NEXUS Console User Manual

(Compatible with version 0.3.2.0)

Bizmuth MBE Ltd

Author:	Faebian Bastiman
Date:	25th Nov 2019 - 29th Oct 2024
Company name:	Bismuth MBE Ltd
Company address:	bastiman@bizmuthmbe.com
Company Phone:	+44 (0) 759 755 4393

Table of Contents

Overview

The NEXUS console is a custom software package designed to control any molecular beam epitaxy (MBE) system. The software package comprises a graphical user interface (GUI) and a backend library (or dynamic link library (DLL)) to schedule tasks and communicate with hardware devices.

The software uses various Configuration text files to save the configuration. Data logging can be configured to frequently log instantaneous values with a timestamp to log files in comma separated value (CSV) format. In addition the Recipes and saved Fluxes are also stored in text files.

The basic architecture is shown in Figure 1.

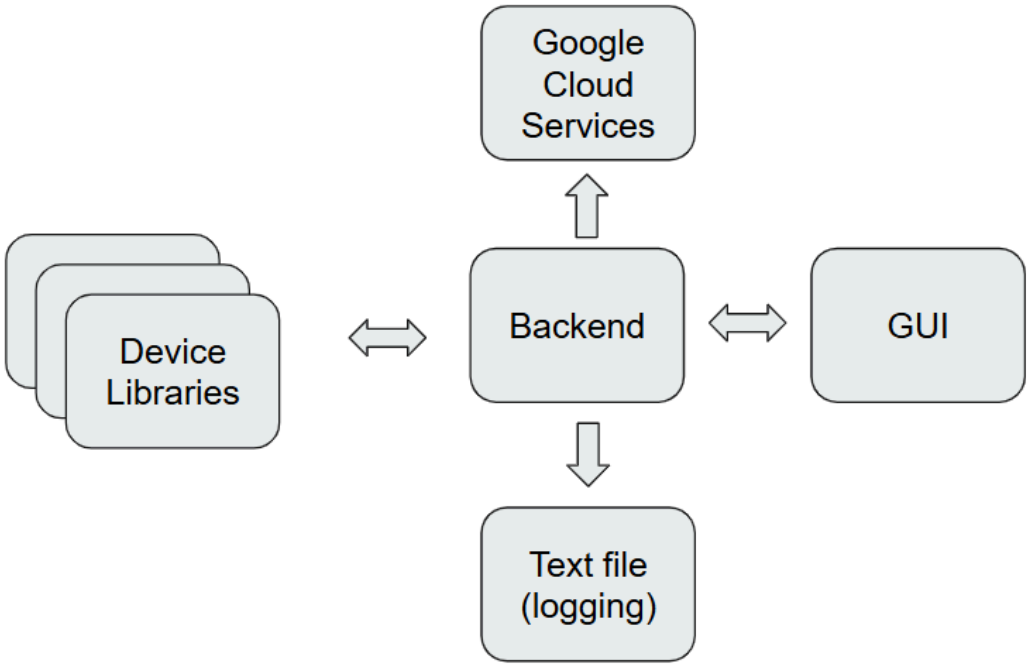

Figure 1: NEXUS console architecture

License

This is a licensed software. A license file containing a unique Hexadecimal license code is required for live capture operation. Contact the author to obtain a license.

Without a license the software can be used in simulation mode for evaluation purposes only.

Starting the software

When starting the software a small slash screen (figure 2) is shown displaying the software name, author and copyright information. A progress bar will fill as the various configuration files are read. The license status is displayed briefly before the software opens.

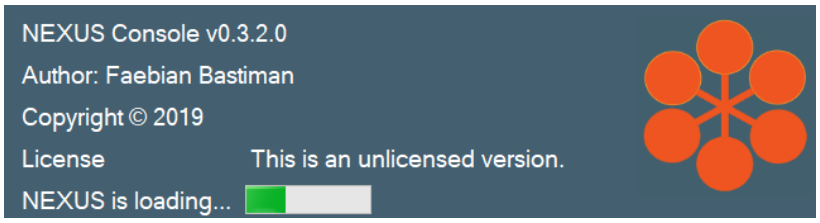

Figure 2: Splash form

Closing the software

When closing the software the small splash screen (figure 2) appears again, but this time with the message that Nexus is closing. The software takes ~5 seconds to safely shut down a variety of background tasks. During which time the progress bar increments. One completed, the software will close automatically.

Forms

The graphical user interface (GUI) is divided into various sections called “forms”. The purpose, function and instructions for usage of the individual forms can be found in the corresponding sections below.

Starting Form: System View

The main container window (figure 3) shows the standard layout of NEXUS Console. There are 5 features of the container:

1. The titlebar across the top of the window
2. The main menu on the left of the window
3. The status strip across the bottom (more detail below)
4. The subform on display is in the center of the window: in this example the System View form
5. If the subform has a menu it will appear on the right hand side, opposite the main menu.

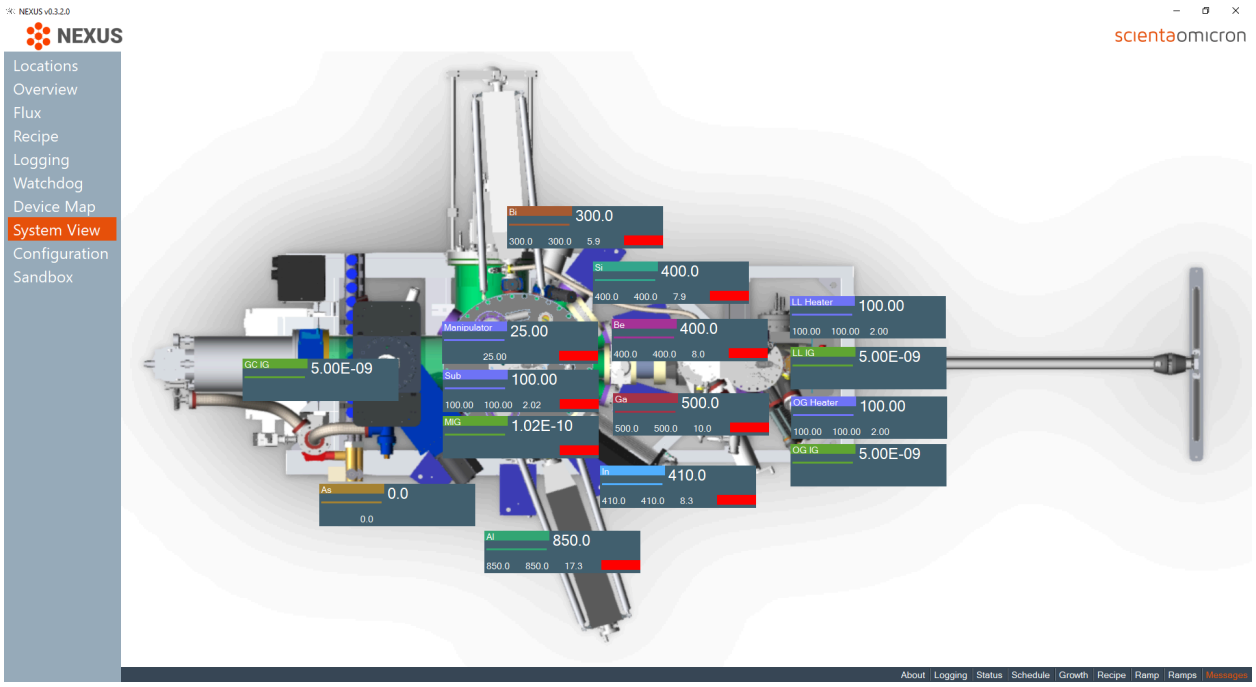

Figure 3: Main container displaying the System View form

Status Strip Forms

The Status Strip (figure 4) along the bottom of the main container form is always visible. The status strip has a total of 9 items that give useful information on the status of the various parts of NEXUS console, as indicated in the following table.

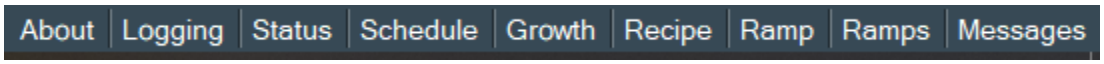

Figure 4: Status strip

Status Strip Item	**Description**
About	About opens a pop up form that displays the current NEXUS Console version, author and license information.
Logging	Opens a floating form that displays a smaller version of the log chart.
Status	Opens a floating form that displays the current MV and Shutter state of all loops. This is a mini-version of the Overview form that can be viewed whilst any form is open.
Schedule	Scheduler opens a pop up form that gives

	information on current scheduled events and their countdown to execution. The scheduler can be turned ON or OFF by right clicking anywhere on the blue menu strip and selecting scheduler. The Scheduler text is grey when it is OFF. Scheduled tasks can be executed immediately, by clicking on the task name on the form and confirming execution in the pop up window that appears.
Growth	Growth displays the current growing layer composition as calculated from the current loop temperatures and shutter states. This requires Flux data for each loop.
Recipe	Recipe indicates the current recipe step and the status of that recipe step for any recipe that is running along with the start time and estimated completion time of the recipe.
Ramp	Ramp opens the ramp dialog used to set an effusion cell temperature
Ramps	Ramps indicates the status of any ramp running and an estimated time to completion.
Messages	Messages shows any system messages including Port status and Resets, System Warning or Errors, it also details timing information on compound recipe commands like BEP, BEPSeries and TuneToFlux which may take >5 minutes to complete. The Messages text will turn Yellow then there are new messages to be read.

Shortcuts

Rather than using the main menu options, you can use keyboard shortcuts to view the desired form. The shortcuts are given in the table below.

