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PROTECTING THE H ALPHA SOLAR SPECTRUM FILTER IN WINTER LOW TEMPERATURES

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Abstract. In this article we describe the developement of an insulated box with a thermostat controller to protect the sensitive Baader Solar Spectrum H alpha filter in the low temperatures of winter. Our goal is to facilitate daily solar synoptic observations in all seasons.

Key words: Sun, chromosphere, astronomical instruments.

1. INTRODUCTION

The Solar Station at AIRA, Bucharest, was upgraded with the instruments needed for synoptic observations in space weather programs (Blagoi and Danescu, 2017). The Baader H alpha Solar Spectrum filter has a minimum storage temperature of 5 °C, under which the sensitive Fabry-Pérot etalon could be irreversible damaged. Therefore, in the absence of appropriate measures of protection, the filter cannot be installed on the dome during the winter. The dome of the observatory cannot be heated and the temperature inside the dome can be lower that outside. An insulated and thermal controlled box was designed and manufactured, using an Internet of Things (IoT) device which can be remote controlled and programmed to protect the filter installed on the Ref.C instrument (Blagoi and Danescu, 2017). This first approach has some disadvantages: we cannot record temperature to be later displayed, and if the internet connection fails, we cannot be certain about the heater functioning properly. After three years of using the first device, we decided to improve the electronic controller in order to be able to record the temperatures and the duty cycle of the heater to be graphically displayed on a web page. We separated the functions of the device in two parts: the thermostat and the monitoring sensors. A proportional-integrative-differential (PID) temperature controller was chosen to avoid the large variations of temperatures in the insulated box. Two digital temperature sensors and a small relay where used to monitor the parameters and send them to the server with an Wemos D1 mini WiFi microcontroller. The software was developed by us, starting from basic tutorials (Santos, 2021), so we have full control of the device. Also, we can monitor the temperature in the dome without checking a meteo station.

2. DEVELOPING PHASE

We analyzed the worst case scenario when the minimum temperature in the dome is as low as -20 °C. We found the following requirements:

1. The temperature inside the box needs to be automatically controlled and remotely verified.
2. The power of the heater must compensate the lost and conduction of heat by the instruments and camera that is installed out of the insulated box.
3. Accordingly to the working safety rules, the electric heater must be powered with a low voltage and appropriate thermal and electric insulation must be provided to avoid any injuries, fire or malfunction of the device.
4. A backup for the power line must be provided to avoid interruption in case of power outages.
5. A separate device for alert in case of failure is needed.

To address the first requirement, a custom insulation box was designed and manufactured to keep the temperature of the Hα Solar Spectrum Filter greater than the limit with a good safety margin of 10–15°C.

Next, we checked some heating elements available with low power and low voltage. One resistive heating element of 12 V / 40 W was selected. For the uniform transmission of the heat to the Hα filter we used an aluminum radiator with a 12 V small fan.

In order to control the temperature from outside the Observatory we searched for an IoT device that is available on the market with good reviews, easy to install and programmed for the temperature control and without any special requirements. The *Sonoff TH 10 WiFi* device was selected to control the temperature, automatically and remotely. A simple Android application is available that can control the device using a smartphone.

We searched for backup power line solutions on the market. A backup Uninterruptible Power Supply (UPS) for central heating systems with an external battery of 100 Ah capacity was selected. The safety margin was chosen to cover an entire weekend if power outages occurs.

2.1. CONSTRUCTION OF THE THERMAL INSULATED BOX

We build an isolated box around the filter from a 20 mm thick polystyrene foam sandwich with 1mm layers of plastic protection. The static air in the foam is blocking the heat transfer. Figure 1.

