Development and testing of a magneto-optical filter for a Compact Doppler Magnetograph

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**ABSTRACT**

A compact version of a Doppler magnetograph is being researched at NASA’s Jet Propulsion Laboratory for space flight imaging of the photosphere of the Sun. Here, we prepare components of the instrument and develop a data acquisition program with LabView - a graphical programming language - to show the voltage consumed by the heaters on the K vapor cell that lies within the magneto-optical filter (MOF). This program was also written to measure the temperature of the G10 housing of the K vapor cell, the magnet assembly, and the outside manifold of the vacuum chamber. Resistance Temperature Detectors (RTD’s) were soldered and wired to a USB-TEMP data acquisition board and then interfaced to the computer along with the USB-2527 data acquisition board to measure the voltage being used by the heaters. The heaters of the K vapor cell were heated at pressures varying between 28-36mTorr over temperatures ranging from 20-120°C. Faulty wiring of the USB-2527 led the reservoir temperature to skyrocket which resulted in disconnecting the data acquisition board to avoid damage to the cell. Temperatures of the components surrounding the K vapor cell were collected showing how long it takes for the instrument to heat up, also allowing a thermal time constant to be determined for the G10 housing of the K vapor cell, and the magnet assembly of the MOF.

**1 Introduction**

Understanding the Sun’s internal structure as well as how it radiates heat is key to enabling us to better predict solar weather phenomena such as coronal mass ejections. To do this, a remote sensing instrument known as a Compact Doppler Magnetograph (CDM) must be developed to take images of the velocity and magnetic fields associated with the Sun. These images are known as Dopplergrams and Magnetograms.

The CDM being researched at JPL is a magneto-optical filter (MOF) based instrument that takes Dopplergrams and magnetograms in the wings of the K 770nm solar absorption line. Figure 1 shows a schematic diagram of the CDM, which is composed of three sections: a polarization analyzer, filter section,
and wing selector. The polarization analyzer converts circularly polarized light into linearly polarized light which then enters through the filter section. The filter section contains the first MOF which produces two transmission pass bands - one on each side of the 770nm solar absorption line. These passband then coincide with the Zeeman-split absorption lines produced by the second MOF in the wing selector. It is here where linearly polarized light then gets split into two beams which are imaged on a CCD camera. (Barajas)

Figure 1: Barajas, Karen Garcia, and Duy Vo. Schematic diagram of the CDM. 2011

2 Methods

2.1 Assembling the platform, pump, and chamber

Previous designs of the CDM that is being researched at JPL did not implement a Vacuum chamber, so the first task at hand was to develop an optical breadboard platform long enough to mount the vacuum chamber - which would house the polarization analyzer, filter section, and wing selector. The platform must also mount the CCD camera on one side of the chamber and a lens which focuses light from the heliostat into the chamber on the other side as shown in Figure 2. After the development of the optical breadboard platform, a vacuum pump was refurbished and connected to the vacuum chamber with a rubber hose of approximately 20 ft in length.

Figure 2: From left to right: vacuum chamber, focusing lens, and heliostat

2.2 Programming with LabView

LabView is a graphical programming language in which a Virtual Instrument (VI) is created to run tasks needed for experimental purposes. The main purpose of the VI created for this particular project was to acquire voltage and temperature data via the USB-2527 and USB-TEMP. The VI was written to scan two channels on the USB-2527 and three channels on the USB-TEMP so that one sample from each channel was acquired every ten sec-
onds. The VI then charted the data obtained from each interface device to respective strip charts. Lastly, the VI combined the two arrays generated by each interface device to a single array with a military time stamp that each sample was taken at, and wrote the array to a spreadsheet file which could then be modified to graph certain sections of the data. Figure 3 shows the output display of the front panel with the array (top) being written, and the voltage and temperature strip charts (bottom) being produced on the left and right respectively.

![Figure 3: Front Panel](image)

### 2.3 Interfacing the USB-2527 and USB-TEMP

In order to acquire the voltage drop through the heaters on the K vapor cell, the channels on USB-2527 (Figure 5) were wired to the precision resistors on the break out board - the board connecting the MOF controller (Figure 5) to the MOF. Additionally, RTD’s were soldered and wired to the USB-TEMP (Figure 4) and then fixed to the G10 housing of the K vapor cell, the magnet assembly, and the outside panel closest to the MOF to monitor the temperature of the surrounding components.

![Figure 4: USB-TEMP](image)

![Figure 5: MOF controller (top) and USB-2527 (bottom)](image)
2.4 Testing

Using the MOF controller, the initial temperature of both the cell body and reservoir were set to 20°C. Once the actual temperature of both the cell body and reservoir reached their set point, the temperature data acquired by LabView was monitored until the system reached a state of equilibrium. This equilibrium point was considered to be when the rate of change in temperature of the surrounding components decreased to less than $1\,^\circ C\,\text{hour}^{-1}$.

Once equilibrium was reached, the set point of the cell body and reservoir were increased to 40°C and 35°C respectively. Equilibrium was then reestablished, and from there the temperatures of the cell body and reservoir were increased in 20°C increments, waiting for equilibrium to be established at each set point until the final temperature of the cell body and reservoir were at 120°C and 115°C respectively. Taking out the K vapor cell in an attempt to make a wiring diagram resulted in short circuiting the cell. This caused the reservoir heater and reservoir RTD to disconnect from the wires going into the MOF controller, ending data acquisition.

3 Results and Discussion

Pressures below 10mTorr were only achievable with a short steel hose of approximately 4 ft in length. Due to the vibrations produced by the pump itself, it was important to have the pump located in the adjacent room to avoid any disturbances caused by the vibrations. This required us to use a much longer hose of approximately 20ft in length which was made out of a rubber material instead of steel. Due to the length and material of the hose, the pressures achieved during the tests varied between 28-36mTorr.

When trying to acquire the voltage drop with the USB-2527, faulty wiring caused more power to go into the cell reservoir than needed. This caused the reservoir to over shoot the set point temperature by over 60°C. The USB-2527 was disconnected from the breakout board and the voltage drop across the resistors of the heaters were then recorded from the breakout board with a voltmeter every 20-30 minutes as appose to every 10 seconds by the VI.

Figure 6 shows the temperature of the G10 housing (left graphs) and magnet assembly (right graphs) acquired by the VI for when the cell body was being heated from 60-80°C (above graphs) and 100-120°C (below graphs). These graphs show how long it takes the instrument to heat up, and also gives the information necessary to determine a thermal time constant for the G10 housing and magnet assembly.

For further development and testing of the CDM, the remaining parts need to be installed and illuminated by the heliostat before images can be taken, and a steel hosed pipe should be implemented on the vacuum and pump instead of a rubber pipe so that lower pressures can be achieved.
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5 References