Bioreactor

Software Manual 0.9.x

Copyright 2019 PSI, spol. s r. o., Drásov 470, 664 24 Drásov, Czech Republic

CONTENT

1. Introduction....4

2. Core Features....5

2.1 Client and Server....5

2.2 Devices and Groups....5

2.3 Experiments....6

2.4 Calibrations....16

2.5 Commander....20

3. Devices and Accessories....21

3.1 Photobioreactor FMT-150....21

3.2 Gas Mixer....27

3.3 Gas Analyzer....28

3.4 Multicultivator MC-1000....28

3.5 Peristaltic Pump....29

3.6 Photobioreactor ND....29

3.7 BR Lights....29

3.8 Probe Master....29

3.9 FluorPen....30

3.10 Mettler Balance....30

3.11 TurbidoStat Module for MultiCultivator....30

4. Quick How To....31

4.1 Start the Client....31

4.2 Connect a USB/Serial Device....33

4.3 Setup a Group....33

4.4 Start Experiment....34

4.5 Change Protocol....34

4.6 Add Experiment Note....37

4.7 Stop Experiment....37

4.8 Export Experiment....37
4.9 Save Protocol....37
4.10 Load Protocol....37
4.11 Browse Recorded Experiments....38
4.12 Change My User or Password....38
4.13 Add New User....39
5. Administration....40
5.1 Installed Linux Applications....40
5.2 Database Backups....40
5.3 Upgrades....40
5.4 Device Firmware Updates....42
5.5 Users and Rights....44
6. Customer Extensions....46
6.1 Scripting....46
6.2 Plugins....47
7. Licensing....48
8. Troubleshooting and Customer Support....50
8.1 Restart Bioreactor Server....50
8.2 Gather Log Files....50
8.3 Gather Service Information....51
9. Appendix....52
9.1 Bioreactor Client Hints....52
9.2 Linux Terminal Hints....52
9.3 Installation....52

1. INTRODUCTION

Bioreactor software provides full control over the PSI Photobioreactor devices like Photobioreactor FMT-150, Multi-Cultivator and large-scale Photobioreactors. It can control several experiments in parallel, each experiment can consist of several distinct devices (photobioreactor, multi-cultivator, gas mixer, …). Cultivation conditions can be dynamically varied according to user defined protocol. The delivered bundle consists of a computer with the Debian Linux operating system and the Bioreactor software itself. Thus, no customer installation is typically required. USB communication cable is provided with the bundle for connecting the RS-232 devices with the computer. The devices can be also operated without the software in the manual mode only. In this mode no data can be recorded.

Photobioreactor FMT-150 combines a cultivation vessel with the built-in fluorometer and densitometer. It is primarily designed for modular and precise phototrophic cultivation of algae, cyanobacteria and bacteria. Light power and spectral composition as well as temperature and aeration gas composition can be set with high accuracy.

Multi-Cultivator MC-1000 is a cost-effective small scale cultivation device consisting of 8 cultivation vessels and developed for cultivation of multiple samples of algae, bacteria or cyanobacteria. An extended version of the device, Multi-Cultivator MC 1000-OD is designed to also monitor growth of cultivated organism by measuring optical density at two wavelengths of 680 nm and 720 nm.

Photobioreactor devices may be supplied with a number of optional accessories – sensors, magnetic stirrer, peristaltic pumps, gas mixer, gas analyzer etc., which can be all controlled via Bioreactor software.

2. CORE FEATURES

This chapter describes core features of the Bioreactor software that are independent on connected devices and accessories.

2.1 CLIENT AND SERVER

The Bioreactor software consists of two components:

- The server that controls devices operation and runs in the background on the computer. The server can handle multiple groups. Each group runs independent experiment that can contain several devices.
- The client, which connects locally or remotely to given server and facilitates the communication with the user. It provides graphical user interface (GUI) to the user.

See chapter 4.1 to start the Bioreactor client. One Bioreactor server can handle multiple Bioreactor clients connected locally or remotely.

2.2 DEVICES AND GROUPS

The Bioreactor software installed on the computer can control the connected devices and record experiment data. The devices are organized in so called groups. When a device is connected first time it is put to *<unassigned>* group, except of master devices (like FMT-150), which create their group automatically. Before using an unassigned device in an experiment it must be moved to respective group. Use drag & drop on the tree nodes representing the devices and move them to desired group. Each group can have one or more devices assigned.

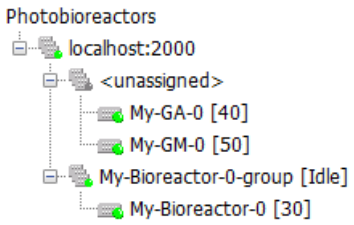

Fig. 1: Unassigned devices

It is possible to move device at any time, however it is recommended to perform an initial devices and groups setup before any experiment is started. Groups and devices can be renamed by choosing live tree context menu.

To display the experiment panel corresponding to a certain group, it is necessary to select the group node in the live tree.

The group node icon indicates the group state:

- Green bullet – all devices connected
- Red bullet – some devices disconnected
- Yellow bullet – group empty or not initialized
- Gray bullet – unassigned devices group

To display device properties panel (Fig. 2), select the device node. The device node icon indicates the device state:

- Green bullet – connected
- Green bullet with red arrow – obsolete firmware
- Red bullet – disconnected
- Yellow bullet – connecting
- Gray bullet – server disconnected/other error
- Yellow star – license error

Each device provides several so called *accessories* – sensors or regulators. Typical sensor is pH and O_2, typical regulator is light, stirrer, thermoregulator and turbidostat. All available accessories of an experiment are displayed in its legend panel in the Bioreactor client.

2.3 EXPERIMENTS

The most important feature of the Bioreactor software is the automatic control and recording of cultivation data in experiment. An experiment is either **live** – currently running or **recorded** – already finished.

2.3.1 LIVE EXPERIMENTS

The *Live* experiments view displays the devices, groups and their running experiments. Each group can be either in *Idle* mode or *Recording* mode.

- **Idle mode** does not persistently record the data, but it still shows the data in graph. The mode is activated automatically when the group is created or after the recording mode is terminated. Anybody with *write* access can make changes to *Idle* experiment.
- **Recording mode** means that sensors and regulators data are persistently recorded to the database. The mode is activated when an experiment is started on the group. See chapter 4.4 on details how to start a recording experiment. Only the user who has started the recording or an administrator can make changes to *Recording* experiment or can stop it.

PROTOCOL

A protocol is set of definitions that describe how to control HW devices and accessories during an experiment. Live experiment protocol can be changed even while recording (see chapter 4.5). The Bioreactor server manages two protocols:

- Idle – protocol used in Idle mode
- Recording – protocol used in Recording mode

When a recording experiment is started, the server uses protocol provided by the user, who started the experiment. When an experiment is finished, the server switches back to Idle protocol. The Idle protocol for each group is automatically generated with empty cycle definitions when the Bioreactor server starts.

A protocol contains set of *accessory cycle* definitions. Each cycle definition can have several *stages*. Each stage defines its duration and type. The accessory stages are periodically evaluated and appropriate actions are taken, e.g. light regulation is performed. The accessory cycle definition is repeated automatically (cycled) until the experiment finishes.

There are two major groups of accessories – sensors (e.g. pH, O_2, CO_2) and regulators (e.g. actinic lights, target temperature). Sensors usually offer only *On* and *Off* stages that define if and how often the measuring is performed and recorded to the database. Regulators offer various stage types and the evaluated value defines the new regulation value to be set in the device.

The sensors action period can be set for all simple sensors in one step using the field in top right corner of protocol legend panel on Fig. 2. Simple sensor is each sensor that does not require any special action before measuring its value. A special action is e.g. stopping the bubbles, thus OD, Ft and QY are not simple sensors.

Specific settings for each sensor can be configured from its context menu.

The protocol legend panel contains also additional accessory markers.

- **M** – means that the accessory phases are locally modified. If the protocol is locally modified, the changes must be uploaded to the server to become active or the changes can be reverted back. This is handled by "Upload" and "Revert" buttons in experiment tool panel.
- **A** – means that the accessory has some phases configured.
- **C** – means that the accessory is currently controlled (e.g. by a regulator) and thus inactive in protocol. For example, operation of peristaltic pump, which supplies a medium to cultivation vessel is controlled by the OD regulator that maintains a given biomass optical density in the cultivation vessel.

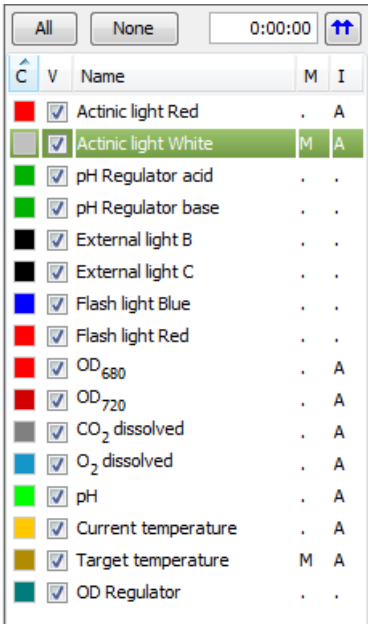

Fig. 2: Protocol legend panel

PROTOCOL STAGE TYPES

- **Off** means that the accessory doesn't measure or regulate
- **On** means that the sensor is recording measured values with given period or the regulator is active (for on/off regulators like valves).
- **Constant** keeps constant regulation during the stage duration (e.g. for lights, temperature)
- **Linear** means linear (growing or sinking) regulation. It specifies initial and final value within given duration (e.g. for lights, temperature)

- **Sine** means harmonic regulation with specified parameters (e.g. for lights, temperature)
- **Script** is driven by a JavaScript that returns a regulation value or measuring period. See chapter 6.1 for details.
- **Flash light** is used to define measuring light pulse and actinic light saturation intensities when measuring Ft and QY. See chapter 3.1.6 for details.
- ***Custom type*** can be implemented by a plug-in. See chapter 6.2 for details. It is usually used for custom accessory. (e.g. pH Regulator Acid)

Constant, Linear or Sine stages can be bound to previous stage when entering **<<** string in the start value field in the panel (see the video tutorials).

The accessory protocol configuration can be also empty. In this case the accessory is not controlled by the software and the device will use the original/last configured value.

The course of actual set of protocol stages is shown in the graph in Protocol panel (see Fig. 3). The slider above the graph panel can zoom the graph in time axis.

Fig. 3: Protocol panel

START EXPERIMENT

See the chapter 4.4 for details how to start a *recording* experiment.

In general, before starting an experiment, it is necessary to:

1) connect devices (chapters 2.2 and 4.2)

2) connect all desired accessories

3) fill the cultivation vessel with medium and inoculum

4) calibrate accessories if necessary – OD sensor pH, O2, CO2 (chapters 3.1.10, 3.1.11, 3.1.12, 3.1.13)

SCHEDULED EXPERIMENTS

Experiment start can be also postponed. To do so, check the postpone checkbox in experiment start dialog and choose a start time of the experiment. This can be used to start several experiments (on several groups) in exactly defined time. See Fig. 41 for details.

RAW SENSOR SIGNAL

Some sensors (pH, O_2, CO_2) can explicitly display raw signal using the context menu on experiment legend panel. Note that raw signal mode is automatically turned on during sensor calibration. See chapter 2.4.

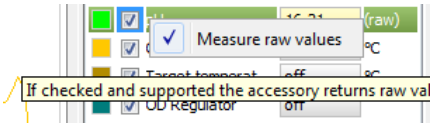

Fig. 4: Experiment legend context menu

2.3.2 RECORDED EXPERIMENTS

This view manages finished experiments that are stored in the server database. Initially it will present empty list with a hint how to perform the search.

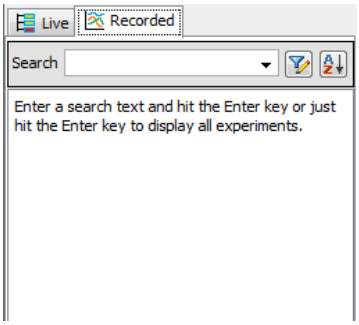

Fig. 5: Recorded experiments view

Recorded experiments can be searched using several criteria. On top of the view on Fig. 5 is a full text search field. It will search for given text in experiment properties.

The *filter* button beside the full text search field will open advanced filter dialog that can be used to fine tune the search criteria.

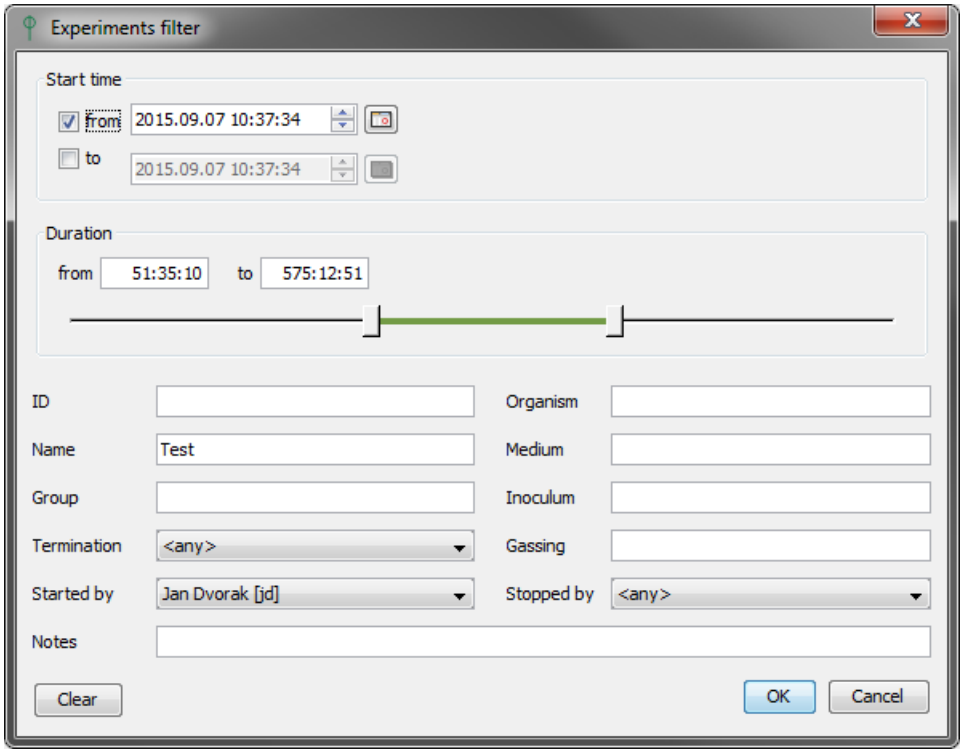

Fig. 6: Experiment filter dialog

When search is finished, experiments matching the criteria are displayed in the list.