The parts of the instrument outside of the insulated box will dissipate some of the heat but the filter can be kept at a safe temperature. The box can be opened for inspection and during the warm days in the summer when cooling of the Hα filter

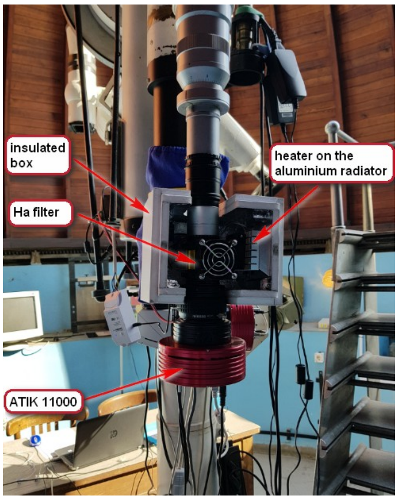

Fig. 1 – Thermal insulated box.

(Solar Spectrum type) is needed. The resistive heater was installed on a radiator provided with a small fan. The circulating air transfer the heat to the filter by convection. The heater is powered by a 12 V / 5 A DC power supply. The internal sides of the box is covered in aluminum foil which reflects the heat inside.

Sonoff TH10 is an IOT device, with WiFi connection and a cloud application that can be run on a smartphone. This device has a digital sensor for temperature and humidity that is displayed in the application. A relay inside can control the heater according to the programming parameters, temperature or humidity. We use the inside temperature as an input variable. The Auto function work all the time, even if the WiFi communication fails.

To avoid power outages, we use an UPS special designed for central heating with external battery of 12 V 100 Ah. The energy provided a backup time longer than 48 hours, enough for the worst case scenario when the temperature is very low and heater runs at all the time. In practice, the duty cycle was never close to 100%.

2.2. TESTING PHASE

With the help of a FLIR Thermal image camera we have measured the temperatures of the box, open and closed. The thermal images are shown in Figure 3.

A minimum temperature was recorded in the 1st of March, 2018. We use a meteorological station to register temperatures in the dome of the Observatory. Outside temperature was recorded by the Filaret Meteorological Station that is near the Observatory. We found the data available for download with enough accuracy, tenths of Celsius degrees, hourly cadence, on the site www.rp5.ru (Raspisaniye Pogodi Ltd.,

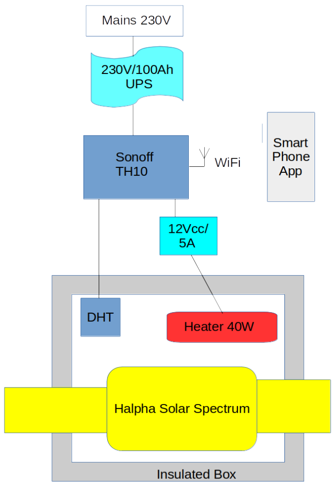

Fig. 2 – Schematic of the heater

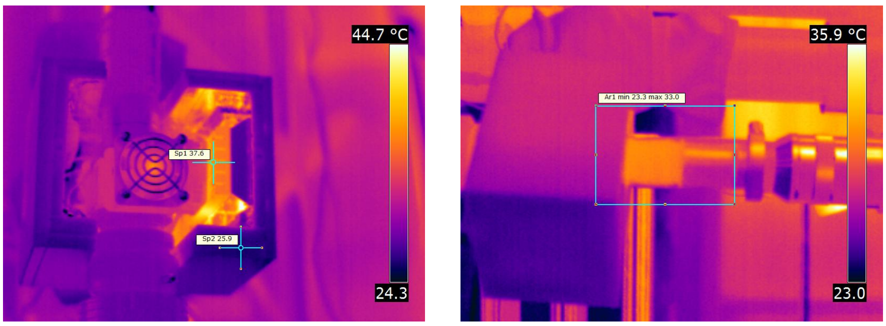

Fig. 3 – Heater open/close - FLIR camera images)

2018). Figure 4 shows the temperatures in the 28.02.2018-02.03.2018 interval.

Unfortunately, the simple Android eWeLink application of the Sonoff TH10 has no temperature history (Itead, 2017). We have only the ON and OFF time when the heater has started and stopped, Figure 8.

Therefore, we studied the correlation between temperature in the Observatory and ON/OFF cycle, when the heater increase temperature inside the box.

The automatic duty cycle was set to start at 15°C and stop at 17°C. There is an hysteresis caused by the thermal inertia of the device and the application use only integer values for the limits. So, the effective temperature in the box was in the 14–22°C range.

