PULsE User Manual

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Introduction

PULsE (Processing Unit for Laser flaSh Experiments) is an advanced analysis program for processing data from laser flash experiments, allowing effective treatment of difficult cases where conditions may not be ideal for simpler analysis. PULsE analyses the heating curves from laser flash experiments and outputs the thermal properties of the sample. PULsE is specifically tailored for use in the Materials Research Facility, and reads ASCII files generated by the Linseis LFA.

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Beta testing and User Manual by Rob Heymer.

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1 Installation

Download and unzip the PULsE package, which should include three folders (Pulse_for_Linux, Pulse_for_Windows, and Required_System_Packages), as well as README.txt and VERSION.txt with information.

1.1 Windows

In the Required_System_Packages folder, double-click "jdk-11.0.4_windows-x64_bin" to install Java (jdk). Append the path to the bin to your path environmental variable. In the File Explorer, right-click "This PC" and select "Properties" as in Fig. 1a (in Windows 10; earlier versions may vary). Then, click "Advanced System Settings" (Fig. 1b) and then "Environment Variables" (Fig. 1c). Double-click on the "Path" User Variable (Fig. 1d) to bring up a list of paths already in the directory (Fig. 1e). Click "New" and past in the path of the Java jdk bin. Leave this window open, as you will need to add paths for other libraries.
Copy javafx-sdk-11.0.2 from the Required_System_Packages to the directory where you installed Java (usually in Program Files). Add the path of the bin (.../javafx-sdk-11.0.2/bin ; use the File Explorer to copy the full path) to the Path environmental variable in the same way as previously.
Run gp527-win64-mingw (in the Required_System_Packages folder) as an Administrator. Copy the path of the bin directory for gnuplot to the Path environmental variable as before.

1.2 Linux

To install the Java jdk, open the Linux terminal and install Java jdk by typing:

```
sudo apt-get update
sudo apt-get install openjdk-11-jre
```

If it does not install, type:

```
sudo add-apt-repository ppa:openjdk-r/ppa
```

and try again. To install OpenJfx, type:

```
sudo apt-get install openjfx
```

into the terminal, and type:

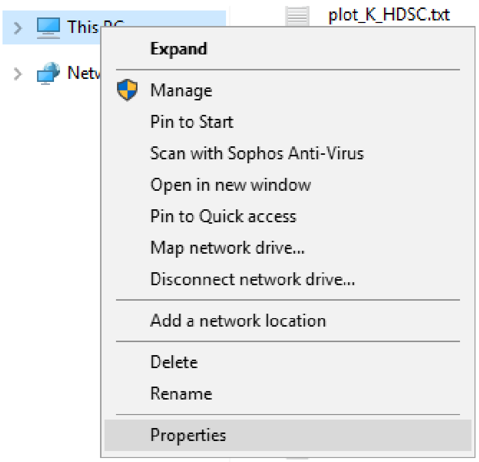
```
whereis openjfx
```

to ensure it has installed. To install gnuplot, in the terminal type:

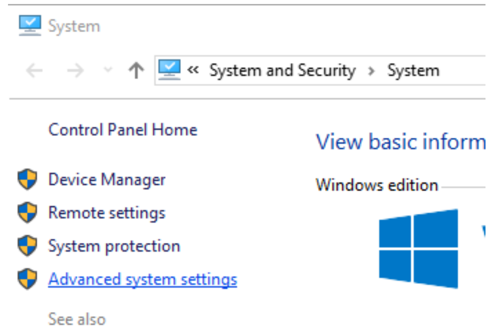
```
sudo apt-get install gnuplot
```

To allow the program to execute, open a terminal in the same folder as PULSE.jar, and into this type:

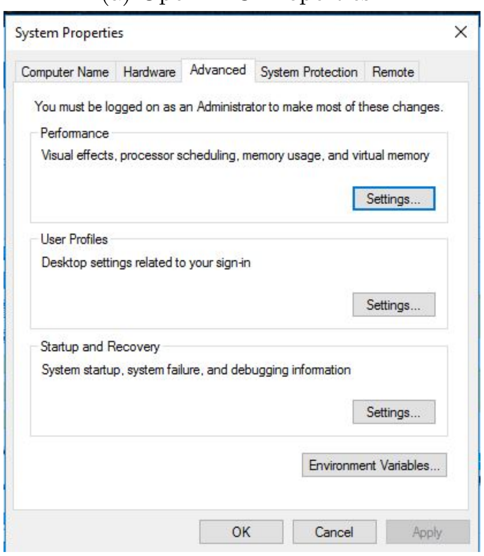
```
chmod +x PULSE.jar
```



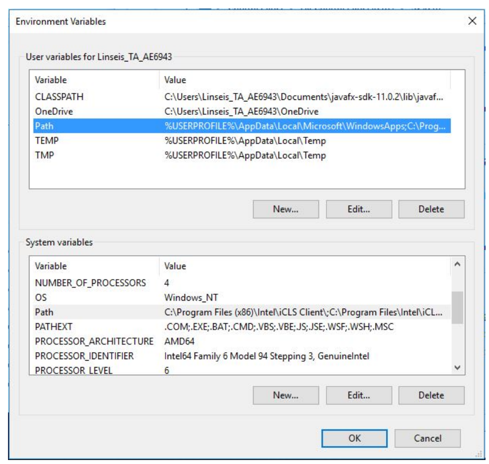
(a) Open "PC Properties"



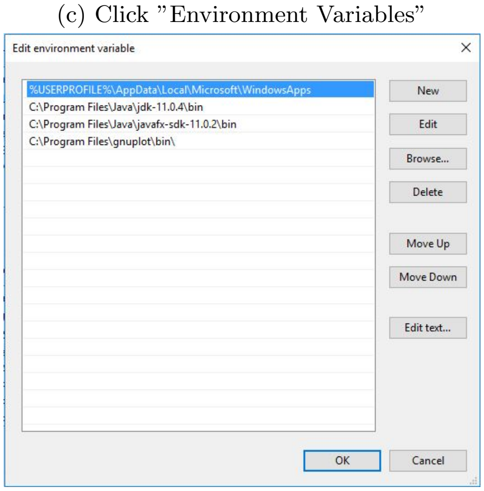
(b) Open "Advanced system settings"



(c) Click "Environment Variables"



(d) Click "Path"