The *sort* button beside the *filter* button will open sort criteria dialog that enables to apply sorting criteria on the displayed list of recorded experiment (Fig. 7).

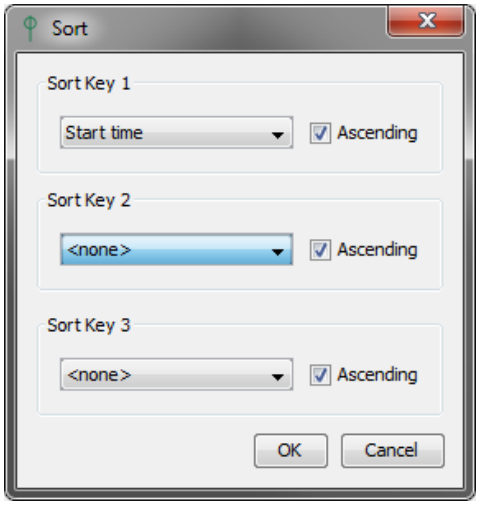

Fig. 7: Recorded experiments sort dialog

It is possible to choose one ore more experiments from the list and display detailed information about the experiment such as accessories data graph, experiment notes and information about the devices. The Fig. 9 shows two recorded experiments selected.

The recorded experiments can be deleted in several ways:

- **<Delete>** key pressed – After confirmation, first selected experiment in panel is deleted.
- **<Shift>-<Delete>** key pressed – After confirmation, all selected experiments in panel are deleted.
- **<Ctrl>-<Shift>-<Delete>** key pressed – After confirmation, all experiments in panel are deleted. (Fig. 8)

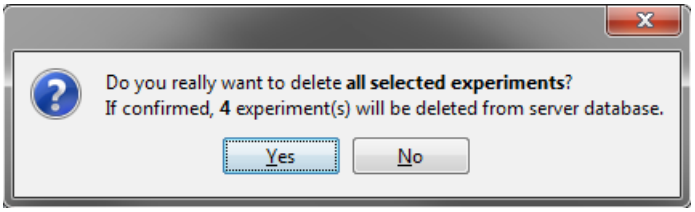

Fig. 8: Experiment delete confirmation

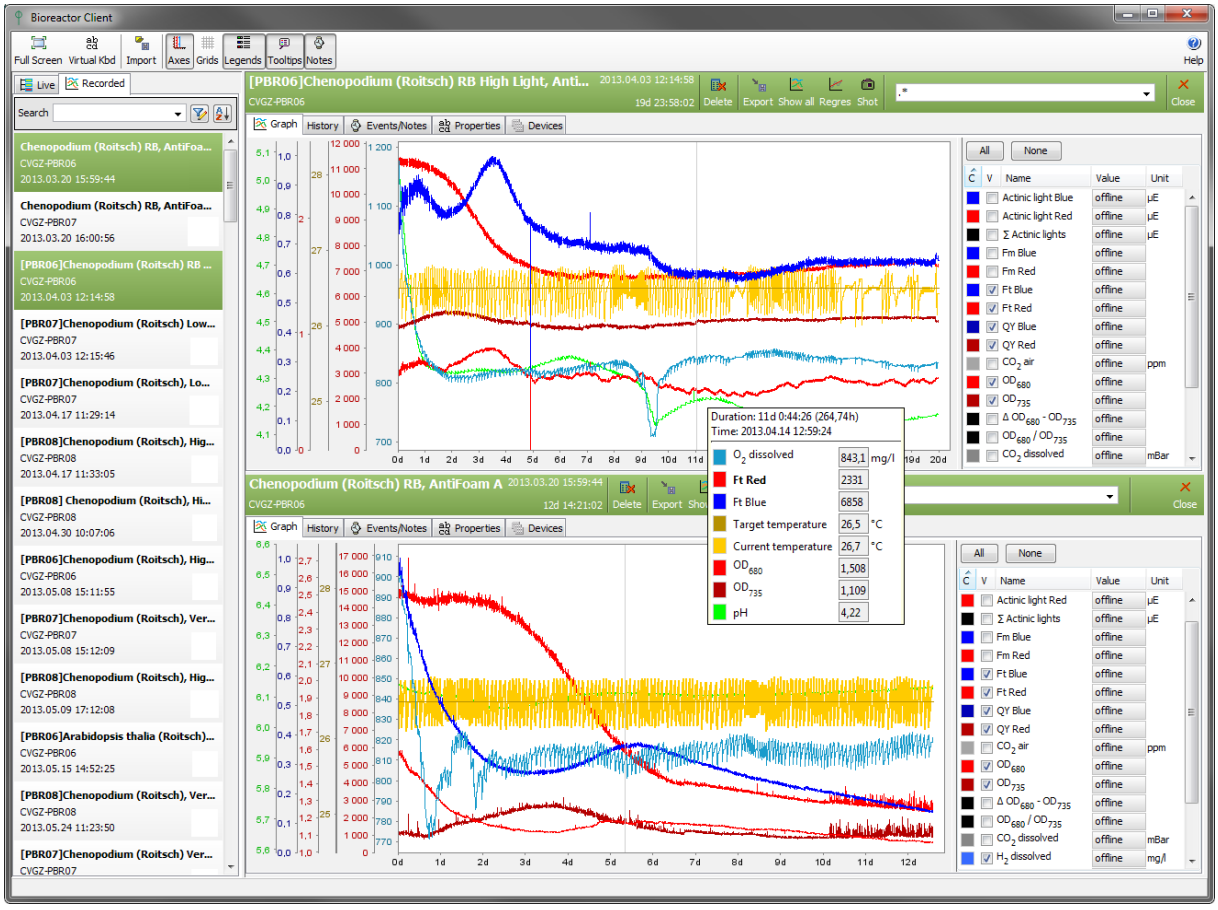

Fig. 9: Recorded experiments view

DEVICES

Recorded experiments displays their devices configuration in the *Devices* tab of the experiment panel.

2.3.3 PROTOCOLS HISTORY

The protocol of Idle or Recording experiment can be dynamically changed. To review the history of protocol changes at any time, the Bioreactor server stores each change in the database. The Bioreactor client displays protocol changes in the *History* tab of experiment panel. The protocol change event is also visible in the *Events* tab.

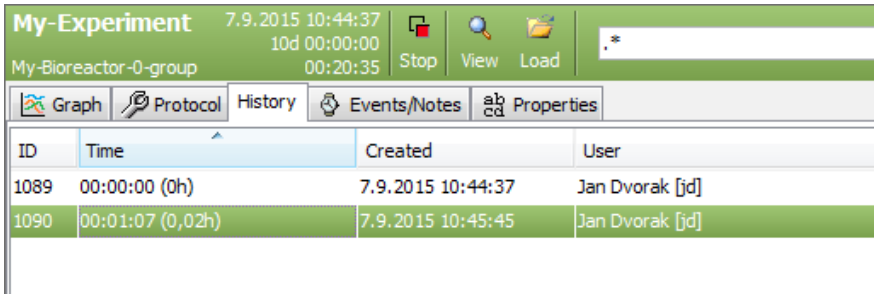

Fig. 10: Protocol history panel

2.3.4 EVENTS AND NOTES

The person that have started the experiment can record additional notes describing the experiment course. The notes are displayed in the Events/Notes tab of the experiment panel. The panel automatically records also some other events like protocol updates, device disconnects and accessory calibrations. Each note or event displays its relative and absolute time, user and message.

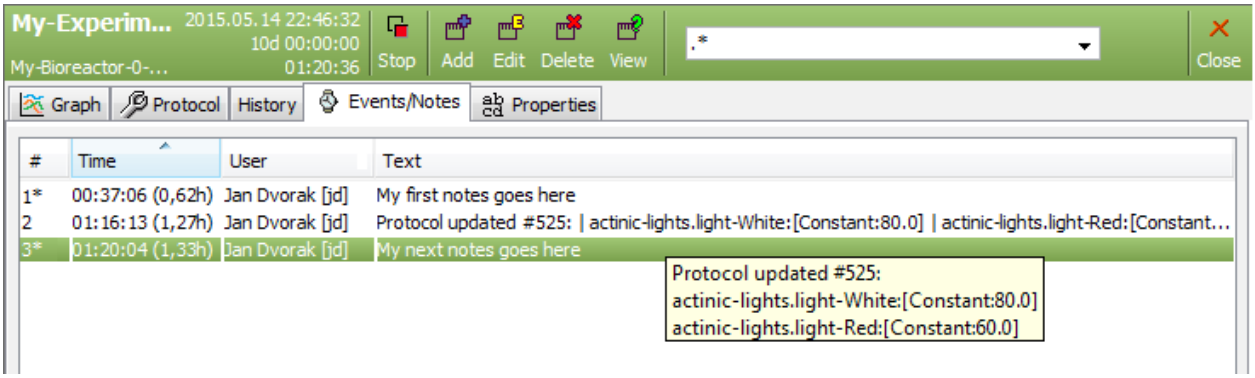

Fig. 11: Experiment events

Privileged user can add new notes or modify and delete existing notes/events. Other users can just display them. System events cannot be deleted.

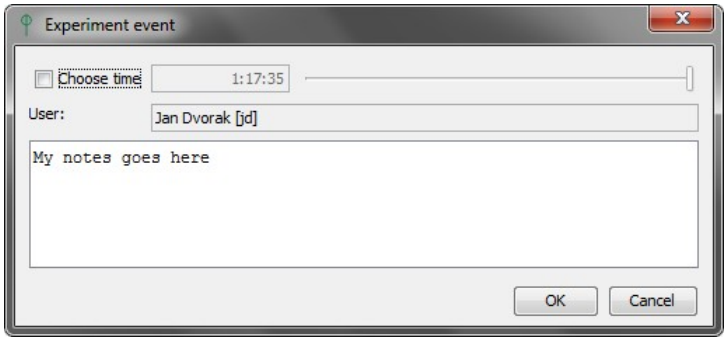

Fig. 12: Experiment event dialog

2.3.5 GRAPH

The experiment or protocol graphs can be controlled by several ways. The *Ctrl* button enabled graph panning. Mouse wheel allow zooming in or out. Zoom in is also possible when selecting a rectangle area with left mouse button.

The scroll bar in the top of the panel allows quickly navigate through experiment course. Clicking on scroll bar area outside the slider will move the graph one day forward or back. Clicking the arrows will move the graph by 3 hours.

Live experiments have by default an auto-range feature which will slide the graph automatically when new data arrive. To restore auto-range after a custom zoom, perform an "inverse" area selection from bottom right corner to upper left corner or scroll the top scroll bar to the right end.

Clicking an accessory data series in the graph will highlight it and focus the accessory row in the legend and vice versa. Double clicking the accessory data series will hide it.

The graph can dynamically display tooltip containing values of visible accessories series in given time (if activated in top toolbar). The accessory which data series is nearest to the mouse cursor is highlighted in the tooltip.

2.3.6 PROPERTIES

Properties of a Live or Recorded experiment can be changed at any time. They can be changed either by a user that has started the experiment or by an administrator. The properties are available in *Properties* tab of the experiment panel.

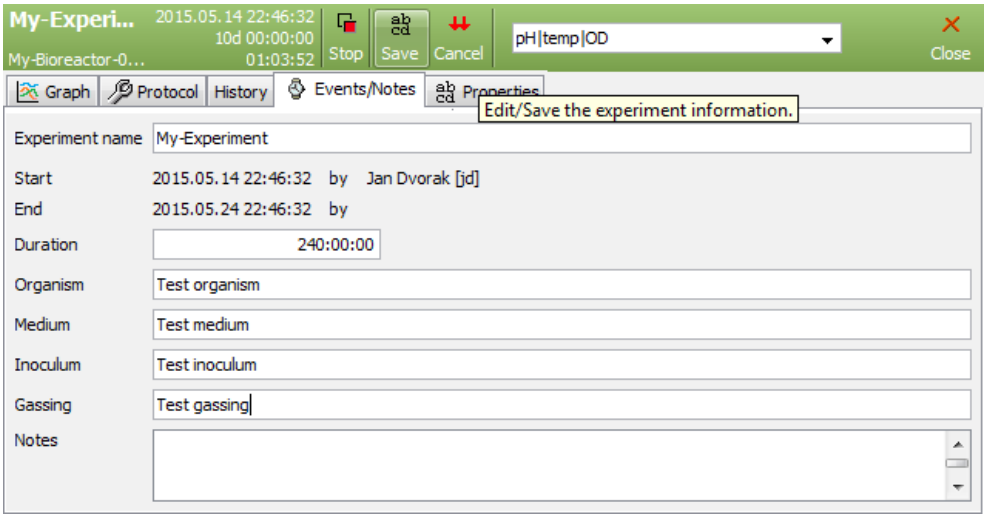

Fig. 13: Experiment properties panel

2.3.7 EXPORTS

Live and recorded experiments can be exported to various formats. It is also possible to select time range, set of accessories and time format. The export dialog is shown on Fig. 14.