Shortcut	**Form**

Ctrl + 1	Locations Form
Ctrl + 2	Overview Form
Ctrl + 3	Flux Form
Ctrl + 4	Recipe Form
Ctrl + 5	Logging Form
Ctrl + 6	Watchdog Form
Ctrl + 7	Device Map Form
Ctrl + 8	System View Form
Ctrl + 9	Config Form
Ctrl + 0	Sandbox
Ctrl + Shift + 1…9	Selects the corresponding tab on the recipe or logging form (whichever is visible)
Ctrl + Shift + N	Creates a new tab on the recipe or logging form (whichever is visible)
Ctrl + Shift + D	Deletes the current tab on the recipe or logging form (whichever is visible)

Locations Form

The locations form (figure 5) is used to track the position and state of the samples in your MBE system. All interactions are done by first right mouse clicking on the desired location label. A context menu is then displayed:

Item	**Function**
Reset	Sets the location back to default values EMPTY and NEW.
Edit	Opens a popup to set the name and description for the sample.
State	Sets the state of the sample: NEW, OUTGASSED, GROWING, DONE
Move	Moves this sample to a new position in the system and swaps the item in that position

	with this sample.

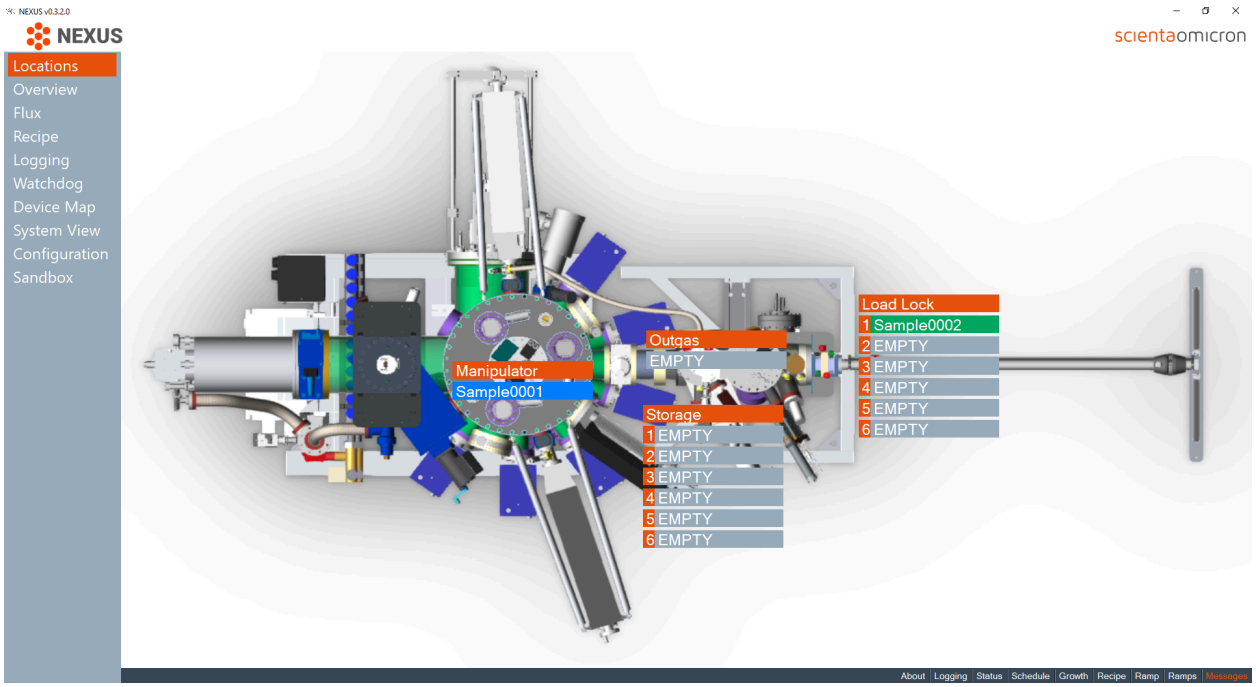

Figure 5: Locations Form

Overview Form

The overview form (figure 6) shows the instantaneous values of the various sources. The individual items will be hidden until data arrives for the first time. Right mouse click anywhere on the form to open a menu to hide / unhide certain columns.

Columns

Item	**Function**
Name	The unique name of loop.
Shutter	The shutter state: Open/Closed. This only displays if there is a shutter.
MV	Measured Value or Process Value, the current loop temperature or pressure.
SP	Setpoint the current calculated value for a ramp based on the end point, the ramp rate and the elapsed time.

EP	End point, the final target value for a ramp
OP	Output, the current applied output power to maintain the MV value
Flux	The current flux of the loop in atoms/nm2/s. This only displays when there is flux calibration data for the loop AND the MV is in the “Operating” range as specified in the loop configuration.
Fill	BETA only. Fill shows the current estimated percentage fill of the source. It can only be used based on historical data. It is explained in the Flux Form section on “Setting Maximum Flux and Calculation Fill”

Name	Shutter	Sparkline	MV	SP	EP	OP	Flux	Fill
Sub	Closed		100.00	100.00	100.00	1.99		
Manipulator	Closed		25.00		25.00			
Ga	Closed		500.0	500.0	500.0	9.9	0.0	88.8
Al	Closed		850.0	850.0	850.0	16.8	0.0	100.0
In	Closed		410.0	410.0	410.0	8.2	0.0	100.0
As			0.0		0.0		0.0	100.0
Bi	Closed		300.0	300.0	300.0	5.9	0.0	100.0
Si	Closed		400.0	400.0	400.0	8.1	0.0	100.0
Be	Closed		400.0	400.0	400.0	8.1	0.0	100.0
MIG	Closed		1.02E-10					
GC IG			5.00E-09					
OG Heater			100.00	100.00	100.00	2.00		
OG IG			5.00E-09					
LL Heater			100.00	100.00	100.00	2.00		
LL IG			5.00E-09					

Figure 6: Overview Form

Opening / Closing Shutters

Left mouse click on a shutter label to change the shutter state.

Ramping to a Setpoint

Left mouse click on a source’s MV, SP or EP label to open the “ramp” dialog at the bottom of the screen. Enter a target value and a ramp rate and click the green “Ramp” or press enter to send the target to the PID controller. Press escape or the “Cancel” button to cancel.

Ramping to a Power

Left mouse click on a source's OP label to open the "power ramp" dialog at the bottom of the screen. Enter a target power and a ramp rate and click the blue "Power Ramp" or press enter to send the target to the PID controller. Press escape or the "Cancel" button to cancel.

If the PID controller is in automatic mode, it will first be switched into manual mode.

Flux, BEP or Growth Rate

Click on the column header "Flux" label to change the displayed information. The information will cycle through Flux in atoms/nm2/s to Beam Equivalent Pressure in mBar to Growth Rate in the unit specified in the global configuration (either nm or µm or ML per s or min or hr).

Fill or Total Flux

Click on the column header "Fill" label to change the displayed information. The information will cycle through Fill in percent to Total Flux in atoms/nm2. For more information see the Flux Form section on "Setting Maximum Flux and Calculation Fill".

Status Colours

The rows are coloured depending on whether the measured value (MV) is at standby (sky blue), operation (green) or critical condition (red) for the particular loop. These values can be altered in the loops configuration.

Flux Form

The flux form (figure 7) allows you to view, modify and utilise flux values.

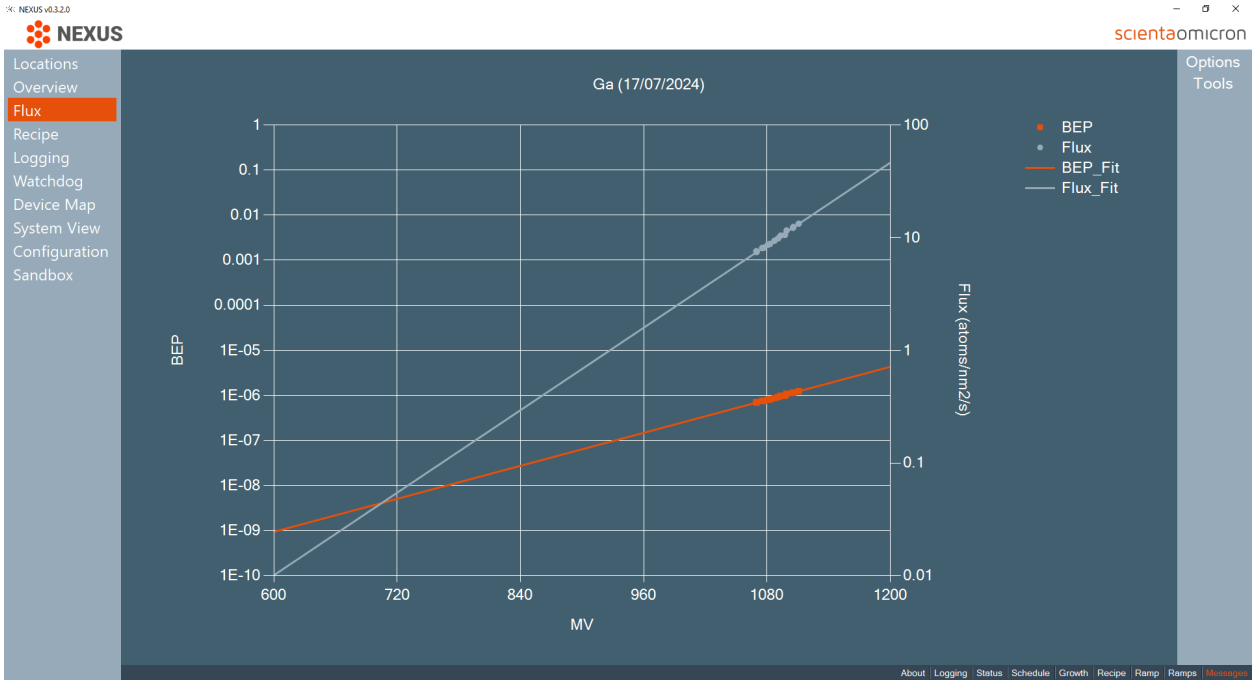

Figure 7: Flux Form

Selecting a Source

Press the source icon ( ) and then select a source from the menu in order to view the flux data of one of the sources. Any flux data that has been gathered automatically will be displayed. If there is no flux data, it can be entered manually. See the section below on “Manual and automatic flux gathering” for more information.

