu, Gerhard Klimeck, and W. P. Kirk, Phys. Rev. B. **68**, 115320 (2003).

FIVE OTHER SIGNIFICANT PRODUCTS

1. *First Principle Analyses of Direct Bandgap Solar Cells with Absorbing Substrates versus Mirrors,* Alexander P. Kirk and Wiley P. Kirk, J. Appl. Phys. **114**, 174507 (2013); http://dx.doi.org/10.1063/1.4829459.
2. *Epitaxial Growth of $Cd_{1-x}Se_xTe$ Thin Films on Si (100) by Molecular Beam Epitaxy Using Lattice Mismatch Graded Structures*, F. Z. Amir, K. Clark, E. Maldonado, W. P. Kirk, J. C. Jiang, J. W. Ager III, K. M. Yu and W. Walukiewicz, J. Crystal Growth **310**, 108 1–1087 (2008).
3. *Electronic and Optical Properties of Beryllium Chalcogenide/Silicon Heterostructures*, Titus Sandu and W. P. Kirk, Phys. Rev. B **73**, 235307 (2006).
4. *Nonparabolicity Effects in the Bipolar Quantum Well Resonant Tunneling Transistor*, K. P. Clark, W. P. Kirk, and A. C. Seabaugh, Phys. Rev. B **55**, 7068 (1997).
5. *Magnetic-Field-Induced Metal-Insulator Transition in Two Dimensions,* T. Wang, K. P. Clark, G. F. Spencer,

A. M. Mack, and W. P. Kirk, Phys. Rev. Lett. **72**, 709 (1994).

SYNERGISTIC ACTIVITIES

1. **Service to scientific community:**
    a. Co-organizer (with John Randall, Rick Silver, James Owen, Neil Zimmerman, Shashank Misra *et al.*) 2018 *2D Quantum Metamaterials Workshop* held April 25 – 26 at the National Institute of Standards and Technology.
    b. Edited four books:
        i. *2D Quantum Metamaterials*, International Journal of Modern Physics: Conference series (World Scientific, 2019) [Accepted for publication] eds. W. P. Kirk, J. N. Randall, and J. H. G. Owen;
        ii. *Nanostructures and Mesoscopic Systems*, Proceedings of International Symposium on Nanostructures and Mesoscopic Systems, Santa Fe, NM (Academic Press, New York, NY, 1992) eds. W. P. Kirk and M. A. Reed;
        iii. *Nanostructure Physics and Fabrication*, Proceedings of International Symposium on Nanostructure Physics and Fabrication, College Station, TX (Academic Press, New York, NY, 1989) eds. M. A. Reed and W. P. Kirk;
        iv. *Quantum Statistics and the Many-Body Problem*, Proceedings of Quantum Fluids and Solids Symposium, Sanibel Island, FL (Plenum Pub. Corp., New York, NY, 1975) eds. S. B. Trickey, W. P. Kirk, and J. W. Dufty.
    c. Serve on the Editorial Board of *Superlattices and Microstructures*, 1992 - present
2. **Technology development:**
    a. Patents on file —
        i. *Gate Adjusted Resonant Tunnel Diode Device and Method of Manufacture*, W. P. Kirk, M. H. Weichold, and W. B. Kinard, U.S. Patent Application, USSN: 07,491,558 (1990);
        ii. *Anode Plate for Flat Panel Display Having Silicon Getter*, R. M. Wallace, B. E. Gnade, and W. P. Kirk USSN: 05,614,785 (1997);
        iii. *Method of Forming Lattice Matched Layer Over a Surface of a Silicon Substrate*, Wiley P. Kirk, Joe. X. Zhou, Bruce Gnade, and Chih-Chen Cho, USSN: 6,419,742 (2002);
        iv. *Monatomic Layer Passivation of Semiconductor Surfaces,* Meng Tao and Wiley P. Kirk, U. S. patent US 6,784,114 B1, (2004).
3. **Enterprise development:**
    a. Founded 3D Epitaxial Technologies, LLC a research and development startup company in Richardson, TX.
4. **Teaching Innovations:**
    a. Over 35 years of continuous teaching experience with undergraduate and graduate level courses in four university systems. Fifteen students have earned Ph.D. degrees and 17 earned M. S. degrees under my guidance. Two students received the Distinguished Graduate Student Doctoral Research Award from the Texas A&M Association of Former Students, in which about 0.5% receive this honor each year.
    b. Developed three graduate level courses: (*i*) Nanostructure Systems and Quantum Electronic Devices, (*ii*) Scientific Instrument Making, and (*iii*) Silicon Integrated Circuit Fabrication Technology.
5. **Undergraduate research initiative:**
    a. Approximately fifty undergraduates have done special projects under my guidance; six were designated Honors Fellows in the University Honors Program.
    b. Each summer work with the UTA College of Engineering as a sponsor, mentor, and leader of either its Girlgeneering one-week long summer camp program and/or the Materials Science and Engineering Department’s ASM International Materials Science Summer Camp program.

Biographical Sketch for

Richard Martin Silver, Ph.D.
Adjunct Professor, Dept of Physics, University of Maryland, College Park
Physicist, National Institute of Standards and Technology, Gaithersburg MD

(a) Professional Preparation

University of California, Berkeley, CA	Physics	B.A., 1986
University of Texas, Austin, TX	Physics	Ph.D., 1992
National Inst. Standards and Technology	Surface Science	Postdoc 1992-1994

(b) Appointments

Adjunct Professor, University of Maryland, Dept of Physics, 2019
Special Faculty Appointment, University of Maryland, Chemical Physics Program 1997-
National Institute of Standards and Technology, Physicist, 1992-

(c) Products

(i) five most significant products closely related to proposal

1. Jonathan Wyrick, Xiqiao Wang, Pradeep Namboodiri, Scott W. Schmucker, Ranjit Kashid, and Richard M. Silver, "Atom-by-atom construction of a cyclic artificial molecule in Silicon", ACS NanoLetters, 18 (12) doi:10.1021/8b02919, 2018.
2. S. Schmucker, P.N. Namboodiri, R. Kashid, X. Wang, B. Hu, J.E. Wyrick, R.M. Silver, M.D. Stewart, Jr., "Palladium silicide contacts to subsurface delta-doped phosphorus devices", Physical Review Applied, 11, 034071, 2019.
3. X. Wang, J. Hagmann, P. Namboodiri, J. Wyrick, K. Li, R. Murray, A. Myer, F. Misenkosen, M.D. Stewart, C. Richter, and R. Silver, "Optimizing Dopant Confinement and Activation in Si:P Atomic Device Fabrication Using Locking Layers," Nanoscale **10**, 4488-4499, 2018.
4. J.A. Hagmann, X. Wang, P. Namboodiri, J. Wyrick, R. Murray, M.D. Stewart Jr., R.M. Silver, and C.A. Richter, "Weak localization thickness measurements of embedded phosphorus delta layers in silicon produced by PH_3 dosing," *Applied Physics Letters* 112, 043102 (2018).
5. "Atom by Atom Fabrication of Single and Few Dopant Quantum Devices," J. Wyrick, X. Wang, R. Kashid, P. Namboodiri, S. Schmucker, J. Hagmann, K. Liu, M. D. Stewart Jr., C. A. Richter, G. Bryant and R. M. Silver, accepted to Adv. Functional Matls Special Issue on Atom by Atom Fabrication, July 2019.

(ii) up to five other significant products.

6. "Atomic-scale Control of Tunnel Coupling," Xiqiao Wang, Jonathan Wyrick, Ranjit V. Kashid, Pradeep Namboodiri, Scott W. Schmucker, Andrew Murphy, M. D. Stewart, Jr., Neil Zimmerman, and Richard M. Silver, arXiv **2019** 1905.00132v2.

7. A. N. Ramanayaka, H.-S. Kim, K. Tang, X. Wang, R.M. Silver, M.D. Stewart, Jr., and J.M. Pomeroy, “STM patterned nanowire measurements using photolithographically defined implants in Si(100),” Scientific Reports 8, 1790 (2018).
8. Deng, X., Namboodiri, P., Li, K., Wang, X., Stan, G., Myers, A. F., Cheng, X., Li, T., & Silver, R. M. (2016). “Silicon epitaxy on H-terminated Si (100) surfaces at 250° C”, Applied Surface Science 378 301-307 (2016).
9. Wang, X.; Namboodiri, P.; Li, K.; Deng, X.; Silver, and R. “Spatially Resolved Scanning Tunneling Spectroscopy of Single-Layer Steps on Si(100) Surfaces,” Phys. Rev. B, (2016), 94.
10. J. Qin, R. M. Silver, B. M. Barnes, H. Zhou, R. G. Dixson and M. A. Henn, "Deep subwavelength nanometric image reconstruction using Fourier domain optical normalization," Light-Sci. Appl. 5, e16038 9 (2016).

(d) Synergistic Activities

1) Technical leader of a broad program to develop atomically precise device fabrication and metrology to enable atom-based Si electronic structures and quantum-based devices that rely on single or few atoms, precisely placed within an epitaxial silicon environment. Hydrogen-based scanning probe lithography is used to enable deterministic placement of individual dopant atoms. The focus is on fabrication, design, and low temperature measurements for solid state quantum computing and quantum metamaterials.

2) Current and past advisor to six PhD theses and two Masters theses for graduate students at the University of Maryland, Physics Dept. and Chemical Physics Program and George Washington University, Mechanical Engineering Department. Recent theses focused on “Developing Atomically Precise Fabrication and Measurement Methods for Single Atom Devices for use in Quantum Information Processing” and “Nanofabrication on Engineered Silicon (100) Surfaces using Scanning Probe Microscopy.”

3) Co-chair of a recent international workshop on 2D Quantum Metamaterials, 2018. Co-organizer and host for a workshop focused on exploring fabrication, theoretical prediction, and alternative approaches to realizing designed quantum materials and to explore atomically precise fabrication of solid state Hubbard model systems.

4) Co-chair: Modeling Aspects in Optical Metrology Conf., SPIE Europe, Co-chair: Nanotechnology in Microlithography Technical Group, SPIE, and Associate Editor, Journal of Micro/Nanolithography, MEMS, and MOEMS.

Biographical Sketch
Peter Engels

Department of Physics and Astronomy, Washington State University,
Pullman, WA 99164-2814
Phone: (509) 335-4674, Fax: (509) 335-7816, Email: engels@wsu.edu
https://labs.wsu.edu/engels/

(a) Professional Preparation

University of Bonn, Germany, Physics, "Vordiplom" (B.S. equivalent), 1993
University of Bonn, Germany, Physics, "Diplom" (M.S. equivalent), 1996
University of Hannover, Germany, Physics, Ph.D., 2000
JILA / University of Colorado, Postdoctoral Research, 2001 – 2004

(b) Appointments

Professor, Washington State University, Pullman, 8/2015 - present
Associate Professor, Washington State University, Pullman 8/2009 – 8/2015
Assistant Professor, Washington State University, Pullman, 8/2004 – 8/2009
Postdoctoral Fellow, JILA, University of Colorado, Boulder, 2/2001 – 8/2004
Graduate Research Assistant, Institute for Quantum Optics, University of Hannover, Germany, 10/1997 – 1/2001
Visiting Graduate Research Assistant, Chemistry Department, Princeton University, 10/1996 – 8/1997

(c) Publications

(i) 5 Publications most closely related to the proposed project

1. Thomas M. Bersano, Junpeng Hou, Sean Mossman, Vandna Gokhroo, Xi-Wang Luo, Kuei Sun, Chuanwei Zhang & Peter Engels, "Experimental realization of a superfluid stripe phase in a spin-orbit-coupled Bose-Einstein condensate enabled by momentum-space hopping", Phys. Rev. A **99**, 051692 (2019).

2. Junpeng Hou, Xi-Wang Luo, Kuei Sun, Thomas Bersano, Vandna Gokhroo, Sean Mossman, Peter Engels & Chuanwei Zhang, "Momentum Space Josephson Effects," Phys. Rev. Lett. **120**, 120401 (2018)

3. M. A. Khamehchi, Khalid Hossain, M. E. Mossman, Yongping Zhang, Th. Busch, Michael McNeil Forbes, and P. Engels, "Negative mass hydrodynamics in spin-orbit-coupled Bose-Einstein condensates", Physical Review Letters **118**, 155301 (2017)

4. M. A. Khamehchi, Chunlei Qu, M. E. Mossman, Chuanwei Zhang, & Peter Engels, "Spin-momentum coupled Bose-Einstein condensates with lattice band pseudospins", Nature Communications **7**: 10867 (2016)

5. C. Hamner, Yongping Zhang, M. A. Khamehchi, Matthew J. Davis, P. Engels, "Spin-orbit coupled Bose-Einstein condensates in a one-dimensional optical lattice", Phys. Rev. Lett. **114**, 070401 (2015)

(ii) 5 other significant publications

1. M. E. Mossman, M. A. Hoefer, K. Julien, P. G. Kevrekidis, & P. Engels, "Turbulence-induced viscous dissipation in a quantum mechanical piston shock," Nature Communications 2018, doi: 10.1038/s41467-018-07147-4

2. T. M. Bersano, V. Gokhroo, M. A. Khamehchi, J. D'Ambroise, D. J. Frantzeskakis, P. Engels, & P. G. Kevrekidis, "Three-component soliton states in spinor F=1 Bose-Einstein condensates", Phys. Rev. Lett. **120**, 063202 (2017)

3. I. Danaila, M.A. Khamehchi, V. Gokhroo, P. Engels, P.G. Kevrekidis, "Vector Dark-Antidark Solitary Waves in Multi-Component Bose-Einstein condensates", Physics Review A **94**, 053617 (2016)

4. M. A. Khamehchi, Yongping Zhang, Chris Hamner, Thomas Busch, and Peter Engels, "Measurement of collective excitations in a spin-orbit-coupled Bose-Einstein condensate", Phys. Rev. A **90**, 063624 (2014)

5. Chris Hamner, Chunlei Qu, Yongping Zhang, JiaJia Chang, Ming Gong, Chuanwei Zhang, Peter Engels, "Dicke-type phase transition in a spin-orbit coupled Bose-Einstein condensate", Nature Communications **5**, 4023 (2014)

(d) Synergistic Activities

1. Development of new experiments and course materials for Phys 415 (advanced quantum lab for senior level undergraduate students), and new curriculum for Phys 561 (graduate level AMO)

2. Co-organizer of AMO journal club at WSU and of the WSU physics colloquium

3. Further current and past department services include: search committee member, prelim exam committee member, graduate student advisor for all first and second year graduate students, tenure and promotion guidelines committee, chair's advisory committee member, member of Technical Services Advisory committee

4. Spearheading the high school outreach program for WSU Physics and Astronomy

5. Member of NW APS Nominating Committee

Ehsan Khatami

(a) Professional Preparation

Isfahan University of Technology	Isfahan, Iran	Bachelor's in Physics	2001
Sharif University of Technology	Tehran, Iran	Master's in Physics	2004
University of Cincinnati	Cincinnati, Ohio	Ph.D. in Physics	2009
Georgetown University	Washington, DC	Cond. Mat. Physics	2009-2013
University of California	Santa Cruz, CA	Cond. Mat. Physics	2012-2013
University of California	Davis, CA	Cond. Mat. Physics	2013-2014

(b) Appointments

2014-present Dept. of Physics Astronomy, San Jose State University Assistant Professor

(c)(i) Five Publications Relevant to This Proposal

"Machine learning in electronic quantum Matter imaging experiments",
Yi Zhang, A. Mesaros, K. Fujita, S. D. Edkins, M. H. Hamidian, K. Ch'ng, H. Eisaki, S. Uchida, J. C. Samus Davis, E. Khatami, and Eun-Ah Kim,
Nature 570, 484-490 (2019)
URL: https://www.nature.com/articles/s41586-019-1319-8

"Spin transport in a Mott insulator of ultracold fermions",
M. A. Nichols, L. W. Cheuk, M. Okan, T. R. Hartke, E. Mendez, T. Senthil, E. Khatami, H. Zhang, and M. W. Zwierlein,
Science 363, 383 (2019)
URL: http://science.sciencemag.org/content/early/2018/12/06/science.aat4387

"Spin imbalance in a 2D Fermi-Hubbard system",
P. T. Brown, D. Mitra, E. Guardado-Sanchez, P. Schaub, S. S. Kondov, E. Khatami, T. Paiva, N. Trivedi, D. A. Huse, and W. S. Bakr,
Science 357, 1385 (2017),
URL: http://science.sciencemag.org/content/357/6358/1385

"Observation of antiferromagnetic correlations in the Hubbard model with ultracold atoms",
R. A. Hart, P. M. Duarte, T.-L. Yang, X. Liu, T. Paiva, E. Khatami, R. T. Scalettar, N. Trivedi, D. A. Huse, and R. G. Hulet,
Nature 519, 211-214 (2015),
URL: http://dx.doi.org/10.1038/nature14223

"Machine learning phases of strongly correlated fermions",
K. Ch'ng, J. Carrasquilla, R. G. Melko, and E. Khatami
Phys. Rev. X 7, 031038 (2017),
URL: http://dx.doi.org/10.1103/PhysRevX.7.031038

(c)(ii) Five Other Significant Publications

"Observation of spatial charge and spin correlations in the 2D Fermi-Hubbard model",
L. W. Cheuk, M. A. Nichols, K. R. Lawrence, M. Okan, H. Zhang, E. Khatami, N. Trivedi, T.

Paiva, M. Rigol, and M. W. Zwierlein,
Science 353, 1260-1264 (2016),
URL: http://science.sciencemag.org/content/353/6305/1260

"Numerical linked-cluster expansions for disordered lattice models",
M. Mulanix, D. Almada, and E. Khatami,
Phys. Rev. B 99, 205113 (2019),
URL: https://journals.aps.org/prb/abstract/10.1103/PhysRevB.99.205113

"Lanczos boosted numerical linked-cluster expansion for quantum lattice models",
K. Bhattaram and E. Khatami,
Phys. Rev. E 100, 013305 (2019),
URL: https://journals.aps.org/pre/abstract/10.1103/PhysRevE.100.013305

"Unsupervised machine learning account of magnetic transitions in the Hubbard model"
K. Ch'ng, N. Vazquez, E. Khatami
Phys. Rev. E 97, 013306 (2018),
URL: http://dx.doi.org/10.1103/PhysRevE.97.013306

"Quantum quenches in disordered systems: Approach to thermal equilibrium without a typical relaxation time",
E. Khatami, M. Rigol, A. Relaño, Antonio M García-García
Phys. Rev. E 85, 050102 (2015),
URL: https://journals.aps.org/pre/abstract/10.1103/PhysRevE.85.050102

(d) Synergistic Activities

- Serving as a member of program committees for the American Physical Society's Division of Computational Physics (DCOMP) and Division of Atomic, Molecular, and Optical Physics's (DAMOP) "Cold Gases" subcommittee.
- Served as a grant and journal reviewer since 2012, including for the National Science Foundation's CMMT program, Department of Energy's Office of Science, and Physical Review, Science and other journals.
- Sorted over 60 abstracts and organized five focus sessions on "Machine Learning in Condensed Matter Physics" sponsored by the Division of Computational Physics for the March Meeting 2018 in Los Angeles, CA.
- Contributed to the "Are machines better at quantum physics than humans?" episode of Public Broadcasting Service (PBS) Digital Studios Webseries *Physics Girl* with over 127,000 views on Youtube,
- Incorporated special topics relevant to my research program, such as basics of low-level and parallel programming, high-performance computing, Monte Carlo simulations, and machine learning techniques in the department's upper-division computational physics course,

Biographical Sketch
Irma Kuljanishvili, PhD
Email: irma.kuljanishvili@slu.edu Phone: (314)-977-8699

a) Professional Preparation

Tbilisi State University, Tbilisi, Georgia	Physics	BS/MS 1991/1994
Michigan State University, MI, USA	Physics	M.S. 2000
Michigan State University, MI, USA	Physics	Ph.D. 2005
Harvard University, MA, USA	Physics	Postdoc 2005-2006
Northwestern University, IL, USA	Physics	Postdoc 2006-2011

b) Appointments

Saint Louis University Department of Physics	Associate Professor of Physics	2019- Present
Saint Louis University Department of Physics	Assistant Professor of Physics	2011- 2018
Michigan State University Department of Physics	Graduate Research Assistant	2000-2005
Michigan State University Department/s of Physics and Chemistry	Graduate Teaching Assistant	1997-1999
Institute of Meteorology and Atmospheric Sciences Tbilisi, Georgia	Technical Research Consultant	1994-1996
Tbilisi State University Quantum Electronic Laboratory Tbilisi, Georgia	Research Assistant	1992-1993

c) Publications

Most relevant publications

I. Kuljanishvili, C. Kayis, S. H. Tessmer, C. Piermarocchi, T. Kaplan, L.N. Pfeiffer, K.W. West , "*Scanning probe spectroscopy of semiconductor donor molecules",* Nature Physics, 4, 227-233, 2008, also see Nature Physics News & Views article by M.Y. Simmons: *"Probing dopants at atomic level*, 4,165-166, 2008

I. Kuljanishvili, S. Chakraborty, I. J. Maasilta, S. H. Tessmer, and M. R. Melloch, "*Modeling electric field sensitive scanning probe measurements for a tip of arbitrary shape*, Ultramicroscopy". 102-1, 7-12, 2004.