Export formats:

- **Simple CSV** – single column CSV format
- **Multi column CSV** – multiple accessory columns CSV format. It can be imported to MS Excel/LibreOffice
- **LibreOffice/Ms Excel** – direct export to ODS format readable by MS Excel and LibreOffice suites

- **Importable XML** – XML format that can be re-imported on another Bioreactor client or processed by custom tools
- **Multi column XML** – XML format for automatic processing by custom tools

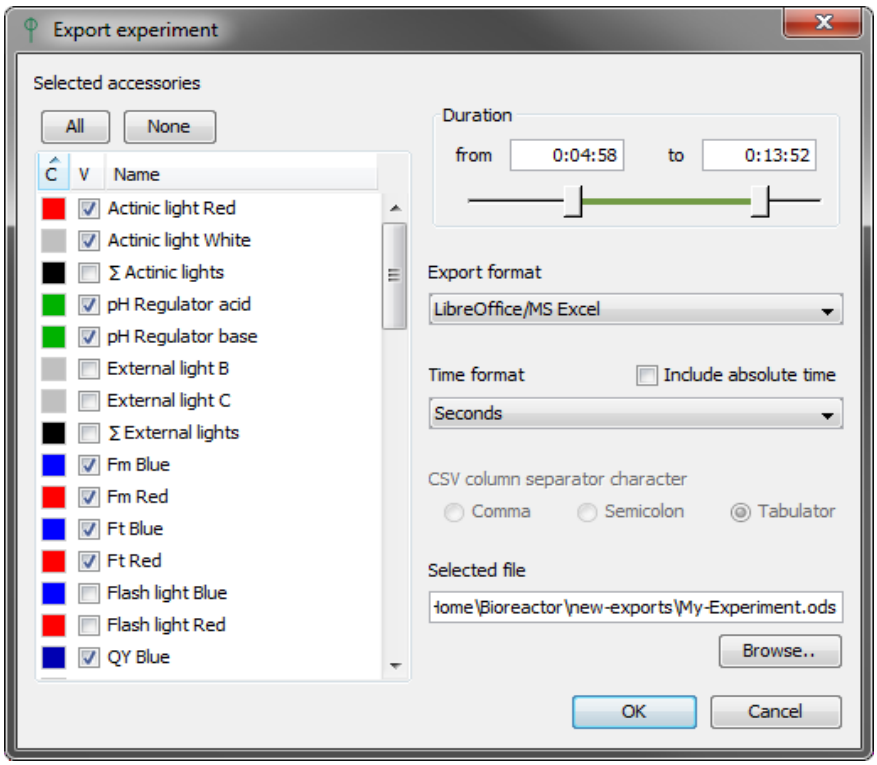

Fig. 14: Experiment export dialog

2.3.8 FILTERING ACCESSORIES

Because number of accessories in an experiment/protocol legend panel can be high, it is possible to simply filter only the items that are currently interesting for the user. The experiment toolbar contains the combo box that performs the filtering (Fig. 15).

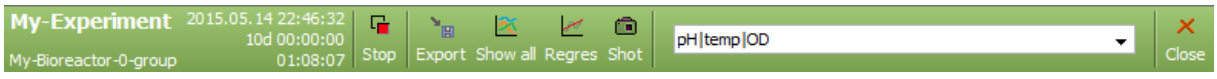

Fig. 15: Experiment graph toolbar

By default all accessories are visible (.*). A filter can be either selected from list of previous filters or typed manually. The filter syntax is defined by Java Regular Expressions. The complete syntax documentation is available at docs.oracle.com/javase/7/docs/api/java/util/regex/Pattern.html

However the usual filter will look like

- `acc1|acc2|acc3`

which means that the legends will display only *acc1*, *acc2* and *acc3*.

A custom item in filter combo box can be removed by pressing <delete> key on it.

There is also a semantic filtering support that cannot be combined with the above syntax. Following flags are supported:

- @S – show sensors
- @R – show regulators
- @E – show accessories in error state
- @A – show artificial accessories. e.g. sums and deltas
- @C – show controlled accessories
- @U – show user defined accessories, e.g. regressions

These filter flags can be combined and negated. Some filter string examples follows:

- @SR – show sensors and regulators
- @!E – show only accessories that are not in error state
- @!CA – all, but controlled and artificial accessories

2.3.9 REGRESSIONS

Bioreactor software can compute regression (trend) curves on selected accessory data series. To display a regression line on given accessory:

1. Select the accessory data series in experiment graph or legend panel.
2. Choose a time range in graph by panning, scrolling or zooming the graph.
3. Press the *Regress* button in experiment toolbar – see Fig. 15.
4. Select proper regression type in displayed dialog – see Fig. 16

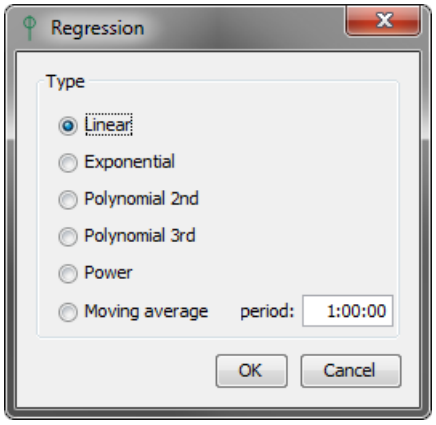

Fig. 16: Regression options dialog

The regression line will be displayed in graph and legend with its parameters (Fig. 17). The time values are converted to hours, when computing the slopes. Several regression curves per accessory are supported. Existing regression curve can be removed by pressing <Delete> key on selected row in legend panel.

Regression types:

- Linear – $y = Ax + B$
- Exponential – $y = Be^{Ax}$

- Polynomial 2nd – $y = Ax^2 + Bx + C$
- Polynomial 3rd – $y = Ax^3 + Bx^2 + Cx + D$
- Power – $y = Ax^B$
- Moving average – $y_m = (y_{m-n} + \ldots + y_{m-1}) / n$

A regression line can be deleted by selection in legend and pressing <Delete> key or from legend context menu.

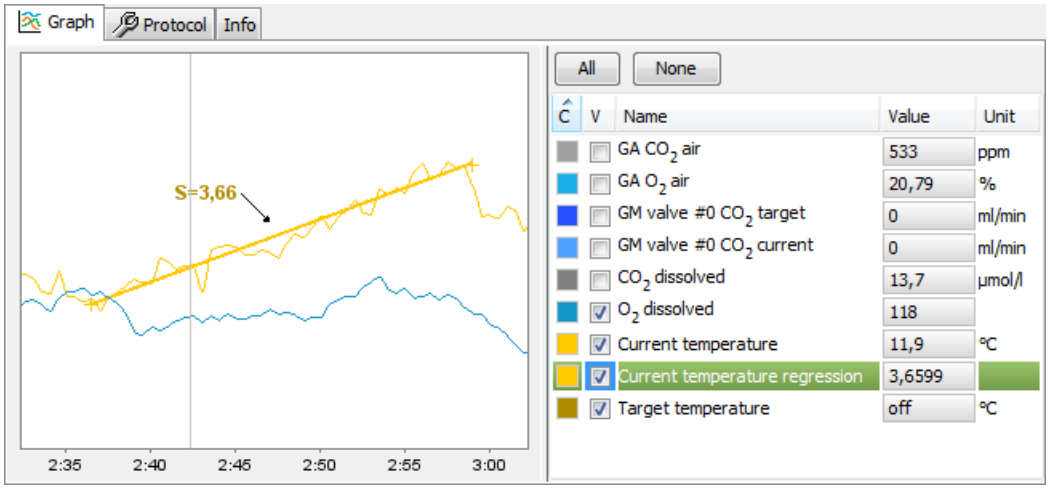

Fig. 17: Linear regression in graph

2.4 CALIBRATIONS

Bioreactor software supports calibrations of various accessories. The calibration process is similar for most of them. Note that calibrations can be performed only in Idle mode and administrator access rights might be required. Each accessory that can be calibrated has either its calibration control panel (Fig. 18) or the calibration actions are available in the legend panel context menu. The panel consists of two buttons.

- The "Show.." button displays the calibration loaded from the device, which is first compared to the last calibration of given accessory stored in database by the software.
- The "Calibrate.." button will open the *calibration wizard* as shown on Fig. 19. The first step in the wizard selects desired calibration action.

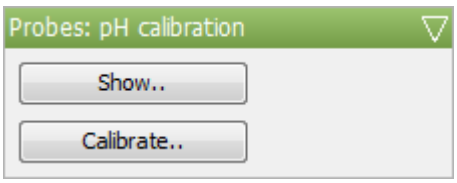

Fig. 18: Calibration control panel

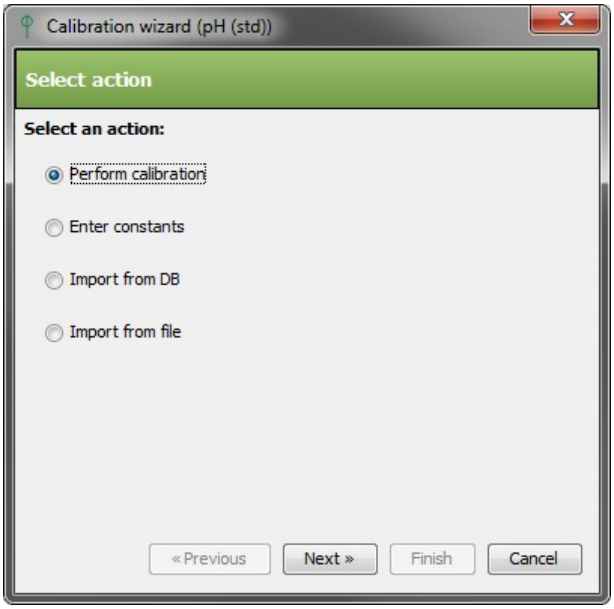

Fig. 19: Calibration action selection step

2.4.1 PERFORM CALIBRATION

The usual calibration wizard consists of three steps. The start step allows to enter calibration notes.

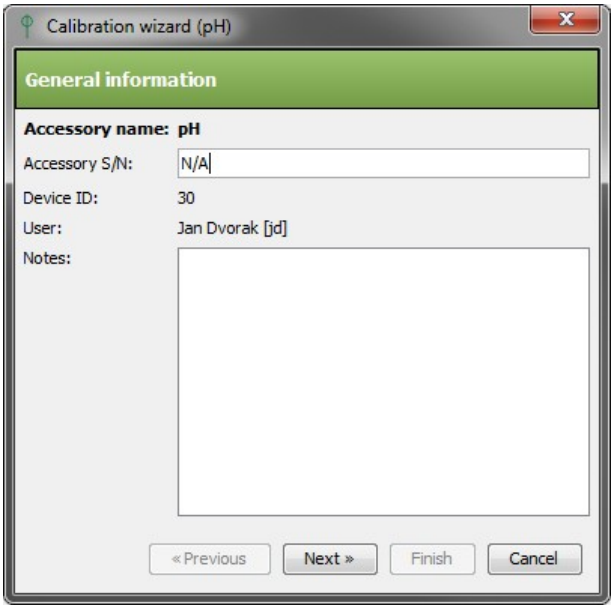

Fig. 20: Start calibration step

In the calibration points step (Fig. 21), the raw values and their corresponding reference values (Standard) are collected. Note that the sensor is automatically switched to raw measuring when this step is activated. For each reference value prepare the conditions and then measure and fill in the raw accessory value. Raw values can be obtained either directly by the *Measure* button or from graph (using tooltips) for long term calibrations and filled

manually. If both standard and raw field are filled, the point can be added to the list with the *Add* button. If the minimum number of points is collected, calibration can continue to the next step.

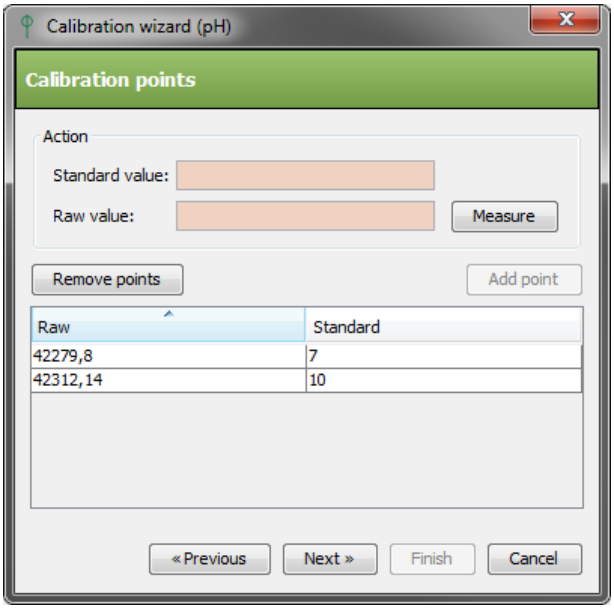

Fig. 21: Calibration points step

Next steps provides an overview of calibration before it is sent to the server and set on the device. It displays the calibration curve and the calibration equation as well as the computed calibration constants.