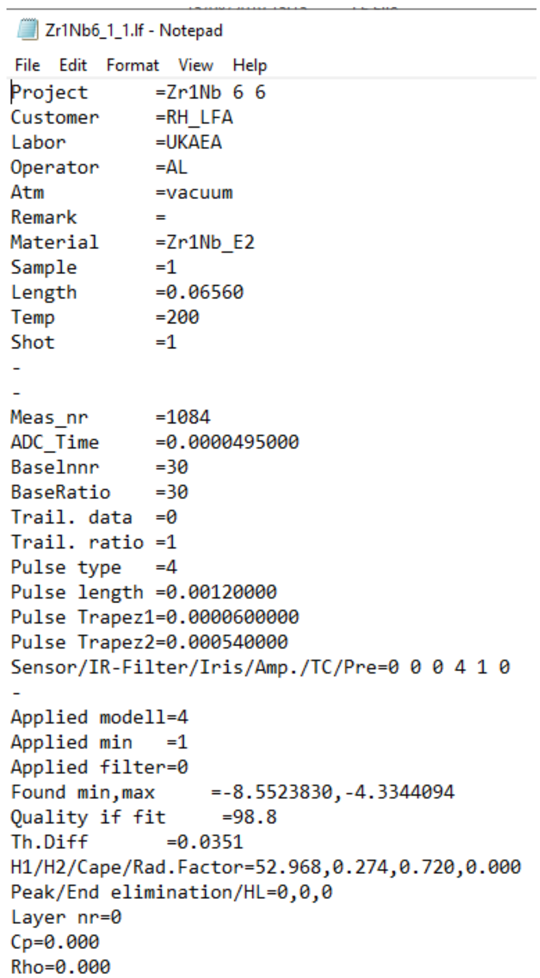
(e) Enter the bin paths

Figure 1: Adding bin paths in Windows

2 Input file formats

2.1 Heating curve data formats

PULsE currently accepts the formats of files output by Linseis LFA systems; these are all in ASCII formats, so results from other systems may be edited to be readable by PULsE.
Linseis automatically outputs .lf files for each shot, containing information about the shot (Fig. 2).
After performing a shot, clicking "Export/Save As" in the Linseis AproSoft program (Fig. 3a) will export the



Zr1Nb6_1_1.lf - Notepad

File Edit Format View Help

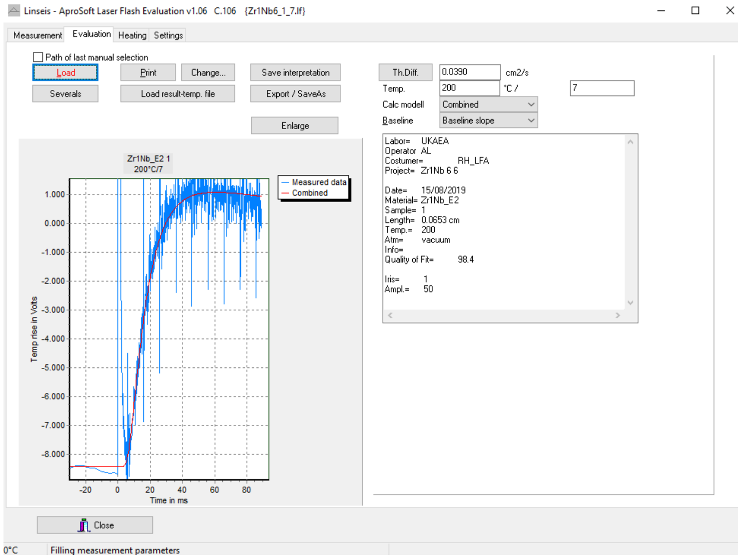
```
Project      =Zr1Nb 6 6
Customer     =RH_LFA
Labor        =UKAEA
Operator     =AL
Atm          =vacuum
Remark       =
Material     =Zr1Nb_E2
Sample       =1
Length       =0.06560
Temp         =200
Shot         =1
-
-
Meas_nr      =1084
ADC_Time     =0.0000495000
Baselnnr     =30
BaseRatio    =30
Trail. data  =0
Trail. ratio =1
Pulse type   =4
Pulse length =0.00120000
Pulse Trapez1=0.0000600000
Pulse Trapez2=0.000540000
Sensor/IR-Filter/Iris/Amp./TC/Pre=0 0 0 4 1 0
-
Applied modell=4
Applied min   =1
Applied filter=0
Found min,max     =-8.5523830,-4.3344094
Quality if fit     =98.8
Th.Diff       =0.0351
H1/H2/Cape/Rad.Factor=52.968,0.274,0.720,0.000
Peak/End elimination/HL=0,0,0
Layer nr=0
Cp=0.000
Rho=0.000
```

Figure 2: .lf file example

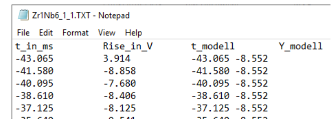
data for the heating curve recorded as a .txt file (Fig. 3b). This should be done for any shot or curve you wish to analyse in PULsE.

After all shots have been recorded, click "Severals" in the Linseis analysis window (Fig. 3a) and select all exported heating curve .txt files for the experiment.
Clicking "Ok" and "Save" on the following windows will create a .lfr file with file locations and data for all the heating curves (Fig. 4). Save this in the same folder as the .txt files.

PULsE also accepts ASCII data for individual shots in a .dat format, where the first row gives the temperature (in degrees Celsius), with a two (or more; here we have uncertainty as a third column) column table below, with columns of time (in seconds) and sample-furnace temperature difference (in degrees Celsius) respectively (Fig. 5).



(a) AproSoft Evaluation screen



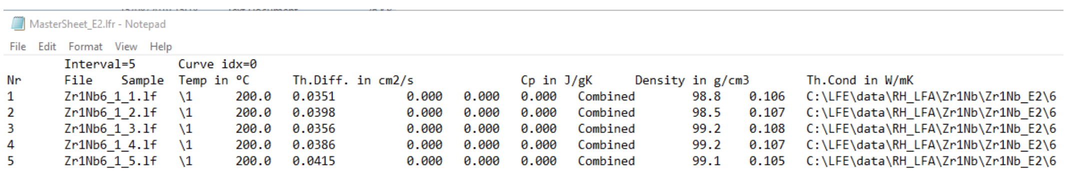
Zr1Nb6_1_1.TXT - Notepad

File Edit Format View Help

t_in_ms	Rise_in_V	t_modell	Y_modell
-43.065	3.914	-43.065	-8.552
-41.580	-8.858	-41.580	-8.552
-40.095	-7.680	-40.095	-8.552
-38.610	-8.406	-38.610	-8.552
-37.125	-8.125	-37.125	-8.552

(b) Exported .txt file example

Figure 3: Exporting in Linseis



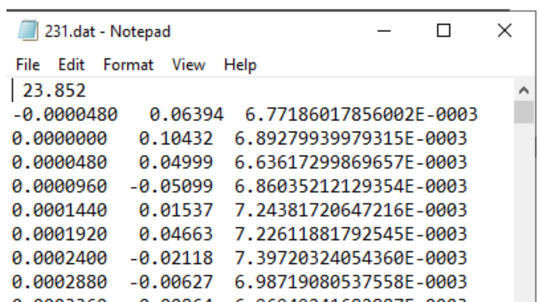
MasterSheet_E2.lfr - Notepad

File Edit Format View Help

Interval=5 Curve idx=0

Nr	File	Sample	Temp in °C	Th.Diff. in cm2/s			Cp in J/gK		Density in g/cm3		Th.Cond in W/mK
1	Zr1Nb6_1_1.lf	\1	200.0	0.0351	0.000	0.000	0.000	Combined	98.8	0.106	C:\LFE\data\RH_LFA\Zr1Nb\Zr1Nb_E2\6
2	Zr1Nb6_1_2.lf	\1	200.0	0.0398	0.000	0.000	0.000	Combined	98.5	0.107	C:\LFE\data\RH_LFA\Zr1Nb\Zr1Nb_E2\6
3	Zr1Nb6_1_3.lf	\1	200.0	0.0356	0.000	0.000	0.000	Combined	99.2	0.108	C:\LFE\data\RH_LFA\Zr1Nb\Zr1Nb_E2\6
4	Zr1Nb6_1_4.lf	\1	200.0	0.0386	0.000	0.000	0.000	Combined	99.2	0.107	C:\LFE\data\RH_LFA\Zr1Nb\Zr1Nb_E2\6
5	Zr1Nb6_1_5.lf	\1	200.0	0.0415	0.000	0.000	0.000	Combined	99.1	0.105	C:\LFE\data\RH_LFA\Zr1Nb\Zr1Nb_E2\6

