LAHM

the Light Absorption Heating Method

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Introduction:

The Light Absorption Heating Method instrument (aka LAHM) has been developed in response to research community needs: a low-cost method to quantify the absorption ability of particles collected on filters. Initially developed for the measurement of light absorbing particles on snow, the LAHM instrument can also be used for air pollution filters (PM2.5 etc.). This document is both an introduction to the theory and a user's manual for the instrument.

Instrument theory:

The LAHM instrument is a "first principles" instrument, taking advantage of the basic laws of physics. Particles, which are captured on a filter, are exposed to visible light. The particles absorb the visible light and as a result increase in temperature. The temperature increase can be directly related to the mass of particles on the filter by using calibration filters with known quantities of light absorbing materials. In practice, it is not that simple, due to the variability of the mass absorption cross section (MAC) of different particles. Different types of soot have been shown to differ by a factor of two in MAC, and dust can have a MAC 60 times smaller than soot. For that reason, results from the LAHM instrument must include a reference to the calibration material. For example, the particles on a filter absorb the same amount of light as XX micrograms of fullerene soot type black carbon (an industrial soot often used for calibration of black carbon measurement instruments).

About us:

Natural Systems Research LLC. is a partnership registered in the state of Colorado in 2016, owned and operated by Dr. Carl Schmitt and Dr. Rebecca Cole. Natural Systems Research LLC. is based in Eldora, Colorado and includes an electronics and machine shop on its premises as well as computing resources sufficient for basic models. Currently we manufacture and sell the LAHM instrument and are applying for SBIR funding to develop further instruments.

When you buy a LAHM, what do you receive?

Your LAHM ships with everything that you need in order to get started. The instrument components are mounted onto a plexiglass base. Figure 1 shows a sketch of the base as well as additional components that you will receive. These include:

A. Base: including power controller, arduino with latest software, instrument base with infrared thermometer.

B, C, D. 2.6 mm thick plexiglass 15 x 15 cm plates: Three plates with 3.0 cm (B), 4.1 cm (C) and 6.5 cm (D) holes drilled in the center.

E, F. 0.4 mm thick plexiglass 2.5 x 15 cm plates: Two strips of plexiglass that provide a gap for warm air above the filter to escape.

G. 0.4 mm thick plexiglass 15 x 15 cm plate: This plate includes four rubber bumpers for placement of the light.

H. Light and cord: A power cord with an LED light.

I. USB connection cord to communicate with the arduino.

J. Optional power convertor for regions with 220V standard power. (Components of the instrument will only function with 110V power.)

K. Several calibration filters.

Figure 1:

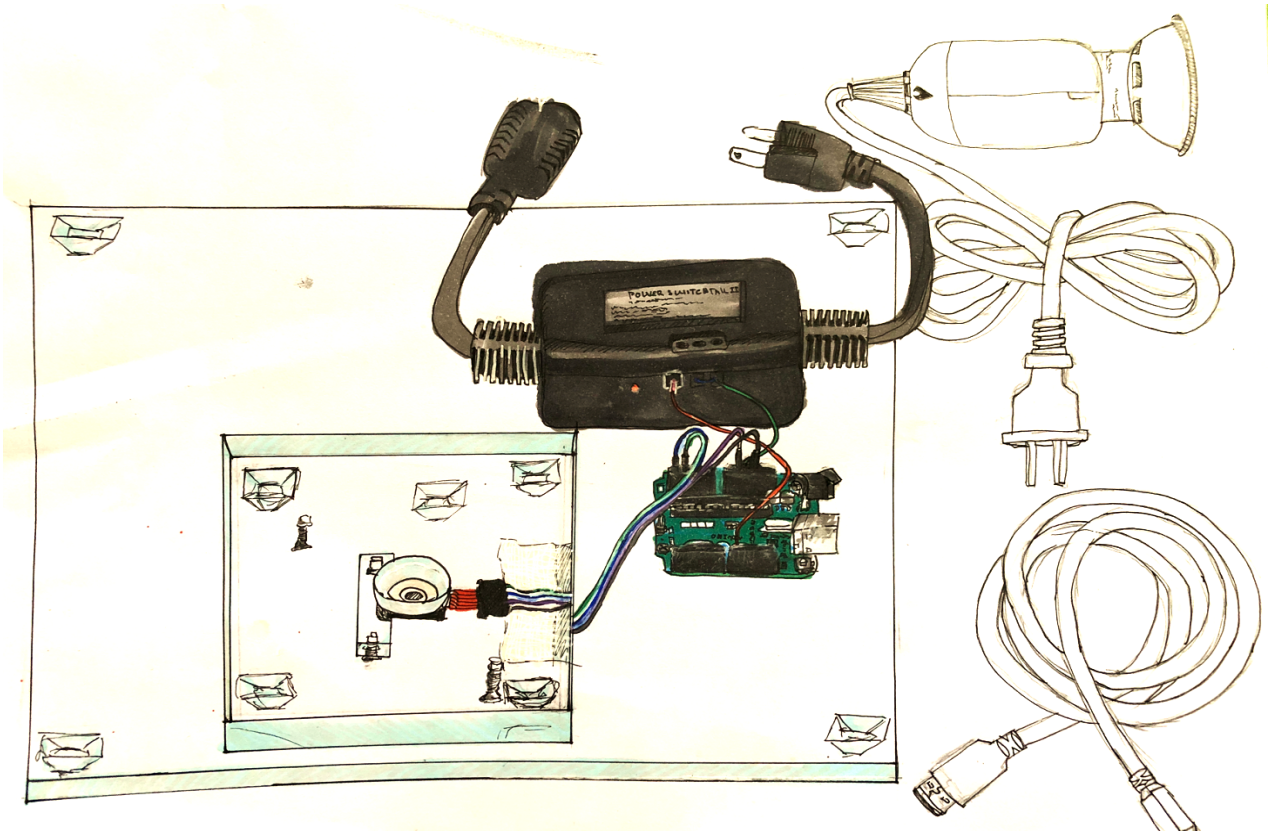


Figure 1: Drawing of the LAHM instrument.

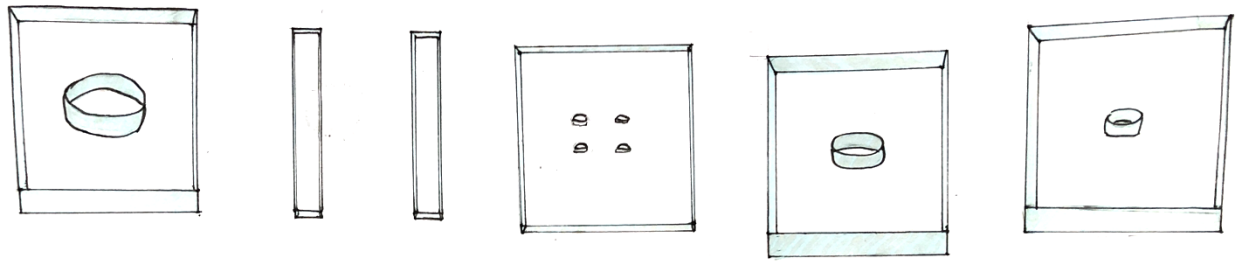


Figure 1b: Additional parts shipped with LAHM instruments.

Building the "Stack"

For conducting measurements with LAHM, it is necessary to construct the stack of plates as shown in Figure 2. The stack consists of five components: Depending on the filter size, either plates B and C or C and D, the two plexiglass strips E and F, and the top plate G.

For 25 mm filters, the stack will consist of plates B and C, then E and F parallel and at the edges of C, then plate G on top. For 47 mm filters, the stack will consist of plates C and D, then E and F parallel and at the edges of C, then plate G on top. For 25 mm filters, the filter is placed directly over the 22 mm hole in the base of the instrument (over the infrared thermometer sensor, see Figure 3). The stack is then placed over the top of the base plate. For 47 mm filters, plate C remains on top of the base and the filter is placed on plate C centered over the hole. The remainder of the stack is placed above. Finally, the light is balanced on the four rubber bumpers over the top of the hole and you are ready for measurements.

