Nathaniel M. Gabor JET Distinguished Associate Professor of Physics

Laboratory of Quantum Materials Optoelectronics
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Education

Massachusetts Institute of Technology	Postdoctoral Fellow	Physics	**2012 - 2013**
Cornell University	Ph.D., M.S.	Physics	**2012**
Pennsylvania State University	B.S. (Highest Distinction)	Physics	**2004**

Selected National and International Awards and Honors

National Academy of Sciences Kavli Frontiers Fellow 2019 – 'The Kavli Frontiers of Science symposium is the Academy's premiere activity for distinguished young scientists.'

Research Corporation for Science Advancement Scialog Fellow 2018 – 'Bringing together promising early career investigators and scientific leaders for the search and discovery of truly transformative ideas.'

CIFAR Azrieli Global Scholar Award 2017 – 'CIFAR invites outstanding early career investigators into research programs addressing some of the most complex challenges facing the world today.'

Research Corporation for Science Advancement Scialog Fellow 2017 – 'Bringing together promising early career investigators and scientific leaders for the search and discovery of truly transformative ideas.'

NSF CAREER Award 2017 – 'The National Science Foundation's most prestigious awards in support of early-career faculty who have the potential to serve as academic role models in research and education.'

Cottrell Scholar Award 2017 – 'Honors outstanding teacher-scholars who are recognized by their scientific communities for the quality and innovation of their research programs and academic leadership skills.'

AFOSR YIP Award 2016 – 'Supports scientists and engineers demonstrating exceptional ability and promise for conducting basic research with relevance to the Air Force mission.'

UCR Junior Faculty Excellence in Teaching (JET) Award 2015 – 'Awarded to teachers whose record shows that they have vibrancy, passion, and devotion to the University of California's teaching mission.'

SPIE International Society for Optics and Photonics Best Paper Award 2014 – 'Given based on originality, depth of research, significance of findings and historical interest.'

MIT School of Science Excellence Award 2011 – 'Acknowledging extraordinary efforts toward fulfilling the goals, values and mission of the Institute. This is among the highest honors awarded by MIT.'

Clark-Russell Award Cornell Physics – 'For extraordinary dedication to undergraduate education. This award honors outstanding teaching and scholarship.'

Spansion Award Cornell Nanoscale Science and Technology Facility (CNF) 2007 – 'Recognizes the demonstration of novel techniques in nanofabrication and device engineering.'

John and Elizabeth Holmes Teas Scholarship 2004 – 'Recognizes and supports excellence in research within the physical sciences and engineering.'

Jean Bennet Physics Award 2004 – 'Acknowledging excellence and leadership among undergraduate students in the Eberly College of Science at the Pennsylvania State University.'

Research Interests

Quantum mechanics is a theoretical description of reality that has been used to understand numerous phenomena at atomic and subatomic scales. It is among the most successful scientific theories, exhibiting not one single contradiction in nearly a century since its inception. The Gabor lab aims to discover new phenomena in emerging quantum material systems including atomically thin two-dimensional (2D) electronic materials such as the transition metal dichalcogenides (TMDs). These materials, many of which can be separated into few or single atomic layers, wires and crystals, exhibit quasi-low dimensionality that may lead to unique quantum electronic behavior.

Scientific Employment: Investigative Roles and Research Grants

Principal Investigator: University of California Riverside Physics **2013 - present**

Designed and constructed low temperature magnetoelectronic and optoelectronic spectroscopy laboratory for investigations of interacting excitons and electron-hole excitations in transition metal dichalcogenides, graphene, bilayer graphene, and topological insulators, leading to the development of two significant experimental techniques to observe the space-time dynamics of energy flow in quantum materials. Developing extensive fabrication of complex nanoscale device structures based on graphene, molybdenum ditelluride, tungsten disulphide, and molybdenum disulphide. Currently supervising 6 graduate students.

