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DESIGN AND INSTRUMENTATION FOR PERMANENT MAGNET SAMPLES EXPOSED TO A RADIATION ENVIRONMENT*

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Abstract

This work is part of a larger program to study the effects of radiation on permanent magnets in an accelerator environment. In order to be sure that the permanent magnet samples are accurately placed, measured, and catalogued we have developed a system of sample racks, holders and measuring apparatuses. We have combined these holders and measurement racks with electronics to allow a single computer to catalogue the position and intensity of the magnet measurements. We outline the design of the apparatus, the collection software, and the methodology we will use to collect the data.

INTRODUCTION

There is an ongoing plan to upgrade the Continuous Electron Beam Accelerator Facility (CEBAF) from its current top energy of 12.1 GeV to over 20 GeV [1]. This plan involves increasing the number of passes through the recirculating linac by adding an FFA lattice to handle the extra passes in a single pair of arcs. These FFA arcs will be constructed using permanent magnets, and in order to be sure that this arrangement will work long term we need to gather information about how the different potential permanent magnet materials withstand the effects of long-term radiation exposure in an accelerator environment.

This experiment will expose a variety of permanent magnet materials in a radiation environment in CEBAF while it is operating, and we will measure the magnetic fields of these samples over time. A more detailed overview of the project is covered in [2], this work details the experimental apparatus.

The lab has strict radiation control rules, which require all materials that have been present in the accelerator enclosure while the beam is on to be surveyed before they can be removed. Therefore, to get a large number of readings of the magnets over time, we will need to measure them in the tunnel. During experimental runs, the tunnel is only open during maintenance periods (normally every two weeks) and only for a limited amount of time. Finally, conditions in the tunnel during maintenance days tend to be hot, with poor air circulation, so getting the data quickly and accurately is the driving motive behind the design of this system.

We will be testing single magnet samples, as well as assemblies of four magnets in various orientations, for different materials. We will also be measuring the amount of radiation dose through a combination of area dosimeters and optichromic rods.

DATA ACQUISITION

The data will be acquired primarily through two instruments: a Senis AG 3MH6-E teslameter [3] which we will use to measure the magnetic field vectors at particular points on the face of each magnet, and a Magnetic Instrumentation, Inc. Helmholtz coil with model 2130 fluxmeter [4] to measure the total integrated flux of each sample.

In order to quickly and accurately perform our measurements in the accelerator enclosure, we have decided to use a single laptop to acquire all of the relevant data. Both the teslameter and the fluxmeter are able to communicate with external computers via RS-232 serial connections. Using a series of external commands in our data acquisition software allows us to pull the data from the required instruments and store it automatically. We developed our own software specifically to perform these tasks, and to log the data.

We are using a barcode reader to keep track of the samples, the dosimeters, and the optichromic rods. Since the barcode reader functions like a keyboard plugged into the computer, we have developed a system of leading and trailing characters in our QR codes that allows the software to sort the relevant data into the proper places. Each code starts with a capture character; Y is for single samples, A is for assembly pairs, R is for optichromic rod tubes, and X is for area dosimeters. The barcode reader has been programmed to append a tilde "~" to the end of every scan which functions as an escape character. For samples, the code after the capture character is the plate number, followed by the slot number on the plate, for assembly pairs there is a sub-slot number as well. This indicates whether it is the left or right pair. So, the code Y-1-2 would be a single sample, plate one, slot two. The code A-1-2-1 would be an assembly pair, plate one, slot two subslot one (left side). The optichromic rod containers are simply numbered, R-12 is the twelfth tube. For simplicity we will use the barcodes already attached to the area dosimeters, all of which start with the letters "XA."

A snapshot of the software GUI is shown in Fig. 1. The data acquisition computer also connects to an Arduino brand microcontroller that is connected to a series of sensors that are used to determine which measuring slot the teslameter's probe is inserted into. The system works by shining a light from an LED through a channel that passes through the measurement slot, and shines on a light sensitive resistor. When the probe is in the slot it interrupts that light and allows the data acquisition computer to assign the measured data to the correct portion of the sample.