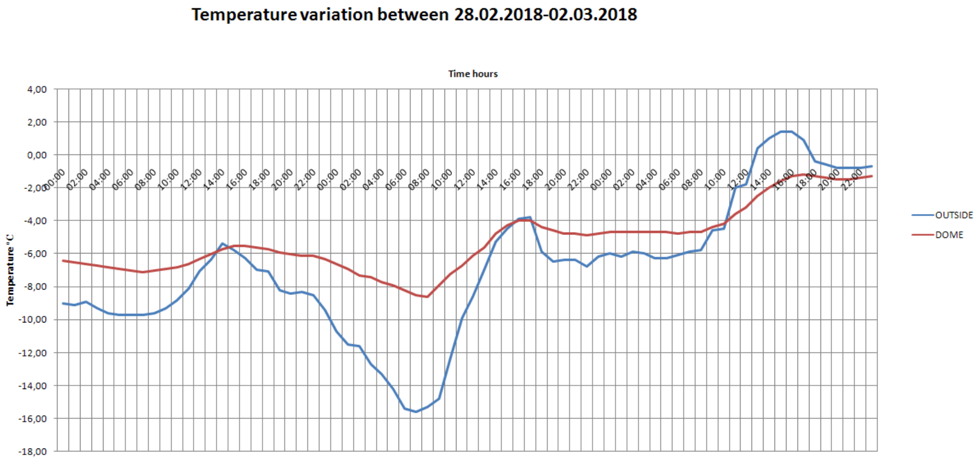

Fig. 4 – Meteo Stations records: blue=Filaret MS, red=Observatory dome

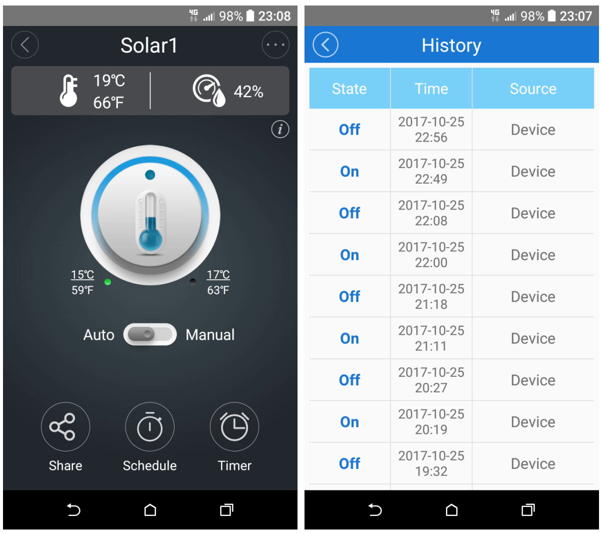

Fig. 5 – eWeLink Android application

The temperature in the dome of Observatory is either greater or lower than the outside temperature by several degrees because the thermal inertia of the concrete building and the wooden dome.

When the outside temperature in the dome is high, the cycle has shorter ON and longer OFF phases. When the outside temperature is lower the ON phase become shorter than OFF phase, approximately 50 % duty cycle is at –10°C in the dome, shown in Figure 6. The duty cycle was not calculated but represented by the red line

Table 1

Observations of the heating cycle in 01.03.2018

Nr. Obs.	Time (hh:mm)		Interval (min)		Temperature (°C)	
	ON	OFF	ON	OFF	Dome	Outside
1	3:45	4:06	21	20	-7.7	-13.3
2	4:26	4:48	22	20	-7.8	-13.8
3	5:07	5:30	23	19	-7.9	-14.2
4	5:49	6:12	23	19	-8.2	-15.4
5	6:31	6:54	23	19	-8.5	-15.6
6	7:13	7:36	23	18	-8.6	-15.6
7	7:54	8:17	23	20	-8.5	-15.3
8	8:37	8:59	22	19	-7.9	-14.8
9	9:18	9:40	22	20	-7.2	-12.3
10	10:00	10:21	21	21	-7.2	-12.3
11	10:42	11:01	21	22	-6.7	-9.9
12	11:23	11:42	19	22	-6.1	-8.6
13	12:04	12:23	19	23	-6.1	-8.6
14	12:46	13:05	19	23	-5.7	-6.1

versus blue line, they met at 21 minutes, corresponding to –10°C. By analyzing the figure, one can see the anti-correlation between temperature and duty cycle. Because the maximum duty cycle was not attained when the temperature was low outside, we deduced that is enough safety margin for colder weather. Thermal inertia of the building helps (gray dotted line versus black dotted line).

