

RPPR Final Report
as of 16-Jan-2020

Agency Code:

Proposal Number: 65487ELH

Agreement Number: W911NF-14-2-0076

INVESTIGATOR(S):

Name: Ramesh Ganapathi Mani

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Principal: Y

Organization: **Georgia State University Research Foundation, Inc.**

Address: PO Box 3999, Atlanta, GA 303023999

Country: USA

DUNS Number: 837322494

EIN: 581845423

Report Date: 31-Jul-2018

Date Received: 20-Dec-2019

Final Report for Period Beginning 01-Sep-2014 and Ending 30-Apr-2018

Title: Microwave and terahertz applications of two-dimensional electron systems

Begin Performance Period: 01-Sep-2014

End Performance Period: 30-Apr-2018

Report Term: 0-Other

Submitted By: Ramesh Mani

Email: rmani@gsu.edu

Phone: (404) 413-6007

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

STEM Degrees: 7

STEM Participants: 10

Major Goals: The microwave and terahertz- bands of the electromagnetic wave spectrum offer many desired characteristics in the areas of communications, chemical sensing, and subsurface imaging. Yet, associated applications have not been fully realized because the present semiconductor technology has been unable to fully provide for existing needs. This project aims to continue a research- and application-oriented- study of microwave/terahertz- photoexcitation-induced physical phenomena in the GaAs/AlGaAs, graphene, and hybrids of these two material systems, with the goal of advancing the capability in the frequency range between the upper microwave ($f > 50$ GHz)- and lower terahertz ($f < 1$ THz) - bands. This study could lead to new radiation sensors, modulators, emitters for the above mentioned upper-microwave- and lower terahertz- portions of the electromagnetic wave spectrum.

Accomplishments: see attached .pdf

Training Opportunities: Nothing to Report

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Results Dissemination: Papers Published:

- 1) B-periodic oscillations in the Hall resistance induced by a dc-current bias under combined microwave excitation and dc-current bias in the GaAs/AlGaAs 2D system, H-C. Liu, C. Reichl, W. Wegscheider, and R. G. Mani, Nature-Scientific Reports 8, 7878 (2018) | DOI:10.1038/s41598-018-26009-z
- 2) Mutual influence between current induced giant magnetoresistance and radiation-induced magnetoresistance oscillations in the GaAs/AlGaAs 2DES, R. Samaraweera, H.-C. Liu, Z. Wang, C. Reichl, W. Wegscheider, and R. G. Mani, Nature – Scientific Reports, 7, 5074 (2017) | DOI 10.1038/s41598-017-05351-8
- 3) Millimeter wave radiation-induced magnetoresistance oscillations in the high quality GaAs/AlGaAs 2D electron system under bichromatic excitation, B. Gunawardana, H.C. Liu, R. Samaraweera, M. S. Heimbeck, H. O. Everitt, C. Reichl, W. Wegscheider, J. Inarrea, and R. G. Mani, Phys. Rev. B 95, 195304 (2017) | DOI 10.1103/PhysRevB.95.195304
- 4) Remotely sensed microwave reflection in the microwave irradiated GaAs/AlGaAs two-dimensional electron system, A Kriisa, H-C Liu, R L Samaraweera, M S Heimbeck, H O Everitt, W Wegscheider and R. G. Mani, J. Phys. Conf. Ser. 864(1), 012057 (2017) | DOI: 10.1088/1742-6596/864/1/012057 (Proc. ICPS 2016).
- 5) Behaviour of Bi-Chromatic Microwave Induced Magnetoresistance Oscillations in High Mobility GaAs/AlGaAs 2D electron Systems, Binuka Gunawardana, Han-Chun Liu, Rasanga L. Samaraweera, C. Reichl, W Wegscheider and R. G. Mani, J. Phys. Conf. Ser. 864(1), 012055 (2017) | DOI: 10.1088/1742-6596/864/1/012055 (Proc. ICPS 2016).
- 6) Evolution of the frequency-dependent polarization-angle phase-shift in the microwave radiation-induced magnetoresistance oscillations, Han-Chun Liu, Rasanga L. Samaraweera, C. Reichl, W Wegscheider and R. G. Mani, J. Phys. Conf. Ser. 864(1), 012056 (2017) | DOI: 10.1088/1742-6596/864/1/012056 (Proc. ICPS 2016).
- 7) Comparative study of microwave radiation-induced magnetoresistance oscillations induced by circularly- and linearly-polarized microwaves, T. Ye, H-C. Liu, R. G. Mani, and W. Wegscheider, J. Phys. Conf. Ser. 864 (1): 012048 (2017) | DOI: 10.1088/1742-6596/864/1/012048, Proc. ICPS 2016.
- 8) Extraction of overlapping radiation-induced magnetoresistance oscillations and bell-shaped giant magnetoresistance in the GaAs/AlGaAs 2DES using a multiconduction model, R L Samaraweera, H C Liu, Z Wang, W Wegscheider and R. G. Mani, J. Phys. Conf. Ser. 864(1), 012050 (2017) | DOI: 10.1088/1742-6596/864/1/012050 (Proc. ICPS 2016).
- 9) Magnetotransport response in the 3D topological insulator Bi_2Te_3 with indium superconducting electrodes, to be published, Z. Wang, T. Ye, and R. G. Mani, J. Phys. Conf. Ser. 864(1), 012040 (2017) | DOI: 10.1088/1742-6596/864/1/012040 (Proc. ICPS 2016).
- 10) Magneto-transport characteristics of a 2D electron system driven to negative magneto-conductivity by microwave photoexcitation, R. G. Mani and A. Kriisa, J. Phys. Conf. Ser. 864(1), 012047 (2017) | DOI: 10.1088/1742-6596/864/1/012047 (Proc. ICPS 2016).
- 11) Angular phase shift in the polarization angle dependence of the microwave-induced magnetoresistance oscillations, H-C. Liu, R. L. Samaraweera, R. G. Mani, C. Reichl, and W. Wegscheider, Phys. Rev. B 94, 245312 (2016) | DOI: 10.1103/PhysRevB.94.245312
- 12) Tunable electron heating induced giant magnetoresistance in the high mobility GaAs/AlGaAs 2D electron system, Z. Wang, R. L. Samaraweera, C. Reichl, W. Wegscheider, and R. G. Mani, Nature-Scientific Reports 6, 38516 (2016) | DOI: 10.1038/srep38516.
- 13) Method for determining the residual electron- and hole- densities about the neutrality point over the gate-controlled n - p transition in graphene, R. G. Mani, Appl. Phys. Lett. 108, 033507 (2016).
- 14) Linear polarization study of microwave radiation induced magnetoresistance oscillations: Comparison of power dependence to theory. T. Ye, J. Inarrea, W. Wegscheider, and R. G. Mani, Phys. Rev. B 94, 035305 (2016).
- 15) Superconducting-contact-induced resistance-anomalies in the 3D topological insulator Bi_2Te_3 , Z. Wang, T. Ye, and R. G. Mani, Appl. Phys. Lett. 107, 172103 (2015).
- 16) Comparative study of microwave radiation-induced magnetoresistance oscillations induced by circularly- and linearly-polarized microwave radiation, T. Ye, H-C. Liu Z. Wang, W. Wegscheider, and R. G. Mani, Nature - Scientific Reports, 5, 14880 (2015).
- 17) Frequency-dependent polarization-angle-phase-shift in the microwave-induced magnetoresistance oscillations, H-C. Liu, T. Ye, W. Wegscheider, and R. G. Mani, J. Appl. Phys. 117, 064306 (2015).
- 18) Evolution of the linear-polarization-angle-dependence of the radiation-induced magnetoresistance-oscillations with microwave power, T. Ye, R. G. Mani, and W. Wegscheider, Appl. Phys. Lett. 105, 191609 (2014).
- 19) Improve contactless sensing technology, R. G. Mani and A. Kriisa, Nature (London), 548, 7665 (2017).
- 20) Hall sign reversal in certain metamaterials, R. G. Mani, Physics Today 70 (7), 13 (2017).