Manual and automatic flux gathering

In order to capture flux data automatically use the recipe commands BEP and BEPSeries. Flux data is displayed in terms of beam equivalent pressure (BEP) and “Flux”in atoms/nm^2/s.

If no source is available, make sure you have specified Loops as having a Source_Type of either Cation, Anion or Dopant (see Loops config).

Zooming on the Flux chart

In order to zoom in on the flux chart simply left click on an axis value label to set the axis minimum to that value or right click on an axis value label to set the axis maximum to that value. Double click anywhere on the chart to reset the zoom.

Showing/hiding chart data

Left click on the legend data label to show/hide an individual data set. Right click on the legend data label to show/hide all but the selected data set. Double click anywhere on the chart to restore all datasets.

Calculating a growth composition

Press the source icon ( ) and then select Calculate Composition from the menu. A popup form will appear showing the loops that contribute to growth with their corresponding shutter states and specified operating MVs. Here you can simulate what the growth will look like without altering the actual loop temperatures. Type in the temperatures and open and close the shutters. The corresponding material composition will appear in the information boxes at the bottom of the popup form.

Select Alternate Date

The most recent flux data is always displayed. You can select flux data from previous days by selecting “Select Alternate Date” from the tools ( ) menu. A small form will then appear with a drop down list populated with all available dates with flux data.

Recalculate Fit

Once data is present, a “X vs Log10(Y) 1st order polynomial” line of best fit can be achieved by selecting “Recalculate Fit” from the tools ( ) menu. The X vs Log(10) conditioning of the data prior to the fit helps to create “quasi-Arrhenius-fit” data for effusion sources and protects against the risk of negative values from valved sources. A 2nd order polynomial more faithfully models a wide range of temperatures for effusion cells and helps with non-linearities in valved source responses. The fit data is stored to file and the line of best fit is displayed graphically.

Note: the polynomial regression only happens if there are >2 BEP data points for a Loop. If there is at least 1 points AND an existing fit already exists, the software will apply an offset to the fit data in order to vertically move the fit data up or down the Y axis and attempt to linear offset the fit data so it fits to the new BEP data.

Recalculate Fit: Degree selection

The default 1st order polynomial is typically the most suitable choice for fitting the fluxes from an effusion cell, however some sources (for example valved sources) have a non-linear behavior. In these instances, selected the “Degree: 2” for a 2nd order polynomial fit or “Degree: 3” for a 3rd order polynomial fit.

Enter BEP to Flux Conversion

In order to make a meaningful growth rate from the BEP value, the relationship between BEP and Flux must be created. This also enables the composition to be displayed for materials and the Flux and Fill values to be used on the Overview form.

The flux is in atoms/nm²/s, and is a midway step used to calculate the growth rate (e.g. atoms/nm2/s, ML/s, nm/s) from the lattice constant specified in Global config. In order to create the relationship select “Enter BEP to Flux Conversion” from the tools ( ) menu. A small form will appear where you can enter a known BEP and the corresponding flux you determined, the relationship or conversion will be calculated automatically.

Item	
Known MV	Enter a known MV that corresponds to a known flux or growth rate. Known BEP will calculate automatically from this value.
Known BEP	Enter a known BEP that corresponds to a known flux or growth rate. Known MV will calculate automatically from this value.
Known Flux	Enter a known flux in atoms/nm²/s derived from a growth rate calculation performed on a grown sample. XRD, RHEED oscillation etc, Known growth rate will calculate automatically from this value.
Known (growth rate units)	Enter a known growth rate derived from a growth rate calculation performed on a grown sample. XRD, RHEED oscillation etc, Known Flux will calculate automatically from this value.
BEP to Flux	Calculated automatically from the BEP and Flux data provided. Can also be input manually.

Enter Manual BEP

To enter data manually press the tools ( ) icon and select “Enter Manual BEP”. A form opens for the current source name where you can enter the date, the measured value (MV), the corresponding BEP. *Please note that the date will default to today’s date, to add data to an earlier or pre-existing flux series, set the date to the date shown in the chart title.* Press save to save the new item to file. The new data will appear when the source is selected once more.

Edit Flux Data

To edit pre-existing Flux data, press the tools ( ) icon and select “Edit Manual Flux”. A form opens displaying all the currently selected source’s flux data on the current series date in tabulated form. Select and edit the values by left mouse clicking in the white data boxes. Finally commit the changes by selecting “Save”.

Delete Flux Data

To delete pre-existing Flux data, press the tools ( ) icon and select “Edit Manual Flux”. A form opens displaying all the currently selected source’s flux data on the current series date in tabulated form. Press the delete button next to any row to delete that item. Finally commit the changes by selecting “Save”.

If all Flux items are deleted, you will need to select a new date to show Flux data.

Calculate Flux / BEP / MV

This function allows you to enter either a Flux, BEP, MV and growth rate and have the other three values calculated / estimated from the Flux Fitting and BEP to Flux conversion values entered previously.

Flux axis units

Use this to set the second Y axis unit to either atoms/nm²/s or the specified growth rate unit. Alternatively click on the second Y axis label directly.

Setting Maximum Flux and Calculation Fill

Pending…

Recipe Form

Recipe Tab Form

The main recipe form (figure 8) comprises a tabulated container. Each tab contains its own unique recipe that can be executed in parallel with any other recipe. Initially, there is only one tab available. To create a tab select source icon ( ) and then select “New Recipe Tab” or use the shortcut CTRL + SHIFT + N. To delete a tab select “Delete Recipe Tab” or use the shortcut CTRL + SHIFT + D. Each tab is uniquely numbered, starting from 1.

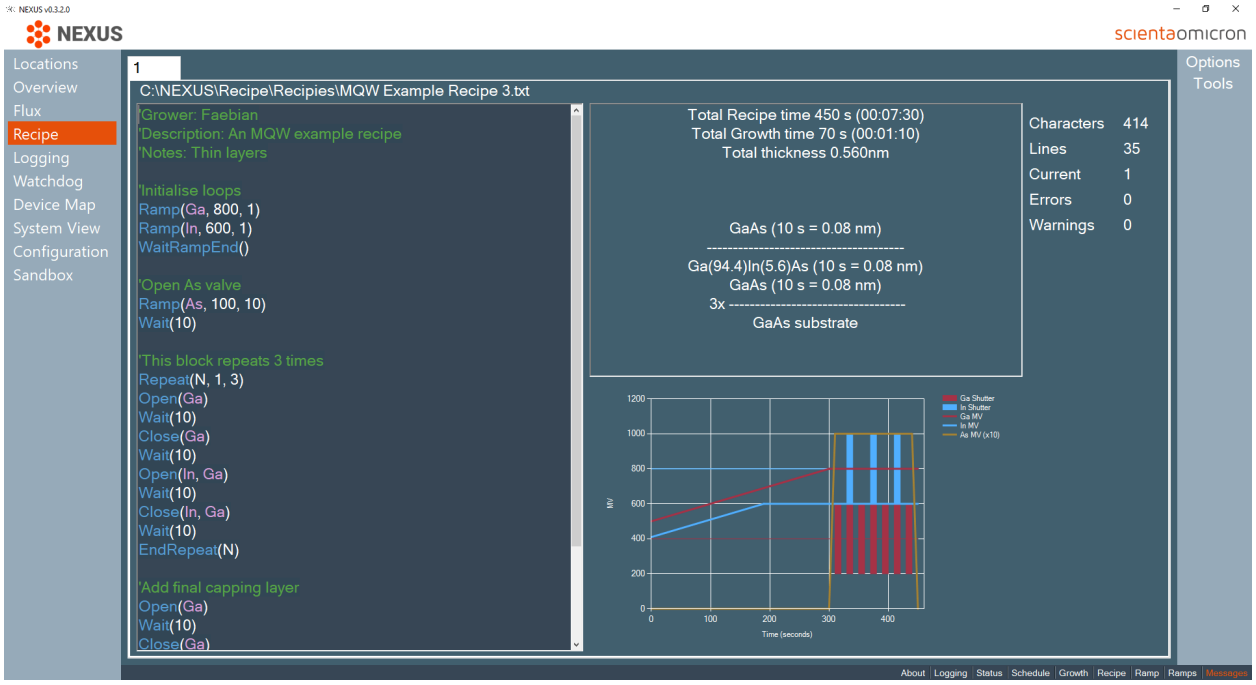

Figure 8: Recipe Form

Recipes Overview

The recipes uses a custom scripting language design around Visual Basic. The recipe form contains a scripting box where you can try the commands of the recipe. The recipe is executed line by line starting at the top. The currently executing line is highlighted in yellow, however since most commands are “instantaneous” only the “Wait” commands appear to be highlighted.

