# Trevor Arp

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# Curriculum Vitae

## Awards and Fellowships:

- *2020 Robert T. Poe Memorial Scholarship*. UCR Physics Department Award
- *Dissertation Year Program Fellowship.* UCR Graduate Division Award, "The DYP awards are intended to provide support to excellent research Ph.D. candidates who are nearing completion of their dissertation research." Funded from September to December 2018.
- *Fellowships and Internships in Extremely Large Data Sets (FIELDS) Graduate Fellow.* A NASA MIRO program in partnership with JPL and UCR that provides fellowship to graduate students to "carry out research in their chosen field of study, while gaining experience in data science techniques and its application to their research." Funded from 3/29/2016 to 6/23/2018.
- *2016 Al Saats Award.* UCR Physics Departmental Award for "Exceptional Skills in Designing and Building Physics Apparatus."
- *2013 Chancellor's Distinguished Fellowship.* Funded from 9/2013 to 9/2014.

## Education:

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| **2013-2020** | Ph.D in Physics | University of California, Riverside |
| **2014** | M.S. in Physics | University of California, Riverside |
| **2013** | B.S. (Physics Major) | University of Washington |

## Accomplishments:

I developed a new optoelectronic technique that has led to the discovery of a novel electronic phase in heterostructures of $MoTe_2$ and deeper insights into the physics of interacting electrons in 2D heterostructures. My technique, called Multi-Parameter Dynamic Photoresponse Microscopy (MPDPM), combines ultrafast optics and scanning beam microscopy with efficient data acquisition and analysis techniques to probe the optoelectronic physics of nanoscale systems.[5] Using MPDPM on a graphene-$MoTe_2$ heterostructure led to the discovery of the 2D electron hole liquid phase that emerges out of interacting excitons even at room temperature in photoexcited 2D $MoTe_2$, recently published in *Nature Photonics*.[4] I have also used MPDPM to understand excitonic physics in Transition Metal Dichalcogenides (TMDCs) and hot-carrier physics in graphene heterostructures. In addition, I have worked to apply concepts from quantum optoelectronics to biological systems, particularly focusing on the importance of quantum structure in regulating photosynthesis, a result recently published in *Science*.[3,6]

## Research Interests:

Nanotechnology has opened a new horizon in physics, allowing access to phenomena arising from reduced dimensionality. In all but the simplest, most perfect systems, reduced symmetry and strong correlations leads to complexity. While much work often goes into reducing complexity and imperfection, complexity has interesting physics all by itself, provided you have the tools to handle it. I am fascinated by the metrology of complex quantum systems and how to overcome their challenges with new technology, especially data science techniques. Complex nanoscale systems are not limited to engineered nanotechnology, biology provides many complex quantum systems that manage to operate in fluctuating, noisy environments. Understanding what allows them to operate despite complexity and fluctuation is a fascinating problem with many applications to future technology.

# Research Experience:

**Graduate Student Researcher: March 2014 – July 2020**
Quantum Materials Optoelectronics Laboratory, University of California, Riverside, CA.
*Advisor: Nathaniel Gabor*

**Novel Instrumentation and Techniques for Optoelectronic Experiments.** Designed, prototyped and built a custom experimental setup that uses a near-infrared ultrafast pulsed laser to probe the nanoscale materials by measuring spatially and temporally resolved photocurrent and reflectance. The setup can apply voltages and magnetic fields (up to 3T) to the sample while controlling for temperature (from 4K to 420K), two-pulse time delay, laser power, wavelength and polarization. Designed and implemented software to rapidly acquire, process and display data. Software simultaneously controls multiple pieces of hardware that vary experimental conditions using a new technique called Multi-Parameter Dynamic Photoresponse Microscopy (MPDPM).[5] Fundamentally MPDPM works by works by distilling the large variable space into something more suited for human intuition; taking data time efficiently over a large variable space then in analysis condensing the data down into dynamical quantities that represent shifts in sample behavior.

**Optoelectronic Dynamics of $MoTe_2$ Heterostructures**. Measured the optoelectronic physics of graphene-$MoTe_2$ heterostructures using MPDPM. Analyzed and modeled the resulting photocurrent data sets to uncover dynamics of excitons formed from photoexcitation. Discovered dynamics dominated by exciton-exciton annihilation and, in the high carrier density limit, the formation of a correlated electron-hole liquid phase that persists at room temperature.[4] Currently expanding focus to the dynamics of other TMDC heterostructure systems, including heterobilayers and the dynamics of interlayer excitons.