The heater has compensated the minimum temperatures on the dome very well. A lower minimum temperature can be programmed, when needed.

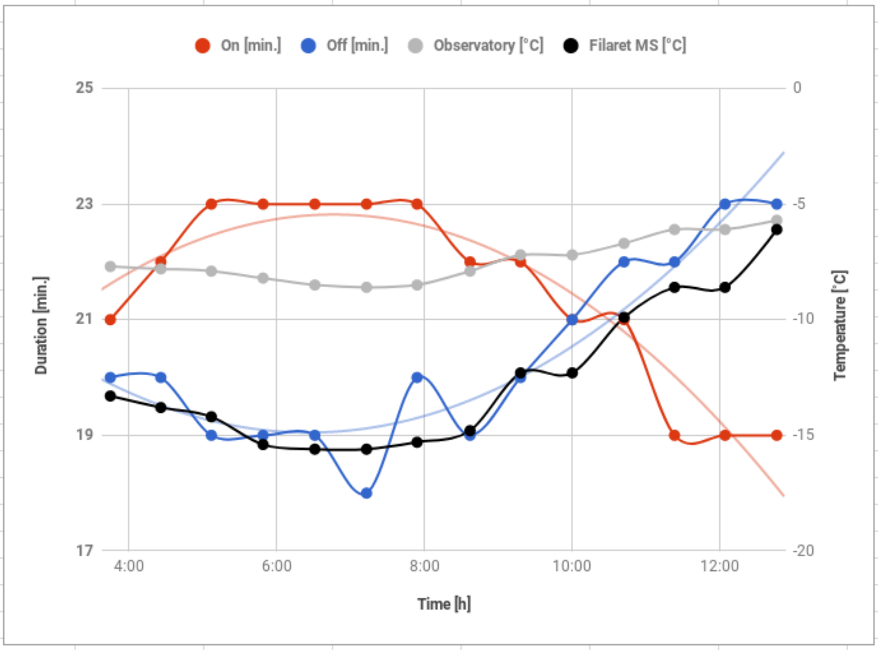

Fig. 6 – Correlation between temperature and duty cycle of the heater.

3. IMPROVEMENTS

The eWeLink application is freeware and depends of third party manufacturer of the Sonoff TH10 device. We cannot alter this application to adjust it for our needs. With this device we have no knowledge of the temperature inside the box and in the dome, so we cannot record and display the values on a web page on our server. Also, when internet outages occurs we cannot check the temperature and be warned if the heater fails.

In the second phase of development we changed the Sonoff TH10 with a PID temperature controller and a separate custom device that measure and record the temperatures to be displayed graphically on our server. The PID (Proportional-Integrative-Differential) temperature controller is an industrial device that control temperatures inside the insulated box with a PWM (Pulse Width Modulation) solid-state relay (SSR) and keep constant the temperature by automatically adjusting the time of heating according to the target temperature. This controller is reliable and separated from the monitoring device.