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15 talks at conferences and universities, 27 Oral presentations at the Annual March Meetings of the American Physical Society, 24 poster presentations at international conferences

Honors and Awards: Nothing to Report

Protocol Activity Status:

Technology Transfer: Nothing to Report

PARTICIPANTS:

Participant Type: PD/PI

Participant: Ramesh Mani

Person Months Worked: 1.00

Funding Support:

Project Contribution:

International Collaboration:

International Travel:

National Academy Member: N

Other Collaborators:

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

Participant: Annika Kriisa

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: Tianyu Ye

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: Zhuo Wang

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: Han-Chun Liu

Person Months Worked: 3.00

Funding Support:

Project Contribution:

International Collaboration:

International Travel:

National Academy Member: N

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Other Collaborators:

Participant Type: Graduate Student (research assistant)

Participant: Rasanga Samaraweera

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: Binuka Gunawardana

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: Rasadi Munasinghe

Person Months Worked: 2.00

Funding Support:

Project Contribution:

International Collaboration:

International Travel:

National Academy Member: N

Other Collaborators:

Participant Type: Graduate Student (research assistant)

Participant: Tharanga Nanayakkara

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: Kushan Wijewrdena

Person Months Worked: 2.00

Funding Support:

Project Contribution:

International Collaboration:

International Travel:

National Academy Member: N

Other Collaborators:

Participant Type: Graduate Student (research assistant)

Participant: Sajith Withanage

Person Months Worked: 3.00

Funding Support:

Project Contribution:

International Collaboration:

International Travel:

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National Academy Member: N
Other Collaborators:

DISSERTATIONS:

Publication Type: Thesis or Dissertation

Institution:

Date Received: 14-Oct-2015

Completion Date:

Title: MAGNETOTRANSPORT AND REMOTE SENSING OF MICROWAVE REFLECTION OF TWO
DIMENSIONAL ELECTRON SYSTEMS UNDER MICROWAVE EXCITATION

Authors:

Acknowledged Federal Support:

Publication Type: Thesis or Dissertation

Institution: Georgia State University

Date Received: 13-Jan-2018

Completion Date: 12/15/16 12:20PM

Title: Polarization Rotation Study of Microwave Induced Magnetoresistance Oscillations in the GaAs/AlGaAs 2D
System