**Phototunneling and Hot Carrier Physics in Graphene Heterostructures**. Probed graphene-hBN-graphene stacked heterostructures with a photon energy below the gap of hBN, measuring the highly non-linear tunneling photocurrent that arises due to the thermal distribution of carriers in the graphene sheets. Analyzed the data to reveal striking negative differential photoconductance near charge neutrality. Modeled the charge carrier thermal distribution formed by photoexcitation to determine the thermal properties of hot carriers in graphene from the data.

**Energy Flow in Noisy Biological Systems**. Simulated energy flow in noisy quantum systems, revealing how regulation can emerge from quantum structure in molecular systems.[3] Adapted this concept to the photosynthesis in multiple biological systems, developed a model that can predict ideal photosynthetic structure from light conditions that compares well with the photosynthetic pigments of real phototrophic organisms.[6]

**Undergraduate Research: March 2011 - August 2013**
Eöt-Wash Gravitational Physics Group, Center for Experimental Nuclear Physics and Astrophysics (CENPA), Seattle WA.
*Advisor: Jens Gundlach*

**Precision Instrumentation** Designed, constructed, optimized and published a new kind of autocollimator for measuring angles to nanoradian precision at low frequencies for use in gravitational experiments.[1,2] Wrote custom data acquisition and analysis software for the autocollimator. In the process, developed a customized fitting algorithm for efficient high speed processing of complex optical fringe data. Designed, constructed and maintained a wireless network of temperature and humidity sensors to continuously monitor environmental conditions in an experimental laboratory containing highly sensitive equipment.

## Teaching Experience:

**Teaching Assistant**, University of California Riverside, 2014-2016
Teaching weekly laboratory and discussion sections for the following courses: Physics 40B and 40C, General Physics for Engineering Students, and Physics 2B, General Physics for Life Science Students.

**FIELDS Outreach**, University of California Riverside, 2016-2018
Designed and implemented an online educational game on the science of wildfires (gridfire.ucr.edu). Participated in presentations at local schools, reaching hundreds of 4$^{th}$ through 6$^{th}$ grade students.

## Technical Skills:

**Coding** I have long been interested in programming and its application to science. I have spent a lot of time learning scientific programming both formally, taking undergraduate courses in programming and scientific computing classes, and informally through experience coding in the lab. I have become proficient in multiple programming languages and in efficient and extensible program design.
*Programming Languages*: Python, C, C++, C#, Java, Matlab/Octave, JavaScript
*Operating Systems*: Linux, Windows
*Other Software*: SolidWorks, Autodesk 3DS MAX, LaTeX, NI-DAQ, LabVIEW

**Instrument Engineering** I have spent much of my research career building novel instruments and pushing the cutting edge of experimental technology. Along the way I have gained experience in the engineering and fabrication of scientific instruments.
*Prototyping*: Building of custom electrical circuitry and optical systems.
*Lasers*: Proficient in the use, maintenance and safety management of ultrafast pulsed lasers.
*Machining*: Proficient in the operation of a mill, lathe, and other common machine shop equipment.

## Publications:

6. "Quieting a noisy antenna reproduces photosynthetic light harvesting spectra" **Trevor B. Arp**, Jed Kistner-Morris, Vivek Aji, Richard Cogdell, Rienk van Grondelle, Nathaniel M. Gabor, *Science* **368**, 1490-1495 (2020).
*Featured*: Science Perspective

5. "Multiple Parameter Dynamic Photoresponse Microscopy for data-intensive optoelectronic measurements of van der Waals heterostructures" **Trevor B. Arp**, Nathaniel M. Gabor, *Review of Scientific Instruments* **90**, 023702 (2019).
*Featured*: Editors Pick, Review of Scientific Instruments

4. "Electron-hole liquid in a van der Waals heterostructure photocell at room temperature" **Trevor B. Arp**, Dennis Pleskot, Vivek Aji, Nathaniel M. Gabor, *Nature Photonics* **13**, 245-250 (2019).
*Featured*: Nature Photonics News and Views

3. "Natural Regulation of Energy Flow in a Green Quantum Photocell." **Trevor B. Arp**, Yafis Barlas, Vivek Aji, and Nathaniel M. Gabor, *Nano Letters* **16** (12) pp. 7461-7466 (2016).
*Featured*: Nature Nanotechnology Research Highlight

2. "A high-precision mechanical absolute-rotation sensor." Krishna Venkateswara, Charles A. Hagedorn, Matthew D. Turner, **Trevor Arp**, and Jens H. Gundlach, *Review of Scientific Instruments*, **85**, 015005 (2014).

1. "A reference-beam autocollimator with nanoradian sensitivity from mHz to kHz and dynamic range of $10^7$." **Trevor B. Arp**, Charles A. Hagedorn, Stephan Schlamminger, and Jens H. Gundlach, *Review of Scientific Instruments*, **84**, 095007 (2013).