*S. H. Tessmer, **I. Kuljanishvili,** Modeling single- and multiple-electron resonances for electric-field-sensitive scanning probe, Nanotechnology, 445503, (2008)

R. Dong, L. Moore, N. Aripova, C. Williamson, R. Schurz, Y. Liu, L. E. Ocola, and ***I. Kuljanishvili**, "*Bottom-up Approach to a Mask Free Selective Growth of WS_2/MoS_2 Heterostructure Systems*," RSC Advances, 2016, 6, 66589–6659

D. Alameri, J. Nasr, D. Karbach, Y. Liu, R. Divan, *S. Das and ***I. Kuljanishvili** *"Mask-free patterning and selective CVD-growth of 2D-TMDCs semiconductors"*, Semiconductor Science and Technology, Vol 34, 8, 2019, https://doi.org/10.1088/1361-6641/ab28db

Other significant products

U.S. Patent Application Serial No. 15/816,574, Filed: Nov 17, 2017, Entitled: Mask Free Methods Of Depositing Compositions To Form Heterostructures, SLU Ref.: 16-018, Other Ref.: USTL.P0081US.P1, (Inventors: ***I. Kuljanishvili**, R. Dong, L. Moore)

R. Dong, L. Moore, Leonidas E. Ocola and ***I. Kuljanishvili**, "*Enabling Quality Interfaces with Mask Free Approach to Selective Growth of MoS2/Graphene Stacked Structures,*" Advanced Materials Interfaces, 2016, DOI:10.1002/admi.201600098

D. Alameri, L. Ocola and ***I. Kuljanishvili**, "Mask-free fabrication and chemical vapor deposition synthesis of ultra-thin zinc oxide microribbons on Si/SiO_2 and 2D substrates" J. Vac. Sci. Technol. A, Vol. 35, Issue 5, (DOI: 10.1116/1.5036533), (published online, July 26, 2018) (also selected as *Editor's Pick*, featured article.

D. Alameri, L. E. Ocola and ***I. Kuljanishvili**, "Controlled selective CVD growth of ZnO Nanowires enabled by mask-free fabrications approach using aqueous iron catalytic inks", Adv. Mater. Interfaces., 4, 1700950 (2017). (Featured on the Cover of the special CVD section, of December Issue, 2017)

***I. Kuljanishvili,** D. Dikin, S. Rozhok, S. Mayle, V. Chandrasekhar, *Controllable patterning and CVD growth of isolated carbon nanotubes with direct parallel writing of catalyst using Dip Pen Nanolithography ",* Small, Vol. 5, Issue 22, 2523, 2009, (Cover page article)

c) Synergistic Activities

- Reviewer for Applied Physics Letters (APL), Physical Review B, Journal of Vacuum Sciences and Technologies B (JVSTB), Carbon (EES International Journal)
- Reviewer for NSF (served on a panel review committee)
- Session Chair in 3rd International Conference and Exhibition on Materials Science & Engineering (Materials Science-2014) Oct 6-9, San Antonio, TX, 2014
- Organized Special Topic Workshop at APS/CNM Annual User Meeting, W10 "2D Materials Beyond Graphene: Exploring the Heterostructures", May 9, 2016 and WK6 "
- Developed new interdisciplinary course at SLU: Nanoscience and Nanofabrication Frontiers, (Fall 2013), (course is available to undergraduate at advanced level and graduate students in STEM fields)

BIOGRAPHICAL SKETCH: JOSEPH W. LYDING

University of Illinois t Urbana-Champaign — Office: Beckman 3065
Department of Electrical and Computer Engineering — Phone: (217) 333-8370
Beckman Institute, Urbana, IL 61801 — E-mail: lyding@illinois.edu

(a) PROFESSIONAL PREPARATION

Northwestern University	Evanston, Illinois	Electrical Eng. & Computer Science	B.S	1976
Northwestern University	Evanston, Illinois	Electrical Eng. & Computer Science	M.S.	1978
Northwestern University	Evanston, Illinois	Electrical Eng. & Computer Science	Ph.D.	1983

(b) APPOINTMENTS

2016-present	Robert C. MacClinchie Distinguished Professor of Electrical and Computer Engineering
2011-present	Chief Technical Officer, Tiptek, LLC, West Chester PA
1993-Present	Professor, Department of Electrical & Computer Engineering, University of Illinois
1988-1993	Associate Professor, Department of Electrical & Computer Engineering, UIUC
1984-1988	Assistant Professor, Department of Electrical & Computer Engineering, UIUC

(c) PUBLICATIONS (of ~200 publications)

I. PUBLICATIONS MOST CLOSELY RELATED TO THE PROPOSED PROJECT

1. J.W. Lyding, T.-C. Shen, J.S. Hubacek, J.R. Tucker, and G.C. Abeln, "Nanoscale patterning and oxidation of H-passivated Si(100)-2x1 surfaces with an ultrahigh vacuum scanning tunneling microscope," *Appl. Phys. Lett.* **64**, 2010 (1994).
2. T.-C. Shen, C. Wang, G.C. Abeln, J.R. Tucker, J.W. Lyding, Ph. Avouris, and R.E. Walkup, "Atomic-Scale Desorption Through Electronic and Vibrational Excitation Mechanisms," *Science* **268**, 1590 (1995).
3. M. C. Hersam, N. P. Guisinger, and J. W. Lyding, "Silicon-based molecular nanotechnology," *Nanotechnology* **11**, 70 (2000).
4. W. Ye, P.A.P. Martin, N. Kumar, S.R. Daly, A.A. Rockett, J.R. Abelson, G.S. Girolami and J.W. Lyding, "Direct Writing of Sub-5nm Hafnium Diboride Metallic Nanostructures," *ACS NANO* **4**, 6818-6824 (2010).
5. Wei Ye, Kyoungmin Min, Pamela Pena Martin, Angus A. Rockett, N.R. Aluru, and Joseph W. Lyding, "Scanning tunneling spectroscopy and density functional calculation of silicon dangling bonds on the Si(100)-2x1:H surface, *Surface Science* 609, 147-151 (2013).

II. OTHER SIGNIFICANT PUBLICATIONS

1. J.N. Randall, J.W. Lyding, S. Schmucker, J.R. Von Ehr, J. Ballard, R. Saini, H. Xu and Y. Ding, "Atomic precision lithography on Si," *J. Vac. Sci. Technol. B* **27**, 2764-2768 (2009).
2. Y. Xu, K.T. He, S.W. Schmucker, Z. Guo, J.C. Koepke, J.D. Wood, J.W. Lyding, and N.R. Aluru, "Inducing Electronic Changes in Graphene through Silicon (100) Substrate Modification," *Nano Letters* 11, 2735-2742 (2011).
3. S.W. Schmucker, N. Kumar, J.R. Abelson, S.R. Daly, G.S. Girolami, M.R. Bischof, D.L. Jaeger, R.F. Reidy, B.P. Gorman, J. Alexander, J. Ballard, J. Randall and J.W. Lyding, "Field-Directed Sputter Sharpening for Tailored Probe Materials and Atomic-Scale Lithography," *Nature Communications* **3**, article 935 (2012).
4. K.A. Ritter and J.W. Lyding, "The influence of edge structure on the electronic properties of graphene quantum dots and nanoribbons," *Nature Materials* 8, 235 (2009).
5. K.T. He, J.C. Koepke, S. Barraza-Lopez and J.W. Lyding, "Separation-Dependent Electronic Transparency of Monolayer Graphene Membranes on III-V Semiconductor Substrates," *Nano Letters* **10**, 3446-3452 (2010).

(d) SYNERGISTIC ACTIVITIES

1. **Service to scientific community:** Awards Committee Chair, IEEE Nanotechnology Council, 2013-2019. Executive Committee, Nanometer Scale Science and Technology division of the American Vacuum Society, 1997-1999. Associate Editor, IEEE Transactions on Nanotechnology, 2014-present.
2. **Technology development:** Translated basic STM research on hydrogen and deuterium passivated surfaces into a technology for dramatically reducing hot-carrier degradation effects in CMOS chip technology. The associated patent portfolio was licensed in 2010 to Samsung for their commercial chip production.
3. **Enterprise development:** Co-founded (with Gregory Girolami and Scott Lockledge) Tiptek, LLC to commercialize the field-directed sputter sharpening process for scanned probe microscopy probes and semiconductor wafer probing, 2011.
4. **Undergraduate research initiative:** Developed a new undergraduate nanotechnology teaching laboratory that is housed in a cleanroom in the new Electrical and Computer Engineering building that opened in the Fall 2014 semester.
5. **Teaching Innovations:** Developed undergraduate course on Nanotechnology with typical student enrollments from eight to ten different departments on campus. As a final project, the students write NSF-style proposals to stimulate 'out of the box' creativity.

Honors and Awards

Arthur K. Doolittle Award (ACS) (1983); Fellow of the APS (1997); University Scholar (UIUC) (1997); Fellow of the AVS (2000); Fellow of the IEEE (2011); IEEE Pioneer Award in Nanotechnology (2012); AVS NSTD Nanotechnology Recognition Award (2013); Research Excellence Award, U. Pennsylvania Nano-Bio Interface Center (2013); AVS Prairie Chapter Award for Outstanding Research (2014); Fellow of the AAAS (2014); Feynman Prize in Nanotechnology (2014); Robert C. MacClinchie Distinguished Professorship (2016)

S. O. Reza Moheimani,

Professor and James Von Ehr Distinguished Chair
Department of Mechanical Engineering
University of Texas at Dallas
800 W. Campbell Rd., Richardson, TX 7580
Tel: 801.581.3450
Email: Reza.Moheiman@utdallas.edu;
URL: http://reza.moheimani.org

I. EDUCATION AND TRAINING

University of New South Wales, Australia	Electrical Engineering	Ph.D., 1996
University of New South Wales, Australia	Electrical Engineering	M.Eng.Sc., 1993
Shiraz University, Iran	Electrical Engineering	B.Sc., 1990

II. RESEARCH AND PROFESSIONAL EXPERIENCE

Professor of Systems Engineering, Professor of Electrical Engineering, Professor of Mechanical Engineering and James Von Ehr Distinguished Chair University of Texas at Dallas, Richardson, TX	May 2015 – Present
Professor of Electrical Engineering	Oct 2007 – April 2015
Associate Professor of Electrical Engineering	Jan 2004 – Sept 2007
Senior Lecturer Research Academic	June 2001 – Dec 2003
University of Newcastle, Australia	Sept 1997 – May 2001
Research Associate University of New South Wales, Australia	Jan 1996 – Aug 1997

III. PUBLICATIONS (350+ refereed papers; 11,000+ citations; h-index 59; Complete list at: http://reza.moheimani.org/publications/)

1. F. Tajaddodianfar, S. O. R. Moheimani, J. Owen, J. N. Randall, On the effect of local barrier height in scanning tunneling microscopy: Measurement methods and control implications, Review of Scientific Instruments, 89 (1), pp. 013701, 2018.
2. F. Tajaddodianfar, S. O. R. Moheimani, J. N. Randall, Scanning Tunneling Microscope Control: A Self-Tuning PI Controller Based on Online Local Barrier Height Estimation. IEEE Transactions on Control Systems Technology, 2019.

3. M. Maroufi, A. G. Fowler, A. Bazaei, and S. O. R. Moheimani, High-stroke Silicon-on-Insulator MEMS nanopositioner: Control design for non-raster scan AFM. Review of Scientific Instruments, 86(2):023705 (12pp), 2015.
4. A. Mohammadi, A. G. Fowler, Y. K. Yong, and S. O. R. Moheimani. A feedback controlled MEMS nanopositioner for on-chip high-speed AFM. IEEE Journal of Microelectromechanical Systems, 23(3):610-619, June 2014.
5. M. G. Ruppert, S. O. R. Moheimani, Multimode Q Control in Tapping-Mode AFM: Enabling Imaging on Higher Flexural Eigenmodes. IEEE Transactions on Control Systems Technology, vol. 24, No. 4, pp. 1149–1159, 2016.
6. Y. K. Yong and S. O. R. Moheimani. Collocated z-axis control of a high-speed nanopositioner for video-rate atomic force microscopy. IEEE Transactions on Nanotechnology, vol. 14, No. 2, pp. 338-345, 2015.
7. S. Wadikhaye, Y. K. Yong, S. O. R. Moheimani: A Serial-Kinematic Nanopositioner for High-Speed AFM. Review of Scientific Instruments, vol. 85, No. 10, 105104 (10pp), 2014.
8. S. O. R. Moheimani and A. J. Fleming, *Piezoelectric Transducers for Vibration Control and Damping,* Springer, New York, 2006, ISBN: 1-84628-331-0.
9. Y. K. Yong, S. Aphale and S. O. R. Moheimani, *Design, identification and control of a flexure-based XY stage for fast nanoscale positioning*, IEEE Transactions on Nanotechnology, vol. 8, No. 1, pp. 46-54, Jan. 2009.
10. A. J. Fleming and S. O. R. Moheimani, *Sensorless vibration suppression and scan compensation for piezoelectric tube nanopositioners.* IEEE Transactions on Control Systems Technology. **14**(1): p. 33 – 44, January 2006.

IV. PATENTS

1. Sebastian, A. Pantazi, C. Pozidis, E. Eleftheriou and S. O. R. Moheimani. *Method of Controlling Movements of a Position of a Microscanner* (US 8,045,444 B2). Publication Date: Oct. 25, 2011.
2. A. Sebastian and S. O. R. Moheimani, *Method and Apparatus for Signal Transformation for Positioning Systems*, (US 7,792,596 B2). Publication Date: Sep. 7, 2010.

V. SYNERGISTIC ACTIVITIES

1. Editor-in-Chief, Mechatronics (since January 2016)
2. Chair, IEEE Control Systems Society Control Systems Technology Award Committee
3. Member, IFAC Nichols Medal Selection Committee (2015-2017)
4. Guest Editor, IEEE Control Systems Magazine special issue on Micro and Nanosystems (2013).
5. Chair, IFAC Technical Committee on Mechatronic Systems (2011-2017).
6. Chair, IEEE Control Systems Society IEEE Transactions on Control Systems Society Outstanding Paper Award Selection Committee (2015-2017).

STEVEN R. WHITE

Distinguished Professor, Dept. of Physics and Astronomy
University of California
Irvine, CA 92697-4058
Email: srwhite@uci.edu, Phone: (949) 824-2256

A.Education and Training

UC San Diego Physics, Math, Economics BA 1982
(triple major, summa cum laude)
Cornell Physics Ph.D., 1988
Thesis title: New methods for electronic structure calculations
UC Santa Barbara Physics Postdoc 1987-89

B. Research and Professional Experience
July 97-present Professor, Physics and Astronomy, UC Irvine
July 93 Associate Professor, Physics and Astronomy, UC Irvine
July 89 Assistant Professor, Physics and Astronomy, UC Irvine

C. Closely related publications (selected from 187 publications, h=70):
1. Density Matrix Formulation for Quantum Renormalization Groups, S. R. White, Phys. Rev. Lett. 69, 2863(1992). (Over 1900 citations, PRL Milestone paper of 1992); http://prl.aps.org/50years/milestones; http://prl.aps.org/pdf/PRL/v69/i19/p2863_1
2. Density Matrix Algorithms for Quantum Renormalization Groups, S. R. White, Phys. Rev. B. 48, 10345 (1993). (Over 1300 citations) http://link.aps.org/doi/10.1103/PhysRevB.48.10345
3. Ab Initio Quantum Chemistry using the density matrix renormalization group, S. R. White and R.L. Martin, J. Chem. Phys. 110, 4127 (1999). http://dx.doi.org/10.1063/1.478295
4. Numerical canonical transformation approach to quantum many-body problems, S. R. White, J. Chem. Phys. 117, 7472 (2002).http://dx.doi.org/10.1063/1.1508370
5. Real time evolution using the density matrix renormalization group, S. R. White and A.E. Feiguin, Phys. Rev. Lett. 93, 076401 (2004). http://prl.aps.org/pdf/PRL/v93/i7/e076401
6. Minimally Entangled Typical Quantum States at Finite Temperature, S. R. White, Phys. Rev. Lett. 102, 190601 (2009). http://link.aps.org/doi/10.1103/PhysRevLett.102.190601
7. Density matrix renormalization group algorithms with a single center site, Phys. Rev. B 72, 180403 (2005). http://link.aps.org/doi/10.1103/PhysRevB.72.180403

D. Synergistic activities
Rahman Prize in Computational Physics, APS, 2003.
Physical Review Letters Milestone Paper of 1992 (selected 2008).
Fellow of the American Physical Society, 1999.
Fellow of the American Association for the Advancement of Science (2008).
Member, American Academy of Arts and Sciences (elected 2016).
Member, National Academy of Sciences (elected 2018).

F. Collaborators and Co-editors
Andrey E Antipov (Michigan), Federico Becca (SISSA) B Bruognolo(Munich), Kieron Burke (UCI), David M Ceperley (UIUC), Garnet Chan (Caltech), Sasha Chernyshev (UCI), Philippe Corboz (Amsterdam), Georg Ehlers (Marburg), Hans Gerd Evertz(Graz), E. Gull (Michigan), David A. Huse (Princeton), Carlos A Jiménez-Hoyos (Caltech), Anna Keselman (Q-Station), Steven A. Kivelson(Stanford), JPF LeBlanc (Newfoundland), J. Lee (Maryland), Zhendong Li (Caltech), Fengjie Ma (William and Mary), Pavel Maksimov (UCI), Yuan Ming Lu (Ohio State), A.J. Millis (Columbia), Naoki Nakatani (Caltech), Reinhard Noack (Marburg), Mario Motta (Caltech), Nikolay V Prokof'ev (U Mass), Subir Sachdev (Harvard), D.J. Scalapino (UCSB), Ulrich Schollwock (Munich), Gustavo E Scuseria (Rice), Sandro Sorella (Trieste), E.M. Stoudenmire (UCI), Matthias Troyer(ETH), Guifre Vidal (Perimeter), Ashvin Vishwanath (Harvard), Michael Zaletel (Princeton), Dominika Zgid (Michigan), Shiwei Zhang (William and Mary)

G. Graduate and Postdoctoral Advisors and Advisees
John Wilkins and Kenneth Wilson, PhD Advisors, Ohio State (Previously Cornell)
Doug Scalapino, Post Doc Advisor, UCSB.
Graduate Advisees: Simeng Yan and Haihui Guo (Private non-research industry)
Postdoc Advisees: Miles Stoudenmire (Simons), Adrian Feiguin (Northeastern), Andreas Weichselbaum (Munich)

Biographical Sketch of Li Yang

a) Professional Preparation

i) Undergraduate Institution

Beijing Normal University, Beijing, China	Physics	B.S.	(1997)

ii) Graduate Institutions

Beijing Normal University, Beijing, China	Physics	M.S.	(2000)
Georgia Institute of Technology, Atlanta	Physics	Ph.D.	(2006)

iii) Postdoctoral Institutions

University of California at Berkeley	Physics		2006 –2009

b) Appointments

Assistant Professor, Department of Physics, Washington University in St. Louis (2009-2015)
Associate Professor, Department of Physics, Washington University in St. Louis (2015-present)

c) Products

i) Most Related Publications

[1] B. Deng, Vy Tran, Y. Xie, H. Jiang, C. Li, Q. Guo, X. Wang, H. Tian, S. J Koester, H. Wang, J. J Cha, Q. Xia, **L. Yang**, and F. Xia, "Efficient electrical control of thin-film black phosphorus bandgap", **Nature Comm.** 8, 144764 (2017).
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5399305/

[2] Ruixiang Fei, Wei Kang, and **Li Yang**, "Ferroelectricity and Phase Transitions in Monolayer Group-IV Monochalcogenides", **Phys. Rev. Lett.** 117, 097601 (2016).
http://journals.aps.org/prl/abstract/10.1103/PhysRevLett.117.097601

[3] Vy Tran, Ryan Soklaski, Yufeng Liang, and **Li Yang**, "Layer-Controlled Band Gap and Anisotropic Excitons in Few-Layer Black Phosphorus", **Phys. Rev. B (Editor's Suggestion)** 89, 235319 (2014).
https://journals.aps.org/prb/abstract/10.1103/PhysRevB.89.235319