Authors: Han Chun Liu

Acknowledged Federal Support: Y

Subject terms: Terahertz, Microwaves, 2 Dimensional electron systems, sensors,

Microwave and terahertz applications of two dimensional electron systems

Interim Progress report for the period: August 1, 2014 – Apr. 30, 2018
Agreement Number: W911NF-14-2-0076,

R. G. Mani,
Department of Physics & Astronomy
Georgia State University
Atlanta, GA 30303

Abstract: The microwave and terahertz- bands of the electromagnetic wave spectrum offer many desired characteristics in the areas of communications, chemical sensing, and subsurface imaging. Yet, associated applications have not been fully realized because the present semiconductor technology has been unable to fully provide for existing needs. This project aims to continue a research- and application-oriented- study of microwave/terahertz- photoexcitation-induced physical phenomena in the GaAs/AlGaAs, graphene, and hybrids of these two material systems, with the goal of advancing the capability in the frequency range between the upper microwave ($f > 50$ GHz)- and lower terahertz ($f < 1$ THz) - bands. This study could lead to new radiation sensors, modulators, emitters for the above mentioned upper-microwave- and lower terahertz- portions of the electromagnetic wave spectrum.

Accomplishments:

Since the Fall of 2014, the ARO has supported the “Nanoscience, Low Temperature, High Magnetic Field Laboratory” of the PI Ramesh Mani and his group at Georgia State University. The initial funding was for the period 8/2014 – 8/2017. A no-cost extension of one year was granted to 4/2018. All funding was expended well before 4/2018. The PI and his group wish to thank the ARO for the support of our research during this period.

In this final technical report, we provide an overall summary the products of the research for the entire term followed by a more detailed list for the past year. Over the entire life of the project period, the PI’s group published approximately 20 peer reviewed papers, 27 talks at conferences/universities, 28 contributed abstracts and presentations at the annual meetings of the American Physical society, and 31 poster presentations at international conferences. The group graduated 4 students with a Masters degree including 1 woman, and 3 Ph.D.’s including one woman.

Publications: Aug. 2014-Apr. 2018

1. B-periodic oscillations in the Hall resistance induced by a dc-current bias under combined microwave excitation and dc-current bias in the GaAs/AlGaAs 2D system, H-C. Liu, C. Reichl, W. Wegscheider, and R. G. Mani, Nature-Scientific Reports **8**, 7878 (2018)| DOI:10.1038/s41598-018-26009-z

2. Mutual influence between current induced giant magnetoresistance and radiation-induced magnetoresistance oscillations in the GaAs/AlGaAs 2DES, R. Samaraweera, H.-C. Liu, Z. Wang, C. Reichl, W. Wegscheider, and R. G. Mani, Nature – Scientific Reports, 7, 5074 (2017) | DOI 10.1038/s41598-017-05351-8
3. Millimeter wave radiation-induced magnetoresistance oscillations in the high quality GaAs/AlGaAs 2D electron system under bichromatic excitation, B. Gunawardana, H.C. Liu, R. Samaraweera, M. S. Heimbeck, H. O. Everitt, C. Reichl, W. Wegscheider, J. Inarrea, and R. G. Mani, Phys. Rev. B 95, 195304 (2017) | DOI 10.1103/PhysRevB.95.195304
4. Remotely sensed microwave reflection in the microwave irradiated GaAs/AlGaAs two-dimensional electron system, A Kriisa, H-C Liu, R L Samaraweera, M S Heimbeck, H O Everitt, W Wegscheider and R. G. Mani, J. Phys. Conf. Ser. 864(1), 012057 (2017) | DOI: 10.1088/1742-6596/864/1/012057 (Proc. ICPS 2016).
5. Behaviour of Bi-Chromatic Microwave Induced Magnetoresistance Oscillations in High Mobility GaAs/AlGaAs 2D electron Systems, Binuka Gunawardana, Han-Chun Liu, Rasanga L. Samaraweera, C. Reichl, W Wegscheider and R. G. Mani, J. Phys. Conf. Ser. 864(1), 012055 (2017) | DOI: 10.1088/1742-6596/864/1/012055 (Proc. ICPS 2016).
6. Evolution of the frequency-dependent polarization-angle phase-shift in the microwave radiation-induced magnetoresistance oscillations, Han-Chun Liu, Rasanga L. Samaraweera, C. Reichl, W Wegscheider and R. G. Mani, J. Phys. Conf. Ser. 864(1), 012056 (2017) | DOI: 10.1088/1742-6596/864/1/012056 (Proc. ICPS 2016).
7. Comparative study of microwave radiation-induced magneto-resistance oscillations induced by circularly- and linearly- polarized microwaves, T. Ye, H-C. Liu, R. G. Mani, and W. Wegscheider, J. Phys. Conf. Ser. 864 (1):012048 (2017) | DOI: 10.1088/1742-6596/864/1/012048, Proc. ICPS 2016.
8. Extraction of overlapping radiation-induced magnetoresistance oscillations and bell-shaped giant magnetoresistance in the GaAs/AlGaAs 2DES using a multiconduction model, R L Samaraweera, H C Liu, Z Wang, W Wegscheider and R. G. Mani, J. Phys. Conf. Ser. 864(1), 012050 (2017) | DOI: 10.1088/1742-6596/864/1/012050 (Proc. ICPS 2016).
9. Magnetotransport response in the 3D topological insulator Bi₂Te₃ with indium superconducting electrodes, to be published, Z. Wang, T. Ye, and R. G. Mani, J. Phys. Conf. Ser. 864(1), 012040 (2017) | DOI: 10.1088/1742-6596/864/1/012040 (Proc. ICPS 2016).
10. Magneto-transport characteristics of a 2D electron system driven to negative magneto-conductivity by microwave photoexcitation, R. G. Mani and A. Kriisa, J. Phys. Conf. Ser. 864(1), 012047 (2017) | DOI: 10.1088/1742-6596/864/1/012047 (Proc. ICPS 2016).
11. Angular phase shift in the polarization angle dependence of the microwave-induced magnetoresistance oscillations, H-C. Liu, R. L. Samaraweera, R. G. Mani, C. Reichl, and W. Wegscheider, Phys. Rev. B 94, 245312 (2016) | DOI: 10.1103/PhysRevB.94.245312
12. Tunable electron heating induced giant magnetoresistance in the high mobility GaAs/AlGaAs 2D electron system, Z. Wang, R. L. Samaraweera, C. Reichl, W. Wegscheider, and R. G. Mani, Nature-Scientific Reports 6, 38516 (2016) |DOI: 10.1038/srep38516.

