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Physics Research at Princeton University
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During the winter of 2023-2024, I used my Byrne Scholar funds to conduct physics research at Princeton University under Professor Nathalie de Leon. My research focused on characterizing a new material, beta phase tantalum, that could be used to make superconducting qubits and resonators. Generally, one combines these qubits and resonators to form a superconducting quantum circuit, which is one prominent hardware platform that is being pursued in order to make a quantum computer. I wanted to make devices out of beta phase tantalum because this material can be deposited at room temperature (unlike many leading materials) which might allow people to make significantly better qubits, provided that beta phase tantalum is a good microwave superconductor. To test this latter hypothesis, I started by depositing the tantalum. Using X-ray photoelectron spectroscopy I determined that the metal grows a native oxide of around 5 nm which is more than other materials. This could be bad since oxides are lossy, but I wanted to nevertheless test the material. Using X-ray diffraction experiments, I was able to confirm that I deposited beta phase tantalum. I then spent about two weeks fabricating coplanar waveguide beta phase tantalum microwave resonators. Once I was able to get consistently good devices, I packaged them up and cooled them down to 10 millikelvin.

Then, I measured the resonators' quality factors at different temperatures and excitation powers. I fit these data to a theoretical model developed by the group which quantifies resonator loss due to nearby two level systems and loss due to thermal excitation of superconducting electron pairs. One interesting thing about my resonators was that they ended up being unconventionally coupled to the excitation lines. This required me to implement a new (to the lab group) fitting algorithm that fits resonator transmission data to more general resonator types. This new fitting algorithm was key to my research, because once I did this, I showed that these beta phase tantalum resonators are quite good compared to the best superconducting resonators being made today. This shows that beta phase tantalum has sufficiently good superconducting properties that qubits may improve significantly if they are made using the room temperature capabilities of this material. I will pursue this research in the future because this possibility is quite exciting!