[4] Yufeng Liang and **Li Yang**, "Carrier Plasmon Induced Nonlinear Band Gap Renormalization in Two-Dimensional Semiconductors", **Phys. Rev. Lett.** 114, 063001 (2015).
http://journals.aps.org/prl/abstract/10.1103/PhysRevLett.114.063001

[5] Shiyuan Gao, Yufeng Liang, Catalin D. Spataru, **Li Yang**, "Dynamical Excitonic Effects in Doped Two-Dimensional Semiconductors", **Nano Lett.** 16, 5568 (2016).
http://pubs.acs.org/doi/abs/10.1021/acs.nanolett.6b02118

ii) Other Significant Publications

[1] Ruixiang Fei and **Li Yang**, "Strain-Engineering Anisotropic Electrical Conductance of Phosphorene and Few-Layer Black Phosphorus", **Nano Lett.** 14, 2884 (2014).
http://pubs.acs.org/doi/abs/10.1021/nl500935z

[2] Ruixiang Fei, Alireza Faghaninia, Ryan Soklaski, Jia-An Yan, Cynthia Lo, and **Li Yang**, "Enhanced Thermoelectric Efficiency via Orthogonal Electrical and Thermal Conductances in Phosphorene", **Nano Lett.** 14, 6393 (2014).
http://pubs.acs.org/doi/abs/10.1021/nl502865s

[3] Xiaomu Wang, Aaron M Jones, Kyle L Seyler, Vy Tran, Yichen Jia, Huan Zhao, Han Wang, **Li Yang**, Xiaodong Xu, Fengnian Xia, "Highly anisotropic and robust excitons in monolayer black phosphorus", **Nature Nanotech.** 10, 517 (2015).

http://www.nature.com/nnano/journal/v10/n6/full/nnano.2015.71.html#close

[4] Likai Li, Guo Jun Ye, Vy Tran, Ruixiang Fei, Guorui Chen, Huichao Wang, Jian Wang, Kenji Watanabe, Takashi Taniguchi, **Li Yang**, Xian Hui Chen, Yuanbo Zhang, "Quantum oscillations in black phosphorus two-dimensional electron gas", **Nature Nanotech.** 10, 608 (2015). http://www.nature.com/nnano/journal/v10/n7/full/nnano.2015.91.html

[5] **Li Yang**, Jack Deslippe, Cheol-Hwan Park, Marvin L. Cohen and Steven G. Louie, "Excitonic Effects on the Optical Response of Graphene and Bilayer Graphene", **Phys. Rev. Lett.** 103, 186802 (2009). http://journals.aps.org/prl/abstract/10.1103/PhysRevLett.103.186802

d) Synergistic Activities

- Reviewer for Nature Materials, Nature Communication, Physical Review Letters, Physical Review B, Nano Letters, ACS Nano, Journal of Physical Chemistry, Small, IEEE the Transactions on Nanotechnology, and Solid State Communications, etc..
- Grant proposal reviewer for National Science Foundation and ACS Petroleum Research Fund
- Session Chair, MRS Spring meeting, San Francisco, CA (2011)
- Awards: 2015 NSF-CAREER, 2017 highly cited researchers by Clarivate Analytics

e) Collaborators & Other Affiliations

i) Collaborators and Co-editors (last five years)

Prof. Parag Banerjee (Washington University); Prof. Eun-Ah Kim (Cornell University); Prof. Jiwoong Park (Cornell University); Prof. Kenneth Kelton (Washington University); Prof. Zohar Nussinov (Washington University); Prof. Cynthia Lo (Washington University); Prof. Jia-an Yan (Towsen University); Prof. Fengnian Xia (Yale University); Prof. Xiaodong Xu (University of Washington); Prof. Han Wang (University of Southern California): Prof. Xiaoqin Li (University of Texas).

ii) Graduate and Postdoctoral Advisors

Graduate advisor:
Prof. Mei-Yin Chou — Georgia Institute of Technology
Postdoctoral advisors:
Prof. Marvin L. Cohen — University of California at Berkeley and Lawrence Berkeley National Lab
Prof. Steven G. Louie — University of California at Berkeley and Lawrence Berkeley National Lab

iii) Thesis Advisor and Postgraduate-Scholar Sponsor

Ph.D. thesis advisor:
Prof. Mei-Yin Chou — Georgia Institute of Technology

iv) Graduate Students Advised (past 5 years)

Shouting Huang (PhD) (2013, Seismic Imager at CGG, Houston, TX); Yufeng Liang (PhD) (2014, postdoctoral fellow in the Lawrence Berkeley National Lab, CA); Ryan Soklaski (PhD) (2015, research scientist, MIT Lincoln Laboratory, MA); Vy Tran (PhD) (2016, IT company in Minnesota); Ruixiang Fei (PhD) (2017, postdoctoral fellow in University of Pennsylvania)

BIOGRAPHICAL SKETCH OF CHUANWEI ZHANG

Chuanwei Zhang

Professor of Physics,

Associate Department Head and Graduate Program Head

Department of Physics,

The University of Texas at Dallas, Richardson, TX 75080

Tel: 972-883-4520

Email: Chuanwei.zhang@utdallas.edu;

Web: http://www.utdallas.edu/~cxz124830/

(a) Education and Training

University of Science & Technology of China	Physics	BS (2000)
University Of Texas at Austin	Physics	Ph.D (2005)

(b) Research and Professional Experience

2016 - present Professor, Department of Physics, the University of Texas at Dallas

2012 - 2016 Associate Professor, Department of Physics, the University of Texas at Dallas

2008 - 2012 Assistant Professor of Physics, Department of Physics and Astronomy, Washington State University at Pullman

2006 - 2008 Postdoctoral Research Associate, Department of Physics, the University of Maryland at College Park

(c) Awards

- Elected Fellow, American Physical Society (2017)
- 2015 American Physical Society Texas Section Robert Hyer Award
- 2010 Defense Advanced Research Projects Agency (DARPA) Young Faculty Award

(d) Publications:

(Peer-Reviewed Publications: total 109, including 1 Nature Physics, 31 Physical Review Letters, 6 Nature Communications, 1 PNAS, 1 Nano Letters)

(i) Five products most related to proposed work:

1. M. E. Mossman, J. Hou, X.-W. Luo, **C. Zhang**, P. Engels, *Experimental realization of a non-magnetic one-way spin switch*, Nature Communications, in press (2019).
2. H. Hu, J. Hou, F. Zhang, **C. Zhang**, *Topological Triply-Degenerate Points Induced by Spin-Tensor-Momentum Couplings*, Phys. Rev. Lett. 120, 240401 (2018).
3. Y. Xu, F. Zhang, **C. Zhang**, *Structured Weyl Points in spin-orbit coupled Fermionic Superfluids*, Phys. Rev. Lett. 115, 265304 (2015).
4. G. Aivazian, Z. Gong, A. M Jones, R.-L. Chu, J. Yan, D. G Mandrus, **C. Zhang**, D. Cobden, W. Yao, X. Xu, *Magnetic Control of Valley Pseudospin in Monolayer* WSe_2, Nature Physics 11, 148 (2015).
5. L. Mao, M. Gong, E. Dumitrescu, S. Tewari, **C. Zhang**, *Hole-doped semiconductor nanowire on top of an s-wave superconductor: A new and experimentally accessible system for Majorana fermions*, Phys. Rev. Lett. 108, 177001 (2012).

(ii) Five other recent products:

6. C.-H. Li, C. Qu, R. J. Niffenegger, S.-J. Wang, M. He, D. B. Blasing, A. Olson, C. H. Greene, Y. Lyanda-Geller, Q. Zhou, **C. Zhang**, Y. P. Chen, *Spin Current Generation and Relaxation in a Quenched Spin-Orbit-Coupled Bose-Einstein Condensate*, Nature Communications 10, 375 (2019).
7. J. Hou, X.-W. Luo, K. Sun, T. Bersano, V. Gokhroo, S. Mossman, P. Engels, **C. Zhang**, *Momentum Space Josephson Effects*, Phys. Rev. Lett. 120, 120401 (2018).

8. J. Hou, H. Hu, K. Sun, **C. Zhang**, *Superfluid-quasicrystal in a Bose-Einstein condensate*, Phys. Rev. Lett. 120, 060407 (2018). See news report from Newsweek
9. X.-W. Luo, K. Sun, **C. Zhang**, *Spin-tensor--momentum-coupled Bose-Einstein condensates*, Phys. Rev. Lett. 119, 193001 (2017).
10. M. A. Khamehchi, C. Qu, M. E. Mossman, **C. Zhang**, P. Engels, *Spin-momentum coupled Bose-Einstein condensates with lattice band pseudospins*, Nature Communications 7, 10867 (2016).

(e) Synergistic Activities

- Editorial Board of Nature Scientific Reports
- Referee for Science, Nature, Nature Physics, Nature Communications, Science Advances, Physical Review Letters, Physical Review X, A, B, Nano Letters, Advanced Materials, J. American Chemical Society, etc.
- Grant Review for ARO, NSF, ACS- Petroleum Research Fund, Netherlands FOM, etc.
- Organizer, Symposium on "Novel Topological Quantum Matter", held in February 2013 at the University of Texas at Dallas.
- APS DAMOP 2020-2022 Program Committee: March Meeting Subcommittee

(f) Identification of Potential Conflicts of Interest or Bias in Selection of Reviewers

- **Collaborators and Co-editors:**

Busch, Thomas	OJST
Chen, Shu	Chinese Academy of Science
Chen, Yong P.	Purdue University
Engels, Peter	Washington State University
Gartstein, Yuri	University of Texas at Dallas
Greene, Chris	Purdue University
Gu, Qing	University of Texas at Dallas
Guo, Guang-Can	University of Science and Technology of China
Jia, Suotang	Shanxi University
Lyanda-Geller, Yuli	Purdue University
Scarola, Vito	Virginia Tech
Stanescu, Tudor	University of West Virginia
Tewari, Sumanta	Clemson University
Zhang, Jing	Shanxi University
Zhang, Fan	University of Texas at Dallas
Zhou, Qi	Purdue University
Zhou, Zheng-Wei	University of Science and Technology of China
Zou, Xubo	University of Science and Technology of China

- **Graduate and Postdoctoral Advisors and Advisees (remainder in COA):**

Niu, Qian	University of Texas at Austin	PhD advisor
Raizen, Mark	University of Texas at Austin	PhD co-advisor
Das Sarma, Sankar	University of Maryland at College Park	Postdoctoral advisor
Hou, Junpeng	University of Texas at Dallas	PhD student
Maisberger, Matthew	University of Texas at Dallas	PhD student
Mahmud, Mohammad Murtaza	University of Texas at Dallas	PhD student
Qu, Chunlei	JILA, University of Colorado	PhD (2015)
Chen, Gang	Shanxi University	Postdoc
Gong, Ming	University of Science and Technology of China	Postdoc

SUMMARY PROPOSAL BUDGET

YEAR 1

ORGANIZATION: **University of California-Davis**			FOR NSF USE ONLY		
			PROPOSAL NO.	DURATION (months)	
				Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: **Richard Scalettar**			AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Richard T Scalettar - PI**	0.00	0.00	1.00	26,116	
2.					
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	1.00	26,116	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (3) GRADUATE STUDENTS				39,827	
4. (1) UNDERGRADUATE STUDENTS				6,000	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (1) OTHER				100,462	
TOTAL SALARIES AND WAGES (A + B)				172,405	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				58,939	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				231,344	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
Computer Cluster $ 60,000					
TOTAL EQUIPMENT				60,000	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				150,000	
2. INTERNATIONAL				0	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ 130,000					
2. TRAVEL 0					
3. SUBSISTENCE 0					
4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				130,000	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				5,000	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				2,718,288	
6. OTHER				415,297	
TOTAL OTHER DIRECT COSTS				3,138,585	
H. TOTAL DIRECT COSTS (A THROUGH G)				3,709,929	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
MTDC (Rate: 57.0000, Base: 1036344)					
TOTAL INDIRECT COSTS (F&A)				590,716	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				4,300,645	
K. FEE				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				4,300,645	
M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $				

PI/PD NAME: **Richard Scalettar**	FOR NSF USE ONLY		
	INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME*: **Kelly Gilmore**	Date Checked	Date Of Rate Sheet	Initials - ORG

 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

SUMMARY PROPOSAL BUDGET

YEAR 2

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
University of California-Davis

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Richard Scalettar

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Richard T Scalettar - PI	0.00	0.00	1.00	27,683	
2.					
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	1.00	27,683	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (3) GRADUATE STUDENTS				41,420	
4. (1) UNDERGRADUATE STUDENTS				6,000	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (1) OTHER				103,476	
TOTAL SALARIES AND WAGES (A + B)				178,579	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				62,579	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				241,158	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) Computer Cluster $ 30,000					
TOTAL EQUIPMENT				30,000	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				150,000	
2. INTERNATIONAL				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 130,000 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				130,000	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				5,000	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				2,803,617	
6. OTHER				416,827	
TOTAL OTHER DIRECT COSTS				3,225,444	
H. TOTAL DIRECT COSTS (A THROUGH G)				3,776,602	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) MTDC (Rate: 57.0000, Base: 796158)					
TOTAL INDIRECT COSTS (F&A)				453,810	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				4,230,412	
K. FEE				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				4,230,412	

M. COST SHARING PROPOSED LEVEL $ 0 AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Richard Scalettar

ORG. REP. NAME*
Kelly Gilmore

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

SUMMARY PROPOSAL BUDGET

YEAR 3

ORGANIZATION **University of California-Davis**				FOR NSF USE ONLY PROPOSAL NO.	DURATION (months) Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Richard Scalettar**				AWARD NO.		
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)	
1. **Richard T Scalettar - PI**	0.00	0.00	1.00	**29,344**		
2.						
3.						
4.						
5.						
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**		
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	1.00	**29,344**		
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)						
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**		
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**		
3. (**3**) GRADUATE STUDENTS				**43,077**		
4. (**1**) UNDERGRADUATE STUDENTS				**6,000**		
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**		
6. (**1**) OTHER				**106,580**		
TOTAL SALARIES AND WAGES (A + B)				**185,001**		
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**66,454**		
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**251,455**		
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)						
TOTAL EQUIPMENT				**0**		
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**150,000**		
2. INTERNATIONAL				**0**		
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ **130,000** 2. TRAVEL **0** 3. SUBSISTENCE **0** 4. OTHER **0**						
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**130,000**		
G. OTHER DIRECT COSTS						
1. MATERIALS AND SUPPLIES				**5,000**		
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**		
3. CONSULTANT SERVICES				**0**		
4. COMPUTER SERVICES				**0**		
5. SUBAWARDS				**2,873,459**		
6. OTHER				**418,510**		
TOTAL OTHER DIRECT COSTS				**3,296,969**		
H. TOTAL DIRECT COSTS (A THROUGH G)				**3,828,424**		
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 57.0000, Base: 806455)**						
TOTAL INDIRECT COSTS (F&A)				**459,679**		
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**4,288,103**		
K. FEE				**0**		
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**4,288,103**		
M. COST SHARING PROPOSED LEVEL $ **0**	AGREED LEVEL IF DIFFERENT $					
PI/PD NAME **Richard Scalettar**				FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* **Kelly Gilmore**				Date Checked	Date Of Rate Sheet	Initials - ORG

 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

SUMMARY PROPOSAL BUDGET

YEAR 4

ORGANIZATION **University of California-Davis**			FOR NSF USE ONLY PROPOSAL NO.	DURATION (months) Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Richard Scalettar**			AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Richard T Scalettar - PI**	0.00	0.00	1.00	**31,105**	
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	1.00	**31,105**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**3**) GRADUATE STUDENTS				**44,800**	
4. (**1**) UNDERGRADUATE STUDENTS				**6,000**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**1**) OTHER				**109,777**	
TOTAL SALARIES AND WAGES (A + B)				**191,682**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**70,532**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**262,214**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**150,000**	
2. INTERNATIONAL				**0**	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ **130,000** 2. TRAVEL **0** 3. SUBSISTENCE **0** 4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**130,000**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**5,000**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**2,961,135**	
6. OTHER				**420,361**	
TOTAL OTHER DIRECT COSTS				**3,386,496**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**3,928,710**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 57.0000, Base: 817214)**					
TOTAL INDIRECT COSTS (F&A)				**465,812**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**4,394,522**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**4,394,522**	
M. COST SHARING PROPOSED LEVEL $ **0**	AGREED LEVEL IF DIFFERENT $				

PI/PD NAME **Richard Scalettar**	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* **Kelly Gilmore**	Date Checked	Date Of Rate Sheet	Initials - ORG

 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

SUMMARY PROPOSAL BUDGET

YEAR 5

ORGANIZATION **University of California-Davis**				FOR NSF USE ONLY PROPOSAL NO.	DURATION (months) Proposed / Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Richard Scalettar**				AWARD NO.	

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Richard T Scalettar - PI**	0.00	0.00	1.00	32,971	
2.					
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	1.00	32,971	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (3) GRADUATE STUDENTS				46,592	
4. (1) UNDERGRADUATE STUDENTS				6,000	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (1) OTHER				113,070	
TOTAL SALARIES AND WAGES (A + B)				198,633	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				74,931	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				273,564	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				150,000	
2. INTERNATIONAL				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 130,000 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				130,000	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				5,000	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				3,037,489	
6. OTHER				422,397	
TOTAL OTHER DIRECT COSTS				3,464,886	
H. TOTAL DIRECT COSTS (A THROUGH G)				4,018,450	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 57.0000, Base: 828564)**					
TOTAL INDIRECT COSTS (F&A)				472,281	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				4,490,731	
K. FEE				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				4,490,731	

M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $		
PI/PD NAME **Richard Scalettar**	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* **Kelly Gilmore**	Date Checked	Date Of Rate Sheet	Initials - ORG

 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

SUMMARY PROPOSAL BUDGET

Cumulative

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months)	
	Proposed	Granted
AWARD NO.		

ORGANIZATION
University of California-Davis

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Richard Scalettar

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Richard T Scalettar - PI	0.00	0.00	5.00	147,219	
2.					
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	5.00	147,219	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (15) GRADUATE STUDENTS				215,716	
4. (5) UNDERGRADUATE STUDENTS				30,000	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (5) OTHER				533,365	
TOTAL SALARIES AND WAGES (A + B)				926,300	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				333,435	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				1,259,735	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) $ 90,000					
TOTAL EQUIPMENT				90,000	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				750,000	
2. INTERNATIONAL				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 650,000 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				650,000	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				25,000	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				14,393,988	
6. OTHER				2,093,392	
TOTAL OTHER DIRECT COSTS				16,512,380	
H. TOTAL DIRECT COSTS (A THROUGH G)				19,262,115	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				2,442,298	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				21,704,413	
K. FEE				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				21,704,413	

M. COST SHARING PROPOSED LEVEL $ 0 AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Richard Scalettar

ORG. REP. NAME*
Kelly Gilmore

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

C *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

9. Budget Justification

The items cited below are per year, for each of the five years of funding requested, unless otherwise noted.

A. Salaries and Wages

- One month summer salary and benefits is requested for the PI, who will lead the computational modeling effort at UC Davis as well as serve as overall PI for the project.
- One academic year graduate student research assistant (GSR) support and two summer GSR positions each year are requested to support students working at UCD on the project. They will be writing and running quantum simulation codes, and analyzing data, under the supervision of the PI.
- Two full time staff positions at the level of Assistant III are requested. Staff members will coordinate Center activities including outreach, website, hiring, meetings and summer schools, external board affairs, inter-group travel, publications, reports, and data management.

B. Benefits

UC Davis Employee Benefit Rates:

- PI: 10.9% - 12.3 %
- GSR: 1.9%
- Staff: 54.6% - 66.3%

C. Equipment

- $60,000 and $30,000 are requested for years 1 and 2 respectively to purchase a computer cluster/servers required for the research effort.

D. Travel

- $10,000 in domestic travel will be used for the PI and graduate student to attend the American Physical Society meetings, and to take research trips to the other co-PI's institutions. (See subcontract list below.)
- $50,000 in domestic travel is allocated for all PIs and their groups to get together for a one week coordination meeting each year.
- $50,000 in domestic travel is allocated for a topical meeting to include both our team and researchers from the broader quantum simulation community, including members of other QLEAP teams.
- $40,000 in domestic travel is allocated for graduate student visits to our SNL, LANL and Zyvex partners.

E. Supplies and Expenses

- $5000 per year for supplies, e.g. to maintain the computer infrastructure.

