Precise Temperature Control of a Laser Room at the Argonne Wakefield Accelerator

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***Abstract*—At the Argonne Wakefield Accelerator (AWA) at Argonne National Laboratory, the main laser that is used in the laser room is delicate when it comes to the operating temperature inside the laser room. The current heating, ventilation, and air conditioning (HVAC) unit that is installed is not efficient enough to have the room temperature controlled in the desired operating temperature. This project aims to create a system that will observe and record the temperature changes in the room at all times, with or without operation of the laser. The system will have 5 wireless thermocouple configurations consisting of: an Arduino MKR WIFI 1010, a SHT-25 temperature and humidity sensor, and a 3.7V, 2.2 Ah Li-Po battery. These will be placed in various locations around the laser room while communicating to a Raspberry Pi 4 that will be logging the data within an online database to be analyzed later. Along with the actual design of the thermocouples, an airflow simulation will be made within ANSYS Fluent to show the current airflow efficiency that is being produced by the current heating and cooling system. From the result of the system and the simulations, a solution to the current HVAC system will be recommended to the researchers at Argonne.**

I. Introduction

The researchers from the AWA at Argonne National Laboratory[1] are in pursuit of a precise temperature control system that should be able to stabilize the temperature within the laser room at the facility. The temperature of the laser room needs to be controlled at a temperature of 70 (°F) with a stability of +/- 0.5 (°F). This is the optimal temperature to be able to use the laser without interference or failure of usage. The laser room at Argonne was recorded with the following dimensions in SI: 7.3m x 4.2m x 2.5m (L x W x H). The current HVAC unit that is operating in the laser room, a Carrier 38TRA036330, is not efficient enough to supply the necessary airflow to the different parts of the room. This HVAC unit has a fixed speed compressor which is set at a desired temperature and once that temperature is achieved, the HVAC unit shuts off until the temperature drops. This results in a temperature change gradient that is too large for the laser to run accurately. The laser room is in need of a new compressor to be installed into the current HVAC unit or to replace the existing HVAC unit altogether.

II. Objective

The goal of this project is to be able to create a series of thermocouples to analyze the areas of the laser room that are contributing to the temperature change. The setup needs to consist of the thermocouples to be wireless so there won't be any restrictions when it comes to placing the thermocouples around the room. To be able to achieve this controlled temperature, the researchers need to know all of the factors that contribute to the change in temperature which includes: thermal noise from different pieces of equipment in the room, poor airflow and efficiency from the current HVAC unit, and poor insulation of the room. Figure 1 shows the laser phase monitor (LPM) temperature and the laser phase that was recorded previously by the researchers at Argonne. This shows the effect the different factors are having on the function of the laser.

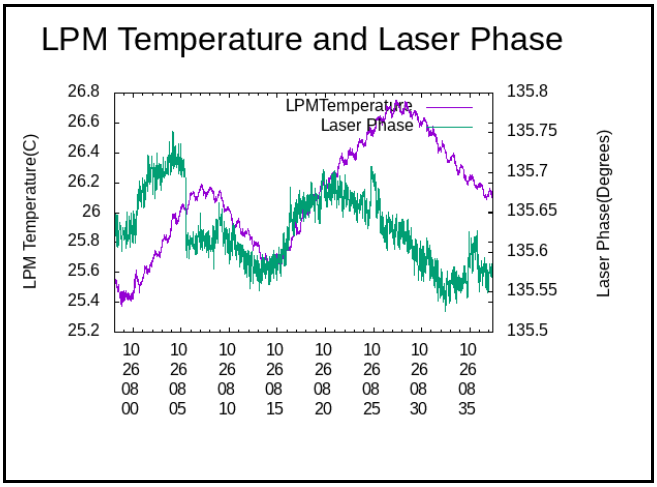

Fig. 1. LPM Temperature and Laser Phase of AWA Laser

The thermocouples will be able to collect the temperature data of the laser room and store it into a database to be referenced later to analyze these factors and where in the room these temperature changes occur. Along with creating a series of wireless thermocouples, the researchers at Argonne are also in need to analyze the airflow of the current HVAC unit through thermal simulation with the use of the program, ANSYS Fluent[2]. With the help of this simulation, the researchers will be able to see where exactly the airflow of the HVAC reaches. Along with these simulations, the researchers at Argonne are in need of a recommendation for a new compressor for the HVAC unit or a completely new HVAC system.