Total Research Funding (including start-up, through 2022): $3,014,959

1. AFOSR YIP Award Biosystems; sole PI (2016-2019): $379,987
2. DoE EFRC SHINES; center co-PI (2014-2018): $450,000
3. NASA/JPL FIELDS Data Science; center co-PI (2015-2018): $240,000
4. UC Office of the President LCFF+; sole PI (2017): $51,241
5. Cottrell Scholar Award; sole PI (2017-2020): $100,000 discretionary
6. NSF CAREER Award DMR; sole PI (2017-2022): $541,794
7. UC Innovative Learning Tech Award; co-PI (2017-2019): $340,000 ($55,000)
8. CIFAR Global Scholar Award; sole PI (2017-2019): $85,000 discretionary
9. GAANN Materials Science; co-PI (2018-2021): $895,500 ($111,937)

Postdoctoral Fellow: Massachusetts Institute of Technology Physics **2010 - 2013**
Mentor: Pablo Jarillo-Herrero

Designed and constructed a low temperature optoelectronic spectroscopy laboratory for investigations of interacting electrons in graphene, bilayer graphene, graphene nanoribbons, and topological insulators leading to the discovery of hot-carrier assisted intrinsic photoresponse in graphene, phonon drag in graphene, and photon-assisted tunneling in graphene heterostructures. Co-authored U.S. Air Force grant for the nanofabrication of graphene-based optoelectronic devices, MIT MISTI grant for collaboration with ICFO Spain, MIT S^3TEC seed grant for solar thermoelectric energy harvesting, DOD MIT seed grant for the Inst. of Soldier Nanotechnologies. Supervised 2 graduate and 3 undergraduate students as the leader of the optoelectronics team in the Jarillo-Herrero lab.

Graduate Research Scholar: Cornell University Physics **2004 – 2010**
Mentor: Paul McEuen

Designed and constructed quantum electronic and optoelectronic experiments that combine ultrafast lasers, supercontinuum light sources, and high power laser sources in a low temperature cryostat for the investigation of graphene interface junctions, nanotube PN junctions, and THz frequency nanotube FETs. Developed extensive fabrication of complex nanoscale device structures based on graphene and carbon nanotubes. Demonstrated strongly interacting Dirac fermions in carbon nanotubes and graphene contributing to the discovery of extremely efficient generation of multiple electron-hole pairs, real-time probe of ballistic motion of electrons, and photo-thermoelectric effect in graphene.

Undergraduate Research Scholar: Pennsylvania State University **2002 - 2004**
Mentors: Jay Maynard, Vincent Crespi

Designed and constructed the magnetic cactus for the investigation of phyllotactic ground states in physical systems leading to the first observation (in over 4 centuries of study) of dynamic phyllotaxis and the annealing of phyllotactic ground states.

Scientific Publications (citations: 2115, mean citations/publication > 100)

23. "Multiple parameter dynamic photoresponse microscopy for data-intensive optoelectronic measurements of van der Waals heterostructures," Trevor B. Arp, Nathaniel M. Gabor*; *under review in* ***Review of Scientific Instruments*** (2018) ArXiv:1812.03232v1. *Corresponding author.

22. "Electron-hole liquid in a van der Waals heterostructure photocell at room temperature," Trevor B. Arp, Dennis Pleskot, Vivek Aji, Nathaniel M. Gabor*; *in press* ***Nature Photonics*** (2018). ArXiv:1711.06917v1. *Corresponding author.

21. "Giant intrinsic photoresponse in pristine graphene," Qiong Ma, Chun Hung Lui, Justin C.W. Song, Jian Feng Kong, Yuan Cao, Nityan L. Nair, Wenjing Fang, Kenji Watanabe, Takashi Taniguchi, Su-Yang Xu, Jing Kong, Nuh Gedik, Nathaniel M. Gabor*, Pablo Jarillo-Herrero; ***Nature Nanotechnology*** (2018). *Corresponding author.

20. "Electron quantum metamaterials in van der Waals heterostructures," Justin C.W. Song, Nathaniel M. Gabor*; ***Nature Nanotechnology*** **13**, 986 (2018). *Corresponding author.

19. "Hot carrier-enhanced electron-hole pair multiplication in 2D semiconductor heterostructure photocells," Fatemeh Barati, Max Grossnickle, Shanshan Su, Roger K. Lake, Vivek Aji, Nathaniel M. Gabor*; ***Nature Nanotechnology*** **12,** 1134, doi:10.1038/nnano.2017.203 (2017). *Corresponding author.

18. "Long lived valley polarization of intra-valley trions in monolayer WSe_2," Akshay Singh, Kha Tran, Mirco Kolarczik, Joe Seifert, Yiping Wang, Kai Hao, Dennis Pleskot, Nathaniel M. Gabor, Sophia Helmrich, Nina Owschimikow, Ulrike Woggon and Xiaoqin Li; ***Physical Review Letters***, **117**, 257402 (2016).

