Prototyping of Superconducting Cage for nEDM Measurement

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1 Introduction

The electric dipole moment (EDM) is a property of particles characterized by electrically positive and negative poles, that defines their torque in electric fields. One of the questions of particle physics that is being experimentally investigated is whether the neutron has a non-zero electric dipole moment. Such a discovery would have important ramifications due to the violation of charge and parity symmetries by the neutron's EDM (or nEDM). It is especially important in regards to baryogenesis, the process by which the early universe had more matter than antimatter and thus, after the two had interacted and nullified each other, was left with the matter that would become our material universe. [2] Experiments to measure the nEDM at Oak Ridge Laboratory's (ORNL) Spallation Neutron Source (SNS) involves inducing Larmor precession of the neutron spin in a strong electric field. While the outside magnetic field will be small, the neutron's large magnetic moment will create a precession in the B field from this spin, and the resulting modulated signal can be detected to measure the nEDM. [2]

The requirement for constant magnetic fields within the small size of the cryostat in which the experiment is being performed could be fulfilled by designing a superconducting cage. Due to the ability of superconductors to maintain a current for an almost infinite amount of time, exposing such a material to an outside B field would induce a current by Lenz's Law that opposes any change in the B field; thus, the B field would be maintained even when the external source is removed. Forming the superconductor into a cage allows for multiple current loops to form around each hole in the cage, "pinning" magnetic field lines such that they stay constant over space and time within the cage [1], thus creating the necessary field for the nEDM experiment that remains unaffected by external fields. Using a prototype superconducting cage design composed of lead, this project will accurately obtain temperature and magnetic field strength data on the cage during testing in liquid helium, and thus determine whether the design is able to produce the desired fields.

2 Procedure

The first step of prototyping was designing the superconducting cage, which occurred before I joined the project. The cage was constructed of leaded PCBs with a grid of small holes, after which multiple pieces were soldered together to create the cage itself. This apparatus was placed on the long end of a rod, so that it could be safely lowered into a dewer holding the liquid helium during testing. Two thermometers and a magnetometer were attached to the cage and had their cables run through the rods. Each thermometer was place on the farthest and closest face of the cage, to be able to measure when the front and back of the cage reached critical temperature and thus confirm the cage is superconducting. The thermometers and magnetometer are attached to separate, external control devices that convert the data from the sensors into voltages, which are then sent to a National Instruments DAQ device that converts the two data streams into a single data stream that can be read by a computer through a single USB port.

My work on the project will start with creating a program to read the data from these sensors and save it in an external file for later data analysis, which is being done using a Python script. Afterwards, testing can begin on the superconducting cage – first a liquid nitrogen test to see how the set-up operates at cryogenic temperatures, and then a liquid helium test to bring the lead cage to its critical temperature, at which point the superconducting properties of the material can be tested. If the cage is able to maintain a magnetic field as predicted, then the design will be useable in the nEDM experiments at SNS.

References

[1] F Gömöry. *Superconductor Dynamics*. 2014.

[2] J. S. Nico and W. M. Snow. "Fundamental neutron physics". In: *Annual Review of Nuclear and Particle Science* 55 (2005).