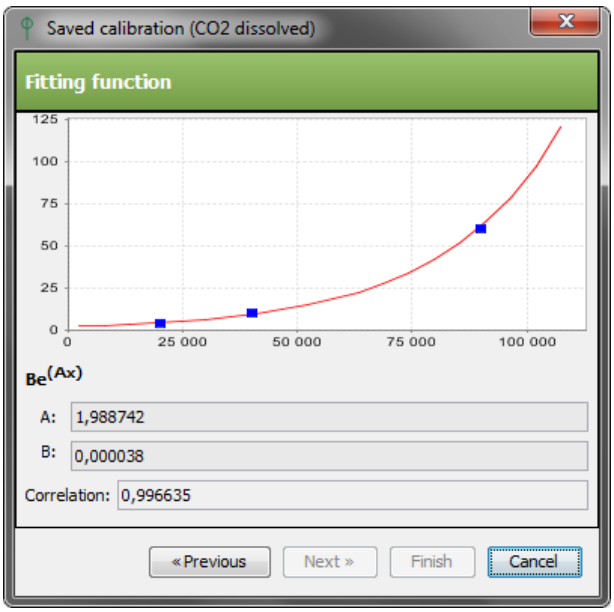

Fig. 22: Fitting function and constants step

Each accessory uses specific calibration equation which is stated in the last calibration step (see Fig. 23 and Fig. 22)

2.4.2 ENTER CONSTANTS

This wizard will directly set calibration constants on the device as shown on Fig. 23. The wizard includes two steps. Start step allows to enter custom notes. The constants are entered in second step. The constants are sent to the device after clicking the *Finish* button.

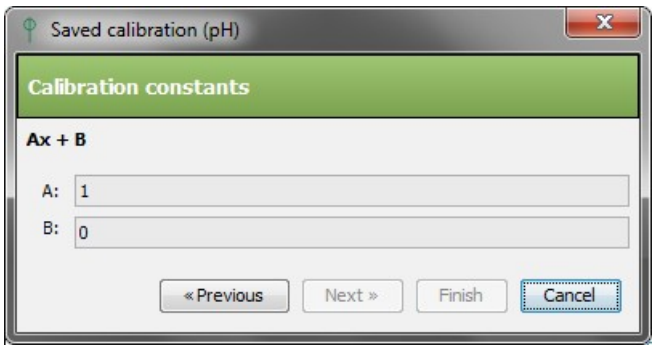

Fig. 23: Enter constants step

2.4.3 IMPORT FROM DB

This wizard will display suitable calibrations saved in DB and let the user choose one (Fig. 24). After a calibration is selected, wizard will preview the selected calibration and after pressing the Finish button send the calibration to the device.

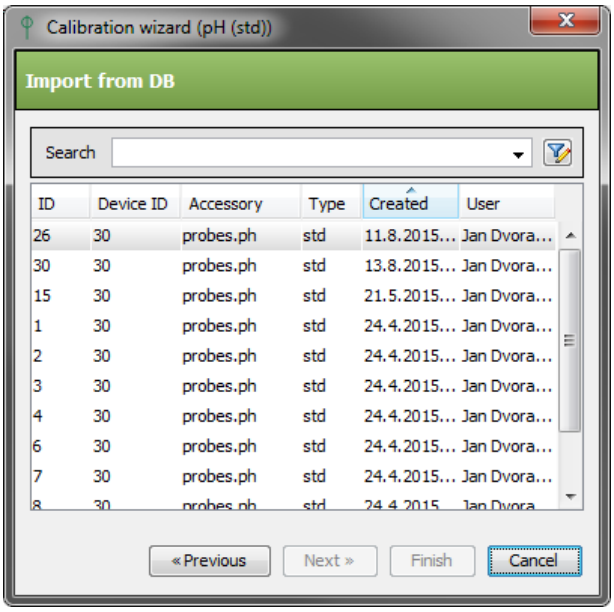

Fig. 24: Import calibration from DB

2.4.4 IMPORT FROM FILE

The wizard loads a calibration previously saved to file. Select file or drop it to the file name field (Fig. 25) and continue to the next step. After a calibration is loaded, the wizard will preview it and let the user apply it or not.

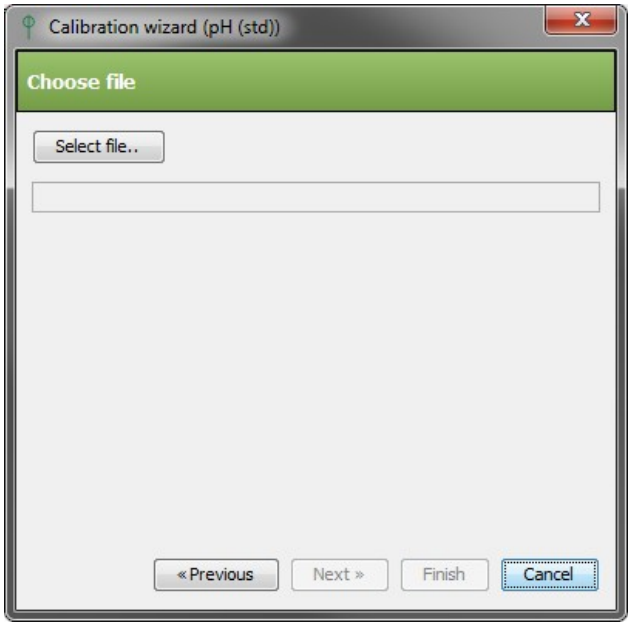

Fig. 25: Import calibration from file

2.5 COMMANDER

The commander allows to send low level device commands to get or set raw device properties. It is not recommended to use commander without PSI service support, because improper use can break the device state or configuration. The right panel displays list of available commands. The bottom left panel shows the commands output. Commander is available only in ADVANCED edition. Non-administrators can see just read-only commands.

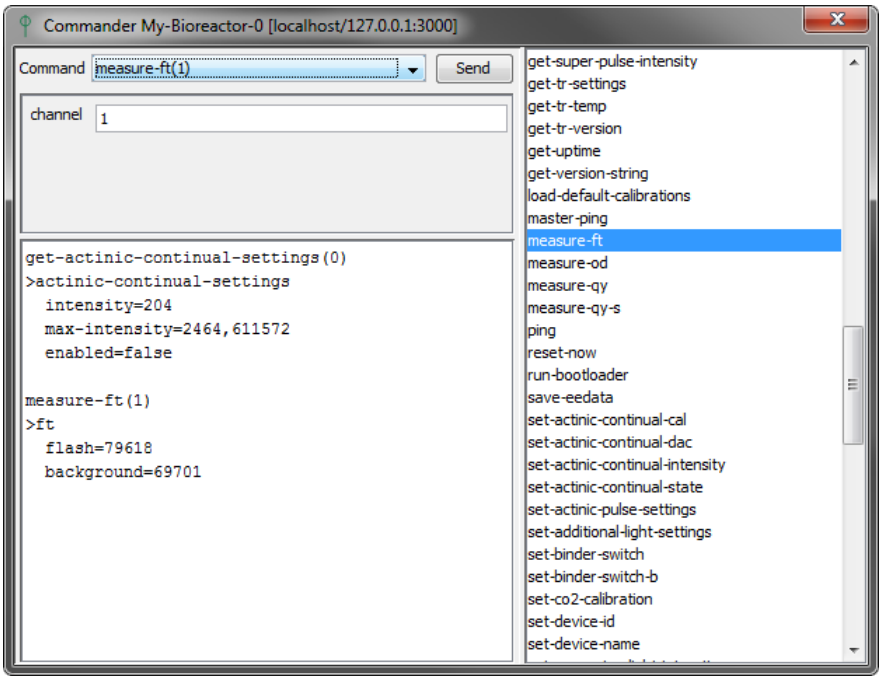

Fig. 26: Device commander

3. DEVICES AND ACCESSORIES

This chapter will enumerate all devices and accessories that can be controlled/measured/regulated by the Bioreactor software.

3.1 PHOTOBIOREACTOR FMT-150

3.1.1 ACTINIC LIGHTS

The protocol of an actinic light specifies the desired light intensity in µE if the light is calibrated, otherwise it uses the % of DAC.

Calibration of actinic lights is available only for PBR administrators. To be able to perform calibration, it is necessary to have a light meter of Photosynthetically Active Radiation to measure real light intensity in µE. The light intensity is then computed from quadratic formula:

$$light_{uE} = A * light_{dac}^{2} + B * light_{dac} + C$$

It is necessary to enter at least 5 `calibration` points.

3.1.2 EXTERNAL LIGHTS

If the external light is not calibrated, the protocol offers the desired light intensity in % of DAC. If the light is calibrated it will use µE to set light intensity. See 3.1.1 for calibration details.

The protocol of an external light specifies the desired light intensity in µE. Calibration of external lights is available only for PBR administrators.

3.1.3 THERMOREGULATOR

Thermoregulation is fully controlled by the FMT-150 firmware. The protocol specifies the desired target temperature, which is then set in the device.

3.1.4 OD REGULATOR

OD regulator (or turbidostat) is designed to control the biomass concentration during cultivation. OD regulation is performed by peristaltic pump [0] see chapter 3.1.7. Before using OD regulator in protocol, it is necessary to assign the OD sensor used by regulator – Fig. 27 shows the configuration panel.

The *Constant* protocol configuration specifies maximum allowed OD. When the OD exceeds this value, the OD pump is started, when the OD sinks to value 2% under the configured value, the pump is stopped again.

The *Range* protocol configuration specifies minimum and maximum allowed OD range. When the OD exceeds maximum value, the OD pump is started, when the OD sinks under minimum, the pump is stopped again.

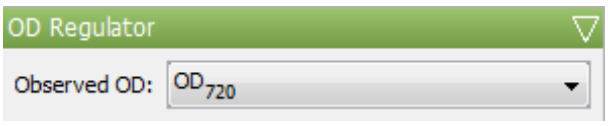

Fig. 27: OD regulator control panel

3.1.5 PH REGULATOR

pH regulator is used to keep pH below and/or above configured value. Note that activating both acid and base regulators in an inconsistent way can lead to unpredictable pumps behavior.

ACID REGULATION

Acid regulation is performed either by peristaltic pump [1] (see chapter 3.1.7) or by a CO2 gas valve. The mode selection is done in protocol stage. The *Constant* protocol specifies maximum allowed pH. When the pH exceeds this value, the acid pump/gas valve is started/opened, when the pH sinks to value 2% under the configured value, the pump/valve is stopped/closed again.

BASE REGULATION

Base regulation is performed by peristaltic pump [2] (see chapter 3.1.7). In addition to single value regulation, protocol offers a *Range* regulation specifying exactly when the base pump should be started and when should be stopped again.

3.1.6 FLUORESCENCE MEASURING

Two fluorescence parameters (Ft and QY) can be measured by using two different lights wavelength (red and blue).

- **Ft**, stands for “non-disturbing” steady-state fluorescence emission. “Non-disturbing” means the measurement itself doesn't influence biomass cultivation.
- **QY** stands for Quantum Yield of PSII (QY). QY should not be measured too often, because of its influence to culture due to the high light saturation pulse used during QY measuring. Therefore, the minimum QY measuring period is 10 minutes. If a protocol would cause measuring in shorter period, the QY accessory will display an error message and will try to perform the measuring in nearest possible time.

To measure Ft and QY, **flash lights** must be correctly set up as well. By default they have empty configuration which means keeping the current values from FMT-150.

3.1.7 PERISTALTIC PUMPS

The PBR device can handle up to 8 Peristaltic pumps. It is necessary to set the ID on each Peristaltic pump device connected to FMT-150. In the control display of Peristaltic pump go to Menu>Setting>Pump-ID [x] and set the required ID as described below:

- [0] should be set for usage with OD regulator
- [1] should be set for usage with pH regulator Acid
- [2] should be set for usage with pH regulator Base
- 3-7 should be set to make the pump configurable in PBR SW protocol

For controlled pumps (ID 0-2) it is essential to set the pump operation flow in µl/min and direction of rotation in the peristaltic pump control panel (Fig. 28). Note that for pumps with ID > 2 the *Flow* field is not editable and the flow of the pump is configured in protocol.

The *Max usage* field can be used to monitor medium consumption from the stock bottle. It should be set to bottle capacity. If value specified in *Max usage* field is exceeded, the server sends an email notification.

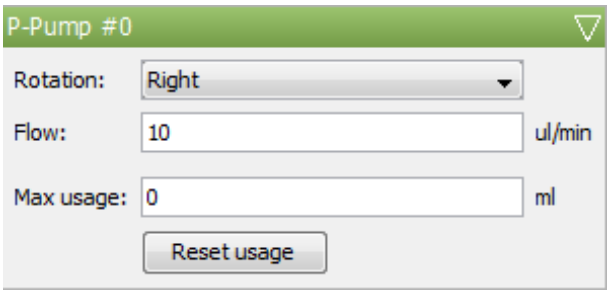

Fig. 28: Peristaltic pump control panel

CALIBRATION

The maximum pump flow is by default configured to 5600 µl/min (PP-500) or factory calibration maximum value (PP-600).

PP-600 PUMP VALVES

The peristaltic pump PP-600 offers four additional valves that can be used independently for various purposes. The valves can be controlled by experiment protocol either using On/Off stages or by scripting stage. An example of valve usage is pH regulation with CO_2. The script will read the pH value and open or close the valve as needed.

```
/*
 * @script pH regulation by pump valve
 * Dummy pH regulation using pump valve based on pH value.
 * The script opens the valve if pH exceeds some value.
 */

// query pH accessory by its key
var curpH = theGroup.getAccessory("probes.ph");

result = 0; // valve closed by default
if (curpH != null && !curpH.hasError()) {
    // get pH value
    var phVal = curpH.getValue();
    if (phVal > 6) {
        result = 1; // valve opened
    }
}
```

3.1.8 PWM PUMP AND STIRRER

PWM connector can be used to plug either a PWM pump or a Stirrer (Fig. 29). The accessory can be regulated within a range of 10-100 %. The PWM accessory is suspended before OD, Ft and QY measuring to avoid disturbance during the measurement.