13. Method for determining the residual electron- and hole- densities about the neutrality point over the gate-controlled $n \leftrightarrow p$ transition in graphene, R. G. Mani, Appl. Phys. Lett. 108, 033507 (2016).
14. Linear polarization study of microwave radiation induced magnetoresistance oscillations: Comparison of power dependence to theory. T. Ye, J. Inarrea, W. Wegscheider, and R. G. Mani, Phys. Rev. B 94, 035305 (2016).
15. Superconducting-contact-induced resistance-anomalies in the 3D topological insulator Bi_2Te_3 , Z. Wang, T. Ye, and R. G. Mani, Appl. Phys. Lett. 107, 172103 (2015).
16. Comparative study of microwave radiation-induced magnetoresistance oscillations induced by circularly- and linearly- polarized microwave radiation, T. Ye, H-C. Liu Z. Wang, W. Wegscheider, and R. G. Mani, Nature - Scientific Reports, 5, 14880 (2015).
17. Frequency-dependent polarization-angle-phase-shift in the microwave-induced magnetoresistance oscillations, H-C. Liu, T. Ye, W. Wegscheider, and R. G. Mani, J. Appl. Phys. 117, 064306 (2015).
18. Evolution of the linear-polarization-angle-dependence of the radiation-induced magnetoresistance-oscillations with microwave power, T. Ye, R. G. Mani, and W. Wegscheider, Appl. Phys. Lett. 105, 191609 (2014).
19. Combined study of microwave-power/linear polarization dependence of the microwave radiation-induced magnetoresistance oscillations in GaAs/AlGaAs devices, T. Ye, H-C. Liu, W. Wegscheider, and R. G. Mani, Phys. Rev. B 89, 155307 (2014).
20. Interaction of microwave radiation with the high mobility two-dimensional electron system in GaAs/AlGaAs heterostructures, A. N. Ramanayaka, T. Ye, H-C. Liu, W. Wegscheider, and R. G. Mani, Physica B 453, 43-48 (2014).

Talks:

1. Combined study of microwave power- and linear polarization rotation- dependence of radiation-induced magnetoresistance oscillations in high mobility two-dimensional electron systems, R. G. Mani, 21st Intl. Conf. On “High Magnetic Fields in Semiconductor Physics” (HMF 21), Aug. 6, 2014, Panama City, FL. Organizers: D. Smirnov and Z. Jiang.
2. Resistively detected hole spin resonance in epitaxial graphene, R. G. Mani, 32nd Intl. Conf. On the Physics of Semiconductors – ICPS 2014, Aug. 14, 2014, Austin, TX.
3. Transport characteristics of the microwave driven 2D negative magneto-conductivity state, R. G. Mani, 32nd Intl. Conf. On the Physics of Semiconductors – ICPS 2014, Aug. 14, 2014, Austin, TX.
4. Size dependent giant magnetoresistance in millimeter-sized GaAs/AlGaAs devices, R. G. Mani, 32nd Intl. Conf. On the Physics of Semiconductors – ICPS 2014, Aug. 15, 2014, Austin, TX.
5. Oscillatory magnetotransport in the high mobility GaAs/AlGaAs system under microwave irradiation: Role of microwave polarization, R. G. Mani, 32nd Intl. Conf. On the Physics of Semiconductors – ICPS 2014, Aug. 14, 2014, Austin, TX.
6. Photoexcited zero-resistance states in high mobility GaAs/AlGaAs devices, R. G. Mani, St. Louis University, Dept. of Physics, St. Louis, MO. Nov. 7, 2014. Host: Dr. Dmitry Solenov.