PID digital temperature controller model XH-W2023 specifications:

Test range	–55–120°C
Control precision	± 0.1 °C to 0.2°C
Refresh frequency:	4 times/s
Input power	DC12 V–24 V
Output	max 10 A
Max power	12 V=180 W, 24 V=360 W
Operating environment	0–50°C max 85 %RH
Size WxHxL	75x35x85 mm

In order to measure and record the inside heated box and ambient temperatures we used a WEMOS D1 mini WiFi microcontroller and two digital temperature sensors type DS18B20 developed by Maxim Integrated. A 12 V relay is used to send the signal from the PID thermostat controller output to a digital port of the microcontroller for galvanic separation of the circuit. In order to avoid transient short pulses (switch bounces) a small ceramic capacitor is used. The schematic diagram of the circuit is shown in Figure 8. Both modules are installed in the same case and powered from the same power supply of 12V/5A DC. The Wemos D1 mini is powered with 5V using a step-down DC-DC converter. One digital temperature sensor was installed in the insulated box, near the thermistor (NTC analog sensor) used by the PID controller. The other digital temperature sensor was left outside the electronic unit, having the purpose of measuring the observatory dome temperature. An external cable between the control unit and insulated box was shielded and DB9 standard connectors where used, secured with screws. The power line of the electronic unit was connected to the uninterruptible power supply.

The PID controller stabilization process begin with some visible fluctuation of the heater temperature, then the amplitude decreased to a negligible range (Figure 9).

The software was developed in the ARDUINO IDE (Arduino, 2021) inspired by a tutorial from randomnerdstutorials.com site (Santos, 2021). The duty cycle of the thermostat is calculated from total ON time in one minute. The microcontroller is connected to the WiFi network and runs a HTTP client software that sends the monitoring parameters to the main server. On the main server a *php* script is running, which read the temperatures and duty cycle from the HTTP POST request and record the time and data on a CSV file on a 1 minute cycle. From the CSV file a graphic diagram is obtained using an automatic *gnuplot* script and displayed on a web page on our server. We can check the variation of the temperatures in time on the web page. The controller box is provided with a 4 digit 7 segments LED display (TM1637) that show connecting information at start, then a sensors check and then the ambient temperature from the observatory dome. The insulated box temperature is shown on the PID controller display. We can select desired temperature in the box with the PID controller panel. In the winter, the device helps to increase the temperature of the H-alpha filter quickly.

DS18B20 temperature sensor specifications:

Manufacturer:	Maxim Integrated
Sensor function:	temperature
Output type:	digital
Resolution:	12 bit
Interface:	1-Wire
Accuracy:	± 0.5°C
Mounting type:	THT
Operating temperature:	–55°C to +125 °C
Operating supply voltage:	3 V to 5.5 V
Package type:	TO–92

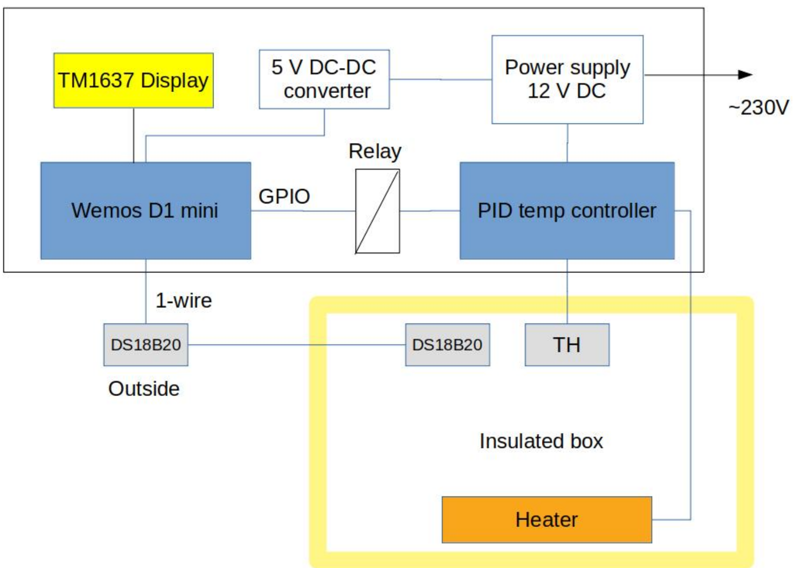

Fig. 7 – Heater controller schematic diagram - improved version.