Recipe Commands

There are currently only a limited number of recipe commands implemented. **You can right mouse click on the recipe text box to open a menu to select a recipe command to avoid typing it.**

Command	Example	Description
‘	‘This is a comment	The single quotation mark is used to identify when the line is a comment. Commented lines are ignored by the recipe interpreter.
Wait	Wait(10)	The wait command waits for a specified number of seconds. The example will wait 10 seconds.
Open	Open(Ga) Open(Ga, In)	The open command will open the corresponding shutter(s). Multiple shutters

		should be separated with a comma.
Close	Close(Ga) Close(Ga, In)	The close command will close the corresponding shutter(s). Multiple shutters should be separated with a comma.
Ramp	Ramp(Ga, 500, 0.5)	The ramp command starts the ramp of a source. The parameters are the source name, the ramp end point and the ramp rate. The example ramps Ga to 500°C at 0.5°C/s.
PowerRamp	PowerRamp(Ga, 10, 1)	The power ramp command starts a ramp of the output power rather than the source temperature of a PID controller. If the controller is in automatic mode, it is first switched to manual mode.
RampToBEP	RampToBEP(Ga, 1E-6, 0.5)	Converts a Target BEP value to a Target end point value, and then ramps the source to that target endpoint using the same logic as the Ramp command above. The BEP is in arbitrary units, but usually this is pressure in mBar or Torr. This command can only execute if there is valid Flux/BEP data gathered for the source and a line of best fit exists for the BEP data. See Flux Form Recalculate Fit.
RampToFlux	RampToFlux(Ga, 1, 0.5)	Converts a Target Flux value to a Target end point value, and then ramps the source to that target endpoint using the same logic as the Ramp command above. The Flux is in arbitrary units, but usually this is atomic flux in atoms/nm2/s or flux induced growth rate in ML/s or nm/s. This command can only execute if there is valid Flux/BEP data gathered for the source and a line of best fit exists for the FLUX data. See Flux Form Enter BEP to Flux Conversion.
WaitRampEnd	WaitRampEnd()	Waits for all current ramps to end before moving to the next step
BEP	BEP(Ga, 3)	Collects BEP readings for the named source (here Ga), repeating and averaging over 3 times in this example. Collects BEP at the current loop MV. Combine with Ramp command before use to set the loop MV.

		In order to use this command a Loop must be created with a Source_Type = BFM / “Beam Flux Monitor”. See Loops configuration for more information. After a BEP is captured, the software automatically attempts to Recalculate Fit (see Flux Form Recalculate Fit)
BEPSeries	BEPSeries(Ga, 800, 1000, 50, 1)	Collects a series of BEP values starting at the start value (here 800) and ending at the end value (here 1000). Values are gathered using the step size (here 50). All ramps are executed at the ramp rate (here 1). In order to use this command a Loop must be created with a Source_Type = BFM / “Beam Flux Monitor”. See Loops configuration for more information. After a BEP is captured, the software automatically attempts to Recalculate Fit (see Flux Form Recalculate Fit)
TuneToBEP	TuneToBEP(Ga, 1E-6, 900, 1000, 1)	Tunes the BEP of the source called Ga to 1E-6 mBar. Tuning is restricted to the range of setpoints specified, here lower 900°C and upper 1000°C. If the BEP is outside the setpoint range, the tune is aborted. All ramps are executed at the ramp rate (here 1). In order to use this command a Loop must be created with a Source_Type = BFM / “Beam Flux Monitor”. See Loops configuration for more information. After a BEP is captured, the software automatically attempts to Recalculate Fit (see Flux Form Recalculate Fit)
Repeat	Repeat(SL, 1, 8)	Repeats a block of code with a unique name (called SL in this example) 8 times in this example. The middle number is always 1.
EndRepeat	EndRepeat(SL)	Any Repeat command must have a corresponding EndRepeat with the same unique name (SL in this example)
AutoSave	AutoSave(True)	Turns the function to automatically save the recipe on completion to on (true) or off (false).

AutoGrowthSheet	AutoGrowthSheet(True)	Turns the function to automatically create a PDF recipe growth sheet on completion to on (true) or off (false).

Clearing the Scripting Box

To clear the scripting box, click the source icon ( ) and then select either “New (Blank)” or “New (Template). This will set the current recipe name to “New Recipe (not saved)” at the top of the screen. Blank is used for calibration recipes, whereas Template is used for sample growth recipes that require an automatically generated Growth Sheet.

Saving a Recipe

To save a recipe, click the source icon ( ) and then select “Save”. A standard windows save file dialog box will appear. Enter a file name and select save. The recipe name, including the full path, will be displayed at the top of the screen.

Opening a saved Recipe

To open a saved recipe, click the source icon ( ) and then select “Open”. A standard windows open file dialog box will appear. Select the file to open and then select open. The recipe name, including the full path, will be displayed at the top of the screen.

When you open a recipe the “Recipe Interpreter” will run automatically.

Running a Recipe

To run a recipe, click the tools ( ) menu and select “Run”. The run command will be disabled whilst a recipe is running.

Editing a running Recipe

To edit an already running recipe, simply update the text below the point of current execution. The point of execution is highlighted in yellow.

Pausing a running Recipe

To pause a running recipe, click pause. It is advisable to pause before editing the recipe, so an automatic error check is run before execution continues. The pause command will be disabled when a recipe is NOT running.

Stopping a running Recipe

To stop the executing current running recipe at the current line, click the stop command. A stop cannot be resumed (see pause for temporary pause and resume). The stop command will be disabled when a recipe is NOT running.

Error checking a Recipe

To check the current recipe for errors click check. An automatic check is conducted when clicking Run or when resuming from a pause. The check command will be disabled whilst a recipe is running.

Skipping a line in a Recipe

To skip the current executing line and resume at the new one, click skip. The skip command will be disabled when a recipe is NOT running.

Interpreting a Recipe

The recipe form has an interpreter, that analyses the recipe and outputs the structure that will be grown in a text list of layers (top right box on the form) and in terms of the temperatures of the various sources and positions of various shutters over time on a graph (bottom right box on the form). An error check is automatically performed before interpreting and the interpreter will be canceled if errors are found.

In order for sources to be included in the layer by layer interpretation they must be configured to be either cation, anion or dopant with their corresponding element (Ga, In, As, etc). See Loops configuration for more information.

Each time the Interpret Recipe command is used, the raw data from the graph and layer information is exported into individual text files. The text files can be found in Recipe\Interpreter in a folder with a numerical representation of the timestamp at the exact time of interpretation. (i.e. The latest interpretation is always in the folder with the largest number)

Create a Growth Sheet

Click “Create Growth Sheet” to create a PDF growth sheet of the recipe. The growth sheet will include the recipe script, interpretation layer sequence and chart and the flux data of any sources shown. In addition the meta-data supplied at the top of the recipe will be included. To add meta-data, add a comment symbol (‘) followed by either Grower, Description or Notes. Open a “New (Template)” recipe to see the format. Growth sheets are saved in the “Growth Sheet” folder in the software’s root directory (C:\NEXUS\Growth Sheets\).

Help

The help menu opens a list of all available recipe commands with notes and examples of usage. You can right click on the recipe textbox to access a menu to automatically enter a recipe command with a prompt.

On recipe completion

On completion of the recipe the recipe will be automatically saved and a growth sheet will be automatically created if the AutoSave and AutoGrowthSheet options are set to true in the Global configuration. If the recipe did not have a name or was not saved already, a temporary name will be assigned with the completion time and date in the format yyyy_MM_dd_HH_mm_ss followed by " Unnamed Recipe.

Logging Data Form

Logging Tab Form

The main logging form (figure 9) comprises a tabulated container. Each tab holds a unique instance of the logging form. Initially only one tab exists. To create a new logging tab select the source icon ( ) and click “New Log Tab” or use the shortcut CTRL + SHIFT + N. To delete a logging tab select the source icon ( ) and click “Delete Log Tab” or use the shortcut CTRL + SHIFT + D.

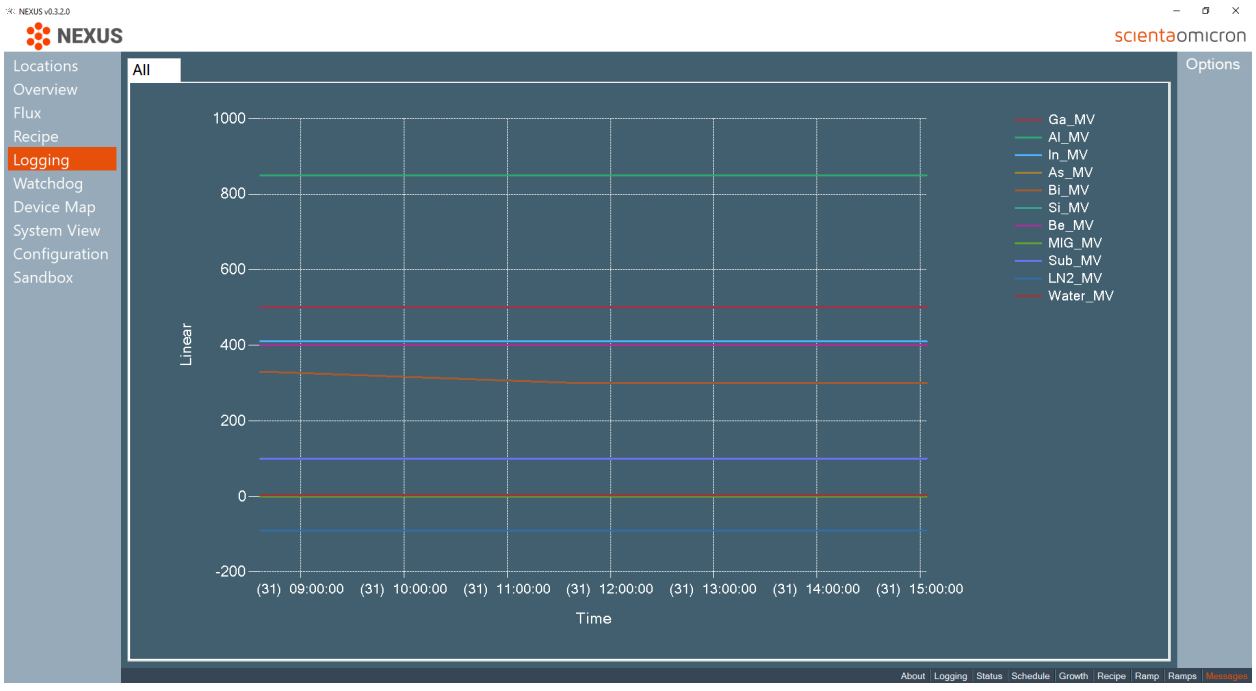

Figure 9: Logging Form

Logging Overview

On the logging data form you will find a single chart that displays all the log data.

