Statement of Purpose DRAFT. V1. (Example: *Columbia*)

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Pursuing my Ph.D. in experimental physics at Columbia University~~~~~ To achieve this Ph.D. goal, I will apply the experience and expertise that I obtained from three key internships in physics research as an undergraduate:

* Internationally, with a research semester at the **Large Hadron Collider at CERN** (Geneva, Switzerland)
* Nationally, as an intern at **Caltech** (Pasadena, CA) in microwave astronomy
* At my home institution, **Georgetown University** (Washington, DC), in graphene nanoelectronics

My long-term goal is to be a major contributor in making the futuristic world of science-fiction blockbusters and shows into reality. This is an exceptionally exciting time to be alive, and my generation is uniquely poised to make greater technological and scientific achievements than perhaps any before.

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) at **Georgetown**, I joined the research group of Prof. 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 for subsequent experiments. The potential applications of graphene seem to be out of a science-fiction dream, such as flexible solar cells built into clothing and high-capacity batteries with ultrafast charging times for the next era of electric vehicles. This excitement has become 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 (to occur in 2024). I designed an experiment to irradiate prototypes, cool them to -30oC, and monitor and record 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.

One interesting and unexpected benefit of my work was how my work help prevent another group from inadvertently forcing a shutdown of the LHC and wasting thousands of dollars and lost time. Coinciding with our experimental timeline, another 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 cause the current increase to diminish. 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 my working at CERN was amazing: I was able to contribute to an enormous collaboration of passionate 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. C. 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 resonators on the chip and reconstruct the signal 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 was able to become a quasi-expert on this readout system, and I acted as a resource for my grop even after my internship; I've been invited to return for the summer 2017.

I am currently working on a Georgetown Senior Honors Thesis in graphene terahertz detectors, under the mentorship in my lab group eith Prof. Barbara. These detectors employ the hot-electron photo-thermoelectric effect, boosted by the plasmonic resonance effect, which is highly dependent on the size of the graphene channel. My research goal is to produce detectors that have greater responsivity than similar devices that have recently been built (e.g., X. Cai, 2014). With this boost from the plasmonic resonance effect, I anticipate that my detectors will have sensitivities unmatched by detectors that rel on the photo-thermoelectric effect alone. To fabricate my detectors, I am exploring two different types of graphene: epi~~~~~~I am a co-author on a paper that is in review (J. 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 Georgetown graphene thz opt into graduate school. My proposal leverages the unique features of graphene that have recently been shown to support population inversion (M. Ryzhii, 2007) and the potential for stimulated emission in the terahertz region. My proposed project is to carry this phenomenon further by exploring terahertz lasers using forward-biased graphene p-i-n junctions to incite population inversion. Such devices could revolutionize terahertz optoelectronics and work to close the so-called “terahertz gap” realized by fields such as astronomy, biomedical science, and more.

Technical reasons that I am applying to Columbia University Graduate School of Physics include:

* Ongoing graphene p-n junction physics research being conducted by Prof. Cory Dean
* Related engineering research in atomically thin materials by Prof. James Hone

For example, Dr. Dean’s work pertains to devices similar to those I have been exploring at Georgetown. It would be exciting for me to achieve the best of both worlds at Columbia. Moreover, during my four years as an undergraduate student conducting advanced graphene research, I have been following the work by Dr. Hone. Interestingly, my professor and my fellow students found ourselves technically “competing” with Dr. Hone’s research; I would welcome the opportunity to be a physics student who also collaborates with Dr. Hone’s engineering work.

With a Ph.D. from Columbia, and the mentorship of my advisor and fellow expert scientists, I envision that I will be equipped to make major contributions to both the physics and engineering communities, as well as make breakthroughs that turn today’s science fiction into reality.