17. "Natural regulation of energy flow in a green quantum photocell," Trevor B. Arp, Yafis Barlas, Vivek Aji, Nathaniel M. Gabor*; ***Nano Letters***, DOI: 10.1021/acs.nanolett.6b03162 (2016). *Corresponding author.

16. "Nd:AlN polycrystalline ceramics: A candidate media for tunable, high energy, near IR lasers," Andrew Wieg, Max Grossnickle, Yasuhiro Kodera, Nathaniel M. Gabor, Javier Garay; ***Applied Physics Letters*** **109**, 121901 (2016).

15. "Trion formation dynamics in monolayer transition metal dichalcogenides," Akshay Singh, Galan Moody, Kha Tran, Marie E. Scott, Vincent Overbeck, Gunnar Berghäuser, John Schaibley, Edward J. Seifert, Dennis Pleskot, Nathaniel M. Gabor, Jiaqiang Yan, David G. Mandrus, Marten Richter, Ermin Malic, Xiaodong Xu, and Xiaoqin Li; ***Physical Review B, RAPID Communications*** **93**, 041401 (2016).

14. "Tuning ultrafast electron thermalization pathways in a van der Waals heterostructure", Qiong Ma, Trond Andersen, Nityan Nair, Nathaniel M. Gabor*, Mathieu Massicotte, Chun Hung Lui, Andrea F. Young, Wenjing Fang, Kenji Watanabe, Takashi Taniguchi, Jing Kong, Nuh Gedik, Frank H. L. Koppens and Pablo Jarillo-Herrero ; ***Nature Physics*** **12,** 455 (2016). *Corresponding author.

13. "Two-Dimensional Materials: Lift off for Graphene," Nathaniel Gabor; ***Nature Photonics*** **9**, 419 (2015).

12. "Competing channels for hot-electron cooling in graphene," Qiong Ma, Nathaniel Gabor, Trond I. Andersen, Nityan L. Nair, Kenji Watanabe, Takashi Taniguchi, and Pablo Jarillo-Herrero; ***Physical Review Letters*** **112,** 247401 (2014).

11. "Photoresponse of an electrically tunable ambipolar graphene infrared thermocouple," Patrick Herring, Allen Hsu, Nathaniel Gabor, Yong Cheol Shin, Jing Kong, Tomas Palacios, Pablo Jarillo-Herrero; ***Nano Letters*** **14(2),** 901 (2014).

10. "Impact excitation and electron-hole multiplication in graphene and carbon nanotubes," Nathaniel Gabor; ***Accounts of Chemical Research*** **46**, 1348 (2012).

9. "Ultrafast measurement of the escape time of electrons and holes in the nanotube p-i-n junction," Nathaniel Gabor, Zhoahui Zhong, Ken Bosnick, and Paul McEuen; ***Physical Review Letters*** **108,** 087404 (2012). ***ArXiv***:1109.0269v1.

8. "Hot-carrier assisted intrinsic photoresponse in graphene," Nathaniel Gabor, Justin C. W. Song, Qiong Ma, Nityan Nair, Thiti Taychatanapat, Kenji Watanabe, Takashi Taniguchi, Leonid Levitov, Pablo Jarillo-Herrero; ***Science*** **334,** 648 (2011). ***ArXiv***:1108.3826v1.

7. "Extremely efficient and ultrafast: electrons, holes, and their interactions in the nanotube PN junction," Nathaniel Gabor, PhD thesis, Cornell University (2010).

6. "Annealing a magnetic cactus into phyllotaxis," Cristiano Nisoli, Nathaniel Gabor, Paul Lammert, Jay Maynard, and Vincent Crespi; ***Physical Review E***, **81**, 046107 (2010). ***ArXiv***:1002.0622v1.

5. "Photo-thermoelectric effect at a graphene interface junction," Xiaodong Xu, Nathaniel Gabor, Jonathan Alden, Arend van der Zande, and Paul McEuen; ***Nano Letters*** **10(2),** 562 (2010). ***ArXiv***:0907.3173v1.

4. "Extremely efficient multiple electron-hole pair generation in carbon nanotube photodiodes," Nathaniel Gabor, Zhaohui Zhong, Ken Bosnick, Jiwoong Park, and Paul McEuen; ***Science*** **325**, 1367 (2009).