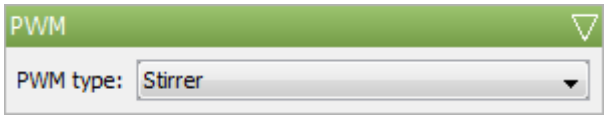

Fig. 29: PWM control panel

PWM PUMP

PWM pump can be used for pumping liquid or gas into the cultivation cuvette. The pump has diverse uses:

1. Controlling air bubbling in the cultivation vessel
2. Single gas input into the vessel
3. When connected to the vessel inlet and outlet simultaneously (closed flow mode), it can be used for suspension mixing (bubbling) in anaerobic conditions.

STIRRER

Magnetic stirrer is used to mix the medium.

3.1.9 BUBBLE INTERRUPTION VALVE

Bubble valve is suspended before OD, Ft and QY measuring to avoid disturbance during the measurement. It is by default enabled in protocol and this setting should not be changed.

3.1.10 OD SENSORS

Prior to the start of each experiment, OD calibration should be performed with the medium used in that experiment. It is important to cover the front side of the vessel with the dark LED panel shield (provided with the system) to avoid possible interference of external light during the OD calibration. OD sensors calibration itself is fully performed by the device firmware.

3.1.11 PH SENSOR

Prior to the initiation of each experiment it is recommended to perform the pH sensor calibration. pH sensor is calibrated using 2 points linear calibration. The standard values for calibration are usually pH 7 and pH 10.

The calibration formula is linear:

$$pH = A * pH_{signal} + B$$

pH sensor can explicitly display raw data using the context menu on experiment `legend panel`.

3.1.12 O_2 SENSOR

The sensors measures dissolved O_2.

CALIBRATION

For experiments with constant temperature, calibrate the O_2 electrode at the experimental temperature. For experiments with mutable temperature calibrate at 25°C and then perform the temperature calibration as well (see below). The calibration procedure is as follows:

Fill the Photobioreactor vessel with the medium. It is recommended to use the same medium as in the experiment, because of possible salinity dependence.

- Set the temperature to the experimental level (or 25°C) and wait for stabilization.
- Bubble the medium with fresh air to get 20.9% dissolved O_2 calibration point. For 25°C the O_2 raw signal should be around 700 (higher signal with increasing temperature). This step takes approximately 15-30

minutes (depending on the temperature, bubbling rate and optional stirring). The O_2 signal can be observed and monitored in the software.

- To get zero point for the electrode calibration, bubble the medium with 100% N_2 to displace the oxygen out of the solution. The raw signal reading should be around 15.
- If N_2 gas is not available, dilute solution of sodium dithionite can be added to the medium. Note: Sodium dithionite is toxic for cultures, thus the cuvette should be carefully cleaned for following cultivation. Alternatively if no zero O_2 reading can be obtained a raw signal value 15 can be entered for zero calibration point.

The output of the O_2 electrode is linear and the calibration formula is:

$$O2_{percentage} = 20.9 * (O2_{signal} - O2_0) / (O2_{21} - O2_0)$$

where $O2_{percentage}$ is actually dissolved O_2 concentration in percents; $O2_{signal}$ is actually measured signal in the Photobioreactor; $O2_0$ is zero calibration point (cca 15); and $O2_{21}$ is “ambient air” point calibration.

TEMPERATURE CALIBRATION

The O_2 electrode signal is quite sensitive to temperature and without temperature calibration its output is not compensated. It is highly recommended to perform the temperature calibration for experiments with variable cultivation temperature. It is necessary to perform standard O_2 calibration at 25°C (see above) before starting the temperature calibration itself. The calibration procedure is as follows:

The calibration procedure is as follows:

- Ensure that normal O2 calibration was performed prior to this.
- Fill the Photobioreactor vessel with the medium. It is recommended to use the same medium as in the experiment (because of possible salinity dependence).
- Bubble the medium with fresh air to get 20.9% dissolved O_2 concentration.
- Start the O_2 temperature calibration wizard
- Fill the desired temperature levels and temperature equilibration time (Fig. 30). The equilibration time specifies how long the temperature must be stabilized before the O2 is measured. Stabilization means that the temperature it is within 0.5°C range.

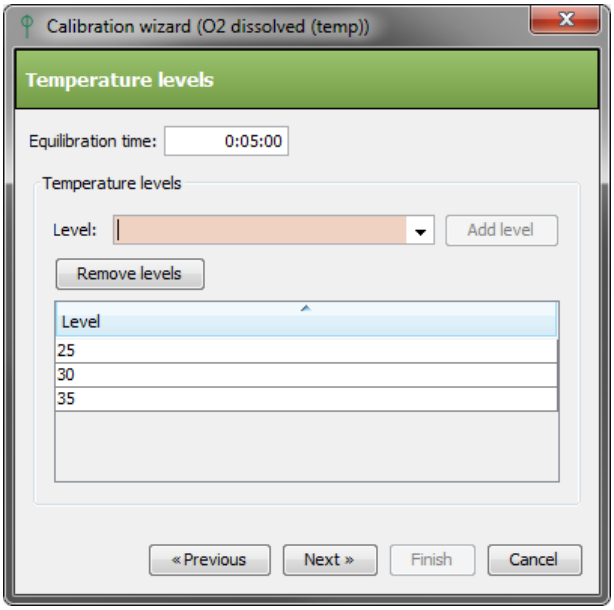

Fig. 30: O2 temperature levels step

- Fill and confirm the calibration experiment properties (Fig. 31)

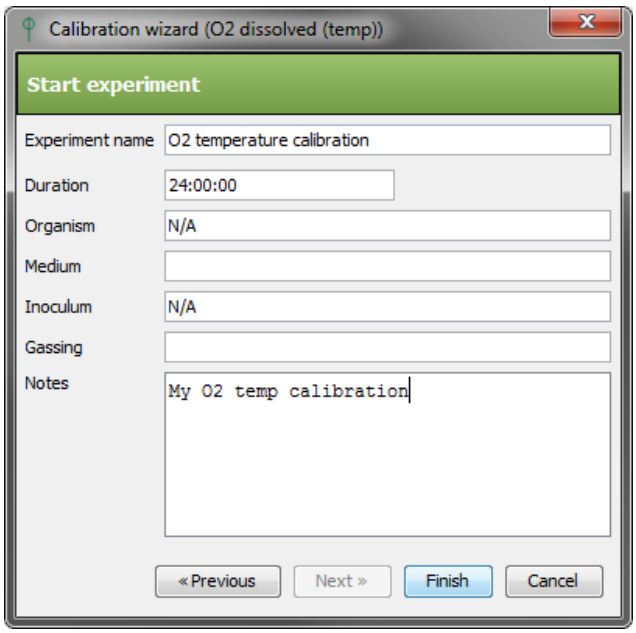

Fig. 31: Start experiment step

Rest of the procedure is driven by the software, it will automatically adjust the temperature and measure O_2 raw signal. The calibration experiment should be terminated automatically and the calibration constants should be set on the device and saved in the database. The calibration experiment can be reviewed in the recorded experiments view.

3.1.13 CO_2 SENSOR

The calibration procedure requires at least three different CO_2 concentrations and it takes about 12 hours. This is due to time required for each CO_2 concentration to equilibrate in the solution and the slow response rate of the electrode itself.

The temperature during calibration should be on the value that will be later used in experiment.

The calibration formula is exponential:

$CO2_{umol/l} = B*e^{(A*CO2_{signal})}$

3.2 GAS MIXER

The Gas Mixer device can be controlled in two modes (Fig. 32).

- **Absolute** – this mode sets absolute flow on valves and the absolute target flow is computed as a sum of valves flow (Fig. 34) thus the *GM target flow* accessory is inactive in protocol.
- **Percents** – in this mode the absolute target flow must be set in protocol. The valve flows are specified as concentrations (in % or ppm). All valves must be configured in protocol, that means none can have empty protocol. At least one valve must be configured as "Automatic". Automatic phase will compute valve flow based on target flow and other valves concentration. Or rather, the automatic valve concentration will be the remaining value such as sum of concentrations from all valves is 100%. See Fig. 33 for example of percent mode in protocol.

If the percent mode is active and the Gas Mixer has CO_2 valve and Air valve, it is also possible to set CO_2 in air. This will recompute the real valve flows based on entered value. The concentrations displayed in client will stay the same.

The flow warning field enables to configure the maximum allowed difference between current flow and target flow before the Gas Mixer LED display starts blinking.

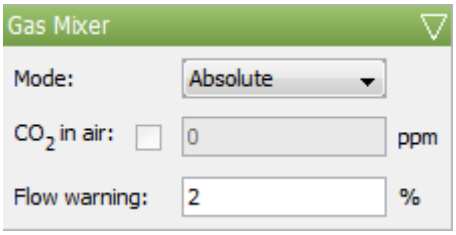

Fig. 32: Gas Mixer control panel

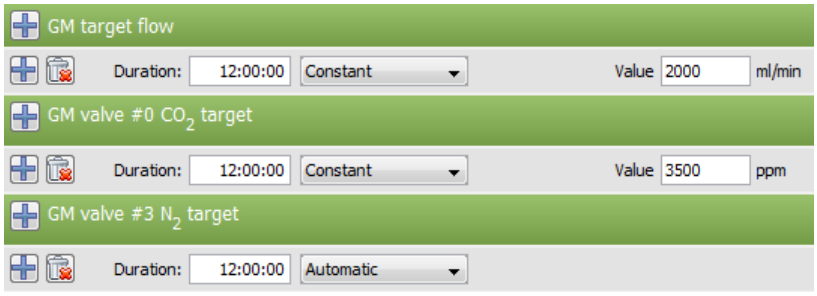

Fig. 33: Gas Mixer protocol in percent mode

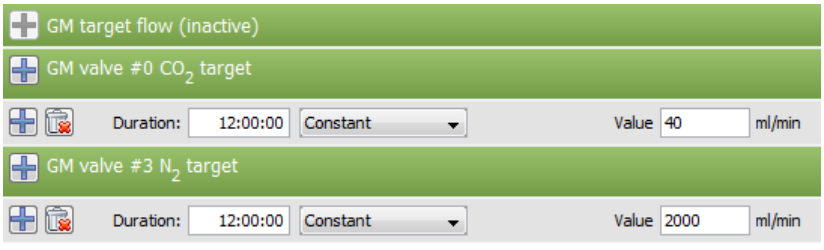

Fig. 34: Gas Mixer protocol in absolute mode

3.3 GAS ANALYZER

Currently only limited subset of Gas Analyzer functionality is supported by the software.

3.4 MULTICULTIVATOR MC-1000

The Bioreactor software supports full control of multicultivator accessories. It can control lights, temperature, air pump and measure OD. The multicultivator has common thermoregulation and air bubbling control and several vessels with independent LED lights.

3.4.1 ACTINIC LIGHTS

The protocol of an actinic light specifies the desired light intensity in µE. Calibration of actinic lights is available only for administrators.

3.4.2 ALL LIGHTS CONFIGURATION

To make the lights configuration more user friendly, the Multicultivator protocol supports configuration of all lights at once. If the *Actinic light ALL* accessory is configured in protocol and uploaded to the server, all lights panels are deactivated in protocol and the lights on device are configured same as the (virtual) *Actinic light ALL*. If the *Actinic light ALL* protocol is deleted and uploaded to server, all light protocol panels are activated again and lights are set back to their original protocol.

3.4.3 AIR PUMP

Air pump is suspended before OD measuring to avoid disturbance during the measurement. It is by default enabled in protocol and this setting should not be changed.

3.4.4 OD REGULATOR

OD regulator (or turbidostat) is designed to control the biomass concentration during cultivation. OD regulation is performed by a peristaltic pump connected directly to the computer see chapter 3.5. Before using OD regulator in protocol, it is necessary to assign the OD sensor and pump used by given regulator – Fig. 35 shows the configuration panel.

The protocol configuration specifies maximum allowed OD. When the OD exceeds this value, the OD pump is started, when the OD sinks to value 2% under the configured value, the pump is stopped again.

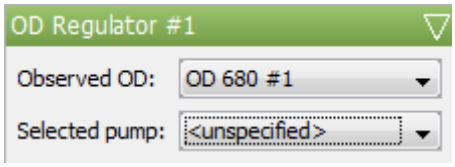

Fig. 35: OD regulator control panel for MC

3.5 PERISTALTIC PUMP

Peristaltic pump device can be also connected directly to the computer with the USB cable or USB converter. See chapter 3.1.7 for details. Such pump cannot be used by FMT-150 OD regulator or pH regulator.

3.6 PHOTOBIOREACTOR ND

This is the photobioreactor device for large vessels.

3.6.1 LEVEL REGULATOR

The vessel medium level can be regulated in three modes that can be configured in protocol. Each mode has several rules that define the level regulator behavior:

- High only
    1. Out-flow pump is started if level is above high.
    2. Out-flow pump is stopped if level is below high.
- Master
    1. Out-flow pump is started if level is above high.
    2. Out-flow pump is stopped if level is below high.
    3. In-flow pump is started if level is below low.
    4. In-flow pump is stopped if level is above low.
- Slave
    1. Out-flow pump is started if level is above high.
    2. Out-flow pump is stopped if level is below high or turbidostat is ON and OD is below limit.
    3. In-flow pump is started if level is below low or turbidostat is ON and OD is above limit.
    4. In-flow pump is stopped if level is above high or turbidostat is ON and OD is below limit.

3.7 BR LIGHTS

This is the device for large scale Photobioreactors. It controls actinic lights. There can be multiple BR Lights devices in one group.

3.7.1 ACTINIC LIGHTS

The lights are controlled in the same way as the lights in the FMT 150. See chapter 3.1.1. Calibration of actinic lights is available only for administrators.

3.8 PROBE MASTER

This is the device for large scale Photobioreactors. The device supports CO_2, pH and O_2 dissolved sensors. None of the sensors can be calibrated in PBR software.

3.9 FLUORPEN

This is the device for large scale Photobioreactors. The FluorPen device is responsible for fluorescence measurements.