Figure 2, the stack:

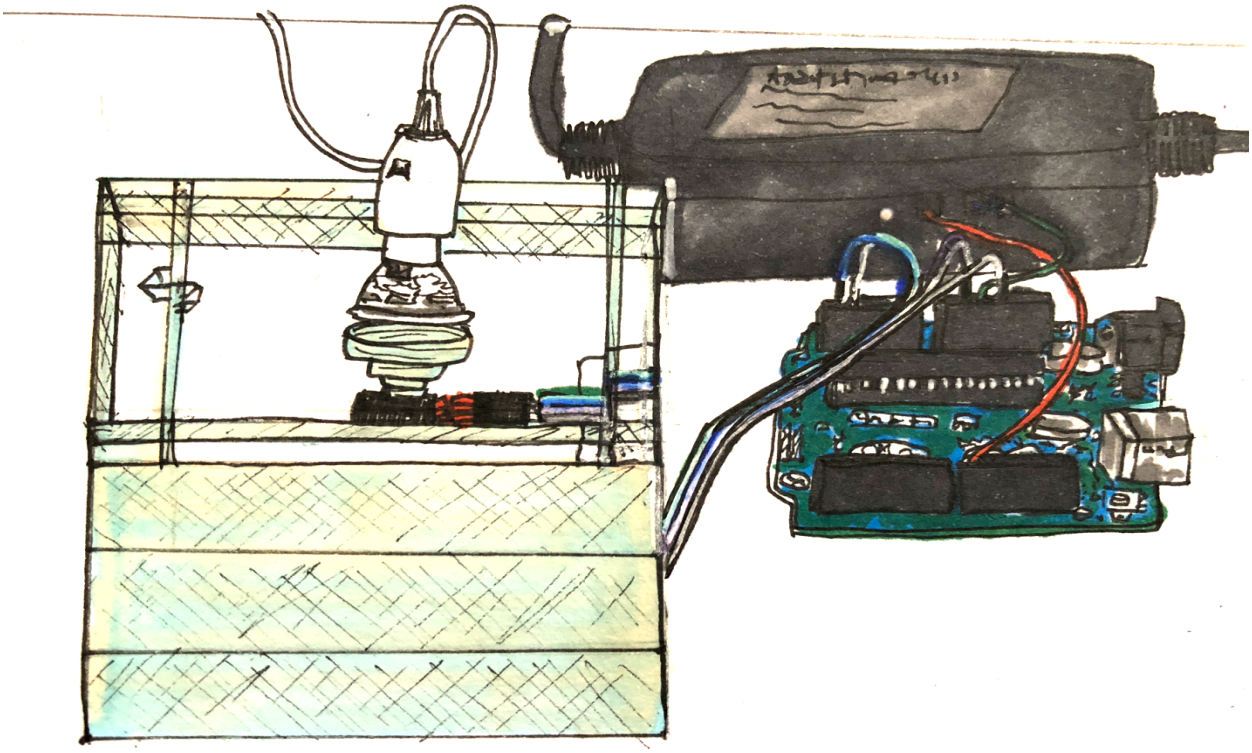


Figure 2: The stack: the instrument base with two thick plates and the measurement plate.

Figure 3, placing filter over hole:

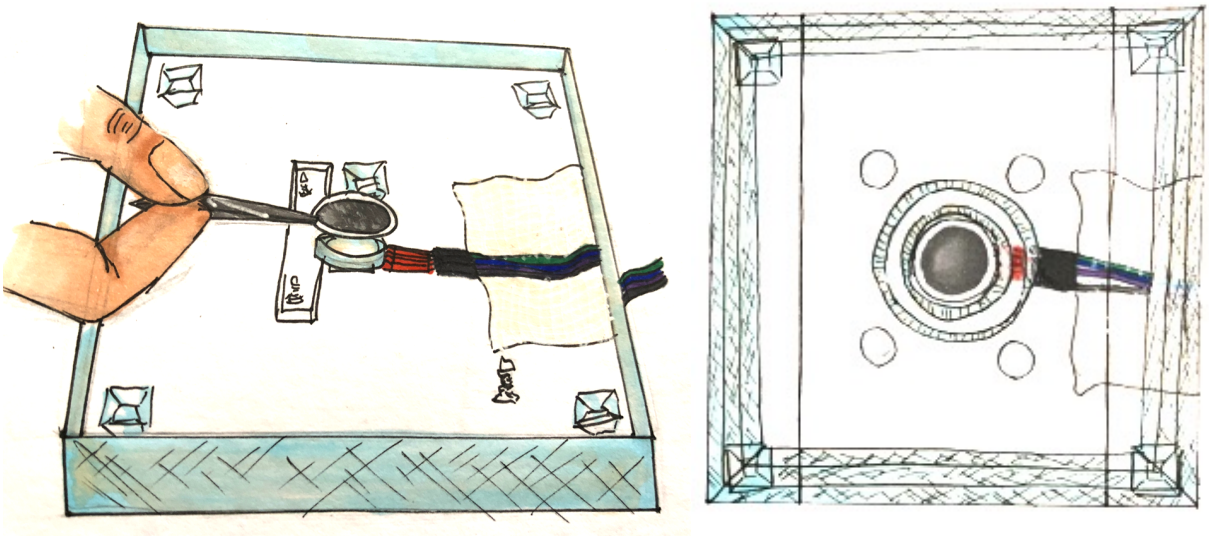


Figure 3: Placing the filter over the sensor (left), and the view from the top with the filter perfectly centered in concentric circles (right).

Software:

Your instrument will come preloaded with the latest software on the arduino microprocessor. It is necessary to use a computer (with a functional USB port) to communicate with the arduino. Install and load the arduino platform software from www.arduino.cc (versions 1.6.5 and 1.8.5 have been tested). The most current version of the operation software will be emailed to purchasers, the code is already loaded onto the arduino. You only need the arduino software to interface with the board.

Operating instructions:

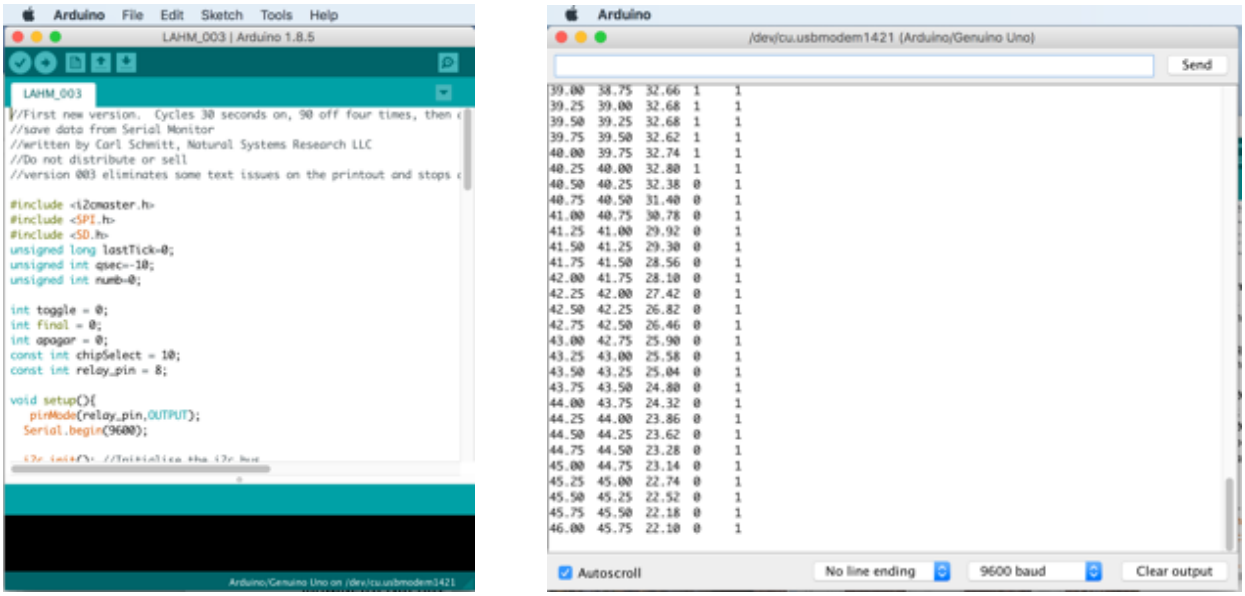
1. Based on the instrument description, place a filter in the instrument and build the stack. Plug the light cord into the receiving end of the PowerSwitch Tail II. Plug the other end of the PowerSwitch Tail II into an extension cord (and if necessary into the power convertor to convert from 220V to 110V), then into a standard outlet.