7. Microwave-induced transport in the GaAs/AlGaAs system, R. G. Mani, Ecole des Sciences Avancees de Luchon – Quantum transport in 2D systems: Session Workshop 2, Luchon-Bagneres, France. 28 May, 2015.
8. Resistively detected spin resonance in graphene, R. G. Mani, 4th International Symposium on Energy Challenges and Mechanics on Small Scales – Graphene Based Nanotechnology for Energy Applications, Session 05G, 13 Aug. 2015. Organizer: Dr. Henry Tan.
9. Simultaneous electron- and hole- currents over the gate-controlled $n \leftrightarrow p$ transition across the neutrality point in graphene, R. G. Mani, XXIC International Materials Research Congress, Aug. 17, 2015, Cancun, Mexico. (S1B-005)
10. Resistively detected spin resonance in epitaxial graphene, R. G. Mani, XXIC International Materials Research Congress, Aug. 17, 2015, Cancun, Mexico. (S1B-0017).
11. Size dependent giant magnetoresistance in millimeter scale GaAs/AlGaAs devices, R. G. Mani, XXIC International Materials Research Congress, Aug. 18, 2015, Cancun, Mexico. (S7E-0013)
12. Magnetotransport studies of low dimensional electron systems based on GaAs/AlGaAs heterostructures and graphene, R. G. Mani, DOE-Experimental Condensed Matter Physics PI Meeting, Gaithersburg, MD. Sep. 27, 2015.
13. A magnetotransport study of graphene, R. G. Mani, National Institute of Science and Technology (NIST), Gaithersburg, MD. Apr. 10, 2016. Host: Dr. R. Elmquist.
14. Zero-resistance states induced by electromagnetic wave excitation in the high mobility GaAs/AlGaAs 2D electron system. R. G. Mani, Indian Institute of Technology – Bombay, Mumbai, India. June 2, 2016. Host: Prof. K. G. Suresh.
15. Size-dependent giant magnetoresistance in millimeter-scale GaAs/AlGaAs 2D electron devices. R. G. Mani, International Conference on Materials Science and Technology (ICMST)-2016, Pala, Kerala. June 6, 2016.
16. A magnetotransport study of graphene. R. G. Mani, Indian Institute of Technology – Madras, Chennai, India. June 14, 2016. Host: Prof. M. Jaiswal.
17. Zero-resistance states induced by electromagnetic wave excitation in the high mobility GaAs/AlGaAs 2D electron system. R. G. Mani, Indian Institute of Technology – Madras, Chennai, India. June 15, 2016. Host: Prof. M. Jaiswal.
18. Extraction of radiation induced magneto-resistance oscillations from the negative giant magneto-resistance in the GaAs/AlGaAs 2DES. R. G. Mani, International Conference on the Physics of Semiconductors, Beijing, China. August 4, 2016.
19. Comparative study of microwave radiation-induced magneto-resistance oscillations induced by circularly- and linearly- polarized microwaves. R. G. Mani, International Conference on the Physics of Semiconductors, Beijing, China. August 4, 2016.
20. Superconducting contact induced resistance anomalies in the 3D topological insulator Bi_2Te_3 , R. G. Mani, The 8th International Conference on Low Dimensional Structures and Devices (LDSD2016), Riviera Maya, Mexico, August 29, 2016. Organizers: M. Henini and I. H-Calderon.
21. Size dependent giant magnetoresistance in millimeter scale GaAs/AlGaAs devices, R. G. Mani, The 8th International Conference on Low Dimensional Structures and Devices

- (LDS2016), Riviera Maya, Mexico, August 31, 2016. Organizers: M. Henini and I. H-Calderon.
22. Size dependent giant magnetoresistance in millimeter scale GaAs/AlGaAs devices, R. G. Mani, ECE Department, University of California – Santa Barbara, Dec. 23, 2016. Host. Prof. Kaustav Banerjee
 23. Resistively detected spin resonance in graphene, R. G. Mani, ECE Department, University of California – Santa Barbara, Dec. 23, 2016. Host. Prof. Kaustav Banerjee.
 24. Something new in something old..., R. G. Mani, School for Advanced Sciences, - Luchon, Bagnères-Luchon (France), May 26, 2017. Host. D. Shepelyansky
 25. Zero-resistance states induced by electromagnetic wave excitation in the high mobility GaAs/AlGaAs 2D electron system. R. G. Mani, Tata Institute for Fundamental Research, Mumbai (India), May 31, 2017. Host: M. Deshmukh.
 26. Study of giant magnetoresistance in the high mobility GaAs/AlGaAs 2D electron system, R. G. Mani, Indian Institute of Technology- Madras, Chennai (India), June 6, 2017. Host. M. Jaiswal.
 27. Hall coefficient sign reversal in certain metamaterials, R. G. Mani, 8th International Conference and Exhibition on Lasers, Optics and Photonics, Las Vegas, NV, November 16, 2017.

Contributed talks at the Annual March Meetings of the American Physical Society. Typically, the entire group travelled to these meetings and the students talked about their own work and attended a large number of sessions to become educated on the latest developments in the field.