3.9.1 FLUORESCENCE MEASURING

Following accessories are supported:

- Flash lights
- Ft
- QY
- OD

See related accessories in the FMT 150 in chapter 3.1.6 for details.

3.10 METTLER BALANCE

The Mettler balance devices are supported. The Bioreactor periodically measures and records the current weight. The serial port of the balance must be marked in the server configuration file to allow the server correctly initiate the communication with the balance. See the */var/psi/bioreactor/server/bioreactor-server.config* file for details.

3.11 TURBIDOSTAT MODULE FOR MULTICULTIVATOR

TurbidoStat module enables turbidostat mode for MultiCultivator devices. More detailed info can be found in the MultiCultivator device manual or at support@psi.cz.

4. QUICK HOW TO

In this section you will find quick description of usual user actions.

4.1 START THE CLIENT

Bioreactor client is a standalone Java GUI application which communicates with the server and attached devices. After the client is started, it asks for login and password and then displays its main window and tries to connect to the Bioreactor server.

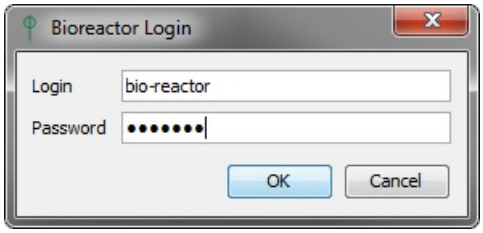

Fig. 36: Client login dialog

If the connection succeeds, the server node is marked with green icon and the device list and other information are queried by the client. If the provided login and password are invalid, the server node is marked with yellow icon, then it is necessary to restart the client or re-enter credentials using “Login” server context menu item.

4.1.1 START ON COMPUTER

After the computer operating system boots up, the Bioreactor client is started automatically. The Bioreactor client can be also started from the Desktop Menu panel (similar to Windows Start menu) in the Bioreactor submenu. The submenu contains also links to Bioreactor manual and video tutorials.

The Bioreactor client asks for login and password before displaying the main application window – see chapter 5.5.2.

4.1.2 START REMOTELY

To access the bioreactors remotely, e.g. from your office, home or hotel, enter the URL of the computer machine in the form ***http://<IP_address>/bioreactor*** in a web browser. Read instructions written on the page and then click on the *Launch application* link. The link points to Java Web Start manifest file (Fig. 38).

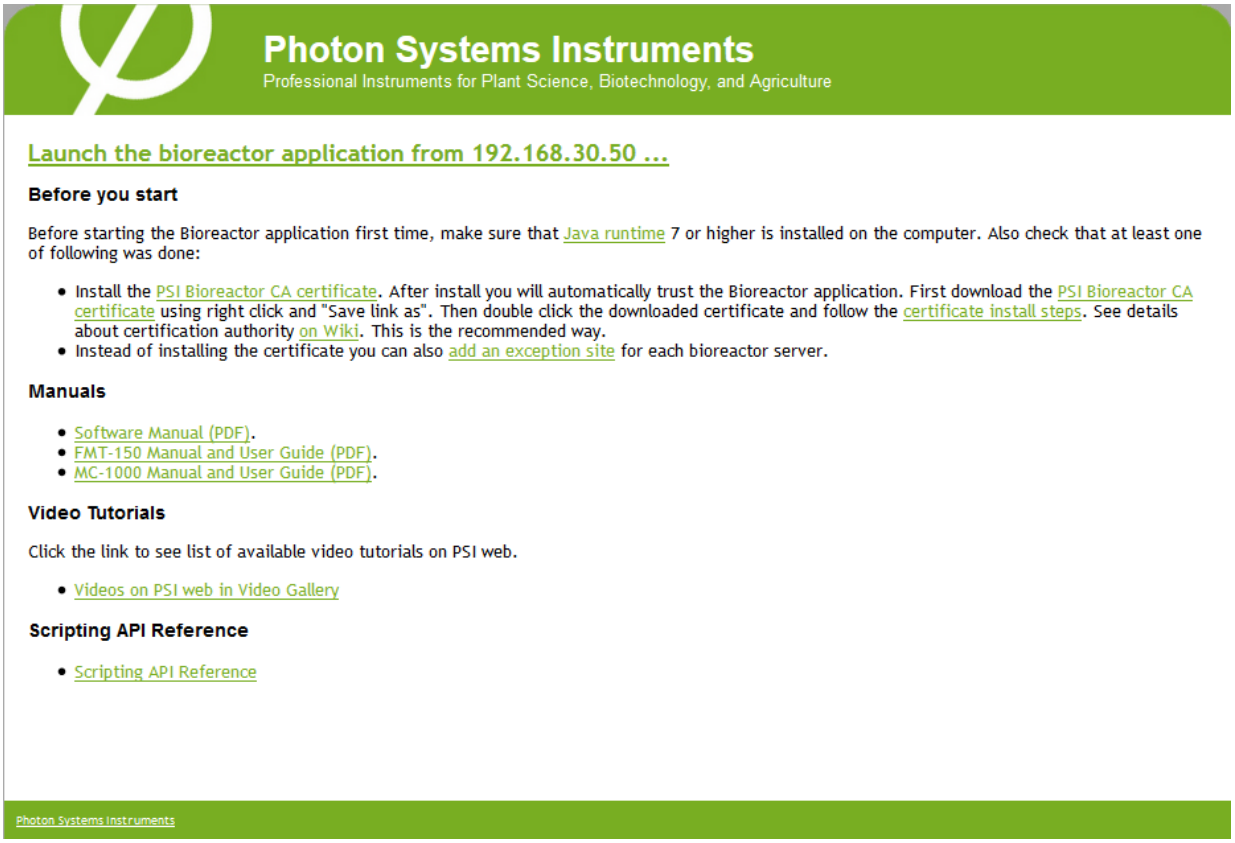

Fig. 37: Start Bioreactor client remotely

Open this file in Java Web Start Launcher to run the Bioreactor client (Fig. 38).

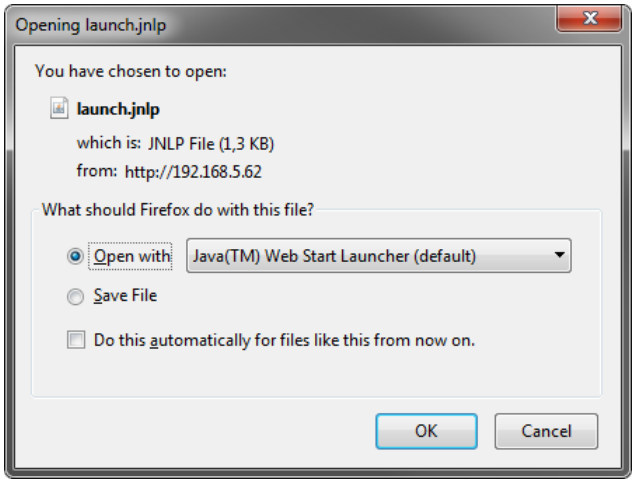

Fig. 38: Open Java Web Start Launcher file

The launcher will downloads the application and asks security questions (Fig. 39).

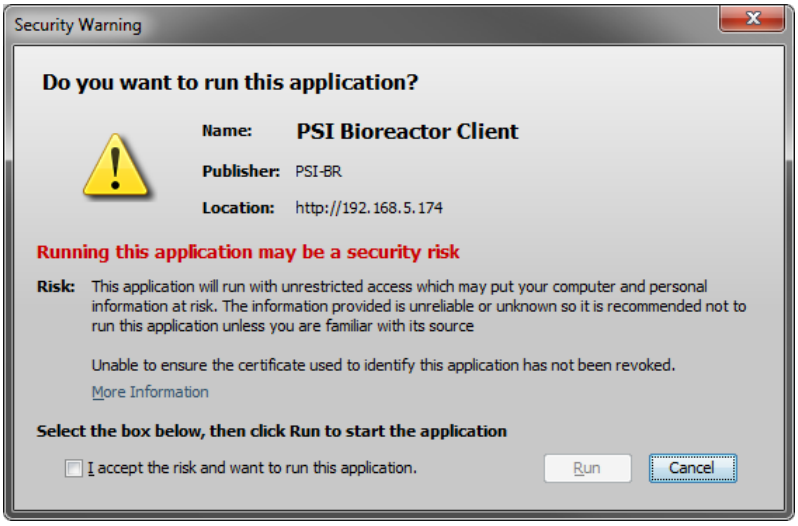

Fig. 39: Java Web Start security questions

If they are agreed it then starts the application itself and connects to the bioreactor server. Several clients may be connected to single bioreactor server at the same time.

To find out the IP address of your bioreactor server system when you are in the Linux desktop, press Ctrl+Alt+t to open the terminal. In the terminal enter:

```
/sbin/ifconfig eth0
```

if the Ethernet interface has assigned IP address, the output will display:

```
eth0 Link encap:Ethernet HWaddr
00:24:8c:d5:e5:bc
inetaddr: 192.168.3.65
Bcast:192.168.3.255 Mask:255.255.255.0
```

Alternatively, if the computer is connected through wifi, enter:

```
/sbin/ifconfig wlan0
```

Use the IP address assigned (as marked above in red) and enter ***http://<IP_address>/bioreactor*** in your web browser to access the Bioreactor server remotely.

4.2 CONNECT A USB/SERIAL DEVICE

To control the operation of a RS-232 device with the Bioreactor software connect the device via USB cable or USB-Serial converter to the computer and turn it on. The Bioreactor server should automatically detect the device and display it in the devices & groups tree of the Live tab. See chapter 2.2 for details.

4.3 SETUP A GROUP

The FMT-150 device as well as Multi-Cultivator device will create their group automatically. However other device types like Gas Mixer and Gas Analyzer are by default put to the <*unassigned*> group. To bind them to the correct group, drag & drop the device node to desired group (Fig. 40).

It is also possible to create custom groups. As a Bioreactor admin choose *Add group* from the server node context menu and fill group name and type.

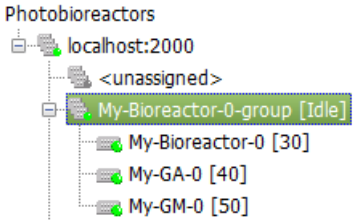

Fig. 40: Group with FMT150, Mixer and Analyzer

4.4 START EXPERIMENT

An experiment can be started only if the group is in Idle mode. Before starting an experiment, it is necessary to prepare its protocol either manually or load an existing protocol – see chapter 4.10. Although the protocol can be updated later, the initial protocol should be defined right before starting the experiment. Prepare the protocol in the Protocol tab and then push the *Start* button in the toolbar to initiate new experiment. Note that the current Idle data will become inaccessible after the *Start* dialog is confirmed.

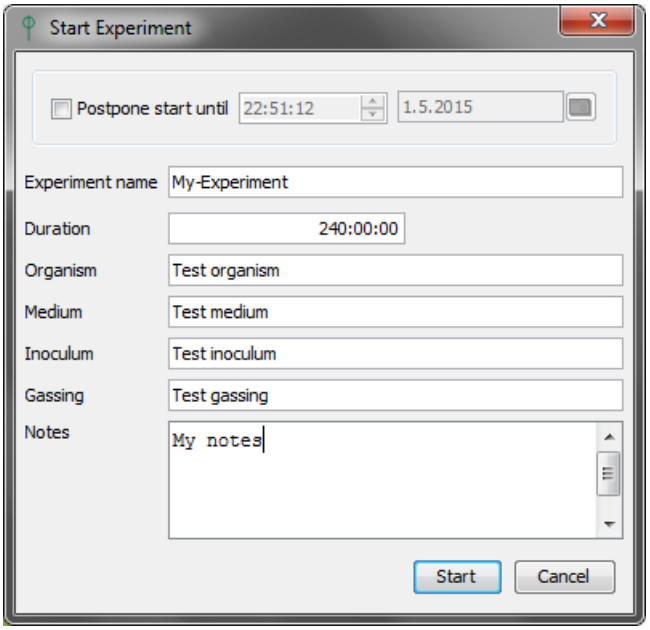

Fig. 41: Experiment start dialog

A start experiment dialog is displayed (Fig. 41). Fill the experiment properties, especially experiment name and planned duration in hours and confirm with *Start* button. Note that all experiment properties including name and duration can be modified at any time during the run time of the experiment – see chapter 2.3.1. The experiment is started on the server with the defined protocol. When the experiment is finished or stopped, the original Idle protocol is automatically loaded again.

4.5 CHANGE PROTOCOL

Experiment protocol can be changed at any time even while recording. To do so change the protocol in the protocol panel. E.g. change the target temperature or actinic light intensity, add or remove stages, change stages duration etc.

The protocol accessory should be marked as modified and the *Upload* and *Revert* buttons in the experiment toolbar should become enabled.

Fig. 42: Protocol panel toolbar

Then push the *Upload* button. The Upload confirmation dialog is displayed (Fig. 43). There are three modes of accessory changes upload.

- **Restart** cycle timing – the accessory cycle time shift is set to current time so the cycle behaves as if it was started at the time of upload
- **Keep** cycle timing – the accessory cycle time shift is not changed. Current time shift, if any, is visible on the cycle panel.
- **Reset** cycle timing – the time shift is set to 0, so the cycle behaves as if it was started at the experiment start.

If not sure, keep the default dialog values. Starting version 0.8.x the time shift is also involved in the protocol preview graph.