F. Other Expenses/Emerging Issues

- $400,000 is requested annually for funding of new projects which emerge as especially promising in the course of this five year, thirteen PI grant. These funds are, at present, in the UC Davis budget, with indirect costs assessed. Once awarded to a collaborator at an existing subawardee, the funds will be rebudgeted and will not incur UCD indirect costs (but will be subject to indirect costs at the subawardee rates). Indirect costs rates across our participating institutions are close enough so that the direct costs available will remain relatively the same (eg. UC Davis 57%, WSU 53%). Emerging issues awards will be made as a decision by the Center's Science Advisory Board in consultation with the PI and Team Leads.

G. Participant Support Costs

- $50,000 is requested annually for a paid high school internship program.
- $80,000 in domestic travel is allocated for a summer school each year.

H. Subcontract

Subcontacts are requested for the co-PIs at each of the participating institutions. Detailed breakdowns are not required at this pre-proposal stage, but these subcontracts involve the same general research categories as above: salaries and benefits for researchers in the project, equipment, travel, supplies, student fees, indirect costs, and an estimated 3% inflation.

Certain administration, management, and evaluation functions, and education, training, and comnunity engagement efforts will be delocalized among participating institutions, and are therefore included in subcontract budgets. This ensures that all PI's and their groups, can be active and effective participants in these activities.

I. Other Direct Costs

Graduate student fee remission is requested.

J. Indirect Costs

Cognizant Agency: DHHS
DHHS Representative: Jeffrey Warren, 415-437-7820
Date of agreement: 08/17/2018 Rates (MTDC)

- Year 1: 57.0%
- Year 2: 57.0%
- Year 3: 57.0%
- Year 4: 57.0%
- Year 5: 57.0%

Summary
Since detailed subaward budgets were not required at this preproposal stage, we have rounded the allocations into the different categories below to the nearest $1000, except for the administration, management, and evaluation line. Calculations are based on the precise subaward totals together with their division into the individual funding areas. Entries in the Table include indirect costs and column totals equal the total budget requested from NSF for the period shown. Support for undergraduate and graduate students was predominantly included under research activities, with appropriate portions under Education, Training and Workforce Development that are part of related research.

Activity	Year One Total	Five Year Total
Focus Research Area 1 Synthesis, characterization, and modeling of 2×2 clusters	$973,000	$5,011,000
Focus Research Area 2 High fidelity qubit initialization; optical tweezers	$629,000	$3,098,000
Focus Research Area 3 Novel superfluid and superconducting phases	$305,000	$1,630,000
Focus Research Area 4 Emergence of topological states with system size	$267,000	$1,475,000
Focus Research Area 5 Quantum simulation, novel geometries/disorder	$246,000	$1,367,000
Focus Research Area 6 Dynamics of quantum states	$346,000	$1,682,000
Research Capacity Coordination; Community Engagement	$478,000	$2,162,000
Education, Training, Workforce Development	$272,000	$1,201,000
Partnerships and Infrastructure Development	$185,000	$1,093,000
Shared Facilities	$295,000	$1,377,000
Administration, Management and Evaluation	$304,645	$1,608,413
Total	$4,300,645	$21,704,413

CURRENT AND PENDING SUPPORT: RICHARD T. SCALETTAR

CURRENT:

Proposal Title: "Quantum Simulations of Strong Correlation Effects at Interfaces"
Principal Investigator: Richard Scalettar
Funding Agency: DOE
Amount: $350,000
Start/Expiration dates: 09/01/18 - 08/31/21
Person-Months per year committed by PI (acad yr/summer): 0.0/0.5

PENDING (INCLUDING THIS PROPOSAL):

Proposal Title: "DMREF: Machine Learning the Relation Between Materials Structure and Magnetism at Extreme Conditions"
Principal Investigators: Valentin Taufour, Nicholas Curro, Shanti Deemyad, Marina Radulaski, Richard Scalettar
Funding Agency: NSF- DMREF
Requested Amount: $1,291,060 (UC Davis); $1,699,760 (all institutions)
Proposed Start/Expiration dates: 08/01/19 - 07/31/23
Person-Months per year committed by PI (acad yr/summer): 0.0/0.35

Proposal Title: "QLCI-CI: Center for the Simulation of Engineered Quantum Materials"
Principal Investigators: Peter Engels, Michael McNeil Forbes, Subhadeep Gupta, Ehsan Khatami, Wiley Kirk, Irma Kuljanishvili, Joseph Lyding, Reza Moheimani, James Owen, John Randall, Rick Silver, Steven White, Li Yang, Chuanwei Zhang
Funding Agency: NSF- QLCI
Requested Amount: $18,971,093 (all institutions)
Proposed Start/Expiration dates: 08/01/20 - 07/31/25
Person-Months per year committed by PI (acad yr/summer): 0.0/1.00

Dr. Michael McNeil Forbes — Washington State University

Current Support:

- **Title:** Quantum Dynamics with Cold Atoms
  Agency: NSF
  Award #: 1707691
  Amount: $376,013
  Period: 9/1/2017–8/31/2020
  Person-months: 0.5 summer
  Project Location: Washington State University – Pullman
  Brief Description: Development of some techniques and tools which will be used as a foundation for the proposed work, but there is no direct overlap with the proposed work.

Pending Support:

- **Title:** Ultracold Atoms for Sensing and Simulating Neutron Stars Physics (current proposal)
  Agency: DoE
  PI: Dr. Peter Engels (WSU), **C**o-PIs: Dr. Peter Engels (WSU), Dr. Chuanwei Zhang (UT Dallas)
  Amount: $1,000,000
  Period: 9/1/2019–8/31/2022
  Person-months: 1.0 summer
  Project Location: Washington State University – Pullman
  Brief Description: Similar techniques to those that will be used in the current proposal, but with different physical applications that have no direct overlap with the current proposal.

- **Title:** QLCI-CI: Center for the Simulation of Engineered Quantum Materials (current proposal)
  Agency: NSF
  Amount: $
  Period: 9/1/2020–8/31/2025
  Person-months: 1.0 summer
  Project Location: Washington State University – Pullman

Subhadeep Gupta
Current and Pending Support

Current
"Interacting Two-Element Bose-Fermi Superfluid"
$270,000
National Science Foundation
Location: Seattle, WA
09/01/2018-08/31/2021
Person-months per year – Acad: 0.00 Sumr 0.20

"Few-body Physics and Chemistry with Ultracold YbLi molecules"
$540,372.
Air Force Office of Scientific Research
Location: Seattle, WA
01/01/2019-12/31/2021
Person-months per year – Acad: 0.00 Sumr 0.50

"Precision Contrast Interferometry with Ytterbium Bose-Einstein Condensates"
$470,000
National Science Foundation
Location: Seattle, WA
08/01/2017-07/31/2020
Person-months per year – Acad: 0.00 Sumr 0.30

"REU Site: University of Washington Physics"
$398,091
National Science Foundation
Location: Seattle, WA
04/01/2019-03/31/2022
Person-months per year – Acad: 0.00 Sumr 0.50

Pending

"QLCI-CI: Center for the Simulation of Engineered Quantum Materials" (This Proposal)
$18,971,093
National Science Foundation
Location: Seattle, WA
09/01/2020-08/31/2025
Person-months per year – Acad: 0.00 Sumr 0.50

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: **Wiley P. Kirk**

Other agencies (including NSF) to which this proposal has been/will be submitted.
None

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:
GOALI: Nanomanufacturing of acceptor dopants for atomically precise 2D bipolar devices with Zyvex Labs
Source of Support: NSF
Total Award Amount: $200,000 Total Award Period Covered: 9/1/2016 - 8/31/2020
Location of Project: UT-Arlington and Zyvex Labs
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: 1

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:
Advanced Semiconductor Development
Source of Support: Texas Instruments, Inc. (gift award)
Total Award Amount: $ 74,988 Total Award Period Covered: 9/1/08 - 8/31/2020
Location of Project: UT-Arlington
Person-Months Per Year Committed to the Project. Cal: 0.1 Acad: Sumr:

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:
Designed Quantum Materials Workshop
Source of Support: NSF
Total Award Amount: $16,032 Total Award Period Covered: 11/1/2017 - 8/31/2018
Location of Project: UT-Arlington and National Institute of Standards and Technology
Person-Months Per Year Committed to the Project. Cal: 0.1 Acad: Sumr:

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:
Atomically Precise Manufacturing for Designed-2D Materials
with Zyvex Labs, NIST, 3D Epitaxial Technologies
Source of Support: DOE FOA 1465
Total Award Amount: $2,457,454 Total Award Period Covered: 04/01/2018-08/31/2021
Location of Project: Zyvex Labs (Texas), 3D Epi Tech.(Texas) and NIST(Maryland)
Person-Months Per Year Committed to the Project. Cal: 1 Acad: Sumr:

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:
QLCI-CI: Center for the Simulation of Engineered Quantum Materials
Source of Support: NSF
Total Award Amount: $ Total Award Period Covered:
Location of Project: various
Person-Months Per Year Committed to the Project. Cal: 1 Acad: Sumr:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Richard Silver

Other agencies (including NSF) to which this proposal has been/will be submit-
NSF

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **This proposal** -
QLeap

Source of Support: NSF – this is the current submission

Total Award Amount: ~ $300K per year Total Award Period Covered: 5 years

Location of Project: NIST/UMD

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Single atom devices for traditional and quantum computing

Source of Support: Innovations in Measurement Science Award: Internal NIST

Total Award Amount: $485K per year Total Award Period Covered: 5 year award

Location of Project: NIST

Person-Months Per Year Committed to the Project. Cal: 2 Acad: Sumr:

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:
Atomically Precise Manufacturing for 2D-Designed Materials

Source of Support: Department of Energy

Total Award Amount: $300K per year Total Award Period Covered: 3 year

Location of Project: NIST

Person-Months Per Year Committed to the Project. Cal: 2 Acad: Sumr:

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Atom based devices for quantum computing

Source of Support: Directors Reserve Targeted Funding, NIST

Total Award Amount: $200K per year Total Award Period Covered: 5 year

Location of Project: NIST

Person-Months Per Year Committed to the Project. Cal: 1 Acad: Sumr:

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: QLCI-CI: Center for the Simulation of Engineered Quantum Materials

Source of Support: NSF

Total Award Amount: ~$265 per year Total Award Period Covered: 5 year

Location of Project: NIST

Person-Months Per Year Committed to the Project. Cal: 1 Acad: Sumr:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Dr. Peter Engels — Washington State University

Current Support:

- **Title:** Zero-G Studies of Few-Body and Many-Body Physics
  Agency: NASA/JPL
  Award #: RSA 1623611
  Amount: $246,136
  Period: 3/16/2019–3/15/2020
  Person-months: 1.0 summer
  Project Location: Washington State University – Pullman
  Brief Description: Investigation of few-body physics, such as Efimov states, using NASA's CAL facility. No overlap with the proposed research.

- **Title:** Quantum Phases and Dynamics of Bose-Einstein Condensates with Artificial Gauge Fields
  Agency: NSF
  Award #: 1607495
  Amount: $586,630
  Period: 9/1/2016–8/31/2019
  Person-months: 1.0 summer
  Project Location: Washington State University – Pullman
  Brief Description: Investigation of novel quantum phases, such as supersolids, and study of their characteristic dynamics. This work will form the foundation for some of the proposed experiments but there is not direct overlap with the proposed work.

Pending Support:

- **Title:** Quantum Phases, Interactions and Topology of Dressed BECs
  Agency: NSF
  Amount: $579,543
  Period: 9/1/2019–8/31/2022
  Person-months: 2.0 summer
  Project Location: Washington State University – Pullman
  Brief Description: Investigation of novel quantum phases, interaction effects and aspects of topology in BECs embedded in tailored light fields. No overlap with the proposed work.

- **Title:** DURIP: Integrated CryoElectronics Test-Bed for Energy-Efficient High-Speed Data Links on Heterogeneous Temperature Platforms
  Agency: DOD/ONR
  Lead PI: Dr. Subhanshu Gupta, WSU
  Amount: $843,997

Period: 2/1/2020–1/31/2021
Person-months: None
Project Location: Washington State University – Pullman
Brief Description: Equipment grant to acquire a cryogenic testbed for evaluating superconducting electronics and interfacing with ultracold atoms. No overlap with the proposed work. I am a co-PI on this proposal. The project is led by Prof. Gupta, department of Electrical Engineering and Computer Science.

- **Title:** Ultracold Atoms for Sensing and Simulating Neutron Stars Physics
  Agency: DoE
  PI: Dr. Peter Engels (WSU), **C**o-PIs: Dr. Peter Engels (WSU), Dr. Chuanwei Zhang (UT Dallas)
  Amount: $1,000,000
  Period: 9/1/2019–8/31/2022
  Person-months: 1.0 summer
  Project Location: Washington State University – Pullman

- **Title:** QLCI-CI: Engineered Quantum Metamaterials and Ultracold Atoms: Complementary Platforms for Quantum Simulation (current proposal)
  Agency: NSF
  Amount: $
  Period: 9/1/2020–8/31/2025
  Person-months: 1.0 summer
  Project Location: Washington State University – Pullman

Ehsan Khatami
Current and Pending Support

Current:

Title: *RUI: Exact Dynamical Properties of Strongly Correlated Materials at Finite Temperatures*
Role: PI
Source of Funding: NSF (DMR CMMT)
Award ID: DMR-1918572
Total award amount: $235,829 for three years
Expected start date: 12/1/2019
Person-months per year committed to the project: Academic year: 0, Summer: 1.5

Title: *RUI: Disorder in strongly-correlated electrons on a lattice*
Role: PI
Source of funding: NSF (DMR CMMT)
Award ID: DMR-1609560
Total award amount: $171,000 for three years
Start date: 12/1/2016
Average person-months per year committed to the project: Academic year: 0, Summer: 1.46

Title: *MRI: Acquisition of hybrid CPU/GPU high-performance computing and storage for STEM research and education at San Jose State University*
Role: co-PI
Source of funding: NSF
Award ID: OAC-1626645
Total award amount: $900,798 for three years
Start date: 8/1/2016
Average person-months per year committed to the project: Academic year: 0, Summer: 0

Pending:

Title: *QLCI-CI: Center for the Simulation of Engineered Quantum Materials* - **THIS PROPOSAL**
Source of Funding: NSF
Total award amount: $... for five years
Expected start date: 9/1/2020
Person-months per year committed to the project: Academic year: 0, Summer: 0.5

Title: *QLCI-CG: The Open Quantum Frontier Institute*
Source of Funding: NSF
Total award amount: $150,000 for one years
Expected start date: 1/1/2020
Person-months per year committed to the project: Academic year: 0, Summer: 0.5

Irma Kuljanishvili, Saint Louis University,

Current and Pending Support

1. Title: "*Bottom-up direct-writing approach to fabrication of 2D heterostructure systems for 3D platforms"*, U.S. Department of Energy, Basic Science, Argonne National Laboratory /Center for Nanoscale Materials User Proposal Allocation (Proposal# 63980), Role- PI, Period: June1 2019 – May30, 2020, (External)

2. Title: *Engineering and Characterizing Novel Nanoscale Platforms with Carbon Nanotube/ZnO Nanowire Heterostructures for Biomedical Applications*". SLU President's Research Fund, Amount $25,000, (Internal), Role: PI, Period: 03/01/2019-02/28/2020 (Internal)

3. Title*: Novel approach to scalable mechanical characterization of nanomaterials through selective controlled synthesis of 1D and 2D structures on MEMS testing platform*", U.S. Department of Energy, Office of Basic Energy Science, Oakridge CNMS Proposal ID: CNMS2019-099, Proposal Allocated Start Date Feb 1, 2019- Jan 30, 2020, Role PI (External)

4. Title: "Enabling Novel Approach to the Fabrication of Freestanding 2D Nanomaterials using a combinations of Two Direct-Writing Technologies", U.S. Department of Energy, Office of Basic Energy Science, Oak Ridge National Laboratory, CNMS Proposal ID: CNMS2019-R-025, User Proposal allocated with Start Date Feb 1, 2019- August, 2019, Role PI, (External)

5. Workshop Title: Optoelectronic devices and mechanical systems based on ultra-thin 2D materials" Argonne National Laboratory, Special Topics Workshop at APS/CNM 2019, Funds $6,500, Role, Workshop organizer, Workshop May 6-9 , 2019, (External)

6. Title: *"Nanotechnology and Undergraduate Engineering Education",* KEEN Engineering Unleashed Program Transformation Grants (PTG), KEEN Program of the Kern Family Foundation, Grant Period: May 2018-August 2019, Role: co-PI, Award Amount $5,000 (External)

7. Title: "QLCI-CI: Center for the Simulation of Engineered Quantum Materials", National Science Foundation, Grant Period: September 2020-August 2025, Role: Senior Personnel, Award Amount: ~$265,000/year (External)

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Other agencies (including NSF) to which this proposal has been/will be submitted.

Investigator: Joseph Lyding

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future

Project/Proposal Title:

Engineering Research Center for Power Optimization for Electro-Thermal Systems (POETS)

Source of Support: **NSF EEC 14-49548 31.2016**

Total Award Amount: **$18,500,000** Total Award Period Covered: **08/01/2015 – 07/31/2020**

Location of Project: **University of Illinois, University of Arkansas, Stanford University, Howard University**

Person-Months Per Year Committed to the Project. Cal: Acad: 0.00 Sumr: 0.0

Relationship to present proposal: **The goal of this research is to develop high thermal conductivity carbon-based materials and electric motors that can operate at temperatures suitable for NASA's planned Venus lander. No overlap with present pro-**

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future

Project/Proposal Title:

Atomically Precise Graphene Nanoribbon Device Structures

Source of Support: **Office of Naval Research N00014-16-1-3151**

Total Award Amount: **$645,564** Total Award Period Covered: **6/1/2016-8/31/2019**

Location of Project: **University of Illinois at Urbana-Champaign**

Person-Months Per Year Committed to the Project. Cal: Acad: 0.06 Sumr: **1.0**

Relationship to present proposal: **This project studies GNRs deposited onto semiconductor surfaces and uses probe-directed synthesis of GNRs. There is no overlap with the present proposal.**

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future

Project/Proposal Title:

Novel superconducting MgB2 nanowire-based qubits constructed by scanning tunneling microscope electron beam induced decomposition of newly developed CVD precursors.

Source of Support: **Army Research Office W911NF1810117**

Total Award Amount: **$1,500,000** Total Award Period Covered: **04/01/2018-3/31/2021**

Location of Project: **University of Illinois at Urbana-Champaign**

Person-Months Per Year Committed to the Project. Cal: Acad: 0.09 Sumr: **0.5**

Relationship to present proposal: **The goal of this project is to develop nanowire transmon qubits. There is no overlap with the present proposal.**

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future

Project/Proposal Title:

Novel Probes for Tip-Based Atomically Precise Manufacturing.