The X axis in a custom time format: (Day)-hour:minute:second.
The Y axis is in number format with one decimal place precision when needed, otherwise no decimal place will display.

You can alter the data displayed, the range, the centre and zoom and the axis type (logarithmic or linear) with a combination of mouse and keyboard button actions.

To view a prompt for how to use the logging form, select the source icon () and click “Help”.

Restoring default layout

Double left mouse click anywhere on the chart to restore the default layout. Alternatively hold CTRL and double click to restore the default view without changing the loops on display (this is useful if you have already hidden loops - see below).

Hiding or Showing Chart Data

To hide a single series from the chart, simply left mouse click on the name in the legend to the right of the chart. The series corresponding to the name will be removed from the chart (and all other series will be recoloured). To show the hidden series, simply left-mouse click on the name in the legend once more. To hide all but one series, right click on the name in the legend.

To hide all series in the chart, left mouse click on any name in the legend whilst holding the CTRL key on the keyboard.

To show all series in the chart, left mouse click on any name in the legend whilst holding the SHIFT key on the keyboard.

Centering and Zooming

To re-centre the chart on any point, simply middle mouse click (or mouse wheel click) anywhere inside the chart area.

To zoom in, scroll the mouse wheel up, the layout will also re-centre on the current position of the mouse cursor.

To zoom out, scroll the mouse wheel down, the layout will also re-centre on the current position of the mouse cursor.

NOTE: Centering and zooming is disabled on a logarithmic plot, instead achieved centering and zoom by left clicking on an axis label to set that value to the minimum or right clicking on the axis label to set that value to the maximum. This can be performed on both the X and Y axis. See: reduce axis range below.

Reduce the axis range

To reduce the range of either access left mouse click on an axis label (the axis numerical value). The axis minimum will be set to the value of the axis label that was clicked.

N.B. This is primarily intended to allow the X-axis to be updated to more recently logged data, but can be used for both axes.

Logarithmic scale

To view any loop on a logarithmic scale, hodl CTRL and left click on the loop name in the graph's legend. A second Y axis will appear on the right of the graph. If the dataset for the loop contains any zero or negative values, it cannot be displayed on a log scale and a message box will pop up to inform you.

If the only loop visible is on the second Y axis, the primary axis will be hidden.

Data grids

The primary data grid visible in the background on the chart is associated with the primary Y axis. To view the logarithmic axis data grid, left mouse click on the axis title. Left mouse click again to switch to the original data grid. Only one data grid is visible at at time.

Inspecting data

To see the precise numerical value of any data point, point the mouse at any line on the chart and left mouse click. A cross will appear briefly on the chart to indicate the nearest data point to the mouse coordinates and a popup data label will appear in the bottom right corner of the chart that displays the loop name, the time index and the logged value. The data label will disappear after 5 seconds.

Log View Depth

Right click on any white space on the chart to open the depth selection menu. The menu appears in the top right corner. A display depth in days can be selected from 1 day to 7 days. Once the depth is changed, the software will display a status bar indicator as multiple logging

files are read and the logging data is updated, this typically takes 5-10 seconds. New logging data will continue to be added to the logging chart for depths of 1 hour to 2 days. No new data is added for depths of 3 to 7 days in order to prevent the software becoming sluggish from updating large amounts of data. To resume seeing new data, return the depth to the 1 hour to 2 days range once more.

Watchdog Form

The watchdog form (figure 10) allows monitoring of system status and to setup protective actions should any item be outside of a predetermined range.

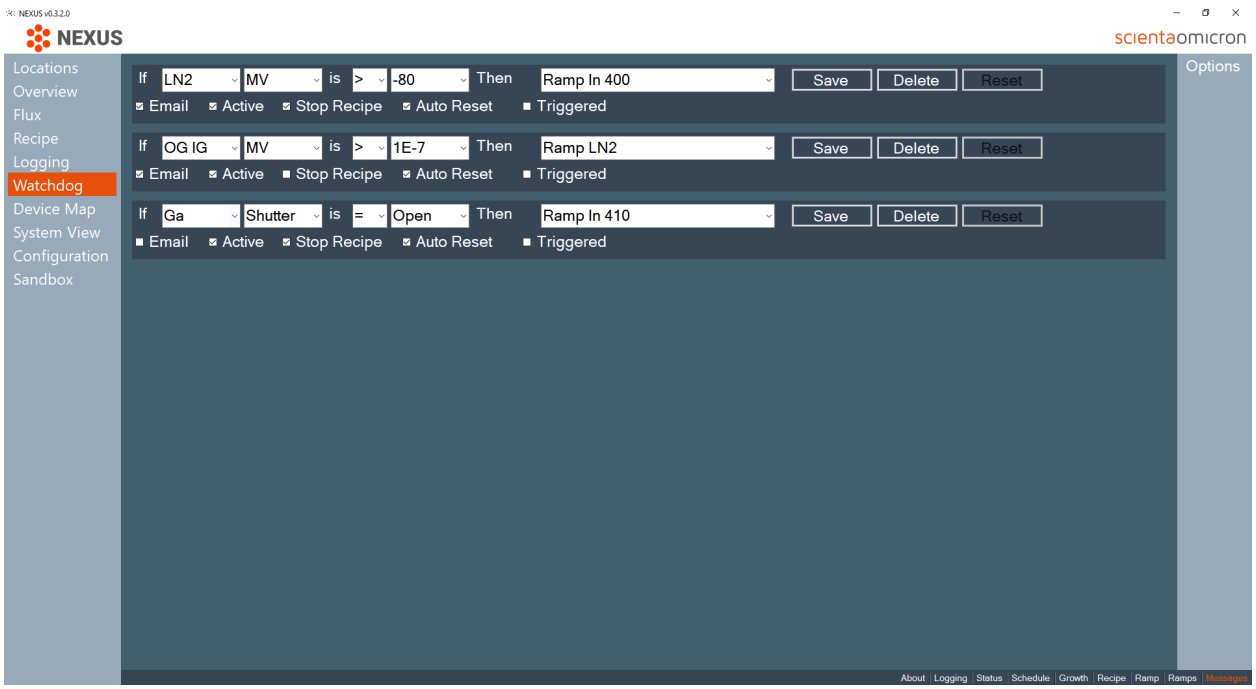

Figure 10: Watchdog Form

The watchdog utlises a “rule” which in turn comprises a trigger condition, a script to execute on when triggered and a number of options to determine whether the rule is active, whether to email the user when the rule is triggered, stop any executing recipe when the rule is triggered, whether the rule is self or automatically resetting and weather the rule is triggered.

Creating a new rule

Click the source icon ( ) and select “New Rule”. The new rule will be blank and read:

If ____ ____ is ____ ____ then _____

The first blank is the loop name and the second blank is the individual register/value of the loop. For example with a loop called LN2 (for liquid nitrogen) and the measured valve of this liquid nitrogen set the first and second blank to:

If LN2 MV is ____ ____ then _____

The third blank is a comparison type, depending on the loop and register this can be equal to, not equal to, greater than, less than, greater than or equal to, less than or equal to. The fourth blank is the comparison target. For example, for LN2.MV we might want to check to see if the value is greater than -80°C:
If LN2 MV is > -80 then _____

The fifth and final blank is the script to run when the rule is triggered. Scripts can be created in the recipe editor but must be saved in the \NEXUS\Watchdog folder (as opposed to recipes that are saved in the \NEXUS\Recipe\Recipies folder). Select the script from the dropdown menubox and the script name will be displayed. The script might be to ramp all the loops to standby and close all shutters in the case the LN2 is greater than -80°C and has therefore stopped cooling, in this example:

If LN2 MV is > -80 then Ramp all loops to standby

Check the appropriate extra actions: Email, Stop recipe and Auto reset. For auto reset the rule is reset after triggering if the opposite condition is true. For example, if the rule triggered when LN2 > -80°C, it will automatically reset when the LN2 <= -80°C.

IMPORTANT: Set the rule to active by checking the active box and finally click “Save”. Unsaved rules will NOT be active, even with the “active” checkbox checked.

When a rule is triggered

This final checkbox called triggered cannot be set by the user, it is only updated if the rule is triggered. When this happens the checkbox will be checked and the entire rule will be highlighted in red, rather than the default gray.

Manually resetting a rule

If the rule is not set to automatically reset, but the trigger condition is no longer true, the rule can be reset by clicking the reset button.

