Upgrade of the ^{37}K asymmetry measurement experiment

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Over the past year, we have continued working to upgrade the experimental apparatus to prepare for a measurement of the β-asymmetry in the decay of ^{37}K. The new ultra high vacuum (UHV) chamber that will house the experimental setup is now complete and has been attached to the TRINAT beam line at TRIUMF in preparation for the upcoming experiment. We are also currently developing a new data acquisition scheme that will accompany the new nuclear detectors described last year. In addition, we have improved our theoretical model of the optical pumping process that polarizes the trapped ^{37}K atoms, allowing a more precise determination of the degree of nuclear polarization. We plan to complete a short trial run of the experiment in October 2012 in fulfillment of a TRIUMF prerequisite to installing a dedicated TiC target for our experiment in December 2012.

With the new chamber in place, we have begun installing further components of the apparatus inside and around the chamber. The completed chamber is shown in Fig. 1 prior to its installation on the TRINAT beam line. Specifically, we have finished fabricating a series of electrostatic hoops that are

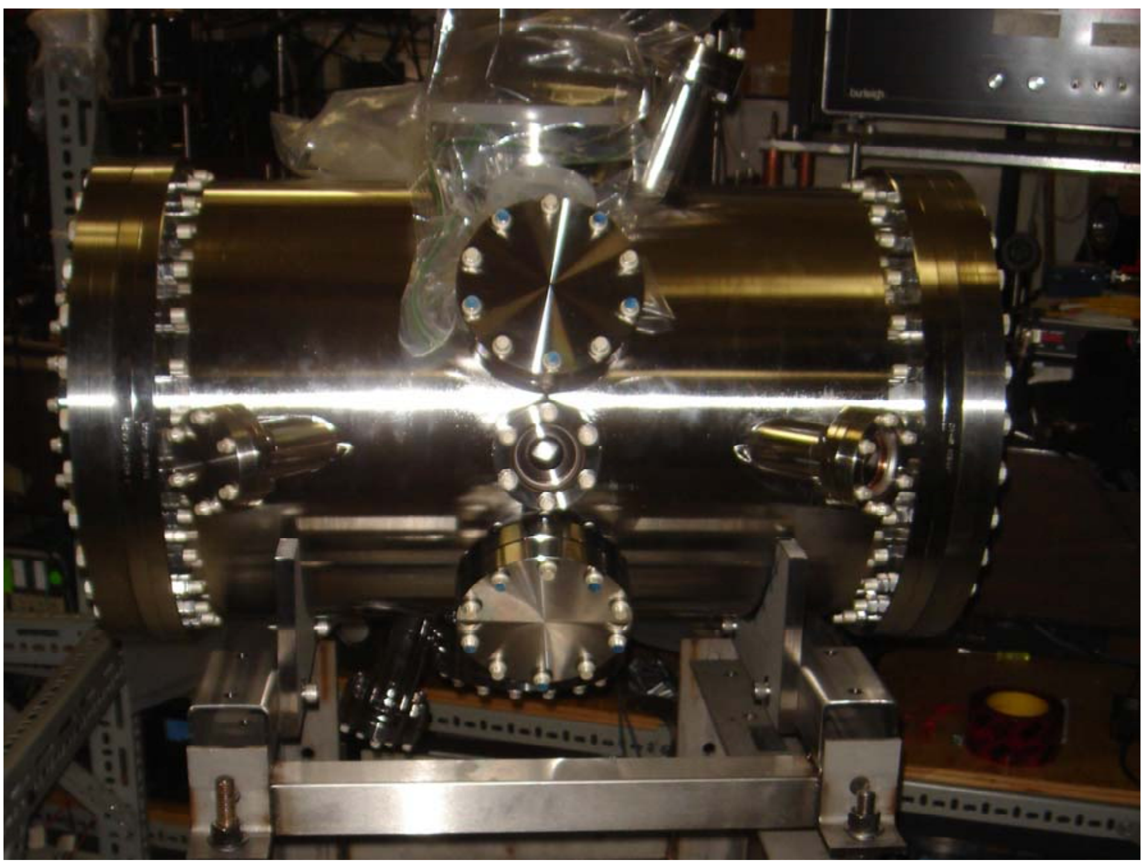

FIG. 1. The UHV chamber before being attached to the beamline. The various ports on the exterior accommodate the laser setup, detector electronics and vacuum requirements.

designed to establish a constant electric field while staying out of the likely path of recoiling ions as much as possible. These hoops are made from glassy carbon and had to be entirely machined on an electron discharge machine because the material is too brittle to withstand traditional machining. We have also installed a set of Helmholtz coils inside the chamber as depicted in Fig. 2. These coils will be operated in the Helmholtz arrangement to produce a constant magnetic field at the trap location, lifting the degeneracy of the magnetic sublevel energies and allowing efficient optical pumping. They will also be operated with current flowing in an anti-Helmholtz arrangement to produce a quadrupole magnetic field, which is necessary for the magneto-optical trap (MOT) to operate. At this point, we have tested the coils in both the Helmholtz and anti-Helmholtz arrangements, and have also successfully tested our ability to efficiently switch from one mode to the other. We have also completed work on the UHV feedthroughs that will carry our MCP signals out of the vacuum chamber. These feedthroughs have been custom designed to satisfy the requirements that the MCP be floated at 10 kV, operate in a UHV setting and have a characteristic impedance of 50Ω to avoid reflecting the signal. We have also recently installed the necessary flow meters and pumps to run cooling water into our magnetic field coils and have also begun the task of installing and aligning all of the optics necessary for the trapping and optical pumping of the ^{37}K.