Source of Support: DOE

Total Award Amount: $1,000,000 Total Award Period Covered: **05/28/2019 – 05/27/2021**

Location of Project: University of Illinois at Urbana-Champaign

Person-Months Per Year Committed to the Project. Cal: Acad: 0.0 Sumr: 0.0

Relationship to present proposal: **Phase I program to develop STM probes for atomically precise manufacturing.**

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future

Project/Proposal Title: **DNA-enabled hierarchical assembly of graphene electronics**

Source of Support: **Office of Naval Research**

Total Award Amount: **$7,499,998** Total Award Period Covered: **06/01/19 – 5/31/24**

Location of Project: University of Nebraska, New York University, University of Illinois, University of Chicago

Person-Months Per Year Committed to the Project. Cal: Acad: 0.0 Sumr: **1.0**

Relationship to present proposal: **This project will use DNA-based assembly to create graphene nanoribbon structures and devices. There is no overlap with the present proposal.**

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future

Project/Proposal Title: **Ultra High-Speed, High-Temperature Motor**

Source of Support: **Department of Energy**

Total Award Amount: **$700,000 / 30 months** Total Award Period Covered: **09/01/19-02/28/22**

Location of Project: **University of Illinois at Urbana-Champaign**

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Relationship to present proposal: **Phase II program to develop STM probes for atomically precise manufacturing.**

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future

Project/Proposal Title: **QLCI-CI: Center for the Simulation of Engineered Quantum Materials**

Source of Support: **NSF**

Total Award Amount: **~$265,000/year** Total Award Period Covered: **09/01/20-08/31/25**

Location of Project: **University of Illinois at Urbana-Champaign**

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: **1.0**

Relationship to present proposal: **Phase II program to develop STM probes for atomically precise manufacturing.**

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Dr. Reza Moheimani

Other agencies (including NSF) to which this proposal has been/will be submitted:

Support: [x] Current [ ] Pending [ ] Submission Planned in Near Future [ ] *Transfer of Support

Project/Proposal Title: Atomic Manufacturing, Micron Assembly

This Proposal? [ ]

Source of Support: Air Force Research Laboratory

Total Award Amount: $ 451,524.00 Total Award Period Covered: 7/17/15 - 9/30/19

Location of Project: The University of Texas at Dallas

Person-Months Per Year Committed to the Project: Cal: 0.00 Acad: 0.00 Sumr: 1.50

Support: [x] Current [ ] Pending [ ] Submission Planned in Near Future [ ] *Transfer of Support

Project/Proposal Title: A Platform Technology for High-throughput Atomically Precise Manufacturing: Mechatronics at the Atomic Scale

This Proposal? [ ]

Source of Support: Department of Energy

Total Award Amount: $ 2,229,238.00 Total Award Period Covered: 6/15/18 - 6/14/21

Location of Project: The University of Texas at Dallas

Person-Months Per Year Committed to the Project: Cal: 2.00 Acad: 0.00 Sumr: 0.00

Support: [x] Current [ ] Pending [ ] Submission Planned in Near Future [ ] *Transfer of Support

Project/Proposal Title: High-Speed Platform for Highly Parallel STM Lithography and Hierarchical Assembly - STTR Phase I

This Proposal? [ ]

Source of Support: Zyvex Labs/Department of Energy

Total Award Amount: $ 89,918.00 Total Award Period Covered: 4/9/18 - 5/27/19

Location of Project: The University of Texas at Dallas

Person-Months Per Year Committed to the Project: Cal: 0.00 Acad: 0.00 Sumr: 1.00

Support: [x] Current [ ] Pending [ ] Submission Planned in Near Future [ ] *Transfer of Support

Project/Proposal Title: High-speed Platform for Highly Parallel STM Lithography and Hierarchical Assembly - STTR Phase II

This Proposal? [ ]

Source of Support: Zyvex Labs/Department of Energy

Total Award Amount: $ 499,931.00 Total Award Period Covered: 5/31/19 - 5/30/21

Location of Project: The University of Texas at Dallas

Person-Months Per Year Committed to the Project: Cal: 1.50 Acad: 0.00 Sumr: 0.00

Support: [ ] Current [x] Pending [ ] Submission Planned in Near Future [ ] *Transfer of Support

Project/Proposal Title: A Transformative System for High-throughput Atomically-Precise Manufacturing: Enabling Atomic Precision Fabrication of Silicon Quantum Devices

This Proposal? [ ]

Source of Support: Army (DURIP)

Total Award Amount: $ 250,000.00 Total Award Period Covered: 1/1/20 - 1/1/21

Location of Project: The University of Texas at Dallas

Person-Months Per Year Committed to the Project: Cal: 0.00 Acad: 0.00 Sumr: 0.00

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Dr. Reza Moheimani

Other agencies (including NSF) to which this proposal has been/will be submitted:

Support: ☐ Current ☑ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: QLCI-CI: Center for the Simulation for Engineered Quantum Materials

This Proposal? ☐

Source of Support: National Science Foundation

Total Award Amount: $ 1,323,385.00 Total Award Period Covered: 9/1/20 - 8/31/25

Location of Project: The University of Texas at Dallas

Person-Months Per Year Committed to the Project: Cal: 0.00 Acad: 0.00 Sumr: 1.00

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

This Proposal? ☐

Source of Support:

Total Award Amount: Total Award Period Covered: -

Location of Project:

Person-Months Per Year Committed to the Project: Cal: Acad: 0.00 Sumr: 0.00

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

This Proposal? ☐

Source of Support:

Total Award Amount: Total Award Period Covered: -

Location of Project:

Person-Months Per Year Committed to the Project: Cal: 0.00 Acad: 0.00 Sumr: 0.00

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

This Proposal? ☐

Source of Support:

Total Award Amount: Total Award Period Covered: -

Location of Project:

Person-Months Per Year Committed to the Project: Cal: 0.00 Acad: 0.00 Sumr: 0.00

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

This Proposal? ☐

Source of Support:

Total Award Amount: Total Award Period Covered: -

Location of Project:

Person-Months Per Year Committed to the Project: Cal: 0.00 Acad: 0.00 Sumr: 0.00

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*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

Steven R. White (PI)

Current Support

Title: Simons Collaboration on the Many Electron Problem
Source of Support: Simons Foundation (319144)
Total Award Period Covered: 03/01/19 – 02/28/23
Total Award Amount: $558,000
Person-Months Per Year Committed to the Project: 1.0 summer
Location of Project: UC Irvine
Role: PI
Overlap: None

Title: Strong Correlation DMRG AND DFT (PI: S. White)
Source of Support: DOE (DE-SC0008696)
Total Award Period Covered: 09/01/18 - 08/31/21
Total Award Amount: $450,000
Person-Months Per Year Committed to the Project: 1.0 summer
Location of Project: UC Irvine
Role: PI
Overlap: None

Title: DMRG Studies of Frustrated and Doped Systems
Source of Support: NSF (DMR-1812558)
Total Award Period Covered: 8/1/18 – 7/31/21
Total Award Amount: $518,388
Location of Projects: UC Irvine
Person-Months Per Year Committed to the Project: 1.0 Summer
Role: PI
Overlap: None

Pending Support

Title: QLCI-CI: Center for the Simulation of Engineered Quantum Materials
Source of Support: NSF
Total Award Period Covered: 09/01/20 – 08/31/25
Total Award Amount: $
Person-Months Per Year Committed to the Project: 1.0 summer
Location of Project: UC Irvine
Role: Senior Personnel
Overlap: None

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Li Yang

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

CAREER: Many-electron interactions and excited-state properties in two-dimensional van der Waals interfaces

Source of Support: National Science Foundation

Total Award Amount: $ 475,000 Total Award Period Covered: 07/01/2016-06/30/2020

Location of Project: Washington University

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: 1

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

EFRI 2-DARE: Few-layer and Thin-film Black Phosphorus for Photonic Applications

Source of Support: National Science Foundation

Total Award Amount: $2,000,000 Total Award Period Covered: 08/01/2015-07/31/2018

Location of Project: Yale University

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: 1

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ Transfer of Support

Project/Proposal Title:

Ferroelectricity, Multiferroics, and Enhanced Magnetoelectric Effect in Single-Atomic Layers

Source of Support: Air Force Office of Scientific Research

Total Award Amount: $228,000 Total Award Period Covered: 08/01/2017-07/31/2020

Location of Project: Washington University

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: 1

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Accelerated Discovery of New Quantum Properties by Proximity Ferroelectric Effect in Two-Dimensional van der Waals Heterostructures

Source of Support: National Science Foundation

Total Award Amount: $2,000,000 Total Award Period Covered: 08/01/2019-07/31/2023

Location of Project: Washington University

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: 1

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: QLCI-CI: Center for the Simulation of Engineered Quantum Materials

Source of Support: NSF

Total Award Amount: ~$160,000/year Total Award Period Covered: 09/01/20-08/31/25

Location of Project: Washington University

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: 1

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support
Chuanwei Zhang

Current support

- **Title**: Quantum phases and dynamics of periodically driven ultra-cold atomic gases
  PI: Chuanwei Zhang
  Agency: Army Research Office
  Award #: W911NF-17-1-0128
  Amount: $560,000
  Period: 03/15/2017-03/14/2021
  Project Location: The University of Texas at Dallas
  Summer month: 1
  Brief description: Studying quantum phases and dynamics of ultracold atoms in the presence of time-dependent potentials and parameters. No overlaps with the proposed research.

- **Title**: Spin - orbital angular momentum coupled ultra-cold atomic gases
  PI: Chuanwei Zhang
  Agency: National Science Foundation
  Award #: PHY-1505496
  Amount: $240,000
  Project Location: The University of Texas at Dallas
  Period: 08/01/2015-07/31/2019
  Summer month: 1
  Brief description: Studying ultracold atomic gases in the presence of spin-orbital angular momentum coupling. No overlaps with the proposed research.

- **Title**: Novel quantum matter in ultra-cold atomic gases with synthetic spin-orbit coupling
  PI: Chuanwei Zhang
  Amount: $360,000
  Agency: Air Force Office of Scientific Research
  Award #: FA9550-16-1-0387
  Project Location: The University of Texas at Dallas
  Period: 09/01/2016–08/31/2019
  Summer month: 1
  Brief description: Explore novel quantum matter in the presence of spin orbit coupling. No overlaps with the proposed research.

- **Title**: Spin tensors in ultracold atomic gases
  PI: Chuanwei Zhang
  Amount: $240,000
  Agency: National Science Foundation
  Award #: PHY-1806227
  Project Location: The University of Texas at Dallas
  Period: 08/01/2018–07/31/2021
  Summer month: 1
  Brief description: Explore the role of spin-tensors in ultracold atomic gases. No overlaps with the proposed research.

- **Title**: Lossless hyperbolic metamaterials: fundamentals and applications
  PI: Qing Gu (UTD), co-PI: Chuanwei Zhang
  Agency: The University of Texas at Dallas (Internal grant)
  Amount: $100,000
  Period: 08/01/2019-07/30/2020
  Project Location: The University of Texas at Dallas
  Summer month: 0
  Brief description: Propose to experimentally and theoretically study lossless hyperbolic metamaterials. No overlaps with the proposed research.

Pending support

- **Title**: Ultracold atoms for sensing and simulating neutron stars physics
  PI: Peter Engels, co-PI: Michael Forbes (WSU), Chuanwei Zhang (UTDallas)
  Agency: Department of Energy
  Amount: $1,000,000
  Period: 09/01/2019-08/31/2022
  Project Location: The University of Texas at Dallas
  Summer month: 1

- **Title**: QLCI-CI: Center for the Simulation for Engineered Quantum Materials
  PI: Richard Scalettar (UC Davis), co-PI: Chuanwei Zhang (UTDallas)
  Agency: National Science Foundation
  Amount: $158,000/year
  Period: 09/01/2020-08/31/2025
  Project Location: The University of Texas at Dallas
  Summer month: 1

Facilities, Equipment, and Other Resources

University of California at Davis

Scalettar's computational facilities at UC-Davis

For carrying out the computations in this proposal, the Scalettar group has a devoted cluster of 37 workstations. Seventeen of these have four cores (2.4 GHz to 3.0 GHz). The remaining 20 have eight 3.2 GHz cores. These 228 cores represent adequate computational resources for the work described here. Jobs are either run in parallel with MPI or as single core jobs to sweep parameter space. The 'Sun Grid Engine' queueing system prioritizes jobs and ensures they run efficiently. In addition, the group has a set of 11 stand-alone desktop machines, each with four to eight cores, for use for further calculations by students and postdocs. These represent a further 60 cores, although they are not set up with a formal queueing system. We have done considerable work optimizing our codes on these platforms. This collection of machines can also be used for the management of data produced by the project.

The Physics Department at UC Davis has a cluster of sixteen four core (3.2 GHz) Linux PC's which are available for undergraduate and graduate student use. The department supplies IT support, printers, internet connections, etc.

In past research projects, we have written successful requests for supercomputer time, and we are prepared to do that here as well. However, given our dedicated cluster, and supercomputer resources available to our collaborators, we do not anticipate the need for such resources for the work described in this proposal.

University of California at Irvine

White's computational facilities at UC-Irvine

The University of California at Irvine is in the midst of a significant upgrade to the campus computing facilities, which would be ideally used for computations by White's group. The upgrade contains contributions from the campus and also from external funding. Two options will be open: per-hour purchases and purchasing physical hardware and then converting to core hours. The current assumption is the recharge rate will be between $0.0125 to $0.014 per core hour. These will be high-capacity nodes with 40 cores per node, large amounts of memory, and nodes with GPUs will also be available. These nodes will be ideal for DMRG calculations, and are expected to come online in Fall, 2019. The recharge rates will be equivalent to about $1,250/(100K hrs.), providing ample computing resources at modest cost to the group.

San Jose State University — California

Khatami's computational facilities at SJSU

High-Performance Computing Cluster: Spartan

Through an NSF Major Research Instrumentation grant (OAC-1626645), on which Dr. Khatami has served as a co-PI, San Jose State University recently acquired a high-performance computing and data storage facility for STEM research and education, which has been operating since summer of 2017. It has the following specifications:

- 72 regular compute nodes, each consisting of 2 fourteen-core E5-2680v4 2.4GHz Intel Xeon processors, 128GB of RAM, and 200GB of SSD,
- 2 high-memory nodes, each consisting of 2 six-core E5-2643v4 3.4GHz Intel Xeon processors, 526GB of RAM, and 800GB of SSD,
- 4 GPU nodes, each consisting of 2 fourteen-core E5-2680v4 2.4GHz Intel Xeon processors, 128GB of RAM, 1TB of HDD, and 2 NVIDIA Tesla K40 GPUs (2,880 cores per GPU),
- 2 login nodes, each with 2 fourteen-core processors,
- 1 DDN GPFS high speed storage (257TB),
- 1 Long-term storage - Pinnacle 4X3601H36, and 2 additional L-T storages (total of 277TB)

Overall, there are 2,208 cores and 10.7TB of RAM. The cluster has an Infiniband network, runs CentOS and has all the common compiler packages installed, ideal for parallel processing.

Other smaller computing facilities in the Physics and Astronomy Department, such as a 4-node cluster with 96 computing threads and 768GB of RAM, are also available for research and instructional purposes.

The Department has a Physics/Astronomy Simulation and Visualization Lab (shown below), which has several Mac workstations, and provides a collaborative research environment for students.

Fig. 1 Spartan high- performance computing cluster at SJSU.

Fig. 2 Physics/Astronomy Simulation and Visualization Lab at SJSU.

University of Texas at Arlington

Kirk's experimental facilities at UT-Arlington

Several high-resolution materials characterization tools at the University of Texas at Arlington are available for this program. These tools are operated by two full-time staff members, Dr. Jiechao Jiang and Mr. David Yan. These facilities fall under the general campus rubric as the Characterization Center for Materials and Biology, which is an open-access, university-wide user facility that encompasses the following four main equipment groups in a ~10,000 sq. ft. space:

X-ray diffraction facility

- Bruker D8 X-ray diffractometer equipped with 6-axis Eulerian cradle, allowing even the most sophisticated X-ray diffraction techniques such as the glancing angle scattering.
- Simens D500 diffractometer equipped 2-axis theta-2theta optics
- Triple axis high resolution X-ray diffractometer for Rocking curve analysis
- X-ray diffraction simulation (RADS, LAUE, JCPD)

Electron Microscopy facility

- Hitachi H-9500 HRTEM with 0.18nm point-to-point resolution with EDX
- JEOL 1200EX STEM with EDX detector
- Hitachi S-5000H high resolution SEM with a cold emission gun
- Hitachi S-3000N environmental SEM
- JEOL JSM 6100 for user training purpose
- HRTEM image simulation software (MACTEMPAS)
- TEM sample preparation facility, including 2 precision ion mills.

Electron & Optical Spectroscopy facility

- Perkin Elmer Phi 560 ESCA capable of conducting XPS and AES analysis and imaging
- Thermo-scientific DXR micro-Raman spectroscopy and microscopy
- Thermo-Nocolet 6700 FTIR spectroscopy and microscopy

Scanning Probe Microscopy facility

- Park XE70 AFM with complete attachments and can produce STM, MFM, EFM, SEPM, SThM images.
- Hysitron Ubi Nano-indenter with AFM attachment

The Shimadzu Institute Nanotechnology Research Center (NanoFAB Center for brevity) was founded by co-PI Kirk in 1989 when he was a full-time tenured professor at Texas A&M University. In 1999 he moved this facility to University of Texas at Arlington (UTA), where it currently resides in a 35,000 square-foot building on the UTA campus outfitted with a general-purpose cleanroom facility and a variety of other fabrication and characterization tools with support staff.

Materials Processing, Device Fabrication, Clean room Environments

Semiconductor materials, synthesis, processing, and device fabrication, as well as teaching, are done in a 9,393 square-foot clean room that is divided into 3,300 sq. ft. of Class 1000, 3,028 sq. ft. of Class 10,000 and 3,065 sq. ft. of accessory space with well-controlled temperature and humidity conditions. A special area is designed for teaching cleanroom procedure and fabrication. The loading dock and storage areas are designed to ensure that safety and security standards are met for gases and chemical handling. The Class 1000 space is divided into an alcove, three bays, and four service chases. The Class 10,000 space is divided into a teaching bay, materials synthesis bay, and three services chases. A research scientist and four senior research associates guide the operation, maintenance, and management of this facility with added support from graduate students and technicians. Major items in the bays are as follows:

Bay 1: Photo Lithography (Yellow Room)

- OAI Model 1806 manual Front/Backside Contact Mask Aligner
- Nanonex NX-B200 Contact Mask Aligner
- Blue M IGP 6680 Inert Atmosphere Oven
- EVG 620 Aligner
- ZEISS 1540XB Cross Beam E-Beam Writer
- Karl Suss MA-56 aligner
- Wild-Leitz 5-160x inspection microscope
- Reichert 300604 Polyvar 2-100x inspection microscope with Polaroid camera attachment
- One 15" Headway resist spinner
- One Macronetics spinner
- Two Blue M 0V-8A bake ovens & two hot chucks for up to 4” diameter wafers
- Bransom 1210 ultrasonic cleaner
- 8-foot Poly acid and 4-foot stainless Steel solvent hoods
- 8-foot SS solvent and 4-foot acid Poly hood

Bay 2: Characterization

- Ocean Optics NC-UV-VIS Reflectometer
- Zeiss LSM 5 Pascal Confocal Microscope
- ZEISS Supra 55 VP Scanning Electron Microscope
- Digital Instruments Dimension 5000 scanning probe microscope up to 8” wafer
- Veeco Instruments FPP5000 4-point probe system
- HP 4061A Automated C-V and I-V system with heated chuck, dark box, and vacuum chamber
- Probe system with motorized chuck & analog curve tracer
- Leitz Ergolux 5-100x inspection microscope with video output
- Assorted inspection microscopes and video inspection microscopes
- Two Ellipsometers (Gaertner Sci. Corp L116A) automated with HP 9826
- West Bond 7476E-79 Wedge Wire Bonder
- KLA-Tencor Alpha-Step IQ Profilometer

Fig. 3 Device characterization Bay 2 in UTA NanoFAB clean room.

- Nomarski Microscope
- Electroglass probe station

Bay 3: Main Processing

- AJA e-gun UHV Evaporation System
- Cressington Gold Sputtering Deposition
- Neocera Pulsed Laser Deposition System
- Custom designed sputtering system with 3” rapid change target, and heated stage
- Oxford Reactive Ion Etching System (Plasma Lab 80 Plus)
- KJL LAB 18 Sputtering
- Diener Electronics Asher
- TRION ORION II PECVD/LPCVD system
- TRION Deep Reactive Ion Etching (DRIE) System
- TRION MINILOCK II RIE System
- AG Associates Heatpulse 210 Rapid Thermal Anneal
- TYSTAR TYTAN Mini 3600 Three Stack Horizontal Furnace System
- TYSTAR LPCVD Nitride
- Two Minibrute oxidation furnaces
- AXIC Jetfirst 150 Rapid Thermal Anneal
- LFE Pos-504 plasma stripper
- Technics Micro-RIE Series 800 reactive ion etcher
- Plasma-Therm model 530 plasma enhanced CVD/etch system
- Supercritical Point Dryer

Bay 4: General Purpose

Bay 5: Alcove

- Plasma Quest Sputtering system with 3-4” rotating targets, heated stage, and load-lock
- CHA Systems cryo-pumped 4-source e-beam evaporator with optical film monitor
- AJA ATC ORION Series Sputtering System

Bay 6: Teaching Fab

- Microscopes
- Karl Suss MJB-3 aligner
- Branson 1200 ultrasonic cleaner
- AJA ATC ORION Thermal Evaporator
- Ovens (prebake and post bake)
- Thermix stirring hot plate 310 T
- MiniBrute Diffusion Furnace
- Lindberg Oxidation Furnace
- HP Electrical Test Station
- Gaertner Ellipsometer
- Jandel Four-Point Probe System with RM3 test unit
- Kilucke & Soffa 4524 Ball Bonder
- NRC Thermal Evaporator
- EVG 5201S Wafer Bonder
- Disco DAD3220 Automatic Dicing Saw
- Microautomation 1100 Dicing Saw

Zyvex Labs (Richardson, Texas)

Owen's and Randall's experimental facilities at Zyvex Labs

Zyvex Labs has all the primary equipment required for the proposed project. At Zyvex Labs: three UHV STMs, a separate chamber for delta layer fabrication, an SEM, AFM, an interferometer, probe stations, and other analytical equipment. Within this program, Zyvex Labs expects to purchase miscellaneous UHV components for simple customization of their UHV STM systems for optical access and felicitous gas delivery. These systems are operating in the $1x10^{-10}$ Torr range or better. Zyvex Labs has developed a real-time STM control system that has 20-bit resolution samples current at 100 kHz and has latencies of no more than a few nS. We have already creep and hysteresis correction and an auto-adjusting PI control loop. The system is highly automated and includes a scripting language and powerful data collection and computing resources making it an ideal tool for machine learning.