III. System Setup

A. Thermocouple Configuration

For the temperature data collection, the temperature that is being measured must be an accurate measurement. The

sensor that is being used to collect this data is a SHT-25 Humidity and Temperature Sensor. This sensor is able to sense the temperature of the laser room with an accuracy of +/- .36 (°F). The SHT-25 is also able to sense the humidity of the room as well that may be analyzed to see if the humidity affects the functionality of the laser. Once this data is collected, the data is transported physically through an I2C connection to an Arduino MKR WIFI 1010. This board is appropriate to be used from its low cost, Wi-Fi compatibility, and battery charging capabilities. This board is able to be hooked up to a 5V USB source and while this is connected, can charge a 3.7V battery while the device is operating. Once disconnected from the USB source, the board will continuously be importing and exporting the data from the SHT-25. The code that will be flashed onto the Arduino MKR will command the board to communicate to the SHT-25 to receive the temperature and humidity and prepare to send it wirelessly to a message queuing telemetry transport (MQTT) broker. The code will also command the board to send the voltage of the battery so the operator of the device may see the battery percentage. This will indicate when the device needs to be connected to the USB and charge the battery. There will be a total of 5 of these sensor configurations setup around the laser room and will be contained in specialized 3D printed housing units. A basic setup of the configuration can be seen in Figure 2 below and the final configuration next to it.

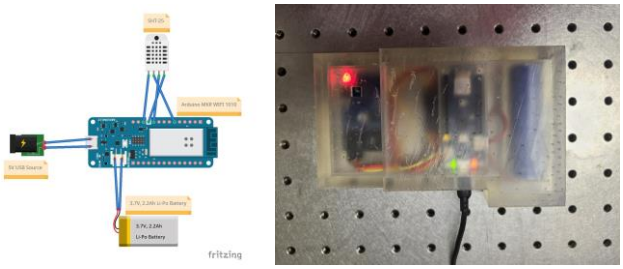

Fig. 2. Wireless Thermocouple Schematic, Final Wireless Thermocouple Configuration

B. MQTT Broker

The microcomputer that will be used as the MQTT broker will be the Raspberry Pi 4. This is a necessary option due to its low cost and ability to have the multiple Arduino MKRs connect wirelessly to it. The Raspberry Pi 4 can be connected anywhere at the Argonne facility and will be connected to the Argonne network. Once connected, the Raspberry Pi will run Node-RED[3], a program that is able to connect wirelessly to the Arduino MKR and will display the data in graphs and gauges. Along with Node-RED, the data will be sent to InfluxDB[4] and Grafana where the data can be stored for long term use and have a more compact way of viewing the incoming data. While the Raspberry Pi is connected to the Argonne network, faculty members are able to access the data from anywhere through the Argonne virtual private network (VPN).

IV. SIMULATION

The airflow simulation of the laser room was done through the program use of ANSYS Fluent. This simulation shows the quality and effectiveness of the airflow that is emerging from the current HVAC system. The results of this gives more insight on how efficiently the current HVAC system is decreasing the gradient in temperature change in the room. After there is additional analysis of the temperature data, the results may be incorporated into the simulations for further understanding of the airflow in the laser room. In Figure 3 below, an airflow simulation may be observed.

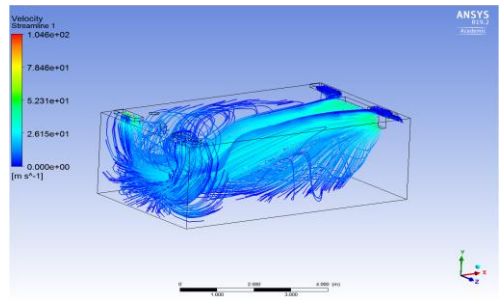

Fig. 3. ANSYS Airflow Simulation

V. CONCLUSION

This wireless thermocouple setup will be able to monitor the temperature changes in the Argonne laser room that will be analyzed in future use. This design is to help the researchers at Argonne understand the current factors that are interfering with the accurate data collection of the laser as well as defining where these factors are occurring the most in the laser room. After an elongated period of time for the temperature data to be collected, the researchers at Argonne may interpret the extent of the simulation and data collection into a decision of either replacing the HVAC system as a whole for a new and more efficient system or implementing a variable drive into the current unit to control the compressor operation.

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