Figure 4: Example .lfr file generated from "Severals"



231.dat - Notepad

File Edit Format View Help

```
23.852
-0.0000480    0.06394  6.77186017856002E-0003
0.0000000    0.10432  6.89279939979315E-0003
0.0000480    0.04999  6.63617299869657E-0003
0.0000960   -0.05099  6.86035212129354E-0003
0.0001440    0.01537  7.24381720647216E-0003
0.0001920    0.04663  7.22611881792545E-0003
0.0002400   -0.02118  7.39720324054360E-0003
0.0002880   -0.00627  6.98719080537558E-0003
```

Figure 5: Example heating curve .dat file

2.2 Metadata format

Metadata for each shot should also be recorded during the experiment in a tab delimited ASCII format, with a .met file suffix (Fig. 6). Constant data should be recorded in tab-separated pairs at the top of the file, such as Sample_Name, Thickness (of the sample, in mm), Diameter (of the sample, in mm), Spot_Diameter (diameter of laser spot, in mm), PulseShape (in capitals; e.g. TRAPEZOIDAL, RECTANGULAR) and Detector_Iris.

Two line breaks below, a tab-delimited table with headers for variables should contain variable data for each shot. These variables should include ID (which should relate to the final number of the file name for each shot), Test_Temperature (in °C), Pulse_Width (the time width of the laser pulse, in ms), Absorbed_Energy (the energy transmitted by the laser, in J), and Detector_Gain (gain of the detector). If any of the "constants" listed above are variable, then they should be included in the variable table, and vice versa.

Zr1Nb_E2_200_to_850_Metadata.met - Notepad

File Edit Format View Help

```
Sample_Name     Zr1Nb_E2
Thickness       0.653
Diameter        10
Spot_Diameter   2
PulseShape      TRAPEZOIDAL
Detector_Iris   1

ID      Test_Temperature        Pulse_Width     Absorbed_Energy Detector_Gain
1       200     1.2     9.83    50
2       200     1.2     9.83    50
3       200     2       15.68   50
4       200     1.8     14.22   50
5       200     1.8     14.22   50
```

Figure 6: Example metadata .met file

2.3 C_p and density file formats

Specific heat capacity and density at different temperatures can be read as ASCII files with a .tbl suffix (Fig. 7), where the first column is temperature (in °Celsius) and the second column is the specific heat capacity (in $Jkg^{-1}K^{-1}$) or density (in kgm^{-3}).

UO2_Specific_Heat.tbl ...

File Edit Format View Help

```
-273    0.0
0       218.2648368
50      239.0325626
100     253.2270824
150     263.2550148
200     270.5584236
250     276.0222064
300     280.2062572
350     283.4759085
400     286.0764962
450     288.1771373
```

(a) Example specific heat capacity .tbl file

UO2_Density.tbl - Notepad

File Edit Format View Help

```
-273    11000.00
0       10959.84
50      10943.82
100     10927.80
150     10911.77
200     10895.73
250     10879.67
300     10863.56
350     10847.41
400     10831.21
450     10814.93
```

(b) Example density .tbl file

Figure 7: Example .tbl input files

3 Basic use and loading curves

3.1 Opening and quitting PULsE

Open PULsE by clicking the PULSE.jar file. If you experience any unexpected errors, open the program instead by typing:

```
java -jar -Dprism.verbose=true PULSE.jar
```

into a Terminal/Console window opened in the same folder as the file. This writes any errors in the Terminal.
PULsE can be quit by clicking the X in the top right corner, which will prompt a confirmation.
You may want to save any results (see “Save Results”, section 6.2) and export your fits (see ”Export and Export All”, section 7.2) before quitting.

3.2 Loading heating curves and metadata

Clicking the PULsE.jar file should open a window (Fig. 8). Loading data, changing calculation settings, exporting

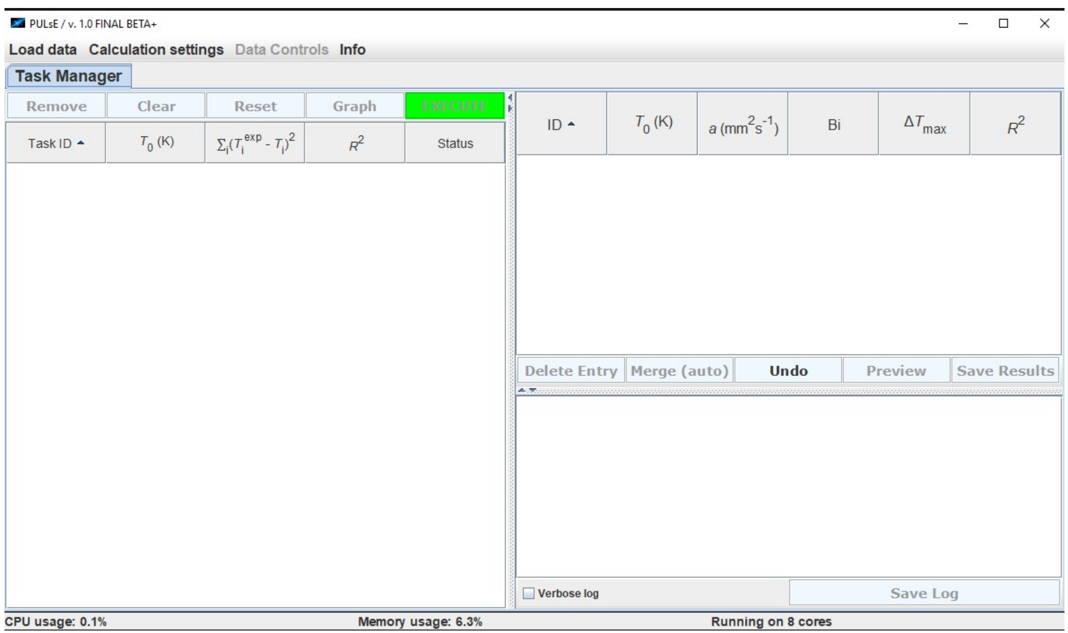


Figure 8: Main PULsE window

data and program information can be done using the menu bar at the top.
The task pane is found on the left; the results pane in the top right; the log in the bottom right.
At the top left, click ”Load Data” (Fig. 9) and then ”Heating Curve(s)...”, and select the .lfr file containing information about all of the curves you wish to analyse. This should load each heating curve as a Task in the task pane on the left side of the screen (Fig. 10).

