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Dear USEQIP and URA coordinators,

I am a third-year undergraduate at Colby College majoring in physics and mathematics and minoring in statistics, and I am applying for the USEQIP and URA at the IQC this summer. I am drawn to problems in quantum information (QI) and atomic, molecular, and optical (AMO) physics research, for they involve a strong interplay between theories and experiments. As I wish to pursue QI research in graduate school, I believe an opportunity at the IQC will be an excellent experience for me. My interest in QI stems from my lab work and desire to describe quantum systems with mathematics. I have been actively involved in AMO physics research at Colby (since 2017) and at the Joint Quantum Institute (JQI) at the University of Maryland, College Park (summer, winter 2019). I am also involved in applied mathematics research at Colby.

At JQI, I joined the Rolston Group where we study ∞-range interactions of Rb atoms trapped around an optical nanofiber (ONF) via their collective decay. One of our future endeavors is to have an optical dipole trap using an ONF. However, unlike in typical free-space dipole traps, a control system for light polarization state is necessary in our setup to account for birefringence and a longitudinal polarization state introduced by the ONF. My contribution was building the Nd:YAG 1064 nm optical arrangement and creating a method to optimize polarization in the ONF. I was able to obtain quasi-linearly polarized light via an imaging system, which I created to quantify circular and elliptical polarizations. The system consists of two orthogonal CCD cameras equipped with polarizing filters from which the ratio of detected optical power characterizes the polarization state in the ONF. I also developed a stand-alone experimental control program in Python using the NI-DAQmx libraries, independent of LabView. At the moment, I am directly involved in the collective decay measurements.

I attribute my opportunity at JQI to more than two years of experience researching Rydberg K atoms at Colby with Professor Conover. In his lab, I have built electronics to stabilize external cavity diode lasers' wavelengths and programmed waveform generators for various purposes including fast MOT field switching to study the dynamics of the MOT cloud in the abrupt absence of the trapping field. In previous years, the Conover Group focused on precision measurements of d-d and s-p Rydberg mm-wave transitions in K. My role over the summer of 2018 was to study Ramsey's separated oscillatory fields as an alternative to our conventional three-step measurement method. I modified the single-pulse excitation scheme to double-pulse and recorded Ramsey fringes and Rabi oscillations. From there, I used a simple two-level atom model to derive mathematical expressions for the observed fringes and oscillations, from which I extracted the desired measurements with only two steps. This work resulted in a poster presentation at my college's research retreat (CUSRR 2018) and another at APS DAMOP 2019.

Beside experimental work, I am fascinated by theoretical physics and the applications of mathematics in QI/AMO physics, which I have been exploring in advanced courses and independent studies. By the end of this academic year, I will have finished the required physics curriculum plus one semester on QI and four on classical field theory and massive gravity. I will also have completed two semesters of linear algebra, abstract algebra (with algebraic geometry), analysis, probability, and differential equations. For my Matrix Analysis final project of Spring 2018, I presented the construction of the tensor product and its application in a simple 2-qubit entanglement quantum circuit. Now, I am researching the convolution powers of complex-valued functions with Professor Evan Randles. I hope to turn my results into an Honors Thesis for the mathematics major.

A summer research at the Institute for Quantum Computing (IQC) will provide me with an excellent opportunity to apply my experience in experimental AMO physics and interest in theory to tackle problems in QI. I have contacted Professor Crystal Senko, whose research on the theoretical aspects and experimental implementation of qudits align exactly with my research interests. We have also discussed possible projects for the summer, many of which I find very enticing. As I wish to pursue QI research in graduate school and academia, I believe a USEQIP and a URA at the IQC will allow me to establish a strong transition.

I appreciate your consideration and look forward to hearing from you.

Best regards,
Huan Q. Bui