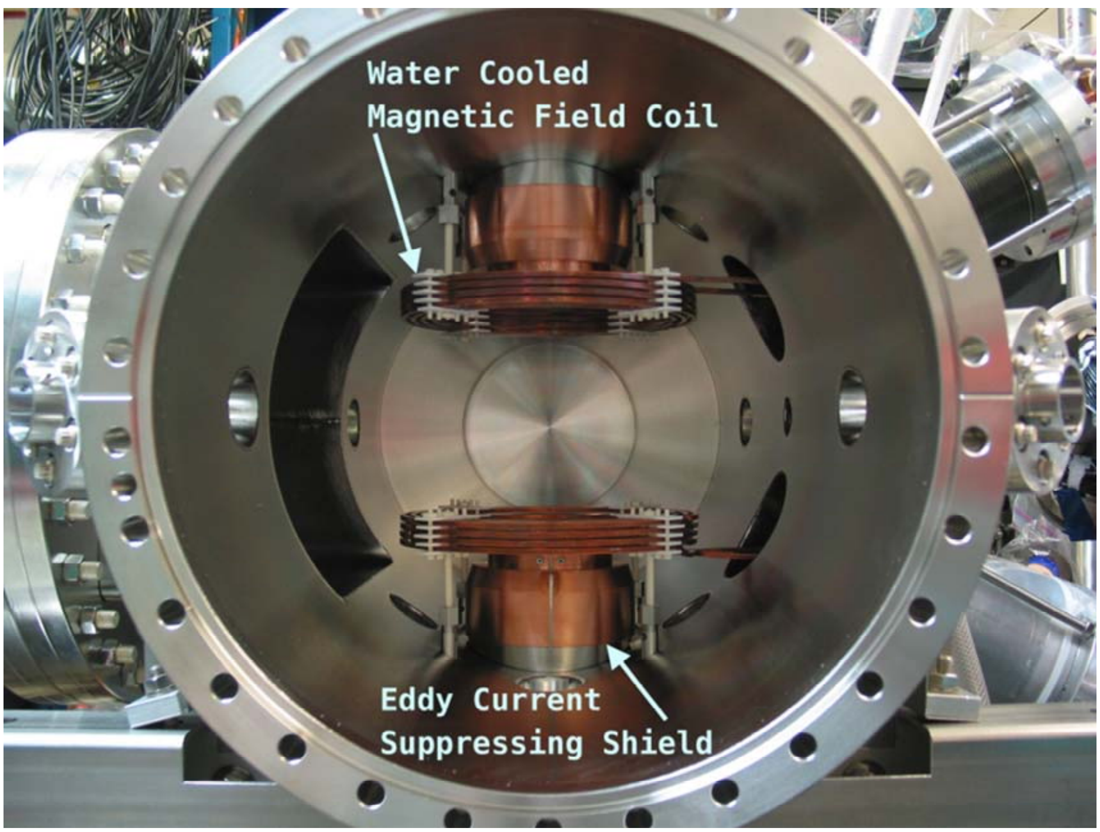

FIG. 2. The chamber with the magnetic field coils installed and the eddy current suppressing shields covering the detector ports and mirror mounts. It became apparent that these shields would be needed after testing the AC-MOT power dissipation from the oscillating magnetic field caused the mirror mounts to heat to 40°C while the thinner beryllium foils remained at 21°C. This large temperature gradient could stress and break the delicate diffusion bond between the stainless steel and beryllium. With the shields in place we saw no measurable heating.

The data acquisition plan for this experiment has now been fully developed and most of the necessary modules acquired. Currently we have built a parallel test setup that allows us to take data from our strip detectors and digitize the signals with a VF48 digitizer that was developed by the DAQ group at TRIUMF. The firmware has been programmed in the module so that if any one of the strips is above a global threshold the module will send a logic signal to a NIMIO32 module that handles coincidence conditions between the front and back of the silicon detector. The NIMIO32 module has multiple slots that can be easily be programmed and will eventually handle the coincidence signals between the strip detector and scintillator.

We have also begun developing a more complete theoretical model for the optical pumping process that is responsible for polarizing the ^{37}K nuclei. The idea of optical pumping is to use circularly polarized light to manipulate the Zeeman sublevel populations, and through the hyperfine coupling of the atomic and nuclear angular momentum, attain both atomic and nuclear polarization. Previously, a phenomenological rate-equation approach has been used to model the optical-pumping process. However, this approach is essentially semi-classical in nature and neglects quantum coherences between atomic states. To account for these effects, we have developed a model using the full density matrix formalism that accounts for quantum coherences and provides a more realistic physical description of the optical-pumping process. The improved model will allow a more precise determination of the polarization of the sample and reducing an important systematic uncertainty from previous experiments.

In the coming months, we plan to complete work on the data acquisition system as well as install the silicon strip detectors and scintillators in the new vacuum chamber. With this complete we will test off-line the new components of the experiment including the new AC-MOT, detectors, and data acquisition hardware and electronics. We have scheduled a short test run in Oct. 2012 as a final test of the apparatus, and a longer production run in December 2012.