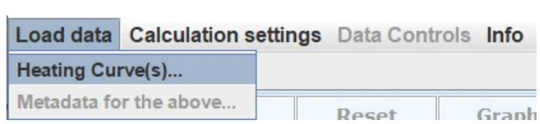


Figure 9: ”Load Data” button

Clicking “Load Data” > “Metadata for the above. . . ” and selecting your metadata file for this dataset will load the metadata for each shot.
A message about truncation may appear (Fig. 11. If the acquisition time for any heating curves is deemed to be too long, PULsE can automatically truncate data if you click “Truncate”. This will generally aid accuracy of

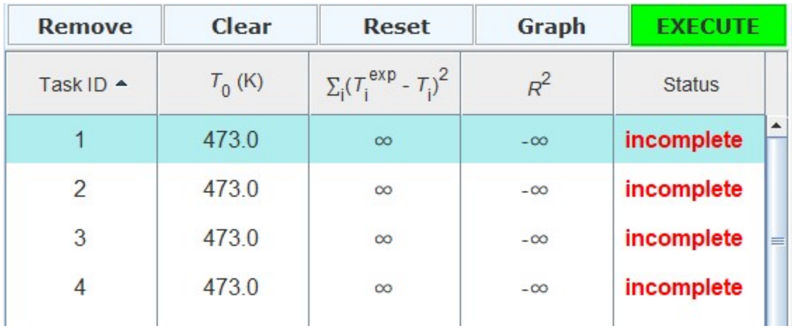


Figure 10: Task pane after loading results

results, as otherwise the model estimates will be biased to fit the 'plateau' of the heating curve data if it is too long.

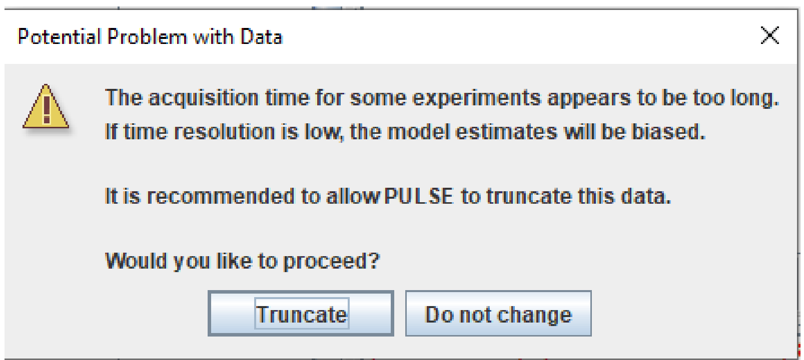


Figure 11: Truncation warning sometimes raised after loading metadata

3.3 Task pane

On the left side of the window, you can find the Tasks (Fig. 10). This shows the task ID for each (an internal value, not necessarily related to the ID of the shot's metadata), the temperature T_0 (in Kelvin), the sum of squares and R^2 value of the fit (if completed) and the Status of each task (see "Statuses", section 5.1). These columns can be sorted by clicking the the corresponding header of the table. Click the same header again to reverse the sorting direction.
Right-clicking on a selected task will bring up a menu (Fig. 12). "Show details…" shows the calculation settings

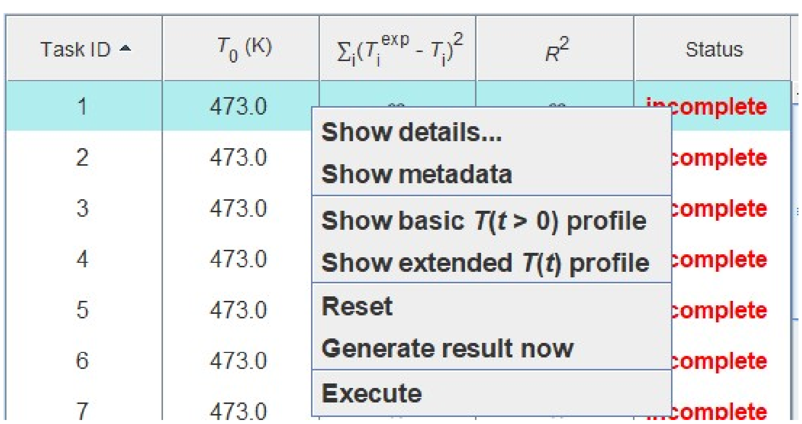


Figure 12: Menu after right-clicking on a task

for the selected task (see "Heat Problem: Statement and Solution", section 4.1).

"Show metadata" shows the metadata for the selected task (Fig. 13). The units here are SI (distances in metres, energy in Joules, temperature in Kelvin) so may differ from the values in the metadata file. "Reset" will reset any

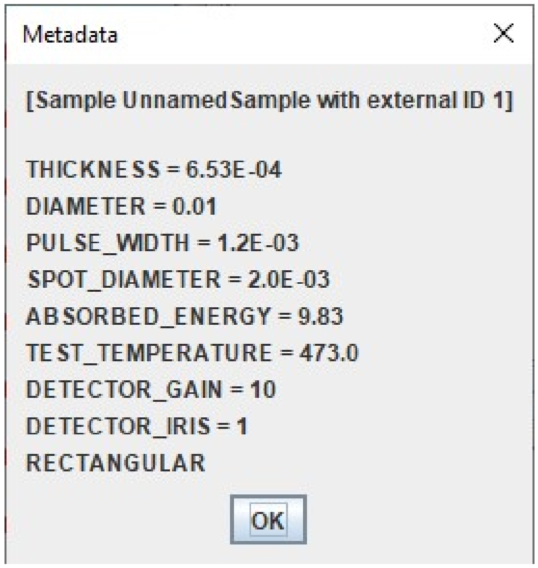
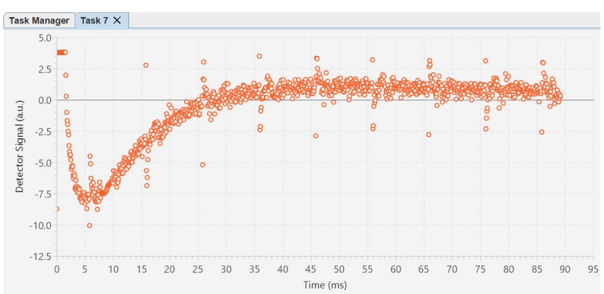


Figure 13: Metadata for a file, accessed through the right-click menu

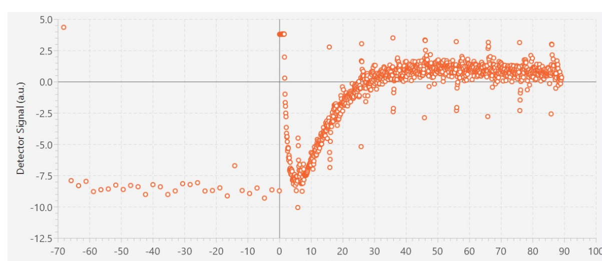
results, calculation settings and time intervals for fitting for that task only.
"Generate result now" will quickly calculate an estimated solution for the selected heating curve, either using the Parker's solution (if the task has not yet been executed) or using the most recent parameter values (if it has been executed). The result will be found in the results table (see "Results", section 6).
"Execute" will execute a full calculation for the selected task only. The result will be found in the results table.
"Show basic T($t > 0$) profile" and "Show extended T(t) profile" will load a Graph tab for the selected task with the heating curve. Clicking the "Graph" action above the task pane will also open the basic profile.