Editing a rule

To edit a rule, simply enter new values in the options in a similar manner to creating a rule and press save.

Deleting a rule

To delete a rule, select Delete.

Device Map Form

The device map form (figure 11) gives a visual representation of the system configuration. Each serial port appears on the left for the form with a name and image. Each device on that serial port appears to the right of the port with the physical device address (0 to 255) and an image of the device.

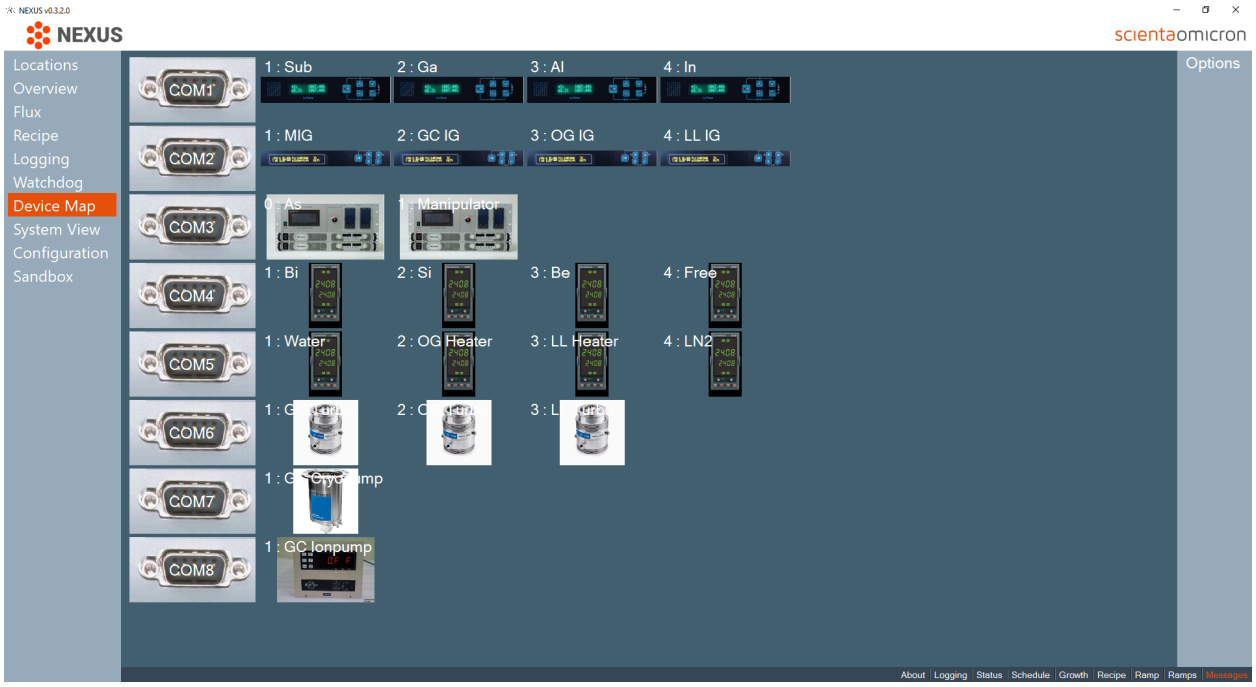

Figure 11: Device Map Form

Adding a port

Click the source icon ( ) and select “add port”. The software opens the relevant section of the config form. Complete the section as instructed in the Config Form Ports section to add the port. Finally select “save” to add the port. The software will show a progress bar whilst the configuration is updated and the changes are applied.

Editing a port

Click the source icon ( ) and highlight “edit port” to open the sub menu and select the name of the port you wish to edit from the list. Alternatively left click on the COM port image to edit the port. The software opens the relevant section of the config form. Change the section as

instructed in the Config Form Ports section to edit the port. Finally select “save” to apply the edit to the port. The software will show a progress bar whilst the configuration is updated and the changes are applied.

Adding a loop

Click the source icon ( ) and select “add loop”. The software opens the relevant section of the config form. Complete the section as instructed in the Config Form Loops section to add the port. Finally select “save” to add the loop. The software will show a progress bar whilst the configuration is updated and the changes are applied.

IMPORTANT: Devices are created implicitly by assigning a COM port and Device address to a loop. When a loop is added or edited with a new device address, it will appear on the Device Map.

Editing a loop

Click the source icon ( ) and highlight “edit loop” to open the sub menu and select the name of the loop you wish to edit from the list. The software opens the relevant section of the config form. Change the section as instructed in the Config Form Loops section to edit the loop. Finally select “save” to apply the edit to the loop. The software will show a progress bar whilst the configuration is updated and the changes are applied.

IMPORTANT: Devices are created implicitly by assigning a COM port and Device address to a loop. When a loop is added or edited with a new device address, it will appear on the Device Map.

View Port Communication Log

To view the individual messages sent and received to all devices on the port right click on the serial port image. The “Comms Monitor” section of the configuration form will open and after a few moments the messages will appear in real time.

View Device registry

To view the device registry of a device on a port, left mouse click on the image of that device. The software opens the relevant section of the Config Form. All times from the device registry are displayed. In order to modify any register, update the value and click “modify”.

View Device Communication Log

Similar to the port communication log, the individual message to a single device on a port can be viewed. To view the individual messages sent and received to a device on the port right click

on the device port image. The “Comms Monitor” section of the configuration form will open and after a few moments the messages will appear in real time.

System View Form

The system view form (figure 12) shows a visual representation of the overview form. The background image can be updated to represent each individual MBE system. The controls initially appear on the left side of the form but can be moved to any location on the form. Similar to the overview form, the controls are interactive and can be used to open/close shutters and to start ramp.

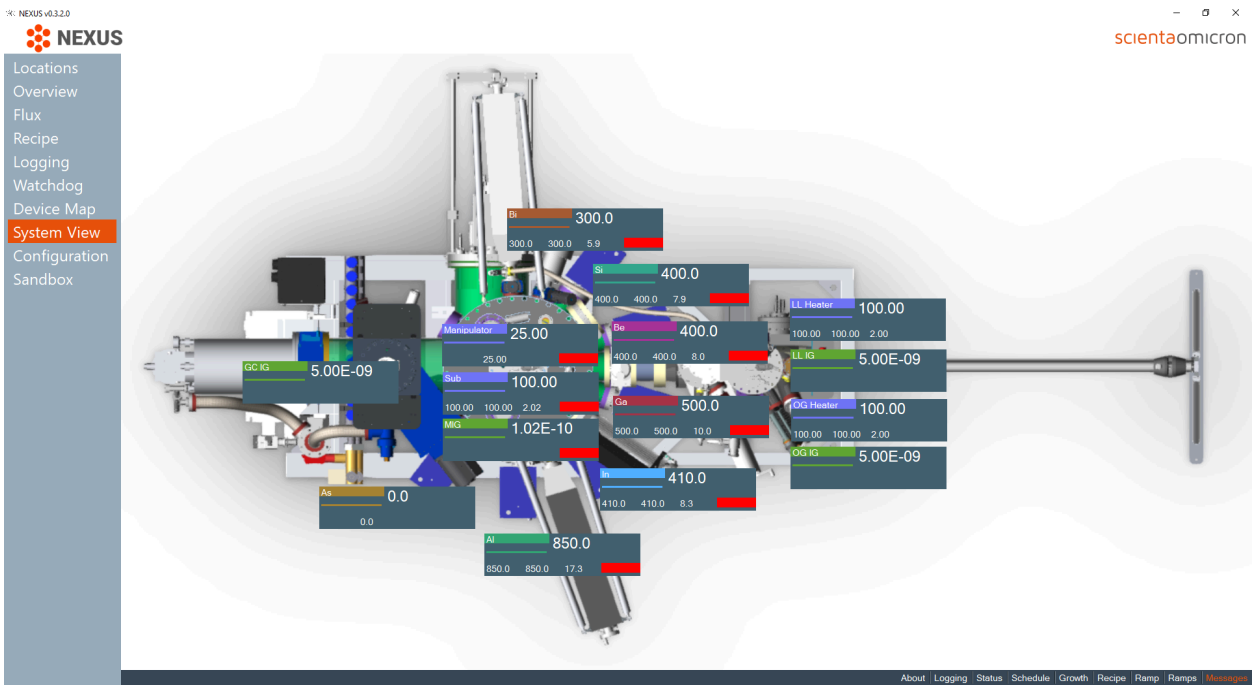

Figure 12: System View Form

An example of the control is shown in figure 13. The control has the loop name in the top left followed by the current measured value directly below. On the right side the endpoint, setpoint and shutter state are visible. The shutter state is red when closed, green when open and yellow when either opening or closing before the change is confirmed.

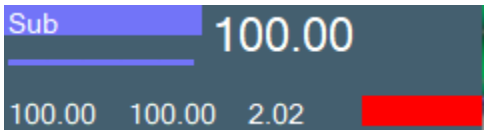

Figure 13: System View Form Control

Setting the background image

The background image can be updated by replacing the “MBE System Layout.bmp” file in the Assets folder. The software must be closed to replace the image. The image must be a bitmap file.

Moving controls

Controls are moved by drag-and-drop. Click-and-hold the left mouse button on any blank space within the control to pick up a control. Then drag the control to the new location and finally release the left mouse button. The control location will be saved and loaded when the software is reopened.

Alternatively, right mouse click on any blank space within the control to open a pop up menu to select the X and Y screen coordinates for the control. The current coordinates will be displayed. Update the values and click save to apply changes. The values must be within the bounds of the screen, if a value outside the allowed range is entered, a warning boy appears.