We tested the system on a worst case scenario when the difference from the heated box and environment temperature is more than 20°C. The PID thermostat had oscillations at first, then the temperature was stabilized to the desired one in an asymptotic curve:

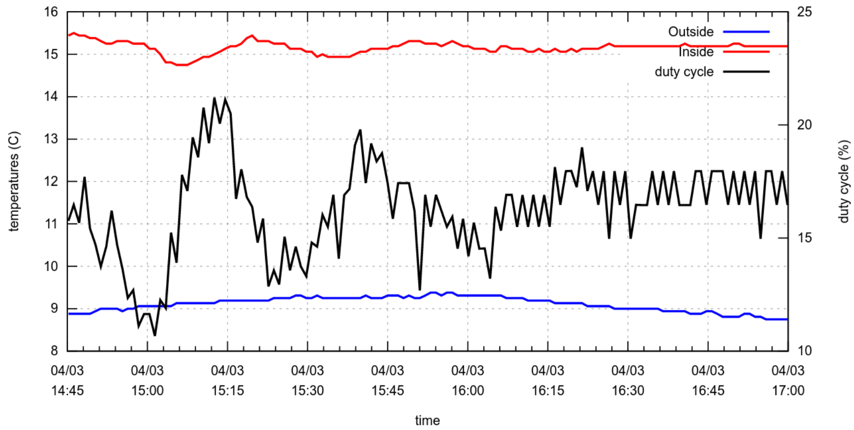

Fig. 8 – PID stabilization process.

The recorded temperatures on one winter week (Figure 8) show the constant temperature inside the insulated box (red line) when outside temperatures varied in a day/night cycle (blue line). The duty cycle (black line) is lower than 45 % when the temperature is around 0°C. The minimum temperature recorded in the Observatory was –8°C, so we are confident that the device can protect the H alpha filter in colder winter.

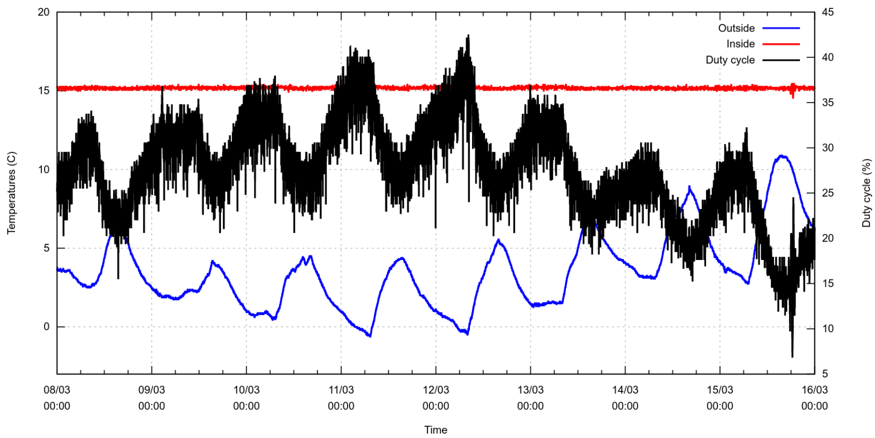

Fig. 9 – 1 week temperatures.

4. CONCLUSIONS

The goals of the work was attained successfully. The thermal insulated box has protected the Hα filter in cold weather for 3 winters (2017–2020) and there is enough safety margin for the coolest days of the next season. There were no failures, no major power line outages and few days in the dome below –10°C. In the winter, it helps to increase the internal temperature of Hα filter quickly. The device used a ready made available component, requiring no programming, can be replaced by anyone with ease. We noted the disadvantages of this first approach: missing accurate temperature measurements, too short event log, no direct information about the duty cycle, large variation of temperature in the box. The Android application was subject of updates and undesired changes of the interface, out of our control.

In the 2021–2023 winters the upgraded PID temperature controller and web page version was in use. The disadvantages of first approach was solved by changing the Sonoff TH10 device with two independent modules, one to automatic control the inside temperature and one for monitoring both the inside and outside values and also the duty cycle of the heater. We could verify the graphic diagram at anytime on our web page. The graphic displays the values on a week time range. Using an industrial standard controller and decoupling it from the monitoring module we have reduced the chances of failures. The device help us to made continuous Sun chromospheric observations, regardless the outside temperature.

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