3. "Static and dynamical phyllotaxis in a magnetic cactus," Cristiano Nisoli, Nathaniel Gabor, Paul Lammert, Jay Maynard, and Vincent Crespi; ***Physical Review Letters*** **102**, 186103 (2009). ***ArXiv/cond-mat***/0702335v2.

2. "Terahertz time-domain measurement of ballistic electron resonance in a single-walled carbon nanotube," Zhaohui Zhong, Nathaniel Gabor, Jay Sharping, Alexander Gaeta, Paul McEuen; ***Nature Nanotechnology*** **3**, 201-205 (2008).

1. "Transport in carbon nanotube p-i-n diodes," Ken Bosnick, Nathaniel Gabor, Paul L. McEuen; ***Applied Physics Letters*** **89,** 163121 (2006).

Selected Invited Talks

13. "From heat engines to green leaves: a physicist's perspective on photosynthesis,"
CEPCEB Noel T. Keen Award Symposium Plant Biology and Physiology, Riverside, CA (2017)
Penn State Physics Colloquium, State College, PA (2018), *LASSP Seminar Cornell University*, Ithaca, NY (2018).

12. "Nanoscience in the Age of Big Data,"
RCSA Cottrell Conference, Tucson, AZ (2017).

11. "Room temperature 2D condensate of electrons and holes in ultrathin MoTe2 photocells,"
Stanford AMO Seminar, Palo Alto, CA (2018), *Caltech Materials Science and Applied Physics Seminar* (2018), *N2D Spain, Workshop on Nanophotonics in 2D Materials*, San Sebastian, Spain (2017), *QCM Workshop Enduring Problems in Quantum Condensed Matter, A Symposium Honoring Chandra Varma,* Riverside, CA (2017).

10. "Three-body electronic interactions in 2D semiconductor heterostructures,"
UT Austin Condensed Matter Seminar, Austin, TX (2017),
SPIE Defense + Commercial Sensing, Anaheim CA (2017).

9. "Why are plants green? And other essential questions about emerging quantum optoelectronic technologies,"
TU Delft Quantum Nanosciences Seminar, TU Delft Netherlands (2017).
University of California Santa Cruz Condensed Matter Seminar, Santa Cruz, CA (2017).

8. "Nonlinear Photoresponse Microscopy of 2D Heterostructures,"
IEEE Photonics, Waikaloa, Hawaii (2016).

7. "Natural Regulation in a Green Quantum Photocell,"
University of California San Diego Condensed Matter Seminar, San Diego, CA (2015),
University of California Santa Barbara Condensed Matter Seminar, Santa Barbara, CA (2016).

6. "Electron-hole excitations in two-dimensional atomic layer materials,"
California State University Physics Colloquium, Los Angeles, CA (2014)
University of California Riverside EE Colloquium, Riverside, CA (2014).

5. "Atomically thin optoelectronics: the ideal semi-metal and the insurmountable insulator,"
University of Washington Molecular Engineering and Sciences Seminar, Seattle, WA (2014).

4. "Photoresponse in graphene: hot Dirac fermions and nonlocality,"
WONTON 2013, Santa Fe, New Mexico (2013),
Harvey Mudd College Physics Colloquium*,* Claremont, CA (2013),
MIT Chez Pierre Seminar, Massachusetts Inst. of Technology, Cambridge, MA (2013),
AAAS Pacific Division Meeting, Riverside, CA (2014).

3. "Hot Dirac fermions in cool quantum systems,"
Energy Frontiers Seminar, Columbia University, NY, NY (2012),
Applied Physics Seminar, *EE Seminar*, Stanford University, Palo Alto, CA (2012),
Micro Nano Seminar MIT Mechanical Eng. Seminar, Cambridge, MA (2012).

2. "Hot-carrier assisted intrinsic photoresponse in graphene,"
IRG Graphene, Cornell University, Ithaca, NY (2011),
American Physical Society March Meeting, Boston, MA (2012).

1. "Extremely efficient multiple electron-hole pair generation in carbon nanotube photodiodes,"
Princeton University Condensed Matter seminar, Princeton, NJ (2010),
Rowland Institute at Harvard University, Cambridge, MA (2010),
American Physical Society March Meeting, Portland, Oregon (2010).