Opening / closing shutters

To open a shutter left mouse click on the shutter state indicator in the bottom right corner of the control (shown in figure 13).

Start a ramp

To start a ramp left mouse click on the measured value status text in the bottom right corner of the control (shown in figure 13). A pop up will appear to enter the setpoint and ramp rate for the ramp in an identical manner to the overview form. Select “ramp” or press enter to start the ramp.

Config Form

To access the Config Form, select the configuration button from the select form or press CTRL + 9. On the config form you can alter the various configuration data of the NEXUS console. A tree view is shown with the various opinions. Clicking on the main branch of the tree opens a form at add a new item into that branch. Click on a pre-existing item on a sub-branch opens a form to edit that pre-existing item.

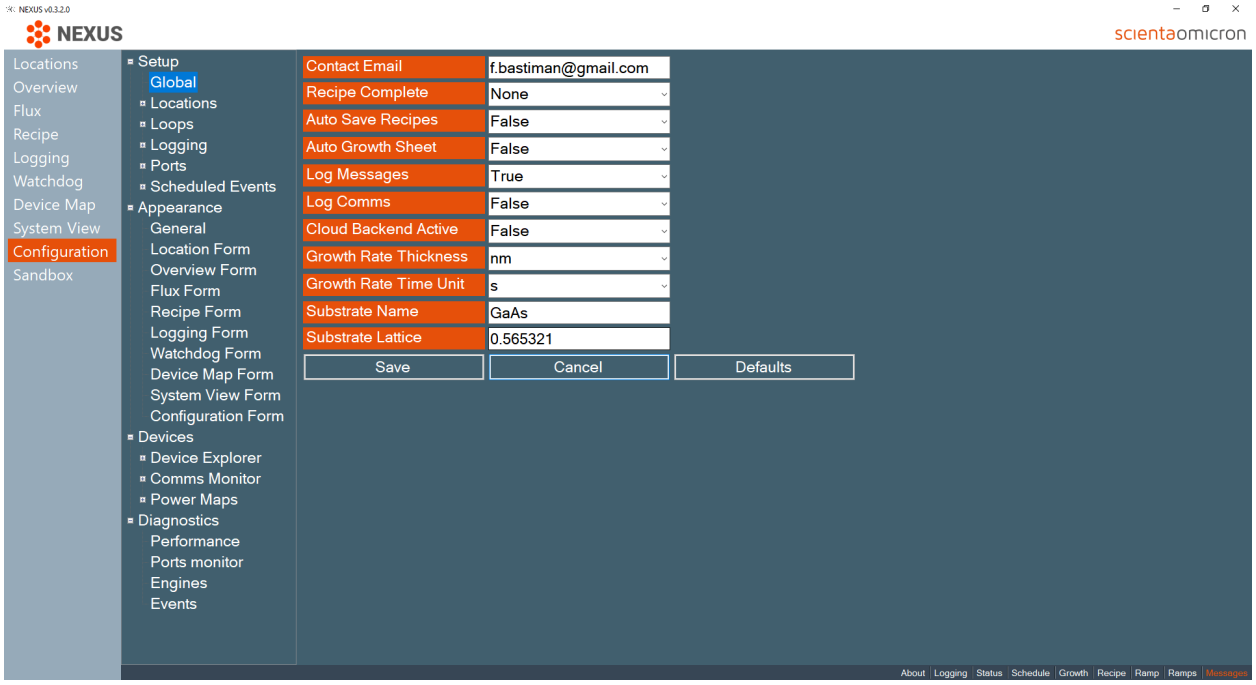

Figure 14: Config Form

Press “Save” to save a new entry or commit the changes when editing a pre-existing entry. Without pressing save, changes will be ignored.

When viewing a pre-existing entry, press “Delete” to delete it. This is permanent. If you simply want to hide an entry, set it to “Enabled = False”.

Global

Global settings correspond to notification settings.

Item	**Description**
Contact Email	This is the default contact email address for all email communication from NEXUS
Recipe Complete Notification	Indicates the type of notification to use once a recipe is complete: None, Message, Prompt, Email.
Auto Save Recipes	Sets whether a recipe will automatically save on completion: True / False
Auto Growth Sheet	Sets whether a PDF growth sheet will be automatically created on recipe completion: True / False
Log Messages	Sets whether status messages are logged to text file: True / False.

Log Comms	Sets whether COM port messages (diagnostic data) is logged to file: True / False.
Cloud Backend Active	BETA only. Sets whether data is sent to the NEXUS Cloud Backend Database for viewing with the companion mobile app: True / False.
Growth Rate Thickness Unit	Sets the growth rate thickness unit for interpreting growth rates in the Overview, Growth, Flux and Recipe forms: nm, µm or ML
Growth Rate Time Unit	Sets the growth rate time unit for interpreting growth rates in the Overview, Growth, Flux and Recipe forms: s, min, hr
Substrate Name	Sets the substrate name for display on the recipe form
Substrate Lattice Constant	Sets the substrate lattice constant for converting BEP and Flux values to growth rates.

Locations

Item	**Description**
Name	This is the name of the location as displayed on the location form
Enabled	A flag to indicate whether the location should be displayed on the location form or not.
Position	The position the item will be displayed on the locations form. 1 = top.

Loops

The term “Loops” is historic, coming from control loops used to monitor and regulate a device. A Loop can have a shutter and one controller (PID Controller, Valve Controller or Ion (Pressure) Gauge Controller). Not all options are available for all loop types.

Item	**Description**
Name	The unique identifying name of the loop. E.g. Ga.
Enabled	A flag to indicate whether the loop should be displayed on the overview form or not.
Position	The position that the item will be displayed on the overview form. 1 = top.

Loop Type	The loop type (PID = Temperature Controller, VC = Valve Controller), or IG = Ion Gauge). The choice will determine which other options are available and how the software interacts with the assigned hardware.
Loop Port Name	All communication is currently via COM ports. The loop port name is the COM port number, e.g. COM1. Only ports that are defined in Port's Config are available, hence the ports should be defined first.
Loop Port Address	The loop port address is the address of the device on that COM port. This is typically 1, any value from 0 to 255 is possible.
Loop Port Option	This is used for when the physical hardware contains multiple quasi-independent devices that are not addressed with unique Loop Port Addresses within the device's architecture. This is most common with an ion gauge controller that has an ion gauge and a pirani gauge.
Shutter Type	Indicates whether the loop has a shutter and, if so, the shutter type. Open/Close is a normal cell shutter. In/Out is only present for future proofing / is unimplemented. A shutter typed called "Valved" is a virtual shutter used for valved sources. Valved indicates that the loop contributes to growth, and is closed when the MV is 0.
Shutter Port Name	All communication is currently via COM ports. The shutter port name is the COM port number, e.g. COM1. Only ports that are defined in Port's Config and ports that are defined with devices that have digital outputs are available, hence the ports should be defined first.
Shutter Port Address	The shutter port address is the address of the device on that COM port. This is typically 1, any value from 0 to 255 is possible.
Shutter Port Option	This is the corresponding number of the digital output, the options available depend on the hardware device.
Maximum Set Point	The maximum permissible set point value for a ramp that will be executed without a warning confirmation dialog.
Minimum Set Point	The minimum permissible set point value for a ramp that will be executed without a warning confirmation dialog.
Operating Set Point	The set point value at which the loop is considered to be "operating" i.e. no longer standby. For an effusion cell this should be non-negligible flux.
Standby Set Point	The default standby set point of the loop. E.g. Ga = 400 °C.
Maximum Ramp Rate	The maximum allowed ramp rate for the loop
Minimum Ramp Rate	The minimum allowed ramp rate for the loop

Default Ramp Rate	The default ramp rate that will be presented in a ramping dialog.
Maximum Ramp Rate	The maximum permitted ramp rate
Minimum Ramp Rate	The minimum permitted ramp rate, not for some PID controllers, this might be implicit at 0.016 °C/s regardless of the value you set here.
MV Number Format	The number format used for MV (and SP and EP) on the overview form. 0.0 = 1 d.p, 0.00 = 2.d.p. Etc. Scientific notation (typically flux gauges) is always 2.d.p and ignores this field.
OP Number Format	The number format used for OP on the overview form. 0.0 = 1 d.p, 0.00 = 2.d.p. etc
Source_Type	Controls this loops behavior in recipe interpretation, BEP and TuenToFlux recipe commands and on the flux form. Cation, Anion, Dopant for loops that contribute to growth. Sample for the substrate heater stage BFM (= Beam flux monitor) for the ion gauge that is used to gather BEP data None for all other loops
Source_Element	Controls the loop's behavior in recipe interpretation The name of the element of the source. E.g. Ga, In, As

Logging

A logging item tells the software which aspect of a loop to monitor. This depends on the registers of the hardware device, but typically consists of measured value (MV), set point (SP) describing the status of a ramp to an end point (EP).

Item	**Description**
Loop	The name of the loop to log, e.g. Ga
Register	The register of the loop to log, most common is MV which is the current measured value.
Enabled	A flag to indicate whether the loop should be logged or not. This can be used to temporarily disable logging.
Interval	The period of logging in seconds, typically 5 - 30 seconds.

Ports

Ports define a COM port and the type of device on that COM port.