2. Connect the USB cable to your computer, then plug the other end into the arduino. This will power the arduino and start a measurement. Note that for best results, the instrument needs to warm up. Do not worry about collecting data when you first power up the arduino. The light should turn on and off from time to time (if it doesn't, check the switch on the light cord).

3. It takes approximately 11.5 minutes for a measurement cycle. In that time, the light will illuminate the filter 5 times, 4 times for 30 seconds and the final time for 2 minutes with 90 seconds for cooling after each illumination period. Allow the instrument to run its full 11.5 minute cycle, then proceed to step 4.

4. Open the arduino software on your computer. You will see something like the right side of Figure 4 below.

5. To start a new cycle for the instrument, choose the "Tools" menu and select "Serial Monitor". This re-starts the software on the arduino as well as shows the raw data in the Serial window. An example is below in the left side of Figure 4:



6. The serial monitor shows the following data:
Column 1: the overall time (0-690 seconds 0.25 per line)
Column 2: the time within the cycle (0-120 for the first four cycles, then 0-210 for the final)
Column 3: the temperature of the filter in C.
Column 4: either 1 (the light is on) or 0 (the light is off)
Column 5: the number of the cycle (1-5).

7. When the measurement is done (691.25 seconds in column 1) the arduino will stop writing data to the serial monitor. Save the data. Place the mouse over the serial monitor and click somewhere on the window to make sure the serial monitor is the active window. Then, choose "select all", from the "edit" menu, then "copy" from the "edit" menu (or control-A, control-C on windows or command-A, command-C on a Mac). Open a plain text file (Notepad on Windows,

TextEdit on a Mac) and "paste" the data into an empty file. (For Mac users, in TextEdit, choose the "Format" menu, then select "Make plain text".) Save the file with an appropriate name for the filter.

8. To analyze the next filter, first remove the stack, replace the filter with the new filter, then replace the stack and light. Then close the "Serial Monitor" window, then open the "Serial Monitor" from the "Tools" menu again (go to step 5 and repeat).

9. When finished, remove the USB cord from the arduino, remove the final filter and store appropriately, and place the LAHM instrument in a secure location with a dust cover if necessary.

Results:

You will have the option of receiving result calculation software in several formats: an excel spreadsheet, or code in Python or IDL.

Excel spreadsheet: To obtain results from the excel spreadsheet, you will copy and paste the data from the text file into the excel spreadsheet. The results will appear in the columns to the right of the data. The excel spreadsheet contains calculations to determine the quantity of effective black carbon on the filter in micrograms (light absorbing capacity in units of light absorption by fullerene soot type black carbon). Also included is a conversion to determine the mass mixing ratio based on the quantity of water filtered (for glacier light absorbing particle work). Results, uncertainties and an explication of the different calculations are given in the spreadsheet. Please refer to the filtering instructions and documentation either included or online at www.naturalsystemsresearch.com for instructions on calculating pertinent values for glacier and snow research.

Technical specifications:

Light Absorption Heating Method LAHM instrument, version 6.1	
Parameter	Specification
Measured parameter	temperature increase from light absorption
Derived parameter	effective black carbon (eBC)
Units	micrograms of black carbon on a filter
Units definition	effective black carbon is a unit of light absorption (not a mass of black carbon). 1.0 microgram of eBC is the amount of light that 1.0 micrograms of fullerene soot absorbs.
Particle size range	filter dependent (approximately 90% of mass caught with pall tissuquartz filters)
Derived quantities	eBC / volume of filtrate (grams of BC per gram of water for example)
Microcontroller	Arduino
Temperature sensor	MLX9061 infrared thermometer module
Calibration	calibrated filter samples provided and back-calibrated to primary unit in US.
Software	Arduino sketch provided
Necessary computing power	Computer with USB port (windows or mac) running Arduino software (1.6.5 tested)
Analysis software	IDL code and/or excel file provided for analysis
Software updates	Provided as necessary for operation and analysis
Operating conditions	Laboratory, out of direct sunlight, preferably at near constant temperature.
Size	base plate: 18x24 inches, height ~10 inches when operating
Weight	approximately 6 pounds
Power requirements	Standard wall plug (110 or 220, must be specified when built)
Options	PM2.5 filter adapter (accommodates 47mm filters, experimental)