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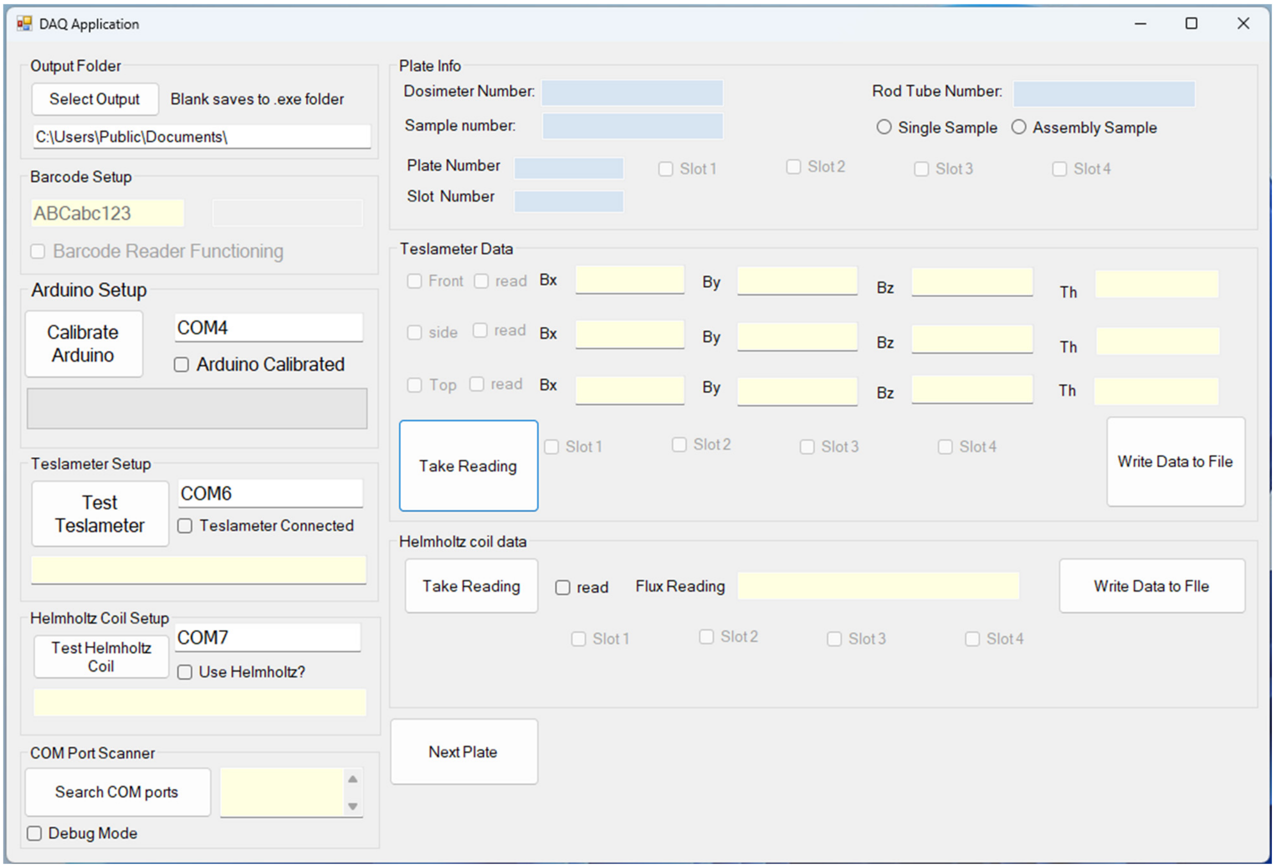

Figure 1: This is a screenshot of the data acquisition software GUI, On the left side are tools to set up for data taking, while on the right are the tools to take the data and write it to a file.

The software is capable of measuring from just the teslameter, just the Helmholtz coil, or both at the same time. It also includes a method to keep track of all of the measurements being made via visible checkboxes. When a sample has been measured by the instrument(s) in use it checks off as complete for that "slot" in a given exposure plate. Once all the samples in a given plate have been measured, we can then push a button and move on to the next plate.

Using the code system for a given sample, the software will change how many checkboxes are available, and look to the proper measuring rig to read its sensors.

EXPOSURE PLATES

The exposure plates are designed to hold the samples and assemblies in the beamline such that they will be exposed to radiation. For exposure to synchrotron radiation in the arcs, we are keeping the samples in a straight line. These plates also contain slots to hold the optichromic rod holders and the area dosimeters.

Notches have been added to the exposure plates such that the user cannot accidentally put the sample into the wrong slot. Designs for the single sample and assembly exposure plates are shown in Fig. 2.

MEASURING RIGS

The measuring rigs were designed to hold the LEDs and light sensitive resistors that the computer uses to assign recorded data to the proper portions of the magnet being measured. Diagrams of two of the measuring rigs are shown in Fig. 3. We are also investigating a design to measure fields of the assemblies while they are still in the assembly holders.