Fig. 4 Views of two of the three Zyvex Labs UHV STM systems.

The following key equipment is available at Zyvex Labs:

- Two Beam Interferometer – SIOS SP 120 DS
- Scanning electron microscope – Hitachi 4700 Field Emission SEM with Oxford X-ray Analysis Unit
- Atomic Force Microscope – Digital Instruments
- UMECH MEMS Motion Analyzer with vacuum and variable temperature stages
- MEMBLER – Custom 5 degree of freedom MEMS assembly robot
- Probe stations
- Two Home Built Ultra High Vacuum Scanning Tunneling Microscopes (shown above)
- A UHV Field Ion Microscope
- A fume hood
- Optical benches with ample optical components
- Multiple computer stations
- SolidWorks with FEA analysis for mechanical and thermal simulations
- Other electronic and analytic equipment

3D Epitaxial Technologies (3DET) (Richardson, Texas)

Kirk's and Maldonado's facilities at 3DET

The proposed project will be supported by 3D Epitaxial Technologies (3DET), which is located at 999 E. Arapaho Road in Richardson Texas, about three-quarters of a mile from Zyvex Labs. 3DET is owned by Wiley P. Kirk and partner Eduardo Maldonado. As part of its business activities, this research and development company provides research space and equipment for students from the University of Texas at Arlington and the University of Texas at Dallas working under Professor Kirk's guidance. The company rents three suites at this location. One suite for office and conference activities occupies 800 square feet, while the laboratory-workspace suites occupy another 1,400 square feet. Within this space are two chemical exhaust fume hoods - a stainless steel unit for solvents and pyrophoric type materials and a second polypropylene hood for acidic and related corrosive materials. Conveniently located in a set of suites that neighbors 3DET's space is High Tech Services. High Tech Services has been in business for more than 25 years. It provides fabrication, repair and maintenance services for high vacuum and ultra-high vacuum equipment and related helium leak detection services. They maintain a complete machine and electronics shop and components stockroom to support these services as well as other customer projects at a nominal charge rate.

The main instruments at 3DET that will be available for this project are tools to do materials and surface synthesis in UHV environments, metal e-beam evaporation for contacts (Pt, Au, Ti, Al), and materials characterization such as magneto-transport and Fourier transform infrared measurements as described below.

Molecular/Chemical Beam Epitaxy

A modified Perkin Elmer UVH system, which consists of a preparation chamber and a growth chamber interconnected via a gate valve, operates at base pressures in the low 10^{-10} mbar range without liquid nitrogen cooling (see Fig. 5). The preparation chamber has a load lock and it is pumped via a combination diaphragm-turbo vacuum system and one ion-pump. Also mounted in the prep chamber is an RGA for gas analysis, FTIR for substrate surface characterization, and an SVT Associates atomic-hydrogen source. The growth chamber has eight ports and corresponding shutters for effusion cells, one port is current occupied with SVT Associates e-beam source for Si, while another has Al K-cell. *In-situ* RHEED in the growth chamber is used to characterize substrate surface conditions. The growth chamber is maintained under UHV conditions using an ion pump, Ti sublimation pump, and a cryopump and has internal liquid nitrogen shrouds to control cross contamination effects from the sources. The rotating substrate heater/holder and sample-puck transport assembly accommodates wafer sizes up to 51 mm diameter.

Magneto transport, optical spectroscopy, and Hall mobility characterization

The magneto transport measurements (van der Pauw and Hall bar) mobility, sheet resistance, sheet carrier density, doping type) characterization tool features four major equipment items: (1)a superconducting cryostat, consisting of (a) liquid helium Dewar with homebuilt probes, (b) 50.8 mm dia. superconducting solenoid (0 - 5 T, with persistent switch) that can cover a temperature range from 2.0 K to 300 K. (2) A closed-cycle cryostat for magneto properties measurements (optical spectroscopy, magnetoconductivity, and van der Pauw and Hall measurements. The cryocooler is manufactured by Advanced Research Systems, Inc. which is a Displex™ Plus Closed Cycle System Model CSW-202+ with an optical access tail section that can be inserted into the pole pieces of standard electromagnet with moveable pole pieces (water cooled, 0 - 1.0 T). This system has a cooling capacity of 50 mW at 4.2 K, and a highest operational temperature of 450 K. (3) A UV-visible monochromator (Newport C-130 UV/VIS 1/8 m Cornerstone) with a motorized scan range of 200 nm – 1600 nm. There is also associated free space optics and a chopper detection system. (4) A computer controlled I – V electronic measurements and data recording (Lab View) system based on instrumentation manufactured by Keithley and HP. The FTIR spectrometer shown in the righthand panel of Fig. 5 is a Thermo Fisher Nicolet 6700 FT-IR Spectrometer with a spectral range of 350 to 7800 cm-1. It has a MCT A liquid nitrogen cooled detector.

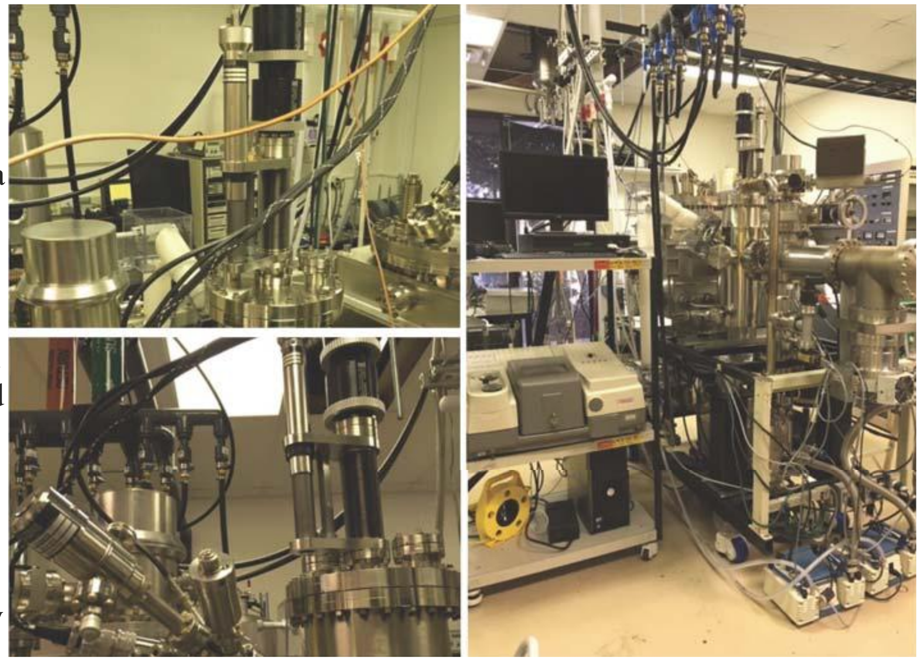

Fig. 5 Alane doping source apparatus.

E-beam evaporation and metal contact processing equipment

The CHA SEC-600-RAP vacuum evaporator shown in Fig. 6(a) is equipped with a 4-pocket e-beam source for 7 cc capacity crucibles. Pumping system is a mechanical pump and a cryo-pump combination. Samples are installed on a rotating plenum for optimal uniformity, and the thickness of deposited layers is measured with a film thickness monitor. Other equipment used to form metal contacts shown in Fig. 6(b), (c), and (d).

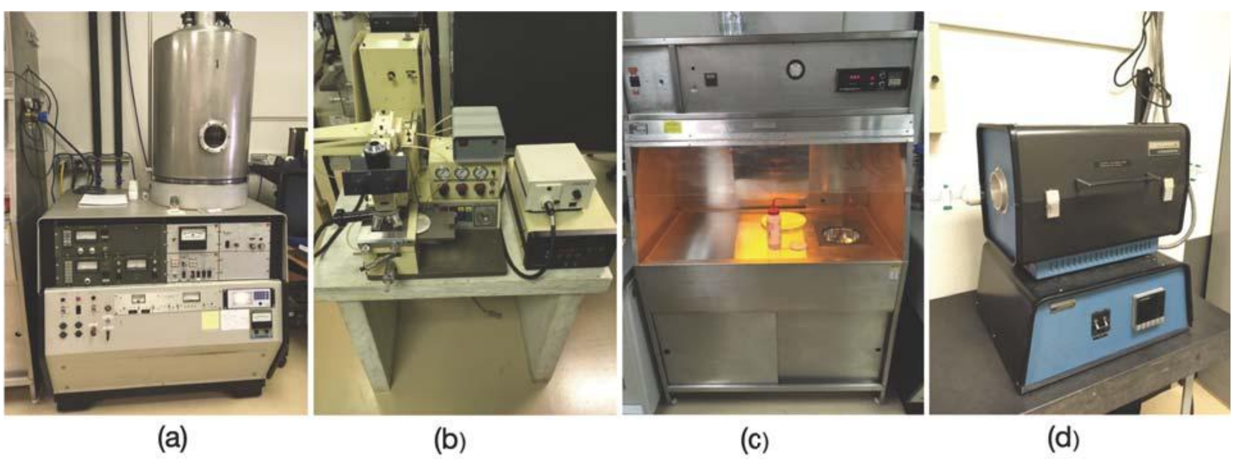

Fig. 6 (a) CHA metal e-beam evaporator, (b) Karl-Suss MJB-3 mask aligner and exposure unit, (c) Photoresist spinner in SS hood, (d) Tube furnace for annealing contacts

University of Texas at Dallas

Moheimani's facilities at UT-Dallas

Laboratory for Dynamics and Control of Nanosystems

PI Moheimani established and directs the Laboratory for Dynamics and Control of Nanosystems at the University of Texas at Dallas. This laboratory was established (and continues to grow) using a STARS grant from the state of Texas to facilitate his relocation from University of Newcastle, Australia to UTD.

This Laboratory is a state-of-the-art research facility for design, modeling, characterization, and control of micro- and nano-systems. The laboratory is housed in a dedicated space of 1,100 sq. ft in ECSW Building on the University of Texas at Dallas campus. It currently has the following equipment:

- Polytec MSA-100-3D 3D-Micro System Analyzer (one of only two in the United States at the moment)
- Zurich Instruments H2FI Lock-in Amplifier (x3)
- AFM-Workshop Atomic Force Microscope
- TPT HB05 Wire-bonding Machine
- CASCADE-MICROTECH Probe Station
- ONOSOKKI FFT Analyzer CF-9400
- KEYSIGHT DSO-X 2024 Digital Storage Oscilloscope
- EK PRECISION 4054 25 MHz Arbitrary Function/Waveform Generator (x2)
- TTi QL564 Power Supply (x4)
- AMScope MX6R Optical Microscope
- Newport Optical Table (x2)
- dSPACE MicroLabBox rapid prototyping system (x3)
- KEYSIGHT E49990A Impedance Analyzer
- Stanford Research Systems SR-560 pre-amplifier (x2)
- FLC Electronics A400DI High Voltage Linear Amplifier (x2)
- PiezoDrive Amplifiers (x5)

As well as several workstations, a soldering station and many other smaller equipment and instruments that are not stated here.

In addition to the laboratory space, Dr. Moheimani's students and postdocs have access to dedicated office space with desks and computers.

Resources Available in the Erik Jonsson School of Engineering & Computer Science

- A machine shop is equipped with 3 CNC lathe machines, one Monarch lathe, 4 CNC mills, 3D printers using ABS as the model material, one plasma cutting station, grinding machines, metal forming machines, welding equipment, *etc*.
- Seven Instron electro-mechanical Instron machines (up to 10 metric ton force) for mechanical testing. Various fixtures are available including a self-aligned tensile fixture, a self-aligned compression fixture and an Arcan fixture for testing under biaxial stress state at both small and large strains. An Instron temperature chamber is available to allow materials characterization on an Instron machine under isothermal condition between -160 ºC and 300 ºC. An MTII SEM Tester for use with an SEM; the tester can apply tension, or compression on a sample, such as a single grain sample while SEM images are acquired.

Resources Located at the Natural Science & Engineering Research Laboratories (NSERL)
Advanced Microscopy Laboratory at UTD (http://mse.utdallas.edu/facilities/overview.html)
The following relevant facilities are available for this project.

- Optical Surface Infrared Spectroscopy
- A FEI Nova 200 NanoLab, which is a dual column SEM/FIB equipped with a Zyvex F100 nano-manipulation state. It combines ultra-high-resolution field emission scanning electron microscopy (SEM) and focused ion beam (FIB) etch and deposition for nanoscale prototyping, machining, 2-D and 3-D characterization, and analysis.
- A JEOL 2100 F high-resolution transmission electron microscope (TEM), which is a 200 kV field emission TEM with a resolution of better than 0.19 nm, and *in-situ* STM/TEM analysis unit.
- A JEOL ARM200F TEM, with atomic resolutions.
- A Rigaku Ultima III X-ray Diffractometer system. The instrument enables a variety of applications such as in-plane and normal geometry phase identification, quantitative analysis, lattice parameter refinement, crystallite size, structure refinement, residual stress, density, roughness (from reflectivity geometries), and depth-controlled phase identification.
- A Raith 150 E-beam system.

Cleanroom Research Laboratory at UTD (http://www.utdallas.edu/research/cleanroom/)
A fully equipped Cleanroom Research Laboratory is available for this project. It is managed and maintained by 6 full-time professionals. The facilities are available to graduate students, and postdocs and the engineer involved in this project. The Lab includes the following major pieces of equipment.
Characterization & Metrology

- Leica INM 200 Optical Microscope
- Leica INM 100 Optical Microscope
- Zeiss Supra 40 Scanning Electron Microscope
- Veeco Dimension 5000 SPM
- Sentech Ellipsometer
- Prometrix Auto 4-point probe
- Alessi 4-point probe
- Thermo Electron FTIR Spectrometer w/Ge ATR
- TOHO FLX2320 Thin Film Stress Measurement
- Veeco Dektak VIII Profilometer
- Nanometrics Nanospec Film Thickness
- Rame'-Hart Goniometer (page under construction)

Deposition

- Tystar LPCVD Furnace
- Plasma-Therm 790 PECVD
- Cambridge Atomic Layer Deposition
- SCS Parylene Deposition

Plasma Etch

- Plasm-Therm ICP-Metal Etch
- Plasma-Therm Dielectric Etch & DSE
- Plasma-Therm III-V

- Technics RIE
- March Asher PX250

Lithography
- Heidelberg DWL66 Laser Writer
- Quintel Q4000-6 Contact Printer
- Karl Suss MA6B Contact Printer
- Obducat Nano-Imprinter NIL-2.5" Imprint
- Ultratech Mask Cleaner
- CEE Spin Coater
- Headway Spinner
- CPK Chrome Etch & Base Develop
- CPK Solvent Develop
- Blue M Ovens
- Cole Parmer Ovens
- HMDS
- Cole Parmer Digital Hot Plates
- TPS Digital Hot Plates
- Raith 150-TWO E-Beam Litho (page under construction)

Packaging
- K&S Ball Wire Bonder
- K&S Chisel Wire Bonder

Thermal Processing
- JetFirst RTP
- MPTC600 RTP
- MiniBrute Furnace
- Tystar Diffusion/Oxidation Furnace

Thin Film Deposition
- Cryo-evaporator e-gun Deposition
- Temescal e-gun Deposition
- CHA Mark 50 e-gun Evaporator
- Denton Vacuum Thermal Evaporator
- Hummer VI Sputter (for SEM samples)
- AJA 1500 Sputter
- AJA Orion Sputter

Surface Chemistry (Wet Processing)
- Avenger Basic Dual Chamber Spin Rinse Dryer
- Tousimis Supercritical Drier (MEM structure release)
- Samco UV Ozone Stripper/Cleaner
- Acid Hood
- Base Hood
- RCA Hood
- General Solvent Hood
- Solvent Hood

Zhang's theory group facilities at UT-Dallas

The numerical simulations at UT-Dallas will be done mainly on a small computer cluster in the Zhang group that consists of 448 cores and one GPU node. For larger scale numerical calculations, if necessary, the Zhang group has access to the Lonestar cluster of the Texas Advanced Computing Center, which has 22,656 cores and eight GPU nodes.

Saint Louis University

Kuljanishvili's experimental facilities at STL

Facilities and Equipment's in the Department of Physics

The Kuljanishvili research labs are located in a total of 920 square feet space (rooms 112 and 110) in Shannon Hall on the North Campus of Saint Louis University.

The Kuljanishvili Laboratory is a nanoscience and nanofabrication laboratory that is equipped with surface science, materials fabrication, and device characterization tools. Atomic Force Microscope (Parks System NX10) and Nanolithography Patterning Platforms (custom built)- both instruments are housed in Room 110, (SPM LAB with enhance vibrational and acoustic noise isolation). The main lab, Rm 112, is equipped with a home built Chemical Vapor Deposition system, clean Chemical Hood (NUAIRE), Spin coater (Laurell Tech. Corp.), ultrasonic cleaner (Thermo Fisher), analytical balance (Mettler Toledo) , and UV ozone cleaner (NovaScan PSD), and Mili-Q water purification system, Cryogenic Probe station, (Lake Shore TTPX System), Nikon Optical Microscope (5x, 20x, 40x, 100x objectives), and two stereomicroscopes are also located in the main laboratory space.

In addition to the equipment in Kuljanishvili Labs in Shannon Hall, a Raman Spectroscopy System located in Monsanto Hall, a shared laboratory space. Raman Spectrometer was purchased in July 2014, with an NSF MRI grant. This instrument is equipped with three lasers (532 nm, 633 nm, 785 nm). The instrument has been actively used by Dr. Kuljanishvili in her research program and in the teaching of upper division Physics courses. Dr. Kuljanishvili currently serves as both the custodian and contact person for this instrument.

Washington University in St Louis

Yang's theory group facilities at WUSTL

1. Washington University will provide necessary office space and administrative help to carry out this proposed research plan.
2. Super computer facility supported from Extreme Science and Engineering Discovery Environment (XSEDE)
   Grant # TG-DMR100005
   Award: 37,347 node hours (reach node contains 64 cores) from the Stampede2 cluster located in the Texas Advanced Computing Center (TACC) (around the similar amount of CPU hours every year)
   Stampede2 is the flagship supercomputer at The University of Texas at Austin's Texas Advanced Computing Center (TACC). A strategic national resource, Stampede2 provides high-performance computing capabilities to thousands of researchers across the U.S. It entered full production in Fall 2017 as an 18-petaflop system that builds on the successes of the original Stampede cluster it replaced. Stampede2 features 4,200 Knights Landing (KNL) nodes — the second generation of processors based on Intel's Many Integrated Core (MIC) architecture —and 1,736 Intel Xeon Skylake nodes.

System features:

- Strategic national resource serving thousands of researchers across the nation
- 18 petaflops of peak performance
- 4,200 Intel Knights Landing nodes, each with 68 cores, 96GB of DDR RAM, and 16GB of high speed MCDRAM
- 1,736 Intel Xeon Skylake nodes, each with 48 cores and 192GB of RAM
- 100 Gb/sec Intel Omni-Path network with a fat tree topology employing six core switches
- Two dedicated high performance Lustre file systems with a storage capacity of 31PB
- TACC's Stockyard-hosted Global Shared File System provides additional Lustre storage

Washington State University

Engels' experimental facilities at WSU

The quantum gas experiments that the Engels group will conduct in the frame of this project will take place in the Fundamental Quantum Physics lab at Washington State University (WSU) which is led by PI Engels. Since 2006, this lab has acquired extensive experience with quantum gas experiments. The apparatus reliably produces Bose-Einstein condensates of ^{87}Rb and degenerate Fermi gases of ^{40}K on a routine basis. Environmental magnetic field fluctuations are actively controlled at the sub-mG level, which is essential for the proposed experiments. Single-mode, single frequency infrared lasers at 830 nm, 1064 nm and 1540 nm are available for the generation of dipole traps and optical lattices. 1D, 2D and 3D static lattices, 1D moving lattices and a superlattice have been realized with this apparatus as well. A Ti-Sapphire laser system is available for driving Raman transitions.

The laboratory is located in a 400 square foot air-conditioned room in the Webster building on the WSU Pullman campus. The PI's space also includes a dedicated electronics room for fabricating custom circuits, and a sample preparation room with glovebox and a HEPA filtered clean air box for the assembly of atomic sources, UHV parts, and sensitive optics. WSU provides student offices directly adjacent to the lab. The computers needed for the data analysis are available in the lab. The department provides computing and networking support and access to a 3D printer.