Item	Description
Name	The unique identifying name of the COM port, COM1 to COM256 are available.
Enabled	A flag to indicate whether the COM port should be sought and used at program start or not.
Baud	The baud rate of all devices on the COM port. Typically 4800, 9600, 19200, 38400.
Parity	The parity of all devices on the COM port. Can be None, Odd or Even.
Data bits	The number of data bits of all devices on the COM port. Typically 8, but 5 - 8 are standard.
Stop bits	The number of stop bits of all devices on the COM port. Typically 1, but 0 - 2 are standard.
Device Type	The name of the device on the port. Note only one type of device can be connected to any one port, but 256 of those devices can be connected with unique addresses. The names of support devices are given in the drop down.
Read Buffer Delay	A delay in milliseconds that corresponds to a delay between the first detected bytes arriving and a check made to see if more bytes are available in the buffer. If the value is greater than 0, then the software will continually check the buffer waiting the delay interval each time until no more bytes arrive.
Next Message Delay	A delay in milliseconds between receiving a response and beginning the next request, some devices hold the hardware in a “ready” state for a short period. In this state no other device on the port can participate in communication.
Timeout	A time in milliseconds between sending a request and receiving no response before the software assumes that there will NEVER be a response and resetting the port and resuming communication.

Scheduled Events

This feature is used to schedule recurring events for the system. These events can be to WakeUp (outgas all cells and tune to fluxes to start the day's growth campaign) every weekday at 09:00:00 or to Sleep (ramp all cells to standby) at 19:00:00 each weekday evening. You can add as many scheduled events as you desire.

The scheduler events actually operate from pre-created recipes saved in the folder “Recipes\Scheduler”. Simply create a recipe in the usual manner, but save it to the “Recipes\Scheduler” folder instead of the default “Recipes\Recipe” folder.

If a recipe is already running when the scheduled events is due to start, the scheduled event is delayed by 5 minutes. Repeating until the current recipe is completed. For example, if the Sleep event is scheduled at 19:00:00, but the last recipe of the day is running at 19:00:00 and actually finishes at 22:33:53, the Sleep event will run at 22:35:00.

Top Tip: The wake up recipe can be started with a Ramp(LN2, -80, 1) immediately followed by a WaitRampEnd() step. This ensures that the system has LN2 running before the cells are outgassed, since the WaitRampEnd() command requires the MV value to reach the SP value before completing and moving onto the next line in the recipe.

Item	**Description**
Name	A unique identifying name. This must correspond to the name of the recipe file to be executed. E.g. Name = Sleep will have a recipe file in “Recipes\Scheduler” folder called Sleep.txt
Enabled	True / False.
Start Time	The start time for the recipe in 24 hour format. E.g. 09:00:00 or 17:30:00
Repetition	The repeat schedule for the event: Daily, Weekdays, Weekends, Mondays, Tuesday, Wednesdays, Thursdays, Fridays, Saturdays, Sundays

GUI

Here you can alter the appearance of the various parts of the software UI, listed below

General GUI Layout Options

Item	**Description**

Form Font Size	The display font on the various forms. Default is 21.
Menu Font Size	The display font on the various menus. Default is 10.
Font Colour	The font colour used on forms. Default is FFFFFFFF = white.
Background Colour	The background colour used on forms. Default is FF4D5459 = dark grey.
Control Colour	The colour of the small box in which values are displayed on forms. Default is FF1674B8 = dark blue.
Graph Marker Size	The size of markers used on graphs. Default is 10. **This item is no longer used. See Logging and Flux layout options below.**

Location Form Layout Options

Item	**Description**
New Forecolour	The text colour that corresponds to a sample with “New” status
New Backcolour	The control colour that corresponds to a sample with “New” status
Outgassed Forecolour	The text colour that corresponds to a sample with “Outgassed ” status
Outgassed Backcolour	The control colour that corresponds to a sample with “Outgassed ” status
Growing Forecolour	The text colour that corresponds to a sample with “Growing ” status
Growing Backcolour	The control colour that corresponds to a sample with “Growing ” status
Done Forecolour	The text colour that corresponds to a sample with “Done ” status
Done Backcolour	The control colour that corresponds to a sample with “Done ” status

Overview Form Layout Options

Item	**Description**
Idle Highlight	True/False. A flag to indicate whether the idle state should be highlighted.

Idle Forecolour	The text colour for the idle state.
Idle Backcolour	The control colour for the idle state.
Operating Highlight	True/False. A flag to indicate whether the operating state should be highlighted.
Operating Forecolour	The text colour for the operating state.
Operating Backcolour	The control colour for the operating state.
Error Highlight	True/False. A flag to indicate whether the error state should be highlighted.
Error Forecolour	The text colour for the error state.
Error Backcolour	The control colour for the error state.
Shutter Closed Forecolour	The text colour for a closed shutter state.
Shutter Closed Backcolour	The control colour for a closed shutter state.
Shutter Open Forecolour	The text colour for an open shutter state.
Shutter Open Backcolour	The control colour for an open shutter state.
Hidden Columns	A list of columns to hide by default, separate multiple items with a comma.

Flux Form Layout Options

Item	**Description**
Marker Size	The size of the marker for BEP data points. Default 10.
Marker Colour	The colour of the marker for BEP data points. Default Red.
Line Width	The width of the line for BEP line of best fit. Default 3.
Line Colour	The colour of the line for BEP line of best fit. Default Blue.

Recipe Form Layout Options

Item	Description
Highlight Colour	The highlight colour for the currently executing line in a recipe.
Warning Colour	The colour that warnings will be highlighted in.
Error Colour	The colour that errors will be highlighted in.

Logging Form Layout Options

Item	Description
Line Thickness	The thickness of each line on the log chart. Default 3.

Devices

The devices option allows for setup and configuration of the hardware devices associated with the system.

Devices lists the COM ports and an inner branch listing the address (available numbers are from 0 to 255) of each device configured on each port. When selecting the device address the entire device registry will be shown. Each register has a name, a value and a “modify” button. To modify a value, simply change the value and click the corresponding “modify” button. The new value will be sent to the device.

Diagnostics

Diagnostics shows developer specific data on the performance and state of the software. It exists to help with new feature evaluation, debugging and troubleshooting.

Item	Description
Comms Monitor	Shows the serial communication messages sent and received either on the entire COM port or on an individual device address on the port.
Performance	Performance indicates CPU and RAM usage of NEXUS Console, including the number of threads.
Ports	Ports shows any port activity in terms of Send / Receive / Idle plus the Round Trip time of the last message send (i.e. the time between sending a request and receiving a response from the device on that port)

Engines	Lists the primary task engines that operate in the software together with their state and the time and data of the last event
Events	Lists the primary events that operate in the software together with their state and the time and data of the last event

Sandbox

The sandbox allows you to add and place controls to create a custom display similar to the Overview and System View forms. You can add:

- Name labels
- Charts of log data
- Clusters which are the System View data boxes
- Lables for MV, SP, EP, etc
- Sparklines

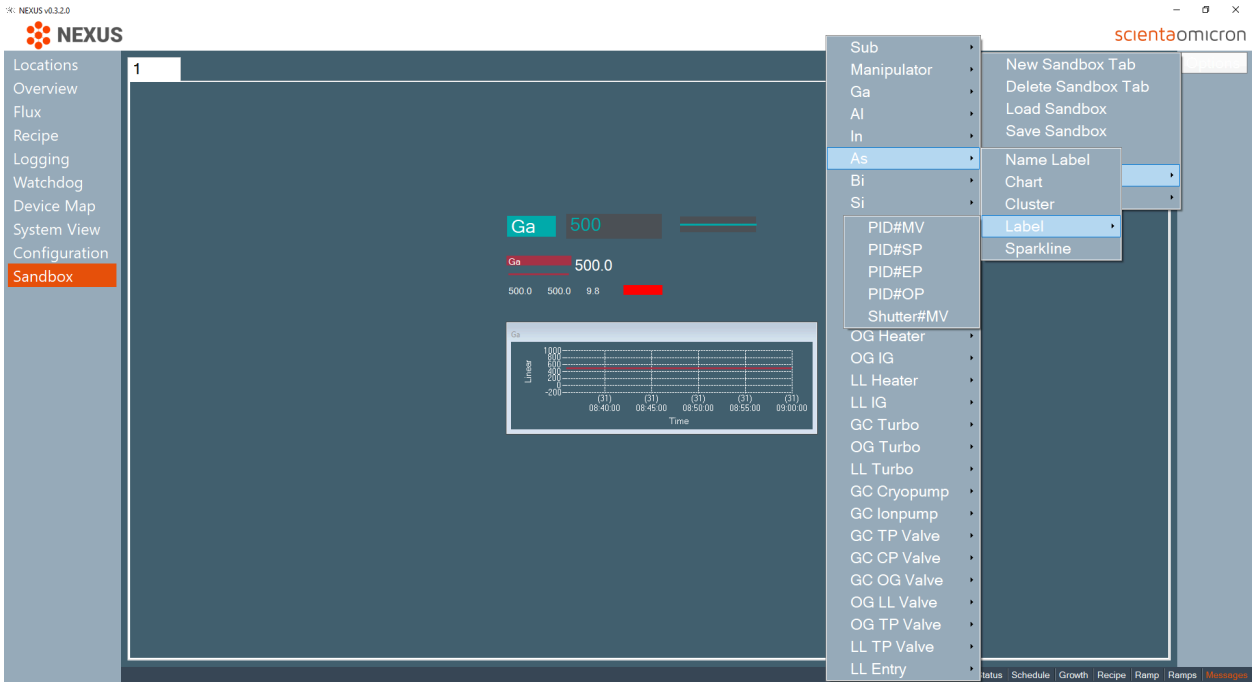

Figure 15: Sandbox Form

Add a new Sandbox Tab

Delete a Sandbox Tab

Add a control to a Sandbox Form

Delete a control from a Sandbox Form

Clear a Sandbox Form

Save a Sandbox Layout

Load a Sandbox Layout