3.4 Graph tab

The basic profile will only show data for $t > 0$ (Fig. 14a), whereas the extended profile (Fig. 14b) shows all data. The extended profile may be useful to ensure that the baseline of the fit agrees with the data for $t < 0$, though this may not necessarily always be the case if there is an unexpected signal or temperature drift. Clicking and



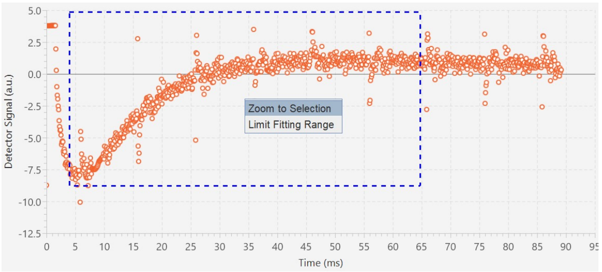
(a) T($t > 0$) graph



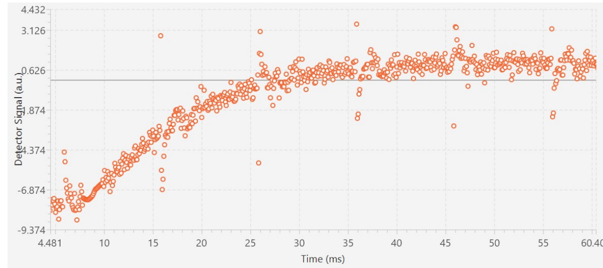
(b) T(t) graph

Figure 14: Basic and extended graph tab

dragging on the graph creates a selection box on the graph and brings up a context menu, with options to zoom to the selection or to limit the fitting range (Fig. 15a).
"Zoom to Selection" zooms so the selected area fills the graphed space for both axes (Fig. 15b). Note that this does not change the data used for fitting.
"Limit Fitting Range" will bring up a confirmation menu (Fig. 15c). Clicking "Apply" will exclude any data outside of the time interval selected for fitting in future calculations.
Once fitting has completed and a solution is found, the curve for the solution is plotted in blue (Fig. 15d).

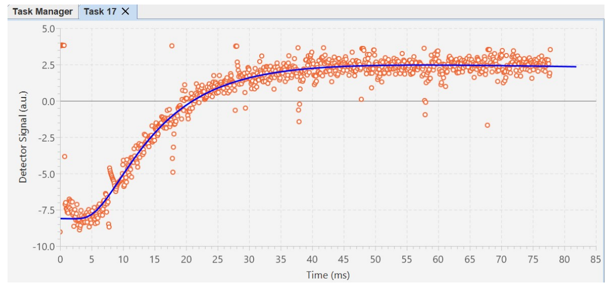


(a) Context menu for zooming and limiting range



(b) Graph after zooming to selection

(c) Confirmation for limiting data range



(d) Graph with solution in blue

Figure 15: Navigating the graph tab

3.5 Actions and other features

On the main window of the program, above the task pane, you can find a row of Action buttons (Fig. 16). "Remove" will remove the task that is currently selected (highlighted).

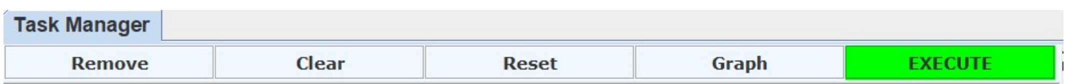


Figure 16: Actions available in PULsE

"Clear" will remove all tasks.
"Reset" will reset all solutions and calculation settings (see next section) for all tasks.
"Graph" will graph the selected task's heating curve. This can also be done from a right click on the selected task.
"Execute" will execute calculation on all heating curves (once calculation settings have been selected for all tasks).
The bottom of the window will show the CPU, RAM and CPU core usage of the program currently (Fig. 17). This section will turn red if the CPU or RAM usage gets too high (above 75%) or amber (if above 50%).

Figure 17: CPU, memory and core usage shown

4 Calculation and Settings

To select or change the settings for the calculation, click "Calculation settings" in the top of the window (Fig. 18).

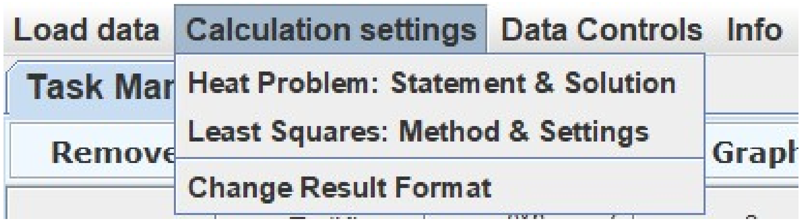


Figure 18: Calculation settings

4.1 Heat Problem: Statement & Solution

"Heat Problem: Statement & Solution" allows the selection of the type of heat problem you would like to model and solve for, as well as the type of solution the program will calculate for it (Fig 19).
Only the 1D heat problem solver has been fully tested; other problem statements and difference schemes are currently being tested and will be disabled in the release version. Future versions may enable solutions for layered problems, 3D heat problems etc. If you would be interested in this capability, please contact the developer.
All values and settings can be changed by clicking the relevant value.

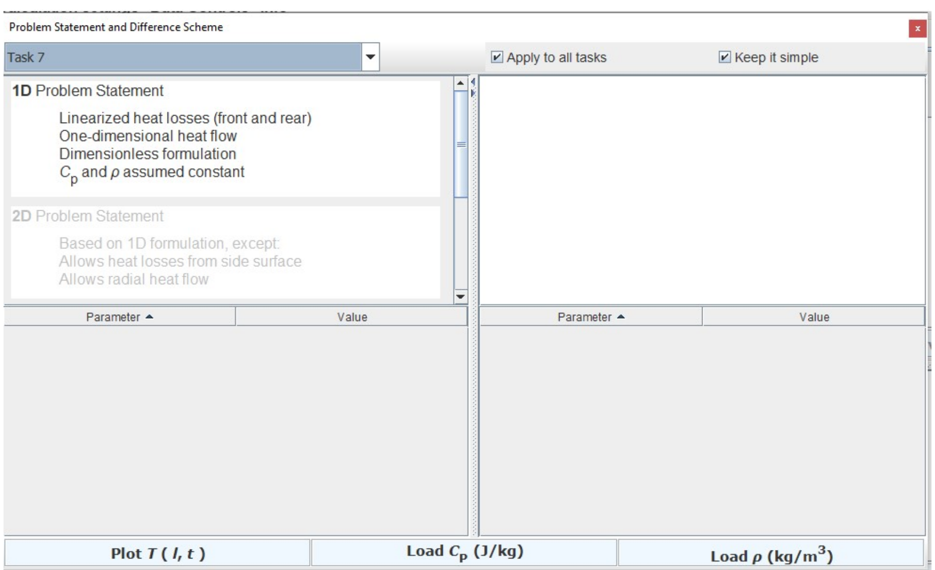


Figure 19: Heat Problem Statement window

The tickboxes in the top right corner, "Apply to all tasks" and "Keep it simple", can be ticked or unticked.
"Apply to all tasks" will apply the settings selected to all tasks.
"Keep it simple" hides some more complex settings and parameters; unchecking it will reveal them and allow them to be edited.
Specific heat capacity and density files can be loaded using the "Load C_p" and "Load ρ" buttons at the bottom of this window, allowing calculation of thermal conductivity. This is not necessary for thermal diffusivity calculation.
Click the X in the top right of the menu to return to the task screen; all settings are automatically saved if values are changed.

