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RPPR Final Report

as of 14-Feb-2020

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Proposal Number: 72209ELRIP

Agreement Number: W911NF-18-1-0201

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Report Date: 23-Aug-2019

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Final Report for Period Beginning 28-May-2018 and Ending 23-May-2019

Title: Development and Construction of 2D THz spectroscopy for the measurement of quantum correlated systems

Begin Performance Period: 28-May-2018

End Performance Period: 23-May-2019

Report Term: 0-Other

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STEM Degrees: 0

STEM Participants: 0

Major Goals: This worked concerned the development of a new kind of spectrometer for characterization of materials with interesting quantum mechanical correlations. Quantum materials as such are one of the most interesting areas of modern condensed matter physics. Strong interactions and topological effects conspire to give novel material properties that have no precedent. They are likely to find use in the next generation of devices. The science pursued in the context of this research will enable these advances. However, despite the overwhelming interest in these systems, it is increasingly clear that we do not have the experimental tools to properly characterize many of their properties. For instance, one of the most notable aspects of many topological spin systems is that they possess "fractionalized" particles. In such systems, the conventional particles and excitations of the material fractionalize into multiple parts. In 1D this fractionalization is quite natural, but in higher dimensional "spin-liquids" it is controversial. However even in 1D, we do not have the proper techniques to measure many of the properties of fractionalized particles and manipulate them. In conventional linear spectroscopy, we measure only broad "continuum" lineshapes in candidate systems that prevent the direct detection of individual particles and obscure their properties if they exist.

In this regard, I propose that the new technique of 2D-THz spectroscopy may give unique insight into many of these material systems. 2D-THz spectroscopy is a "pump" and "probe" techniques in which sequential THz pulses will be used to interrogate the non-linear response of materials. In 2D spectroscopy in general, one excites the system at one frequency, probes at another, and ultimately plots a 2D spectrum of the response along excitation and probe frequency axes. However, unlike most pump-probe measurements the system is excited coherently and so one can discriminate homogeneous and inhomogeneous broadenings and explicitly probe the couplings between excitations. In its optical and NMR versions it has revolutionized the study of electronic and vibrational couplings in solids, liquids, biological and molecular systems. Nonlinear two-dimensional (2D) spectroscopy in the ultrafast time domain has also become an essential tool for unravelling the dynamics and couplings of elementary excitations in condensed-phase systems. The realization of 2D spectroscopy in the THz regime is made possible by the recent development of high-intensity THz pulses in a tabletop setting. The development of 2D-THz will be the development of what is essentially a form of THz range electron spin resonance.

Accomplishments: We have constructed this system and it works as intended. We have no published papers yet, but are currently taking extensive data on topological materials.

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Training Opportunities: Two students and one postdoc were involved with building this system and received training on ultrafast and intense spectroscopies.

Results Dissemination: No papers have resulted yet, but I have give a talk at UCLA on the method.

Honors and Awards: Nothing to Report

Protocol Activity Status:

Technology Transfer: Nothing to Report

PARTICIPANTS:

Participant Type: Postdoctoral (scholar, fellow or other postdoctoral position)

Participant: Fahad Mahmood

Person Months Worked: 3.00

Funding Support:

Project Contribution:

International Collaboration:

International Travel:

National Academy Member: N

Other Collaborators:

Participant Type: Graduate Student (research assistant)

Participant: Dipanjan Chaudhuri

Person Months Worked: 4.00

Funding Support:

Project Contribution:

International Collaboration:

International Travel:

National Academy Member: N

Other Collaborators:

Participant Type: Graduate Student (research assistant)

Participant: David Barbalas

Person Months Worked: 4.00

Funding Support:

Project Contribution:

International Collaboration:

International Travel:

National Academy Member: N

Other Collaborators:

Nothing to report in the uploaded pdf (see accomplishments)