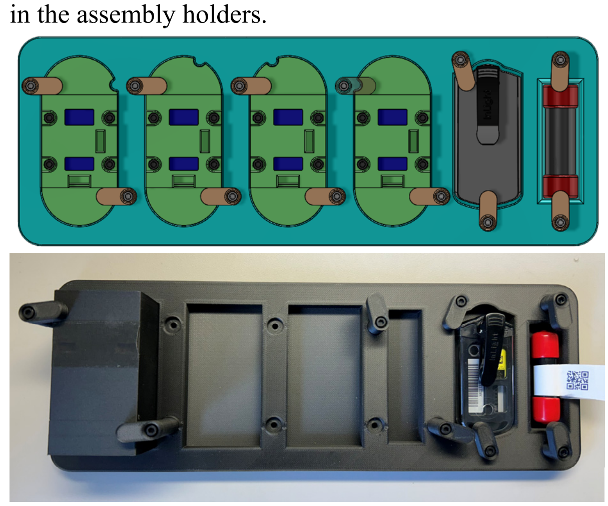
Figure 2: On the top we see the design for the single sample exposure plate. On the bottom we see a prototype for the assembly holder exposure plate with one assembly in the far-left slot, as well as an area dosimeter and an optichromic rod tube.

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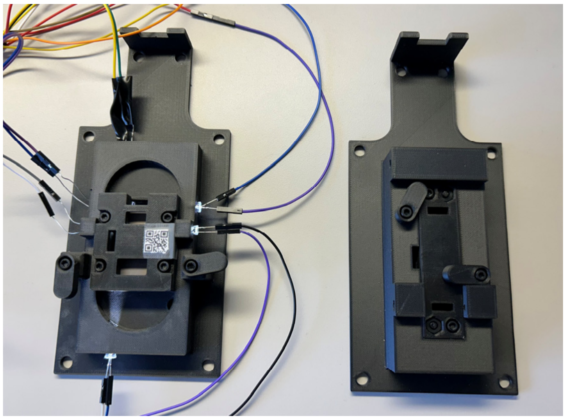

Figure 3: On the left we see the single sample measuring rig, which has been fully wired up to connect to the data taking computer. On the right we see the assembly pair measuring rig.

EXPERIMENTAL SETUP

The equipment will have to be stored outside the accelerator enclosure and brought in for data taking, due to size constraints on the elevators used to access the accelerator enclosure, as well as the need to remain mobile once in the tunnel we plan on using a pair of carts to carry all of the equipment. An image of the experimental setup as it currently exists is shown in Fig. 4.

We will need to keep the carts near an available wall outlet inside the accelerator tunnel, and the teslameter requires a warm-up period before we can begin taking data so we will have to optimize how often we move the experimental carts vs going and retrieving the samples from various points in the beamline.

TYPICAL DATA TAKING PROCEDURE

During a typical measurement session when the experiment is underway, we will start by setting up the equipment and software. First, we will use the calibration QR code to make sure the barcode reader is functioning. Then we would calibrate the light sensor system using the Arduino. This turns off and on the LEDs in the measuring rigs so that the computer will have the information needed to determine whether or not the probe is in a particular slot. Then, if we are using the teslameter, we will test the connection to be sure that it is sending and receiving data correctly. If we are also using the Helmholtz coil, we will test that connection as well.

Now that the machine is set up, we can start collecting magnet data. The magnets are organized by exposure plate. Each plate has a dosimeter and a rod holder which are bar coded, we scan those into the software. Each sample will have its own barcode which tells us which plate and slot it is stored in. We will then scan each face with the teslameter and/or measure the integrated field with the fluxmeter. These will then be recorded to data files on the computer along with a time stamp. Once all of the samples in a given plate have been recorded, we can switch to the next.

Figure 4: Two different views of the experimental setup as currently envisioned.

CONCLUSIONS AND FURTHER WORK

For our project to measure the effects of radiation in an accelerator environment on the fields of permanent magnets we have made a great deal of progress. We have a conceptual design for how the magnets will be stored and exposed to the radiation. We also have designs and prototypes for most aspects of the project. We have a piece of software that allows us to collect all of our required data, as well as a barcode system to keep track of all of the samples. We also have a system that makes sure our data is consistent and automatically stored in the correct place.

We will continue to refine the design of this experimental apparatus, as well as its software as we get closer to using it in the tunnel. Error catching and beta testing will need to be performed before we can fully utilize this system, but it will allow us to quickly and accurately measure the strength of these magnets in the accelerator enclosure. We will also need to practice and develop procedures when setting up and taking data with this equipment.

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