4.2 Least Squares: Methods & Settings

"Least Squares: Methods & Settings" allows the selection of the search methods, variables and settings used in the fitting algorithm (Fig. 20).
Choose one option from the upper and lower pane on the left side. For best results, choose "Approximated Hessian Method" and "Wolfe Conditions".
After this, the parameters to be searched for can be changed by single clicking the "true" or "false" value on

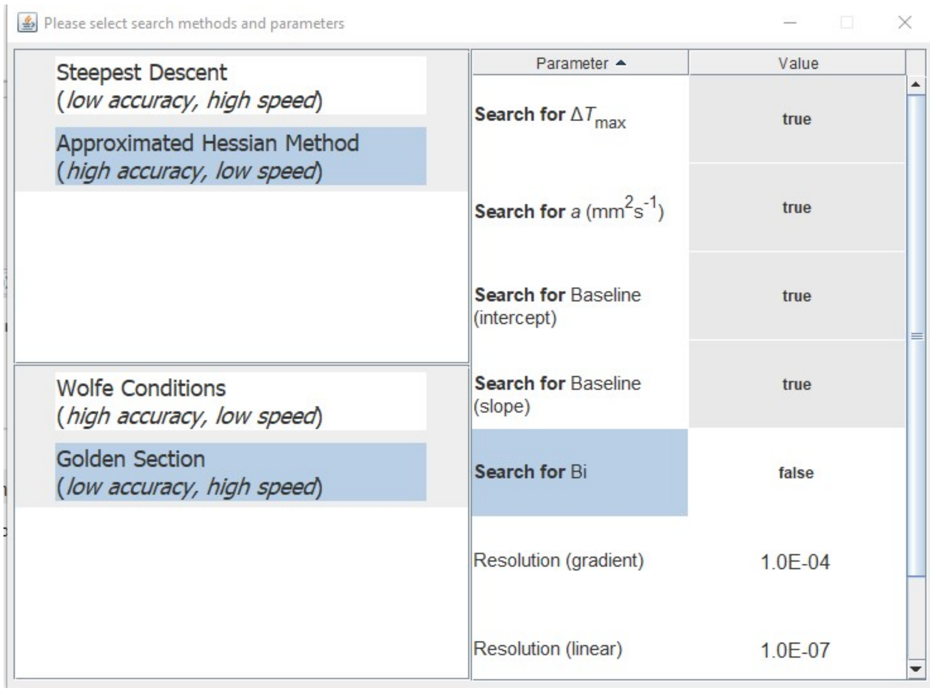


Figure 20: Least squares search methods window

the right side. The other settings (resolutions) can be changed by clicking their value also. The default (generally recommended) values for these are 1E-4, 1E-7 and 1E-3 for gradient, linear and total, respectively.

4.3 Change Results Format

"Change Result Format" allows the selection and ordering of fitted result values (Fig. 21). Changing the letters in the text box at the bottom of the window and clicking "Apply" will select the corresponding outputs to be recorded and displayed in the results table on the top right pane of the main window (Fig. 22) Hover over the headers for a tooltip definition. These can be sorted by clicking the header similar to the task table. The columns can also be rearranged by clicking and dragging the column headers into the desired order.

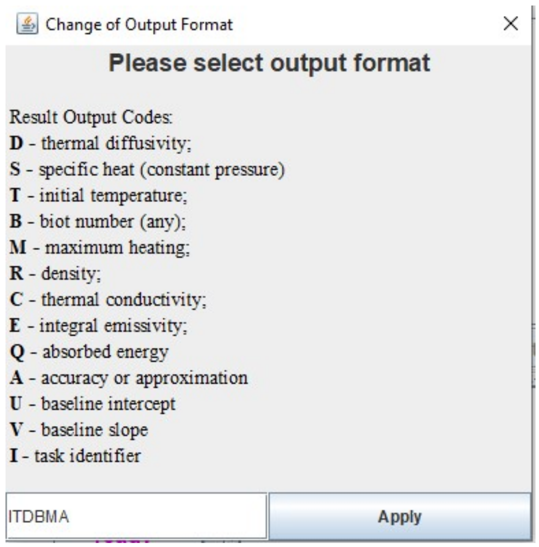


Figure 21: Change result format menu

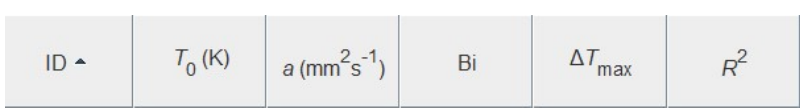


Figure 22: Headers of results pane

5 Execution

Clicking the "Execute" action (Fig. 16) will execute calculation for all tasks, according to the settings previously selected.
When execution is in progress, the "Execute" action button is replaced by a red "STOP" button (Fig. 23). Clicking this will stop calculation of any tasks that have not yet recorded results, and changes their status to "terminated".

Figure 23: Stop button

5.1 Statuses

The statuses of tasks will change as a result of this (Fig. 24). "ready" means that the settings have been chosen

8	473.0	∞	-∞	ready
9	473.0	∞	-∞	queued
10	572.0	306.95689	0.98184	done
11	573.0	509.31304	0.95583	timeout
12	573.0	∞	-∞	incomplete
13	573.0	455.79095	0.95646	terminated

Figure 24: Examples of tasks with statuses

for the task, but calculation has not yet been executed.
"queued" means that the task will execute once other tasks have finishing executing.
"done" means that the calculation for the task has completed. You can find the results for this task in the results pane.
"timeout" means that the calculation took too long to complete. This may be due to an error in calculation (if the R^2 looks particularly low) or due to the fitting algorithm being unable to find the optimal values fast enough. The results will not be shown in the results pane. Right-clicking the task and clicking "Execute" for this task only will continue calculation, and may be able to complete the calculation. Right-clicking the task and choosing "Generate result now" will generate a result immediately based on the most recently output values.
"incomplete" means that no execution has taken place yet as the settings (heat problem and least squares methods) have not yet been chosen. Additional status description will appear in a pop-up window if appropriate.
"terminated" means that the execution was manually stopped before completion. Similar to tasks with a "timeout" status, re-executing may allow completion of the calculation.