1. Transport and reflection from the microwave and mm-wave photo-excited high mobility GaAs/AlGaAs 2D electron system, A. Kriisa, R. L. Samaraweera, M.S. Heimbeck, H. Everitt, W. Wegscheider, R. G. Mani, BAPS.2018.Mar.C07.12. March 5, 2018.
2. Bichromatic microwave-induced oscillatory differential resistance in the high mobility GaAs/AlGaAs heterostructure system, B. Gunawardana, C. R. Munasinghe, R. L. Samaraweera, T. R. Nanayakkara, A. Kriisa, U. K. Wijewardena, C. Reichl, W. Wegscheider, and R. G. Mani, BAPS.2018.Mar.C07.13. March 5, 2018.
3. Dependence of the electron temperature on the incident microwave power in the photo-excited GaAs/AlGaAs 2D electron system, T. Nanayakkara, R. Samaraweera, B. Gunawardana, C. R. Munasinghe, A. Kriisa, C. Reichl, W. Wegscheider, and R. G. Mani, BAPS.2018.Mar.F07.14. March 6, 2018.
4. Study of current bias induced carrier heating effect in the regime of the Shubnikov-de Haas oscillations in high mobility GaAs/AlGaAs two dimensional electron system. C. R. Munasinghe, B. Gunawardana, R. L. Samaraweera, T. Nanayakkara, Z. Wang, A. Kriisa, U. K. Wijewardena, C. Reichl, W. Wegscheider, and R. G. Mani, BAPS.2018.Mar.F07.15. March 6, 2018.
5. Study of a weak localization like negative magnetoresistance effect in the high mobility GaAs/AlGaAs 2DES. R. Samaraweera, B. Gunawardana, A. Kriisa, T. Nanayakkara, C. R. Munasinghe, C. Reichl, W. Wegscheider, R. Mani, BAPS.2018.Mar.H07.13. March 6, 2018.
6. Synthesis of single crystal graphene by chemical vapor deposition. S. Withanage, R. Samaraweera, T. Nanayakkara, U. K. Wijewardena, A. Kriisa, and R. G. Mani, BAPS.2018.Mar.S36.02. March 8, 2018.

7. Transport properties of CVD graphene cooled with a biased gate voltage, U. K. Wijewardena, R. Samaraweera, A. Kriisa, B. Gunawardana, T. Nanayakkara, C. R. Munasinghe, and R. G. Mani, BAPS.2018.Mar.V40.06. March 8, 2018.
8. Expectations for photo-excitation induced oscillatory magnetoresistance in graphene, R. G. Mani, BAPS.2017.Mar.V33.2. March 16, 2017.
9. Structural corrugation of graphene oxides, U. Wijewardena, S. Brown, R. G. Mani and X-Q. Wang, BAPS.2017.Mar.X31.2. March 16, 2017.
10. Study of possible electron heating induced by microwave excitation in the GaAs/AlGaAs 2D electron system, T. Nanayakkara, R. Samaraweera, Z. Wang, B. Gunawardana, C. Reichl, W. Wegscheider, and R. G. Mani, BAPS.2017.Mar.B27.8. March 13, 2017
11. Effect of excitation parameter on the damping of microwave induced magnetoresistance oscillations in the GaAs/AlGaAs 2D electron system, R. Samaraweera, B. Gunawardana, H. C. Liu, C. Reichl, W. Wegscheider, and R. G. Mani, BAPS.2017.Mar.K27.4. March 15, 2017
12. Current bias and temperature effect on the Shubnikov-de Haas oscillations in high mobility GaAs/AlGaAs system, C. Munasinghe, R. Samaraweera, B. Gunawardana, Z. Wang, C. Reichl, W. Wegscheider, and R. G. Mani, BAPS.2017.Mar.K27.6. March 15, 2017
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20. Study of magnetotransport across the neutrality point in CVD graphene, R. G. Mani, BAPS.2016.Mar.B15.5. March 14, 2016.

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The following posters presented at the specified conferences:

1. Study of phase shift under rotation of linear microwave polarization in microwave induced oscillations, H-C. Liu, T. Ye, W. Wegscheider, and R. G. Mani, 21st Intl. Conf. On “High Magnetic Fields in Semiconductor Physics” (HMF 21), Aug. 4, 2014, Panama City, FL. Organizers: D. Smirnov and Z. Jiang.
2. Size dependent giant magnetoresistance in millimeter scale GaAs/AlGaAs devices, R. G. Mani, A. Kriisa, and W. Wegscheider, 21st Intl. Conf. On “High Magnetic Fields in Semiconductor Physics” (HMF 21), Aug. 4, 2014, Panama City, FL. Organizers: D. Smirnov and Z. Jiang.
3. Proximity effect in the 3D topological insulator Bi_2Te_3 , Z. Wang, T. Ye, and R. G. Mani, 21st Intl. Conf. On “High Magnetic Fields in Semiconductor Physics” (HMF 21), Aug. 4, 2014, Panama City, FL. Organizers: D. Smirnov and Z. Jiang.
4. Magneto-transport characteristics of a 2D electron system driven to negative magneto-conductivity by microwave photoexcitation, R. G. Mani and A. Kriisa, 21st Intl. Conf. On “High Magnetic Fields in Semiconductor Physics” (HMF 21), Aug. 4, 2014, Panama City, FL. Organizers: D. Smirnov and Z. Jiang.
5. Influence of sample geometry on the phase shift in the linear-polarization-angle dependence of radiation-induced magnetoresistance oscillations in the GaAs/AlGaAs