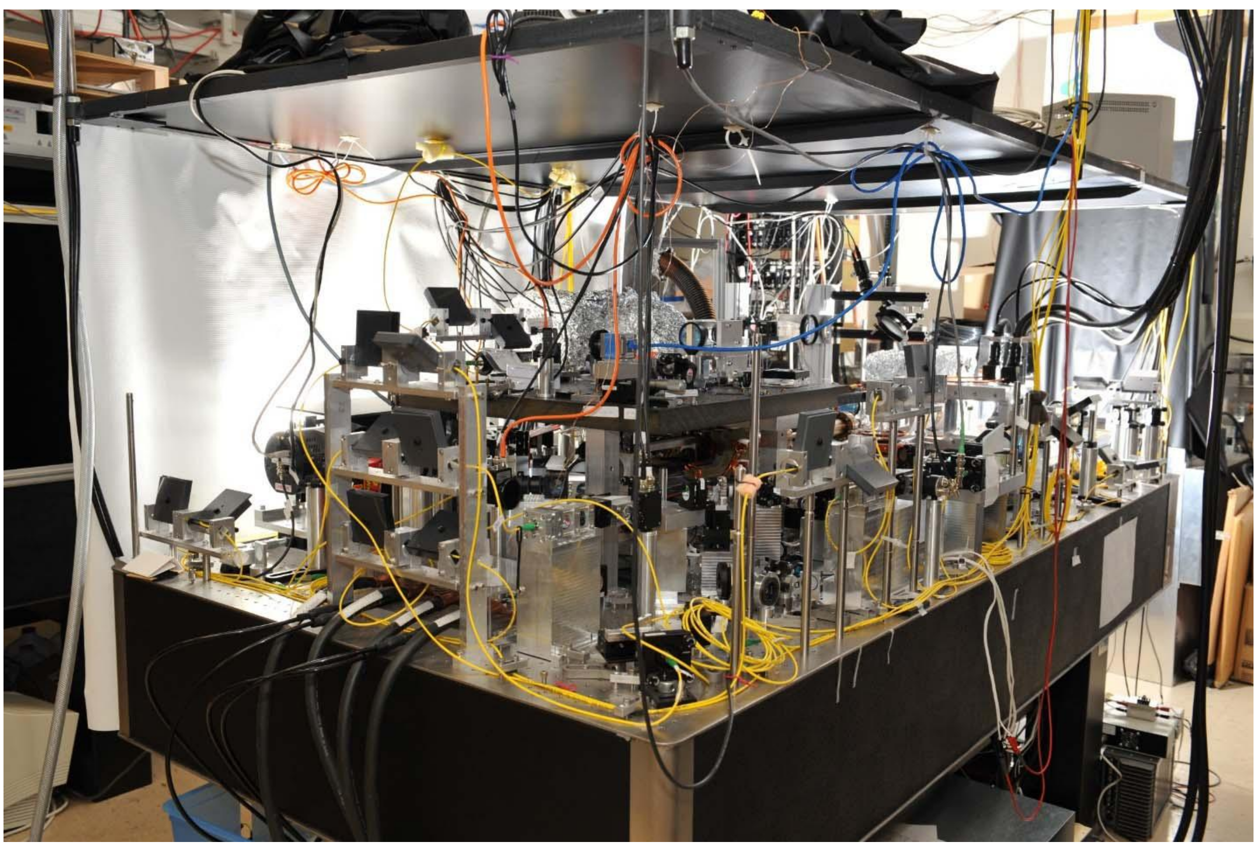

Fig. 7 Quantum gas apparatus in the Engels lab at WSU. Additional optics tables, not shown in this image, hold the optics and lasers that provide laser light needed to cool, trap, manipulate, and detect ultracold quantum gases.

All students involved in this project will have full access to a student machine shop equipped with a milling machine, three lathes, a drill press, band saw, shear, and a variety of hand tools. Professional machining services are provided by WSU's Technical Services unit, located in the same building as the Department of Physics and Astronomy. The Technical Services instrument shop employs a team of skilled technicians providing custom solutions. This is a state-of the art facility which is well known throughout Eastern Washington for its outstanding expertise and instrumentation. The instrumentation includes, among others, four-axis CNC milling machines with 20"x40" capacity, CNC lathes, a welding shop that can produce UHV parts, an industrial-grade 3D printer, *etc*. The instrument shop is capable of handling a wide variety of materials, including exotic components such as metal-ceramic composites and high-temperature alloys. Electronics support is provided by the Technical Services Electronics shop. An electrical engineer employed by this shop has professionally designed numerous electronic circuits for the experiment in the past, including high-current servo loops, shutter drivers, photodiode detectors, laser support electronics *etc*.

Forbes' theory group facilities at WSU

All the software used is based on open-source projects. Development work can be done on existing personal computers, Dell Precision T1700 MT BTX Base computers, with NVIDIA Quadro K2200 4 GB graphics cards, and computers provided by the department and students. For more serious calculations, we have access to a variety of medium-scale computing resources through the WSU center for institutional research computing (CIRC). WSU has made an important investment in support of research computing for its researchers by acquiring a $1.3M condominium-style computational cluster referred to as the Kamiak cluster. This is a heterogeneous architecture for testing different development strategies, including 32 CPU compute nodes (two Intel E5D2680v2, 20 total cores / 40 total threads: 256 GB random access memory (dram), 400 GB SSD, 10 GbE, FDR Infiniband), 2 GPU nodes (two Intel E5D2670v3, 24 total cores / 48 threaded cores 2 Tesla KD80 GPUs / 9984 CUDA Cores: 256 GB ram, 400 GB SSD, 10 GbE, FDR Infiniband), and one Phi (Intel Xeon) GPU node. PI Forbes sits on the Strategic Planning committee for the WSU CIRC. Extremely large-scale simulations (*i.e.* for fermionic superfluids) will be performed at leadership class computing facilities supported through programs such as INCITE, XSEDE, and the partnership for advanced computing in Europe (PRACE).

University of Washington

Gupta's experimental facilities at UW

Dr. Gupta's group occupies a 600 sq. ft. laboratory space in the University of Washington Physics and Astronomy Building. This laboratory is well equipped to carry out the proposed research program. Within this space is an Yb quantum-gas apparatus. It features a 40 mW, 399 nm laser system (TOptica BlueTune) and a 600 mW, 556 nm laser system (TOptica TA-SHG-Pro) for the ytterbium optical transitions needed for laser cooling and momentum space manipulations; 18 W, 532 nm solid state laser (Coherent Verdi) for optical dipole trapping. Additional equipment includes vacuum apparatus and associated equipment to do Yb quantum degenerate gas preparation.

Adequate computer equipment for controlling experimental apparatus, for data acquisition, and to do data analysis is available.

Office space is available for the PI, with Ethernet connections to the Department's computing facility. Additional office space adjacent to the lab is also available for the graduate students.

Finally, the Physics and Astronomy Department operates a well-equipped Instrument and Electronics shops, which are available as no cost-centers.

University of Illinois at Urbana-Champaign

Lyding's experimental facilities at UIUC

Four UHV STM systems are available for the proposed research program. They feature ultra-low thermal drift scanners designed by Lyding that have achieved thermal drift of <0.1 nm/hr. at room temperature. Two of these systems are equipped with capillary dosers that can be xyz positioned for sub-mm proximity to the STM probe-sample junction. These systems are currently configured for nanoscale metal deposition, boron dopant incorporation, and silicon deposition; all under the control of STM lithography. These systems also feature repeatable sample positioning so the same atomic location can be relocated after the sample has been removed and subsequently returned to the STM. A large suite of STM imaging, spectroscopy and lithography software has been developed for these systems. The lithography software suite includes feedback-controlled lithography for atomically precise patterning; a technique originally developed by Lyding.

University of Maryland and National Institute of Standards and Technology

Silver's experimental facilities at UM and NIST

STM facilities:

- Omicron STM 1. A full UHV facility with Omicron Variable Temperature STM, high temperature sample processing, hydrogen termination, phosphine gas dosing, LEED, AUGER, and a complete field ion field electron microscope (FIFEM). This system routinely fabricates atom-scale devices, single electron transistors *etc*., using the STM PH_3 dosing process. This system routinely operates in the low $1x10^{-11}$ torr regime and sits on a 20,000 lb. isolation slab in a 60 ft. underground temperature-controlled environment.
- Omicron STM 2. A full UHV facility with Omicron Variable Temperature STM, high-temperature sample processing, hydrogen termination, phosphine gas dosing, LEED, and AUGER. This system routinely fabricates atom-scale devices, single electron transistors *etc*., using the STM PH_3 dosing process. This system routinely operates in the low $1x10^{-11}$ torr regime and sits on a 20,000 lb. isolation slab in a 60 ft. underground temperature-controlled environment. This facility has been recently upgraded with several XHV upgrades in vacuum system preparation, gauging, coatings *etc*. to achieve $1x10^{-12}$ torr.
- Low Temperature Omicron STM. A full UHV facility with Omicron Low Temperature 3K STM, high-temperature sample processing, hydrogen termination, and phosphine gas dosing. This system has an extensive analysis chamber with XPS, LEED, and AUGER. This system routinely fabricates atom-scale devices, single electron transistors *etc*. using the STM PH_3 dosing process. The system is currently fitted with a diborane gas delivery system. This system routinely operates in the low $1x10^{-11}$ torr regime and has several vacuum upgrades to approach the $1x10^{-12}$ torr range and also sits on a 20,000 lb. isolation slab in a 60 ft. underground temperature-controlled environment. The STM at low temperature is at even lower vacuum conditions, during low-*T* vacuum processing.

Low-temperature measurement capabilities:

- 2.8 K dry cryostat with low-noise electronics and a 2 T coiled magnet. Fast turnaround cryostat for measuring a variety of devices and electronic properties and routinely used to baseline characterize devices before measuring in a dilution refrigerator. This system has 4 coax low noise lines and a variety of twisted pair DC measurement lines. There is a complete suite of control and measurement electronics for single-electron transistor measurement and other transport measurements, such as Hall, weak localization, *etc*.
- 3 K wet cryostat with low-noise electronics in a low-vibration environment. Fast turnaround cryostat for measuring a variety of devices and electronic properties and routinely used to baseline characterize devices before measuring in a dilution refrigerator. This system has 10 coax low noise lines and a variety of twisted pair DC measurement lines. There is a complete suite of control and measurement electronics for single-electron transistor measurement and other transport measurements, such as Hall, weak localization, *etc*.

- DR2: 20 mK base temperature Bluefors dilution refrigerator with a large bore 12 T magnet. This system has 10 coax low noise lines, 4 SMK high frequency 45 GHz coax lines and 6 SMA high frequency 20 GHz lines, and a variety of twisted pair DC measurement lines. There is a complete suite of control and measurement electronics for single electron transistor measurement, single atom devices, donor dot qubits, spin to charge conversion and adding rf reflectometry. We have a full suite of high-frequency control electronics, vector network analyzer, 32 GHz microwave generator, high-end variable waveform generator and other high-speed control electronics for gate operations in qubit manipulation and measurement.
- DR: 20 mK base temperature Bluefors dilution refrigerator with a large bore 14 T magnet. This system is being fitted with 8 coax low noise lines, 4 SMK high frequency 45 GHz coax lines and 4 SMA high frequency 20 GHz lines, and a variety of twisted pair DC measurement lines. There is a complete suite of control and measurement electronics for single electron transistor measurement, single atom devices, donor dot qubits, spin to charge conversion and high-frequency microwave electronics. We have a full suite of high-frequency control electronics, vector network analyzer, 32 GHz microwave generator, high-end variable waveform generator and other high-speed control electronics for gate operations in qubit manipulation and measurement.
- ^{3}He refrigerator: 275 mK base temperature Janis ^{3}He refrigerator with a small bore 10 T magnet. This system is fitted with 10 coax low noise lines, 6 SMK high frequency 45 GHz coax lines and 4 SMA high frequency 20 GHz lines, and a variety of twisted pair DC measurement lines. There is a complete suite of control and measurement electronics for single electron transistor measurement, single atom devices, donor dot qubits, spin to charge conversion and high frequency microwave electronics. We have a full suite of high-frequency control electronics, vector network analyzer, 45 GHz microwave generator, high-end variable waveform generator and other high-speed control electronics for gate operations in qubit manipulation and measurement.

Cleanroom fab equipment:

Printed circuit board design and fabrication capabilities for high-frequency, low-temperature circuit boards to allow filtering and measurement of samples at low temperatures. This includes a suite of design tools for atom scale devices and complex device layouts.

Complete NanoFab Cleanroom with daily access by many key staff members:

- ASML PAS5500/275D Stepper: It is a fully automated wafer handling system using i-line and utilizes 5X reduction and projection capability with step and repeat to transfer photomask patterns onto user substrates using 365 nm wavelength light. It has a resolution of 280 nm and Overlay accuracy of 40 nm.
- JEOL JBX 6300-FS Direct Write Electron Beam Lithography System: This is a direct write electron beam lithography system that allows users to quickly and directly pattern a variety of substrate materials with features down to 10 nm. The JBX 6300-FS offers a large 1 mm field size as well as the ability to write on curved substrates. The high precision stage provides excellent pattern stitching. It has a spot size of 2 nm. The 19-bit DAC resolution, stitching and overlay accuracies are better than 20 nm.

- Suss MicroTec MA8 Contact Aligner: This tool allows users to align patterns on the front of a substrate and to print feature sizes down to 1 µm. This tool offers a variety of exposure methods with overlay accuracy better than 500 nm.
- Heidelberg MLA150 Maskless Aligner: We use this tool for fabricating various test features for process development because of its direct-wafer writing capability and easy operation. It overcomes some of the limitations of photomask-based exposure technologies because MLA150 exposure is non-contact approach. Minimum feature size is 1 µm, overlay accuracy is 500 nm
- Heidelberg Instruments DWL 2000: This equipment is primarily used as a mask writer. It uses a high-resolution laser to expose photoresist for substrate patterning of features as small as 700 nm. The system is used both for patterning chrome on glass photomasks and sometimes used also for direct substrate writing.
- The Suss MicroTec ACS200: This is an automated photoresist coating and baking station with cassette-to-cassette substrate operation. It supports both spin coating and spray coating of photoresist on a variety of substrates.
- The Suss MicroTec Delta12AQ: This is an automated photoresist developer station, which supports temperature-controlled spray photoresist development.

Dry Etch Tools

- Unaxis 790 Reactive Ion Etcher: There are two of these tools serving as a general-purpose parallel plate plasma etching systems using fluorocarbon gases and oxygen to etch various materials. These are used for etching shallow fiducial marks (50 nm - 100 nm) on wafers
- Unaxis Shuttle line DSEII Deep Silicon Etcher: This is an inductively coupled plasma (ICP) etching system used for etching deep features in silicon. The tool uses a fast switching Bosch process that produces smooth sidewall profiles while etching silicon up to 15 µm per minute. This used for making e-beam alignment marks on chips.

Fab Metrology Tools

Nanofab has a variety of metrology tools for post fabrication analysis such as various high-resolution, stereo-optical microscopes for imaging, profilometers (Bruker Dektak XT, 6M) spectroscopic ellipsometers for thickness measurements. It also houses various electrical measurement capabilities such as four-point probes, parametric test station with the ability to measure capacitance at multiple frequencies

Thin Film Deposition and Processing

- E-beam Evaporators: Denton Vacuum Infinity 22 – These are used for depositing thin films and are capable of loading up to six source materials for deposition. The evaporator is equipped with an ion gun to clean substrates prior to deposition and to densify dielectric films during deposition. A rotating planetary substrate holder ensures deposition uniformity on substrates ranging from 150 mm diameter wafers down to small pieces.
- 4Wave IBD/BTD Cluster Sputter Deposition: This system can automatically load and unload two six-target chambers to provide users a largely unattended 24/7 deposition capability along with the densest available thin films via room temperature

physical vapor deposition. An ion-beam deposition chamber yields high density films that are pinhole-free and very smooth.

- AnnealSys RTA: This is a single-wafer, rapid-thermal process system that supports annealing processes in the NanoFab cleanroom. This tool supports anneals under several gas flows and below atmosphere pressure. This will provide an automated single-wafer annealing process for implant and ohmic contact annealing, rapid thermal oxidation, and general densification annealing.

Back-End-of-Line Tools

- Disco DAD-341 Dicing Saw: This equipment is used to cut multi-device substrates into individual chips. The system can accommodate substrates up to 4 mm thick and supports sizes ranging from 200 mm diameter wafers down to small pieces.
- Kulicke and Soffa Model 4526 Wedge Wire Bonder: This equipment is used to make electrical interconnects between a device chip and package using thin aluminum or gold wires. The NanoFab has two wire bonders, one dedicated to gold wire bonding and the other to aluminum wire bonding.

7. Data Management Plan

Well-controlled and efficient data management is an important component of our project, and will enable us to uncover new relationships through effective data acquisition, efficiently compare results from different experiments and/or simulations, and assess implications for the engineering of quantum simulators. In order to ensure strong standards to guarantee data accuracy, systematic archiving, and data-sharing with the community, our plan consists of the following components. We will use established best practices for data management and sharing, designed to ensure the integrity, preservation, and availability of all of data.

A. Types of Data

The content of the data produced in this projects include:

- Electronic data acquired by a charge-coupled device (CCD) camera representing atomic distributions obtained by optical imaging as well as oscilloscope traces of experimental elements for diagnostics.
- Image files created by microscopy techniques, such as STM, AFM, scanning electron microscopy (SEM), high-resolution transmission electron microscopy, etc.
- First-principles simulations mainly produce two types of data. One type is a large size of temporary binary data created during the simulations. They include the wavefunctions of electronic states and dielectric function matrices in plane-wave basis. The other type is the ASCII-format data. They include the output quasiparticle energy spectra, charge densities, and atomic structures of dopants in crystals.
- Data produced during materials characterization measurements.
- Data from ab initio calculations, involving QUANTUM ESPRESSO and other packages, for characterization of condensed matter nanostructures, and QMC, and other data from numerical simulations of quantum lattice models for spin, charge or superconducting properties at different temperatures, chemical potentials, correlation strengths, lattice geometry etc.

Raw research data in standard formats will be retained for appropriate periods of time by personnel (graduate and undergraduate students) working on the project, and overall by the principal investigators. As subsets of these data are extracted, regular backups of servers will preserve the entirety of the data locally in each group.

Well-documented primary experimental and simulation data, samples, and other supporting materials created or gathered in the course of this project will be made publicly available for free to the community for the validation of the results within appropriate time frames upon request. Each group will make sure that the primary data are preserved for at least five years after the completion of the project with at least one backup, and that their policies are in compliance with those of their institution and conform to NSF policy on the dissemination and sharing of research results.

Analyzed research results for the project will be shared with the community as soon as it is feasible to ensure that the public has access to the data in a timely manner. This will be done through usual means of publication in peer-reviewed scientific journals, poster and oral presentations, department seminars, and workshops. The digital machine-readable format of the data displayed in charts, figures, etc., as well as subsets of the STM, AFM, SEM, QMC data for other examples and limiting cases, will be included in the electronic supplements to the extent allowed by the journal. In other cases, they will be available upon request.

B. Source Code and Analysis Tools

In addition to the data themselves, data management and analysis tools, with additional documentation, examples, publications and presentations, when appropriate will be made available for download at the locally maintained research group websites and public sites Github.com, bitbucket.org, ResearchGate.net and/or eScholarship.

Much of the development work for this project uses open-source languages and software tools. The code will be managed under version control systems (Mercurial and Git) archiving the exact version of the code used to produce the results for each publication and analysis. The code will be managed in multiple redundant copies:1) on development machines of the PIs and their students, 2) on clusters where production runs will take place, 3) through the purchased storage devices, and 4) on public and institutional cloud servers.

Each organizational group involved with the project will utilize their respective Information Technology E-Repository archive websites to provide to the extent possible a searchable digital base that allows researchers among all workers to store and retrieve data, posters, and manuscripts in most cases at no charge. For example, research articles archived in eScholarship, are available to the public at no charge via the University of California Open Access Policy in place since July 24, 2013. A license will be granted to the University of California prior to any contractual arrangement with publishers. Universities will also automatically archive an electronic copy of any PhD thesis resulting from this work, readily available from their library webpage.

C. Data Management Support

Every campus has its own IT staff who will be providing data management support and advice on best current practices to their respective personnel involved in this project:

At UC Davis, the Department of Physics has two full-time IT staff, as well as shared IT staff with the UC Davis College of Mathematical and Physical Sciences, who provide computer support, best-practice guidelines, and advice on data management issues. They have established and maintain a cybersecurity program, and support a department website.

WSU has a center for research computing (CIRC) which manages the local Kamiak cluster (see Facilities and Equipment), providing both computing and storage options for researchers. The Department of Physics and Astronomy has 1 full-time IT support staff.

At SJSU, the University's IT Division and College of Science's Network and Computing Service have state-of-the-art security and monitoring measures in place, set forth by the California State University, and the Department of Physics and Astronomy has one full-time IT staff.