6 Results

The results pane is found in the top right of the main window. Once execution has completed, it will look similar to Fig. 25. Actions that can be performed on these results are found beneath the table (Fig. 26) “Delete Entry”

ID ▲	T_0 (K)	a (mm^{2}s^{-1})	Bi	ΔT_{max}	R^2
1	473.0	2.89137	0.0	6.2999	0.86677
2	473.0	3.0207	0.0	7.20452	0.91056
3	473.0	3.07793	0.0	12.59312	0.95283
4	473.0	3.23303	0.0	12.48943	0.95984
5	473.0	3.54459	0.0	11.88069	0.96842
6	473.0	3.41588	0.0	11.14843	0.96963
7	473.0	3.54116	0.0	10.11162	0.94447

Figure 25: Results table with solutions to completed tasks

Figure 26: Results actions

removes the selected result from the table.
“Merge (auto)” allows averaged results to be obtained for tasks of a similar temperature. Clicking this will bring up a context window, allowing the selection of the range of which temperatures the data will be averaged for. This will group results in the results pane (Fig. 27). Clicking “Undo” returns the results to their individual values,

T_0 (K) ▲	ID	a (mm^{2}s^{-1})	Bi	ΔT_{max}	R^2
473.0 ± 0.0	5.0 ± 1.4	3.33 ± 0.14	0.0 ± 0.0	10.3 ± 1.1	0.944 ± 0.017
572.86 ± 0.16	13.9 ± 1.0	4.287 ± 0.014	0.0 ± 0.0	11.71 ± 0.49	0.9699 ± 0.00
722.67 ± 0.21	20.5 ± 0.76	3.943 ± 0.079	0.0 ± 0.0	4.456 ± 0.085	0.872 ± 0.01
873.72 ± 0.33	27.0 ± 0.96	4.54 ± 0.18	0.0 ± 0.0	4.76 ± 0.67	0.905 ± 0.019
1023.84 ± 0.1	33.5 ± 0.76	5.25 ± 0.13	0.0 ± 0.0	4.03 ± 0.4	0.877 ± 0.016
1123.58 ± 0.3	40.2 ± 1.0	4.94 ± 0.27	0.0 ± 0.0	2.14 ± 0.26	0.836 ± 0.064

Figure 27: Results table after merging with a range of 10°C

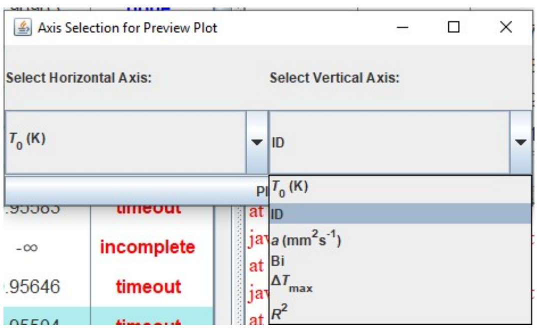
ungrouping them.

6.1 Preview

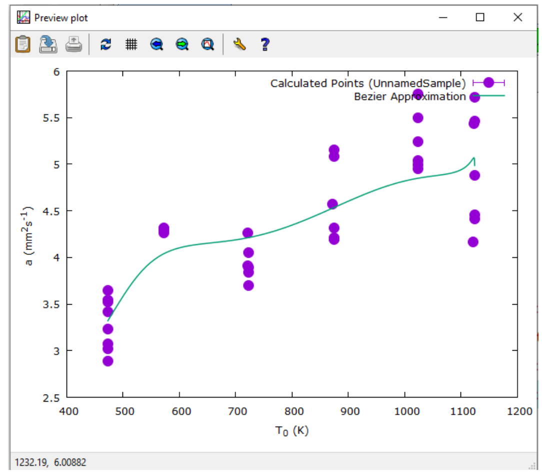
“Preview” allows you to preview the graph of the results recorded. Clicking it brings up an axis selection window (Fig 28a). Clicking the combo boxes allows the selection of any of the results as either axis for the graph. Once axes are selected, ”Plot” will plot the results in a gnuplot window (Fig. 28b). The graph can be saved and exported by clicking the corresponding icons in the top left of the window.

6.2 Save Results

In the main PULsE window, at the bottom of the results table, clicking “Save Results” will save the results table in its current format (see Fig. 29a). .html and .csv are supported formats. Saving while the results are merged will save both the merged results and the individual results (Fig. 29b).



(a) "Preview" axes selection window



(b) Gnuplot graph of thermal diffusivity against temperature

Figure 28: Plotting a "Preview" graph

T_0 (K)	ID	a (mm^2s^{-1})	Bi	ΔT_{max}	R^2
473.0	1	2.89137	0.0	6.2999	0.86677
473.0	2	3.0207	0.0	7.20452	0.91056
473.0	3	3.07793	0.0	12.59312	0.95283
473.0	4	3.23303	0.0	12.48943	0.95984

(a) Saved results table (unmerged)

T_0 (K)	ID	a (mm^2s^{-1})	Bi	ΔT_{max}	R^2
473.0 ± 0.0	5.0 ± 1.4	3.33 ± 0.14	0.0 ± 0.0	10.3 ± 1.1	0.944 ± 0.017
572.8 ± 0.16	14.0 ± 1.0	4.2994 ± 0.0076	0.0 ± 0.0	12.18 ± 0.34	0.9755 ± 0.0026
722.67 ± 0.21	20.5 ± 0.76	3.943 ± 0.079	0.0 ± 0.0	4.456 ± 0.085	0.872 ± 0.01
873.72 ± 0.33	27.0 ± 0.96	4.54 ± 0.18	0.0 ± 0.0	4.76 ± 0.67	0.905 ± 0.019
1023.84 ± 0.16	33.5 ± 0.76	5.25 ± 0.13	0.0 ± 0.0	4.03 ± 0.4	0.877 ± 0.016
1123.58 ± 0.35	40.2 ± 1.0	4.94 ± 0.27	0.0 ± 0.0	2.14 ± 0.26	0.836 ± 0.064

INDIVIDUAL RESULTS

T_0 (K)	ID	a (mm^2s^{-1})	Bi	ΔT_{max}	R^2
1	473.0	2.89137	0.0	6.2999	0.86677
2	473.0	3.0207	0.0	7.20452	0.91056
3	473.0	3.07793	0.0	12.59312	0.95283

(b) Saved results table (merged)

Figure 29: Saved results tables (in html format)

7 Data Controls and Exporting Fits

Clicking "Data Controls" in the top left corner (Fig 30) allows you to view the Parker's solution for a selected graph and allows exporting of raw data.

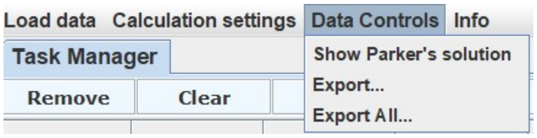


Figure 30: Data Controls menu

7.1 Show Parker's Solution

On an open Graph tab, clicking "Show Parker's solution" will draw the analytical solution stated by Parker et al. (1961) [1] for the heating curve as a green line (Fig. 31)

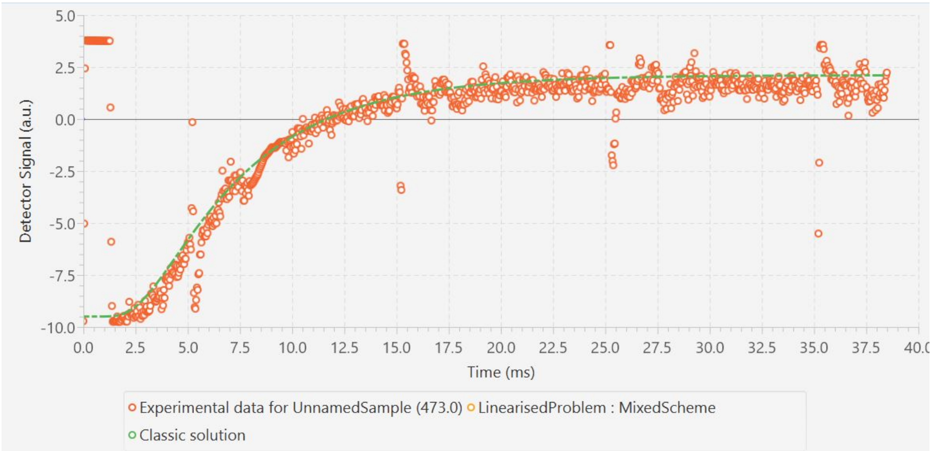


Figure 31: Parker's solution, drawn in dashed green, on a heating curve

7.2 Export and Export All

"Export" and "Export All" saves the experimental data points, the fitted heating curve data points, the log and the metadata for the selected task and for all tasks, respectively (Fig. 32).