- system, H-C. Liu, T. Ye, R. G. Mani, and W. Wegscheider, 32nd Intl. Conf. on the Physics of Semiconductors – ICPS 2014, H2 Aug. 12, 2014, Austin, TX.
6. Combined study of microwave-power dependence & linear polarization dependence of microwave radiation-induced magnetoresistance oscillations, T. Ye, H. C. Liu, R. G. Mani, and W. Wegscheider, 32nd Intl. Conf. on the Physics of Semiconductors – ICPS 2014, H1 Aug. 12, 2014, Austin, TX.
 7. Size dependent giant magnetoresistance in millimeter scale GaAs/AlGaAs devices, R. G. Mani, A. Kriisa, and W. Wegscheider, 21st International Conference on Electronic Properties of Two-Dimensional Systems. 26 July 2015, Sendai, JP. (Mo-PE-40)
 8. Magneto-transport Characteristics of a 2D Electron System Driven to Negative Magneto-conductivity by Microwave Photo-excitation, R. G. Mani and A. Kriisa, 21st International Conference on Electronic Properties of Two-Dimensional Systems. 26 July 2015, Sendai, JP. (Th-PE-65)
 9. Simultaneous power-and linear-polarization-angle-dependence study of microwave induced magnetoresistance oscillations, T. Ye, H-C. Liu, R. G. Mani and W. Wegscheider, 21st International Conference on Electronic Properties of Two-Dimensional Systems. 26 July 2015, Sendai, JP. (Mo-PE-41)
 10. Proximity Effect in 3D Topological Insulator Bi₂Te₃, Z. Wang, T. Ye, and R. G. Mani, 21st International Conference on Electronic Properties of Two-Dimensional Systems. 26 July 2015, Sendai, JP. (Mo-PE-93)
 11. Frequency-dependent polarization-angle-phase-shift in the microwave-induced magnetoresistance oscillations. H-C. Liu, T. Ye, R. G. Mani, and W. Wegscheider, 21st International Conference on Electronic Properties of Two-Dimensional Systems. 26 July 2015, Sendai, JP. (Tu-PE-38)
 12. Microwave radiation-induced magnetoresistance oscillations in the high mobility GaAs/AlGaAs system under bichromatic excitation, Binuka Gunawardana, Han-Chun Liu, Rasanga L. Samaraweera, C. Reichl, W. Wegscheider and R. G. Mani, ICPS 2016 – 33rd International Conference on the Physics of Semiconductors. 8/2/2016, Beijing, China. Tu-P.156
 13. Remotely sensed microwave reflection in microwave irradiated GaAs/AlGaAs two-dimensional electron system, Annika Kriisa, H-C. Liu, R. L. Samaraweera, M. S. Heimbeck, H. O. Everitt, W. Wegscheider, and R. G. Mani, ICPS 2016 – 33rd International Conference on the Physics of Semiconductors. 8/2/2016, Beijing, China. Tu-P.157
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 15. Simultaneous electron- and hole- currents over the gate-controlled $n \leftrightarrow p$ transition across the neutrality point in graphene, R. G. Mani, ICPS 2016 – 33rd International Conference on the Physics of Semiconductors. 8/4/2016, Beijing, China. Th-P.072
 16. Evolution of the frequency-dependent polarization-angle phase-shift in the microwave radiation-induced magnetoresistance oscillations, Han-Chun Liu, Rasanga L. Samaraweera, R. G. Mani, and W. Wegscheider, ICPS 2016 – 33rd International Conference on the Physics of Semiconductors. 8/1/2016, Beijing, China. Mo-P.156

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18. Superconducting-contact-induced resistance-anomalies in the 3D topological insulator Bi₂Te₃, Zhuo Wang, Tianyu Ye, and R. G. Mani, ICPS 2016 – 33rd International Conference on the Physics of Semiconductors. 7/31/2016-8/5/2016, Beijing, China.
19. Giant magneto-resistance induced by a dc current bias in the high mobility GaAs/AlGaAs system, Zhuo Wang, R. Samaraweera, W. Wegscheider, and R. G. Mani, ICPS 2016 – 33rd International Conference on the Physics of Semiconductors. 8/4/2016, Beijing, China. Th-P.149
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21. Study of the quasi-continuous evolution of the phase shift in a linear polarization angle of the microwave radiation-induced magnetoresistance oscillations, H-C. Liu, R. L. Samaraweera, C. Reichl, W. Wegscheider, and R. G. Mani, LDSD 2016 – The Eight International Conference on Low dimensional Structures and Devices, Maya Riviera, Mexico. August 31, 2016. Organizers: M. Henini and Isaac Hernandez-Calderon. (Tu-P23)
22. Magnetoresistance oscillations induced by bichromatic microwave excitation in the high mobility GaAs/AlGaAs system, B. Gunawardana, H-C. Liu, R. L. Samaraweera, W. Wegscheider, and R. G. Mani, LDSD 2016 – The Eight International Conference on Low dimensional Structures and Devices, Maya Riviera, Mexico. August 31, 2016. Organizers: M. Henini and Isaac Hernandez-Calderon. (Tu-P.22)
23. Study of co-existing radiation-induced magneto-resistance oscillations and bell-shape negative magnetoresistance in the GaAs/AlGaAs 2DES. R. L. Samaraweera, H-C. Liu, Z. Wang, W. Wegscheider, and R. G. Mani, LDSD 2016 – The Eight International Conference on Low dimensional Structures and Devices, Maya Riviera, Mexico. August 31, 2016. Organizers: M. Henini and Isaac Hernandez-Calderon. (Tu-P25)
24. Microwave reflection from a high mobility GaAs/AlGaAs 2DES at large filling factors, A. Kriisa, H-C. Liu, R. L. Samaraweera, M. S. Heimbeck, H. O. Everitt, W. Wegscheider, and R. G. Mani, 22st International Conference on Electronic Properties of Two-Dimensional Systems. 1 August 2017, Penn State Univ., PA. (PS1-2DT-23).
25. Angular phase shift in polarization –angle dependence of microwave-induced magnetoresistance oscillations, H-C. Liu, R. L. Samaraweera, R. G. Mani, C. Reichl, and W. Wegscheider, 22st International Conference on Electronic Properties of Two-Dimensional Systems. 1 August 2017, Penn State Univ., PA. (PS1-2DT-24)
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27. Lineshape of radiation-induced magnetoresistance oscillations under bichromatic photo-excitation in the GaAs/AlGaAs 2D electron system, H. Gunawardana, H-C. Liu, R. L.

