Statement of Purpose (DRAFT) (*Ex.: Cornell*)

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Imagine the fantastic future that we see in so many science-fiction blockbusters and shows. My dream is to spend my life working on the edge of knowledge, doing physics research that will help turn this science-fiction fantasy into a reality. Pursuing a Ph.D. in experimental physics is my best next step toward reaching this goal. I have already been a part of some of the exciting forefronts of science with the following three undergraduate research endeavors:

* Internationally, with a research semester at **CERN** (Geneva, Switzerland); where my work helped to prevent a temporary *shutdown of the Large Hadron Collider*.
* Nationally, with a summer internship at **Caltech** (Pasadena, C.A.); where I worked with brilliant scientists who invent cutting-edge technologies to further microwave astronomy.
* At my home institution, **Georgetown University** (Washington, D.C.), where I develop graphene-based terahertz optoelectronics, and where my passion for future technologies is fueled by realizing the exciting potential applications of graphene.

Cornell University--with its expert faculty and strengths in condensed matter physics--is the ideal place for me to further my scientific career and my goal of contributing to the technologically advanced future.

In 2013, I graduated high school as valedictorian in my home state of New Hampshire. Of several universities that accepted me, I chose to attend Georgetown University in Washington, D.C., because it offers strengths in physics research, and is devoted to public service. During the second semester of my freshman year (2014), I joined the research group of Professor Paola Barbara, a group that specializes in atomically thin materials, and have continued this research for my remaining years as an undergraduate. I began working on microelectronic devices such as FET’s and photodetectors on monolayer graphene. I have gained the skills needed to successfully fabricate and analyze custom microelectronics in a clean room environment. From flexible solar cells built into clothing, to high-capacity batteries with ultrafast charging times for the next era of electric vehicles, the potential applications of graphene seem to be out of a science-fiction dream. This excitement fuels the passion that propels me into graduate school.

After my sophomore year, I took a semester off from Georgetown to pursue an internship at the **Large Hadron Collider** at **CERN** (fall 2015) that was arranged and funded by the University of Michigan. I was one of five students accepted nationwide. I worked on the ATLAS Experiment under the mentorship of Professor Richard Teuscher of the University of Toronto. My goal was to understand the response to radiation of new ATLAS semiconductor tracker electronics being designed for the Phase-II upgrade of the LHC (coming in 2024). I designed an experiment to irradiate prototypes, cool them to -30oC, and monitor their behavior. I also programmed a graphical user interface to control the electronics during a continuous, eight-day testing campaign. At the end of my internship, I gave presentations to my colleagues and published an Internal Note to the CERN document server for subsequent use by ATLAS personnel.

An unexpected benefit of my work was how it helped prevent another group from forcing a shutdown of the LHC and wasting thousands of dollars. Coinciding with our experimental timeline, a subsystem of ATLAS began to have problems with its readout electronics. These electronics were drawing too much current in response to total ionizing radiation, the very same phenomenon that we were investigating with our electronics, which were of a similar design. In short, our results showed that with *more* radiation, an annealing mechanism would take over in their devices and curtail the current increase. People were anxious to hear our results when we presented them at an ATLAS meeting the day after our testing campaign. The concerned group took our advice to keep their electronics running, and after more exposure to radiation in the LHC, the current returned to safe levels. This one example shows how at CERN I was really able to contribute to this enormous collaboration of people designing the most sophisticated experiments in the world to understand the most fundamental questions of the universe

After my semester at CERN, I submitted a successful project proposal to the **Caltech Summer Undergraduate Research Fellowship** (summer 2016) to work on a new type of on-chip spectrometer being developed for sky-surveys of high-redshift galaxies. My mentor was Dr. Charles Matthew Bradford, of the Caltech Sub-mm astronomy group. This chip, “SuperSpec,” uses a filterbank of microwave resonators to decompose incident radiation. I designed and built a system to read out a comb of frequencies and discern the amplitude of the response from each of the 250+ resonators on the chip and reconstruct incident microwave signals digitally. My system worked effectively for all of our testing purposes, and following my work, the group decided to continue with my system and use it to develop future prototypes of the SuperSpec chips. It was really exciting to be on the forefront of applying new physics to real-world devices to create something that has never been possible before. I became a quasi-expert on this readout system, and I acted as a resource for my group even after my internship.

I am currently working on a Georgetown senior honors thesis in graphene terahertz detectors, under the mentorship of Professor Barbara. My detectors use the hot-electron photo-thermoelectric effect in graphene to detect incident terahertz radiation. They aim to have greater sensitivity than similar devices that have recently been built (e.g., X. Cai, 2014), by exploiting the plasmonic resonance effect in graphene to boost the photoresponse. Collective oscillations in the population of free charge-carriers on a graphene microstrip can be excited to a resonant frequency that depends on the microstrip’s size. My detectors exploit this effect in an effort to achieve greater sensitivities than detectors that rely on the photo-thermoelectric effect alone, while being able to operate at near-room temperatures. To fabricate my detectors, I am exploring two different types of graphene: epitaxial graphene from external sources and CVD graphene that we grow ourselves. I am an author on a paper in review (2D Materials): *Facile Fabrication of Graphene/MoS2 Heterostructure Devices on Arbitrary Substrates by Photolithography.*

In October, 2016, I took the initiative to submit a proposal to the **NSF Graduate Research Fellowship** for a project to extend my terahertz graphene optoelectronics research into graduate school. Graphene has recently been shown to support population inversion (M. Ryzhii, 2007) and the potential for stimulated emission in the terahertz region. My proposal aims to carry this phenomenon further by exploring terahertz emitters using forward-biased graphene p-i-n junctions to incite population inversion. The development of efficient graphene terahertz detectors and emitters would work to close the so-called “terahertz gap” realized by fields such as astronomy, biomedical science, and more.

I am most excited by the opportunity to continue my research career at Cornell because of: 1) ongoing research in graphene microelectronics by Professor Paul McEuen and 2) related engineering research by Professor Fahran Rana. Professor McEuen’s group has recently published a very interesting study of graphene plasmon modes that is exceptionally relevant to my research in graphene plasmonic terahertz detectors. I would cherish the opportunity to apply my undergraduate experience to research ventures in his lab. Furthermore, Professor Rana publishes prolifically on atomically thin materials and microscale electronics. His group’s work has provided much of the basis for my research in graphene optoelectronics, and we rely on his publications for many of my lab's other projects relating to two-dimensional materials. I would welcome the opportunity to be a physics student who also collaborates with Professor Rana’s engineering work. The close relationship between Cornell's engineering and physics departments, such as that which encourages the close the collaboration between Professor McEuen and Professor Rana, makes Cornell even more appealing to me as a productive research environment in which to pursue my Ph.D.

With a Ph.D. from Cornell, and the mentorship of its expert scientists, I envision that I will earn the experience necessary to make contributions to both the physics and engineering communities, and make breakthroughs that work to turn today’s science fiction into reality.