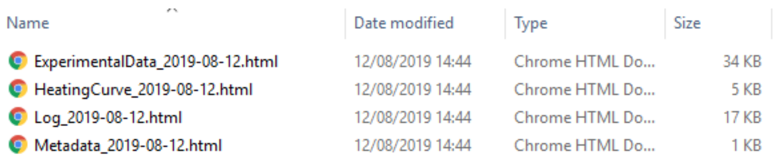
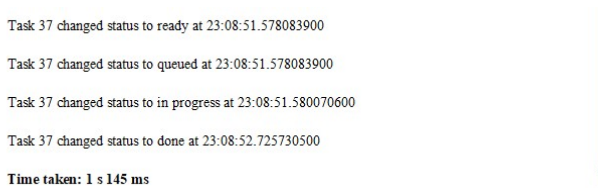


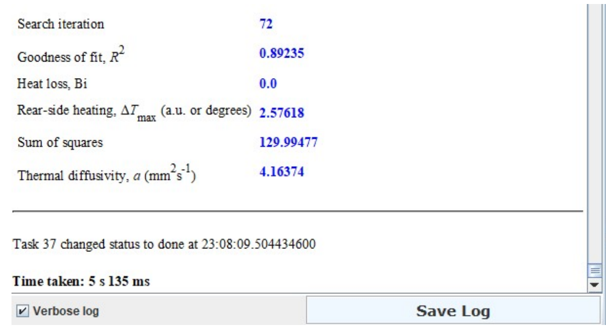
Figure 32: Files exported for an individual task

8 Log

The log pane is found in the bottom right of the main window, and displays the status of currently executing tasks (Fig. 33a). Clicking “Verbose log” expands the log to show the values of various fitting parameters (Fig. 33b). Clicking “Save Log” saves the current contents of the log to a location of your choice.



(a) Not verbose



(b) Verbose

Figure 33: Log window

9 Advice to maximise accuracy

Identifying erroneous data from preview graphs

The Preview graph is useful for identifying which data points may be from erroneous heating curves or fits, if any points are far outside the expected range. Once the corresponding task is identified in the results table, it may be worth viewing the heating curve graph for that task to see if it is a good fit or not.
If not, it may be worth manually changing the measurement time or changing individual Heat Problem parameters, removing the current result for the task, and right clicking the task to Execute it again, to achieve better results.

Clipping measurement time (excluding pulse/noise, better manual truncation)

Manually selecting the time range you would like the program to fit (see "Graph Tab", section 3.4) may improve results by excluding erroneous data.

Changing individual settings

Right click a problematic task, click "show details", and ensure "Apply to all tasks" and "Keep it simple" are unticked. Changing settings such as the initial thermal diffusivity a, baseline slope and baseline intercept to expected values and re-executing only that task (through the right-click menu) may also improve results. Comparing the fitted baseline to the T($t < 0$) data seen in the "show T(t) profile" in the right-click menu may be of use when choosing values for the baseline.

10 Troubleshooting

Errors

If you encounter any errors, red text should appear in the log. If you are able to, copy this text into an email and send it to artem.lunev@ukaea.uk with the subject “PULSE Bug”.. If the error disappears before you can copy it, try running PULSE from the Terminal by opening a terminal in the same folder as PULSE.jar and typing:

```
java -jar -Dprism.verbose=true PULSE.jar
```

and repeating what caused the error.

If the program does not open or if the Preview graph does not load

Ensure all steps of the installation are followed, including changing the environmental variables to include the path to the bins of java, javafx and gnuplot (if on Windows). If on Linux, try using

```
sudo apt-get update
```

in the terminal.

Ensure proper metadata formatting

Make sure the variable names in the metadata file is correct (see “Metadata Format” 2.2), especially if the metadata for a given task is not as you expected or if an error is encountered immediately after loading the metadata.

Ensure there are no unexpected zero values in the .lfr file

If the heating curve recorded by Linseis is erroneous, it may record a zero in the .lfr file for a crucial parameter such as thermal diffusivity . This can cause “divide by zero” errors in the program, often resulting in an infinity handling error. Remove this heating curve from the file and try again.

Check CPU and RAM usage

During execution, CPU usage can be very high; this can cause the program to be slow to respond if run on a low-end computer. Usually, this will return to normal after execution is complete. If not, try removing half of the tasks from the queue before executing next time, which may improve performance.
Opening graphs multiple times sequentially may increase RAM usage. If this gets too high, then it may cause performance issues on low-end computers.

If any issues or errors cannot be resolved, please contact Dr. Artem Lunev (email artem.lunev@ukaea.uk) with the subject “PULSE Bug” and detail what you were doing before the error or issue occurred.

11 Quick analysis guide

Install PULsE and create the .lfr and .met files as detailed at the start of this manual (section 1). To quickly analyse a dataset:
Open PULsE.
"Load Data" > "Heating Curve(s)..." and load the .lfr file containing your curve details
"Load Data" > "Metadata for the above..." and load your .met metadata file.
"Calculation Settings" > "Heat Problem: Statement and Solution" to load the heat problem window. Select "1D" and "Fully Implicit", ensure the sample thickness is correct, and close the window.
"Calculation Settings" > "Least Squares: Method and Settings" to load the search settings window. Select "Approximated Hessian Method" and "Wolfe Conditions", and select "true" for ΔT_max, a, baseline intercept (and baseline slope if you suspect the baseline is sloped). Close the window.
Click "Execute" and wait until all tasks have the "done" status. Right-click ¿ "Execute" any tasks with the "time-out" status.
In the results pane, drag the "T_0" header to the left.
"Merge (auto)" > "10" > "Apply".
"Preview" > choose "T_0" as x-axis, "a $(mm^2s^(-1))$" as y-axis > "plot" > Save or Export graph. Close window.
"Save results" and choose the save name.
"Data Controls" > "Export all" and choose the location to export all information to.

References

[1] W. J. Parker, R. J. Jenkins, C. P. Butler, and G. L. Abbott. Flash method of determining thermal diffusivity, heat capacity, and thermal conductivity. *Journal of Applied Physics*, 32(9):1679–1684, 1961.