- Samaraweera, M. S. Heimbeck, H. O. Everitt, J. Inarrea, C. Reichl, W. Wegscheider, and R. G. Mani, 22st International Conference on Electronic Properties of Two-Dimensional Systems. 3 August 2017, Penn State Univ., PA. (PS2-QH-25)
28. Study of electron heating via the shubnikov- de Haas effect under a current-bias in the high mobility GaAs/AlGaAs 2D electron system, C. Rasadi Munasinghe, R. L. Samaraweera, B. Gunawardana, Z. Wang, C. Reichl, W. Wegscheider, and R. G. Mani, 22st International Conference on Electronic Properties of Two-Dimensional Systems. 3 August 2017, Penn State Univ., PA. (PS2-QH-26)
 29. Possibility of Electron Heating Induced by Microwave Photo-excitation in the GaAs/AlGaAs 2D Electron System, Tharanga Nanayakkara, Rasanga Samaraweera, Zhuo Wang, Binuka Gunawardana, Rasadi Munasinghe, Ramesh G. Mani, C. Reichl, and W. Wegscheider, 22st International Conference on Electronic Properties of Two-Dimensional Systems. 3 August 2017, Penn State Univ., PA. (PS2-QH-27)
 30. Separation and study of overlapping current induced giant magnetoresistance and radiation-induced magnetoresistance oscillation in the GaAs/AlGaAs 2DES, R. L. Samaraweera, H. C. Liu, Z. Wang, R. G. Mani, C. Reichl, and W. Wegscheider, 22st International Conference on Electronic Properties of Two-Dimensional Systems. 3 August 2017, Penn State Univ., PA. (PS2-QH-28)
 31. Current tunable giant magnetoresistance in the high mobility GaAs/AlGaAs 2D electron system, Z. Wang, R. L. Samaraweera, C. Reichl, W. Wegscheider, and R. G. Mani, 22st International Conference on Electronic Properties of Two-Dimensional Systems. 3 August 2017, Penn State Univ., PA. (PS2-QH-29)

Ph.D's were awarded to : (1) Tianyu Ye, Ph.D. (Physics) – 6/2015: “Magnetotransport and remote sensing of microwave reflection from two-dimensional electron systems under microwave excitation.” (2) Han-Chun Liu, Ph.D. (Physics) – 12/2016: “Polarization rotation study of the microwave induced magnetoresistance oscillations in the GaAs/AlGaAs system,” (3) Zhuo Wang, Ph. D. (Physics) – 02/2017 : Magneto-transport study of the 3D topological insulator BiTe and GaAs/AlGaAs 2D electron system.

The MS degrees were awarded to: (1) Rasanga Samaraweera, MS (Physics) – 12/2016: “Extraction of overlapping radiation induced magneto-resistance oscillations and bell-shape negative-GMR using multi-conduction model in the GaAs/AlGaAs 2DES,” (2) Binuka Gunawardana, MS (Physics) – 12/2016: “ Transport under bichromatic excitation in the GaAs/AlGaAs 2DES,” (3) Tharanga Nanayakkara, MS (Physics) – 5/2018: “Electron heating under microwave photoexcitation in the GaAs/AlGaAs 2D electron system”, and (4) Rasadi Munasinghe, MS (Physics) – 5/2018: “Study of current bias induced carrier heating effect in the regime of Shubnikov-de Haas oscillations in high mobility GaAs/AlGaAs two-dimensional electron systems”.

People who worked in the group over the period Aug. 2014-Apr. 2018:

- Dr. Ramesh Mani, PI
- Dr. Annika Kriisa, Post-doc
- Mr. Tianyu Ye, Graduate Student
- Mr. Han-Chun Liu, Graduate Student

- Ms. Zhuo Wang, Graduate Student
- Mr. Rasanga Samaraveera, Graduate Student
- Mr. Binuka Gunawardana, Graduate Student
- Ms. Rasadi Munasinghe, Graduate Student
- Mr. Tharanga Ranjan, Graduate Student
- Mr. Kushan Wijewardena, Graduate Student
- Mr. Sajith Vithanage, Graduate Student
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