At the University of Washington, the Department of Physics and Astronomy has 4 full-time IT support staff.

At Saint Louis University, in the Department of Physics, the Kuljansihvili Research Share – a dedicated t-drive – is currently used to store copies of all data: AFM images, SEM images, and Raman spectroscopy data. Individual PI shared drives are securely maintained by SLU IT stuff personnel. Drives are also backed up on Institutional servers.

D. Supervision

Each Senior Investigator working on the project will carefully instruct and constantly monitor all personnel under their guidance, including students and staff, on the proper use and secure methods for data management. Also the same guidance and monitoring will be practiced by senior investigators with respect to physical sample and device storage and all data produced in laboratories and offices. In cases where personnel leave the project or the institutions they are affiliated with, the responsibilities for sample, device, and data management will be transferred and retained by the remaining senior investigators or other responsible officials so that the samples, devices, and data are not lost.

E. Personally Identifiable Information

No Personally Identifiable Information will be collected or stored as part of this project.

8. Postdoctoral Mentoring Plan

The PIs and other senior personnel on this proposal will play a primary role in mentoring the postdoctoral researchers (PRS) in advancing their scientific knowledge and research skills, as well as other aspects of career development. In these activities, we will be guided by *The Post-doctoral Scholars Mentoring Checklist*, authored by Shawn G. Hayes and The UC Council of Postdoctoral Scholars. This checklist was designed to assist PRS and their mentors develop the best postdoctoral experience possible by providing a framework for periodic discussions. The checklist items are based on the experiences of many PRS from around the world, and offers a range of issues to consider at various stages in the postdoctoral appointment.

The team leaders of the project will also encourage their PRS to take advantage of the extensive campus-wide programs organized by postdoctoral associations or other units in each campus. These include, orientation meetings for new PRS, sponsored by the Human Resources Departments at each institution (Benefits) and/or the Office of Graduate Studies.

Although each PR will be hired at an individual institution, and have a lead mentor at that institution, we will also assign each PRS to a secondary mentor at a different institution. For example, a PRS in an AMO experimental group will be partnered with a co-PI in a CM experimental group, or a co-PI in a theory group, depending on which synergy is most useful.

Travel support will be provided for the PRS to visit partnering institutions as well as conferences and workshops. Funds are also provided for PRS at any institution to attend a professional development series (PDS), offered free of charge by the Office of Graduate Studies at UC Davis and co-sponsored by other units, providing a variety of training opportunities on topics of professional development of interest to postdoctoral scholars including workshops on effective presentation, writing a Curriculum Vitae, publishing, getting funding, job interview skills, etc. They will also be encouraged to take advantage of other networking opportunities at their respective institutions.

Mentors will encourage PRS to develop professional relationships outside of the group and maintain a broad perspective on the field. The PRS will present his/her research work at participating institutions during project workshops or in form of department seminars and at conferences in form of oral and/or poster presentations. At least one conference presentation and one seminar at a participating institution will be arranged for each PRS with several opportunities for research talks in more informal settings.

Each group leader will arrange to have periodic one-on-one discussions with PRS to establish and refine research plans. Careful assessment and feedback will be provided to the PRS in each session, keeping in mind both the research agenda of the project and the PRS's career goals. The leader will also provide opportunities for PRS to contribute to grant writing if their time with the group coincides with a grant writing cycle. This includes grant opportunities PRS can apply to independently, such as obtaining external supercomputer resources. The PRS will also play a substantial role in the writing of research articles that are based on their work in the group.

In addition to taking part in all aspects of each group's research activities, PRS will be provided opportunities to pursue activities specifically designed to promote their professional development as independent scientists and research directors in preparation for an independent academic career. For example, they will be assigned responsibility for mastery and maintenance of major instrumentation, as well as training new users. An important role of the PRS will be to help guide and mentor graduate and undergraduate students from diverse backgrounds in each group. Team leaders will set examples by fostering a collaborative and respectful work environment and demonstrating sensitivity to the needs of the diverse population of students in their respective group.

SJSU SAN JOSÉ STATE UNIVERSITY

Physics and Astronomy
College of Science

San José State University
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TEL: 408-924-5210
FAX: 408-924-2917

July 30, 2019

To: NSF Quantum Leap Challenge Institutes (QLCI) Program

If the proposal submitted by Dr. Richard Scalettar entitled "QLCI - CI: Center for the Simulation of Engineered Quantum Materials" is selected for funding by NSF, it is my/our intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment and Other Resources section of the proposal.

Sincerely,

Ehsan Khatami
Associate Professor
San Jose State University,
Department of Physics & Astronomy

UNIVERSITY OF TEXAS ARLINGTON | DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING

July 20, 2019

To: NSF Quantum Leap Challenge Institutes (QLCI) Program

If the proposal submitted by Dr. Richard Scalettar entitled “QLCI-CI: Center for the Simulation of Engineered Quantum Materials” is selected for funding by NSF, it is my intent to collaborate and commit resources as detailed in the Project Description or the Facilities, Equipment and Other Resources section of the proposal.

Sincerely,

Wiley P. Kirk
Research Professor
University of Texas at Arlington
Materials Science and Engineering Department

Washington University in St. Louis

Department of Physics

To whom it may concern:

If the proposal entitled (QLCI - CI: Center for the Simulation of Engineered Quantum Materials) is selected for funding by the National Science Foundation, it is my intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment and Other Resources section of the proposal.

Sincerely,

Li Yang

Associate Professor
Department of Physics
Washington University in St Louis

(314) 935-9453
lyang@physics.wustl.edu

UTD

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PHYSICS DEPARTMENT
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(972) 883-4520 FAX (972) 883-2848
e-mail: chuanwei.zhang@utdallas.edu
Web: http://www.utdallas.edu/~cxz124830/

To: NSF Quantum Leap Challenge Institutes (QLCI) Program

If the proposal submitted by Dr. Richard Scalettar entitled "QLCI-CI: Center for the Simulation of Engineered Quantum Materials" is selected for funding by NSF, it is my/our intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment and Other Resources section of the proposal.

Sincerely yours,
Chuanwei Zhang

Professor of Physics
Department of Physics
The University of Texas at Dallas
Richardson, Texas 75080
Email: chuanwei.zhang@utdallas.edu
Website: http://www.utdallas.edu/~cxz124830/

Washington State University
Department of Physics and Astronomy

From: Washington State University, Department of Physics & Astronomy
Dr. Peter Engels and Dr. Michael Forbes
Subject: Letter of Collaboration for Quantum Leap Challenge Institutes (QLCI) Preliminary Proposal
Date: July 17, 2019

To: NSF Quantum Leap Challenge Institutes (QLCI) Program

If the proposal submitted by Dr. Richard Scalettar entitled "*QLCI-CI: Center for the Simulation of Engineered Quantum Materials*" is selected for funding by NSF, it is my/our intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment and Other Resources section of the proposal.

Sincerely,

Dr. Peter Engels

Professor, Washington State University
Department of Physics & Astronomy

Dr. Michael Forbes

Asst. Professor, Washington State University
Department of Physics & Astronomy

PO Box 642814, Pullman, WA 99164-2814
509-335-1698 | Fax: 509-335-7816 | physics@wsu.edu | physics.wsu.edu

UNIVERSITY OF WASHINGTON

07/31/2019

To: NSF Quantum Leap Challenge Institutes (QLCI) Program

If the proposal submitted by Dr. Richard Scalettar entitled "QLCI-CI: Center for the Simulation of Engineered Quantum Materials" is selected for funding by NSF, it is my/our intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment and Other Resources section of the proposal.

Sincerely,

Subhadeep Gupta
Professor of Physics
University of Washington
Seattle, WA 98195

UNIVERSITY OF ILLINOIS
AT URBANA-CHAMPAIGN

Department of Electrical and Computer Engineering
Electrical and Computer Engineering Building 306 North Wright Street
Urbana, IL 61801

Quantum Leap Challenge Institutes - Statement of Commitment

TO: National Science Foundation
SUBJECT: Program Solicitation NSF 19-559

If the proposal submitted by Dr. Richard Scalettar entitled "QLCI-CI: Center for the Simulation of Engineered Quantum Materials" is selected for funding by NSF, it is my/our intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment and Other Resources section of the proposal.

Joseph W. Lyding

Professor Joseph Lyding, July 30, 2019

DEPARTMENT OF SYSTEMS ENGINEERING
Erik Jonsson School of Engineering and Computer Science
University of Texas at Dallas

800 West Campbell Rd., EC-39, Richardson, TX 75080-3021
972-883-4479, SystemsEngineering@utdallas.edu

July 23, 2019

To: NSF Quantum Leap Challenge Institutes (QLCI) Program

If the proposal submitted by Dr. Richard Scalettar entitled "*QLCI-CI: Center for the Simulation of Engineered Quantum Materials*" is selected for funding by NSF, it is my intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment and Other Resources section of the proposal.

Sincerely yours,

S. O. Reza Moheimani
Professor and James Von Ehr Distinguished Chair

To: Richard Scalettar
Subject: Letter of Collaboration - Rick Silver_UMD

From: Silver, Richard M. (Fed) <richard.silver@nist.gov>
Sent: Wednesday, July 31, 2019 8:04 AM
To: Krystal J Scruggs <kjscruggs@ucdavis.edu>; Richard Scalettar <scalettar@physics.ucdavis.edu>
Subject: Letter of Collaboration – Rick Silver_UMD

To: NSF Quantum Leap Challenge Institutes (QLCI) Program

If the proposal submitted by Dr. Richard Scalettar entitled "QLCI-CI: Center for the Simulation of Engineered Quantum Materials" is selected for funding by NSF, it is my/our intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment and Other Resources section of the proposal.

Sincerely,

Richard Silver
Adjunct Professor, University of Maryland
Department of Physics

UNIVERSITY OF CALIFORNIA, IRVINE

BERKELEY • DAVIS • IRVINE • LOS ANGELES • RIVERSIDE • SAN DIEGO • SAN FRANCISCO SANTA BARBARA • SANTA CRUZ

Steven R. White
Professor of Physics and Astronomy
(949) 824-2256 * (949) 824-2174 FAX

DEPARTMENT OF PHYSICS AND ASTRONOMY
UNIVERSITY OF CALIFORNIA
IRVINE, CALIFORNIA 92697-4575

July 25, 2019

To: NSF Quantum Leap Challenge Institutes (QLCI) Program

If the proposal submitted by Dr. Richard Scalettar entitled "*QLCI-CI: Center for the Simulation of Engineered Quantum Materials*" is selected for funding by NSF, it is my/our intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment and Other Resources section of the proposal.

Sincerely,

Steven R. White
Distinguished Professor, UC Irvine
Department of Physics and Astronomy

From: Dr. Ghanshyam Pilania
Materials Science and Technology Division
Materials Science in Radiation & Dynamics Extreme
Group MST-8, Mail Stop G755
Los Alamos, New Mexico 87545

Telephone: (505) 665-7694
Fax: (505) 667-8021
E-mail: gpilania@lanl.gov

Subject: Letter of Collaboration for Quantum Leap Challenge Institutes (QLCI) Preliminary Proposal

Date: July 30th 2019

To: NSF Quantum Leap Challenge Institutes (QLCI) Program

I am writing to confirm that if the proposal submitted by Dr. Richard Scalettar entitled “QLCI-CI: Center for the Simulation of Engineered Quantum Materials” is selected for funding by NSF, it is my intent to collaborate and/or serve as a LANL host for student visits on the project.

Should the need arise, please do not hesitate to contact me at gpilania@lanl.gov.

Sincerely,

Ghanshyam Pilania
Scientist
MST-8, Los Alamos National Laboratory

T-1 Group, Physics and Chemistry of Materials
Los Alamos National Laboratory
PO Box 1663, B221
Los Alamos, NM 87545
505-667-6870

Date: July 31, 2019

Subject: Letter of Collaboration for Quantum Leap Challenge Institutes (QLCI) Preliminary Proposal

To: NSF Quantum Leap Challenge Institutes (QLCI) Program

If the proposal submitted by Dr. Richard Scalettar entitled "*QLCI-CI: Center for the Simulation of Engineered Quantum Materials*" is selected for funding by NSF, it is my/our intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment and Other Resources section of the proposal.

Sincerely,

Dr. Kipton Barros

Staff Scientist, Los Alamos National Laboratory, Theoretical Division

Sandia National Laboratories

Operated for the United States Department of Energy
by National Technology and Engineering
Solutions of Sandia, LLC.

P.O. Box 5800
Albuquerque, NM 87185-0101

Phone: (505) 844-9644
Fax: (505) 844-7833
Email: drsandi@sandia.gov

David R. Sandison
Program Manager

July 30, 2019

Quantum Leap Challenge Institutes
National Science Foundation (NSF)
Mathematical and Physical Sciences/Office of Multidisciplinary Activities (MPS/OMA)
2415 Eisenhower Avenue
Alexandria, VA 22314

To NSF Quantum Leap Challenge Institutes (QLCI) Program:

If the proposal submitted by Dr. Richard Scalettar entitled "QLCI–CI: Center for the Simulation of Engineered Quantum Materials" is selected for funding by NSF, it is my/our intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment and Other Resources section of the proposal.

Sincerely,

David R. Sandison For: DRS

July 31, 2019

To: NSF Quantum Leap Challenge Institutes (QLCI) Program

If the proposal submitted by Dr. Richard Scalettar entitled "QLCI-CI: Center for the Simulation of Engineered Quantum Materials" is selected for funding by NSF, it is my/our intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment and Other
Resources section of the proposal.

Sincerely,

John N. Randall PhD
President
Zyvex Labs

UNIVERSITY OF CALIFORNIA, DAVIS

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ONE SHIELDS AVENUE
DAVIS, CALIFORNIA 95616

July 30, 2019

To **NSF Quantum Leap Challenge Institutes (QLCI) Program**

If the proposal submitted by Dr. Richard Scalettar entitled *QLCI - CI: Center for Simulation of Engineered Quantum Materials* is selected for funding by NSF, it is my intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment or Other Resources section of the proposal.

Sincerely,

Annaliese K. Franz, Ph.D.
Faculty Director, Undergraduate Research Center
University of California, Davis
akfranz@ucdavis.edu

SAINT LOUIS
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www.slu.edu

Department of Physics

College of Arts and Sciences

To: NSF Quantum Leap Challenge Institutes (QLCI) Program

If the proposal submitted by Dr. Richard Scalettar entitled "*QLCI-CI: Center for the Simulation of Quantum Materials*" is selected for funding by NSF, it is my/our intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment and Other Resources section of the proposal.

Sincerely,

I. Kuljanishvili

Irma Kuljanishvili,
Associate Professor,
Saint Louis University
Physics Department
Phone 314 977 8699

4. Institutional Support

As outlined in the Facilities & Resources section, all the participating institutions have invested millions of dollars in buying equipment and building specialized facilities such as materials characterization centers, computer facilities, cleanrooms, etc. Some of the equipment was purchased via extramural equipment grants, but most of the infrastructure originated in universities making long term commitments in building out facilities over a period of many years using internal funds. A detailed list of these assets is in the Facilities document of this proposal.

We also have a number of specific instances of institutional support.

- In Spring 2019, following a competitive process, the University of Texas, Dallas (UTD) funded the *Center for Atomically Precise Fabrication of Solid-State Quantum Devices*. PI Moheimani serves as the Director, and PI John Randall (an adjunct UTD faculty) is also a member. The Center has guaranteed funding for four years.
- San José State University (SJSU) provided a competitive start-up package for PI Khatami, in summer salary, release time, travel funds, and computational infrastructure. In addition, the institution has committed Undergraduate Research Grants and Research Scholarship and Creative Activity awards for students under the PI's supervision. The PI also receives travel and equipment awards from the SJSU College of Science.
- The UCD Undergraduate Research Center (URC) is funded by the UCD campus with a mission to encourage and facilitate research opportunities for undergraduates, offering awards and activities to support research across the university. The URC promotes research as a high impact student experience to enhance readiness to succeed in future careers. It offers one-on-one and small group advising sessions; informational sessions and workshops; sponsored programs providing academic enrichment and funding support; and organizes the annual Undergraduate Research, Scholarship and Creative Activities Conference. *Scalettar* sits on the URC executive committee. The URC will help coordinate and organize undergraduate research activities across our QLEAP Center. See attached Letter of Collaboration from the URC Director, Prof. Annaliese Franz.
- WSU provides institutional support for computation and machining as listed in the Facilities. In addition the Department employs a full-time staff member coordinating outreach activities, such as high-school visits, and student training for the machine shop. At an institutional level, WSU provides workshops on grant writing, and general career counseling for postdocs and staff. Both the department and institution provide scholarships and seed grant opportunities.

5. Management and Integration Plan

Group Effort Coordination and Integration of Disciplinary Components are summarized in the organizational figure below. The overall project will be headed by PI Richard Scalettar of UCD and co-Director Rick Silver of the University of Maryland and NIST, in consultation with an External Advisory Board. The Board will hold quarterly meetings online (i.e. Skype or Zoom) where members will be consulted to ensure the Center is focused on issues of interest and importance to the community. Board membership includes researchers with disciplinary expertise to advise on project specifics.

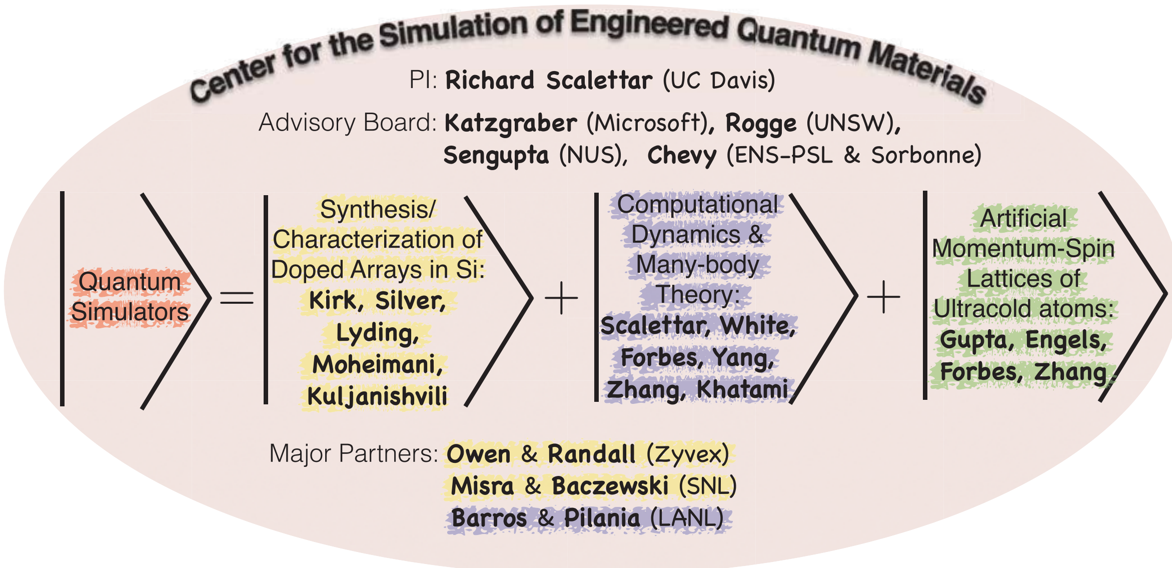

Figure 1: Our team comprises three main areas of expertise: the synthesis of atomically precise dopants in silicon, artificial spin-momentum lattices in ultracold gases/Qubit control, and computational quantum dynamics/many-body physics. Each group will have a team lead, or shared-team leads. In addition, we have major partnerships with Sandia and Los Alamos National Laboratories.

Each group will have a weekly meetings online, and all three groups – i.e. the entire team – will meet monthly to coordinate. Annual in-person meetings of all PIs and their students and postdocs will be held, supported by the budget of the Lead Institution (UCD). It is expected that significant fractions of the Team will also attend the annual Topical meeting (also supported by the UCD budget) in order to interact with other QLEAP teams and researchers in the quantum simulation community.

In addition to their primary advisors, all graduate students and postdoctoral researchers will select a second PI as a mentor to ensure interdisciplinary training, partnering experiment with theory, or condensed matter experiment with atomic and molecular physics.

The following scientists have agreed to serve on the External Advisory Board:

- **Prof. Sven Rogge**: Scale-up Engineering Work Package Leader Silicon Qubit Environment & Interface Program Manager Scientia Professor of Physics, the University of New South Wales (UNSW) Sydney.
- **Prof. Frédéric Chevy**: Professor at the École Normale Supérieure in Paris.
- **Helmut Katzgraber**: Director, Azure Quantum-Inspired Optimization Solutions & Senior Principal Research Manager, Microsoft Quantum Redmond, Washington.
- **Pinaki Sengupta**: Center for Advanced 2D Materials, National University, Singapore.