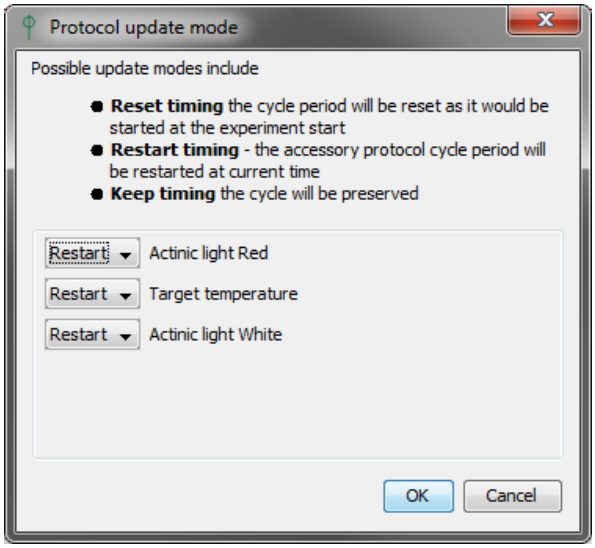

Fig. 43: Protocol update dialog

The new protocol is uploaded to the server and the protocol history record is written to database.

4.5.1 COPY/PASTE CYCLE

In the ADVANCED edition, the protocol cycle can be also modified by copying and pasting a XML cycle definition from the same or another protocol, from clipboard or from a file. Open the source protocol (e.g. a saved protocol) and select an accessory to copy. In the accessory cycle panel press the *Copy* button in the top right corner of the panel (Fig. 44). The cycle definition is exported to XML and placed to the the system clipboard. Go to target protocol panel and select the desired accessory. In the accessory cycle panel press the *Paste* button. If the accessories are compatible, the configuration should be copied (Fig. 44). Then upload the changes to the server.

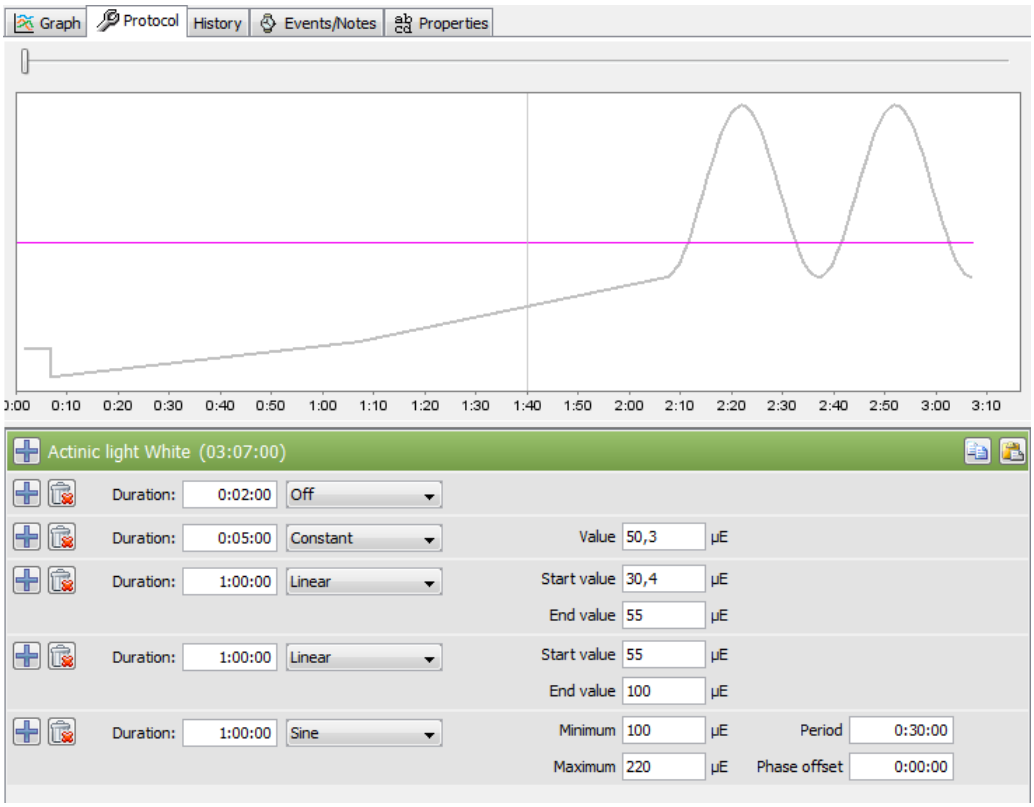

Fig. 44: Protocol cycle pasted from a sheet

It is also possible to export the cycle to the file by pressing *Copy* and then opening a file in text editor and pressing Ctrl-V. Such file can be then directly dragged & dropped on the cycle panel title bar or its content can be copied to clipboard and pasted to the cycle panel with *Paste* button.

The copy/paste feature can be used also from an Excel sheet (or CSV content), which rows has following format (Fig. 45):

|stage duration in seconds |decimal value | decimal value | …

- If no decimal value is defined then the row is converted to *Off* stage.
- Single decimal value is converted to *Constant* stage.
- Two decimal values (start value, end value) are converted to *Linear* stage.
- Four decimal values (minimum, maximum, period, phase) are converted to *Sine* stage.

	A	B	C	D	E
1	120				
2	300	50,3			
3	3600	30,4234234	55		
4	3600	55	100		
5	3600	100	220	1800	0

Fig. 45: Sample Excel protocol cycle definition

4.6 ADD EXPERIMENT NOTE

In the Live view select an experiment (group). When the experiment panel is displayed, select the *Events/Notes* tab. The user must be privileged to add new notes – only the user that have started the experiment or an administrator can add new notes in Recording mode. Any user with write access can add notes in Idle mode.

Press the Add button in the experiment toolbar and fill the dialog fields. The note time is by default set to current time, but it can be overridden using the time field or slider. See chapter 2.3.4.

4.7 STOP EXPERIMENT

Push the *Stop* button to stop running experiment. You must be logged as a user that have started the experiment or as an administrator (see chapter 5.5.3). The experiment group should be switched to Idle mode and the experiment will be moved to recorded experiments. The original Idle protocol is automatically loaded.

4.8 EXPORT EXPERIMENT

Push the *Export* button in the experiment panel toolbar. The export dialog will display. See chapter 2.3.7 for details.

4.9 SAVE PROTOCOL

Switch to the *Protocol* tab on the experiment panel, click the *Save* button on the experiment toolbar and enter protocol name (Fig. 46). The protocol will be saved to server database and can be later loaded for use in another experiment.

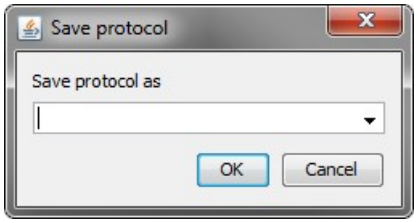

Fig. 46: Save protocol dialog

In the ADVANCED edition, the protocol can be also exported to an XML file. Click the *Export* button on the experiment toolbar and select the file location. The protocol will be saved and can be later imported for use in another experiment or just some cycles can be copied/pasted from the XML file content.

4.10 LOAD PROTOCOL

Switch to the *Protocol* tab on the experiment panel and click the *Load* button on the experiment toolbar. The Saved protocols dialog is displayed (Fig. 47). The dialog lists protocols available in server database. When double clicking a protocol row, the protocol is loaded to the protocol panel and is marked as locally modified. Such protocol can be reviewed, modified and used to start an experiment. It is also possible to copy/paste just some cycle from saved protocol.

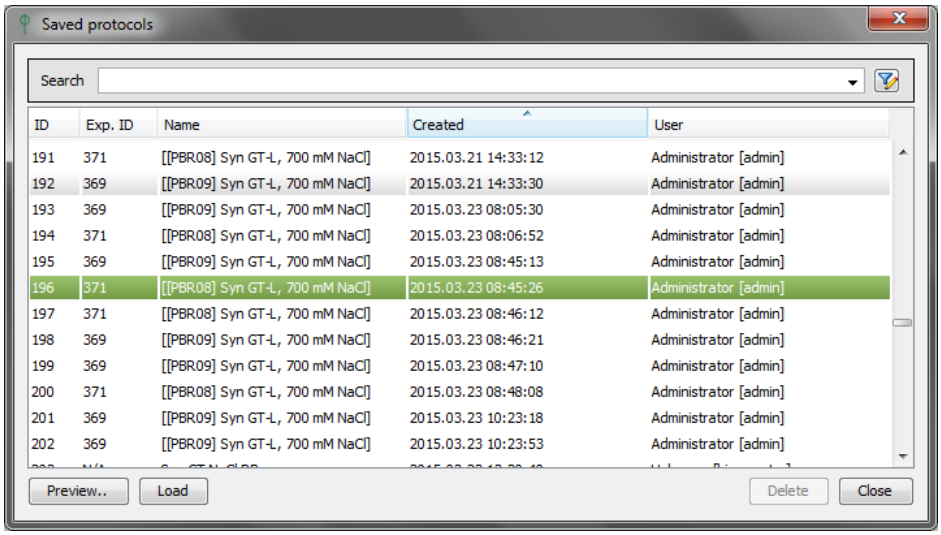

Fig. 47: Saved protocols dialog

In the ADVANCED edition, the protocol can be also imported from an XML file. Click the *Import* button on the experiment toolbar and select the file to import. The protocol will be loaded on client and can be later modified and uploaded to the server.

4.11 BROWSE RECORDED EXPERIMENTS

The *Recorded* experiments tab displays finished experiments from the server database. The experiments are listed by their start time, name of the experiment and group name. Experiments can be filtered and sorted by various criteria. See chapter 2.3.2 for detailed description.

4.12 CHANGE MY USER OR PASSWORD

In the Bioreactor client display the context menu of server node and choose the item *Modify my user account.*

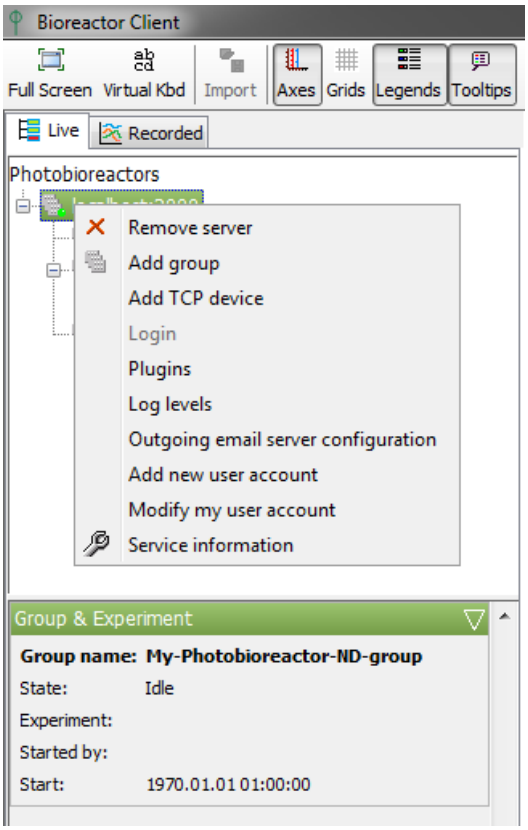

Fig. 48: Server node context menu

The Add/modify user dialog will be displayed. It is possible to change login, password, full name, email and received emails level. Existing users cannot change their role.

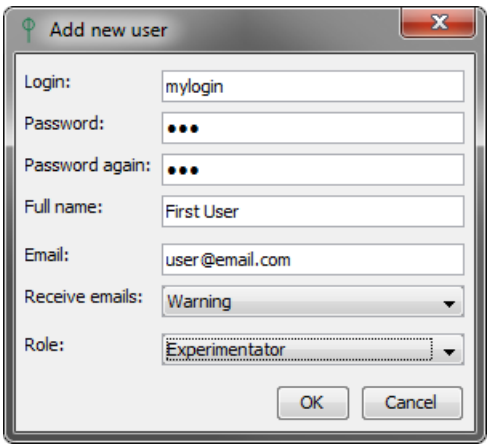

Fig. 49: Add or modify user dialog

4.13 ADD NEW USER

In the Bioreactor client display the context menu of server node and choose the item Add *new user account.* Note that you must have administrator rights to do it.

5. ADMINISTRATION

5.1 INSTALLED LINUX APPLICATIONS

The Debian Linux operating system on the computer is preinstalled with set of user applications. The application can be started from the Desktop Start menu or from a terminal.

- **Thunar** – file manager equivalent to Windows Explorer (browse/copy/move/delete user files)
- **Chromium** – clone of Chrome web browser.
- **ePDFViewer or Evince** – pdf viewer (to display manuals)
- **VLC** – audio/video player (to play video tutorials)
- **Terminal Emulator** – the Linux terminal
- **Synaptic Package Manager** – manages installed applications
- **Mousepad** – simple text editor (to edit text files)
- **unzip** – unpack the database backups if necessary

5.2 DATABASE BACKUPS

The server database contains all protocols, experiments and user data and is by default automatically backed up every 10 days. To keep your data safe, copy these backups regularly to a location on a different computer. The database backups are located in folder

```
/var/psi/bioreactor/
```

The files can be copied e.g. by the WinSCP application.

5.3 UPGRADES

The software can be manually upgraded to latest available version. The upgrade can be performed by an administrator from Bioreactor client or from command line on computer. In all cases running experiments are restored after the upgrade finishes. Idle experiments are not restored and are started from scratch again.

5.3.1 UPGRADE FROM CLIENT

If the PBR computer is connected to the Internet, the upgrade can be invoked directly from the PBR client. Login as administrator and focus the server node. In the server control panel (Fig. 50) push the *Check* button. If a new upgrade is available the *Upgrade* button should be activated. Push the *Upgrade* button to see list of packages to upgrade and confirm it.

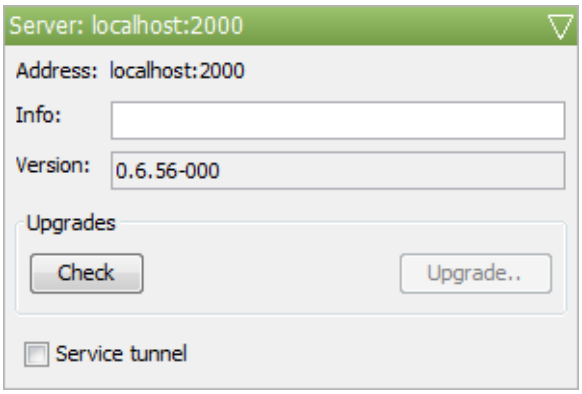

Fig. 50: Server control panel

The server will start the upgrade process and after a while should disconnect all clients (Fig. 51) and start again automatically.

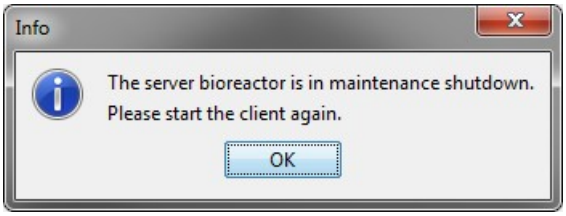

Fig. 51: Server shutdown notification

5.3.2 ONLINE UPGRADE FROM THE COMPUTER

If you want to see more detailed information about the upgrade progress or if the upgrade from client failed it is still possible to upgrade the software from the PSI online repository. Login to Linux terminal as *root* and go to folder

```
/var/psi/bioreactor/server
```

Then enter the command

```
./swManualUpgrade.bat
```

This will start the upgrade process and report the progress in the terminal.

5.3.3 OFFLINE UPGRADE FROM THE COMPUTER

The offline upgrade is used when the Internet connection on the computer is not available. In this case the offline upgrade file must be manually downloaded from www.psi.cz/products/photobioreactors/photobioreactor-fmt-150

and copied to a new (or empty) folder on the computer with e.g. USB stick. The upgrade file name has form

bioreactor_<version>.bin

where *<version>* is the version string like *0.6.59*. Then login to a Linux terminal as *root*, go to folder with the upgrade file and enter following commands:

```
chmod +x ./bioreactor_<version>.bin
./bioreactor_<version>.bin
```

This will start the upgrade process and report the progress in the terminal and log file.

5.3.4 SYNAPTIC

The Debian operating system contains a package management tool named *Synaptic*. This tool can be used to add/remove operating system software and check the Bioreactor software installation status.

5.4 DEVICE FIRMWARE UPDATES

The PBR software provides automatic firmware update detector and uploader. It supports following devices:

- FMT-150
- GSM-150
- GAS-150
- MC-1000
- PP-600
- large scale PBR devices

If the Internet connection is available, the software periodically checks for new firmwares directly in PSI repository. If a newer firmware package is released, it must be installed via SW upgrade (see chapter 5.3) and after installation the new firmwares are visible to the devices.

When Internet is not available, the current firmware files can be still installed offline using the

bioreactor-firmware-<variant>_<version>.bin

offline file (see section 5.3.3 for similar SW offline file installation). The variant can be either *small* for small bioreactors or *large* for large scale photobioreactors.

Devices with a new firmware available are displayed with different icon in the live tree view (see Fig. 52).

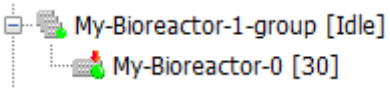

Fig. 52: Device firmware update available

Note that firmware uploads can be performed only in group Idle mode and with PBR administrator rights. The device control panel contains the firmware upload button which opens the upload dialog. The dialog displays firmwares that can be uploaded to various device boards (see Fig. 53). Proper firmware file for the board is selected automatically, but can be overridden in special cases.

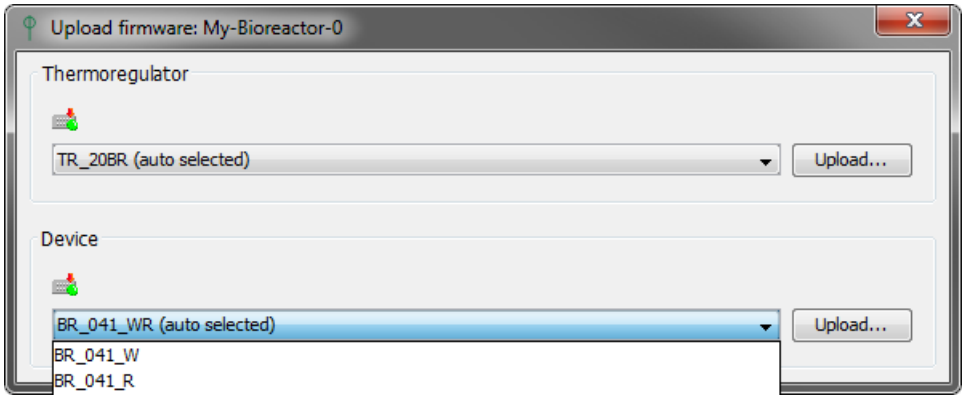

Fig. 53: Choose firmware to upload

Note that current device calibrations and settings maight be lost during firmware update (see Fig. 54)**.** Although the PBR software tries to backup and restore most of device calibrations and settings, it can happen that some settings are lost during firmware upload. Please backup the device settings if necessary or contact the PSI support if unsure.

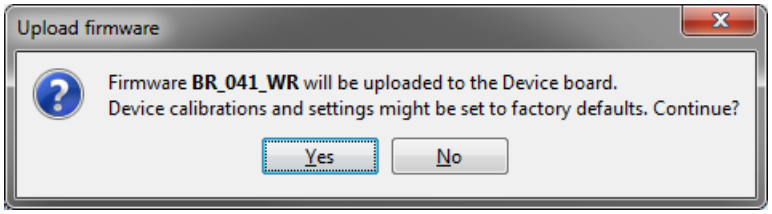

Fig. 54: Confirm firmware upload

If the upload is confirmed, the firmware upload status and progress are reported to the client. Please contact PSI support in case of any error.

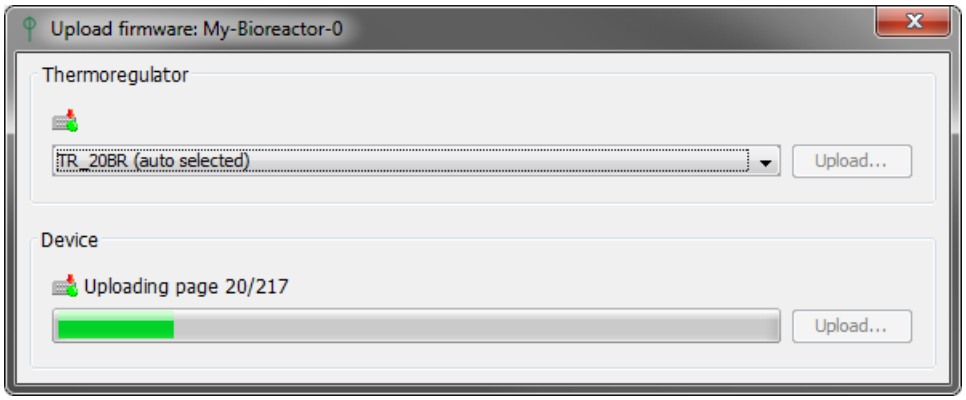

Fig. 55: Firmware upload progress and status

5.4.1 REINITIALIZE LIGHT CALIBRATIONS OF FMT150

If the previous firmware version was too old, it is necessary to reset light calibrations after new firmware upload. It can be done in the PBR client. It is necessary to update the PBR client to latest version - see chapter 5.3.

Start the PBR client and login as admin. Select the group node of the Photobioreactor device. Ensure that no experiment is running on the group. Open the actinic light context menu in experiment legend panel. Choose *Calibrate...* menu item. There are more possibilities how to load the new calibrations:

- **Using importable XML file** – this case can be used when the PSI support has provided light calibration XML files. Follow the section 2.4.4.
- **Enter calibration constants** – in this case the constants are entered manually by the user. Follow the section 2.4.2.

When all lights are uploaded, restart the PBR server to reload the new configuration - see PBR SW manual chapter 8.1.

5.4.2 EMAIL NOTIFICATIONS

The bioreactor server supports email notifications on several kinds of events:

- disconnected HW device (Photobioreactor, gas mixer, gas analyzer,….)
- accessory error

- computer power outage
- server watchdog – frozen server thread
- max/min accessory value exceeded (temperature, medium usage,….)
- difference between a regulator and its sensor value exceeded allowed threshold
- experiment started
- experiment finished
- upgrade available
- database error

Outgoing SMTP server must be configured before notifications can be sent. The SMTP configuration consist of email server address and port and credentials of email that is used as notifications sender (Fig. 56). There is also experimental support for Gmail outgoing server, but note that this feature is still subject of change.

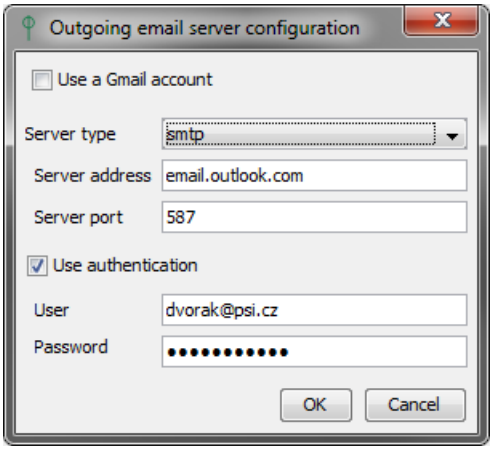

Fig. 56: Outgoing email server configuration

Emails are sent to bioreactor users that have specified email address and a notification level. See chapter 5.5 for users configuration.

5.5 USERS AND RIGHTS

5.5.1 LINUX ACCOUNTS

The Linux operating system is preinstalled with *bio-reactor* Linux account. The account password is *reactor*. The password of the administrator account *root* will be provided individually when e.g. changing license or upgrading software from terminal.

5.5.2 BIOREACTOR USERS

The Bioreactor software manages users and their roles to be able to manage access rights and audit user actions. Bioreactor software comes with several preinstalled accounts:

- **bio-reactor** – read/write rights (start/stop experiments, manage/update protocols)

login: bio-reactor
password: reactor
role: Experimenter

- **admin/admin** – administration rights (create and configure other users, configure mail server, work with commander)
  login: admin
  password: admin
  role: Administrator
- **guest –** read only rights (can display running and recorded experiments)

  login: guest
  password: guest
  role: Watcher

It is recommended to change default passwords and create a Bioreactor user account for each person that will work with the software. Than it is possible to audit important actions like start experiment, stop experiment, protocol changes, calibrations and user notes. Note that the Bioreactor and Linux *bio-reactor* accounts are different, thus changing password of one of them does not change the other.

5.5.3 BIOREACTOR ROLES

The Bioreactor software defines so called roles. Each user has assigned a role. Currently the software supports following roles:

- **Watcher** – has read only access to the system.
- **Experimenter** – has rights to start experiments, stop experiments started by him, change protocol of his experiment, calibrate most of accessories
- **Administrator** – in addition to experimenter has rights to stop any experiment, configure email notifications, add new users, perform upgrades, run commander tool.
- **Service** – only for PSI service use.

6. CUSTOMER EXTENSIONS

The software can be extended using two mechanisms – scripting and plugins. Scripting is used in protocol to fine tune the regulation/measuring conditions. Plugins can be used to extend the Bioreactor software capabilities to support e.g. new devices and sensors.

6.1 SCRIPTING

The experiment protocol can be fine tuned by scripting. Scripting is used in a protocol stage definition. The scripting language is JavaScript. The protocol script is a piece of code that is executed when evaluating accessory value during experiment. The script should save the value in variable named *result*. This value is then used as new value for the accessory protocol. The script execution in experiment protocol is guarded by a watchdog. If the script duration exceeds configured time (default 1 seconds), it will be interrupted and an event is reported.

For debugging purposes is possible to report script execution times (in milliseconds) to server log file. As an PBR administrator display the server node context menu in the PBR client live tree and choose *Log levels* (see Fig. 48). The enter following line in the logging configuration dialog:

```
psi.bioreactor.core.scripting.ScriptExecutor.level=FINE
```

To revert back enter:

```
psi.bioreactor.core.scripting.ScriptExecutor.level=INFO
```

6.1.1 SCRIPTING API

There are some global variables that are used to access various server objects from the script:

- **theAccessory** – instance of the accessory that is currently configured (IServerAccessory)

```
var val = theAccessory.getValue();
```

- **theExperiment** – instance of current experiment (ILiveExperiment)

```
var duration = theExperiment.getDurationSec();
var name = theExperiment.getName();
```

- **theGroup** – instance of current group (IGroup)
- **theServer** – can be used to obtain other groups or experiments on the server (IServer)
- **theLogger** – report user debugging information to server log file (java.util.logging.Logger)

```
theLogger.info("Hello world");
var x = 20;
theLogger.info("x=" + x);
```

The objects (interfaces) provide set of methods that can be called on them. The methods of each interface are listed in bioreactor scripting API documentation, which is provided in form of JavaDoc. The documentation is available either on the PSI Photobioreactors web in Download section or referenced from the PBR client remote start page (Fig. 37) or in the (auto-hiding) taskbar start menu in the PBR computer desktop (Fig. 63).

6.1.2 SAMPLES

A sample script that adjusts actinic light intensity depending on measured OD is shown below. This script is then setup in actinic light protocol stage as shown on Fig. 57. The script name displayed in PBR client protocol can be set with the *@script* tag as shown below.

```
/*
 * @script Example temperature dependency
 */
```

```
var od680 = theGroup.getAccessory("od-sensors.od-680");

if (od680 == null || od680.hasError()) {
    result = 6; // light intensity
}
else {
    var odVal = od680.getValue();
    if (odVal > 2)
        result = 400; // light intensity
    else if (odVal > 1)
        result = 200; // light intensity
    else
        result = odVal * 200;
}
```

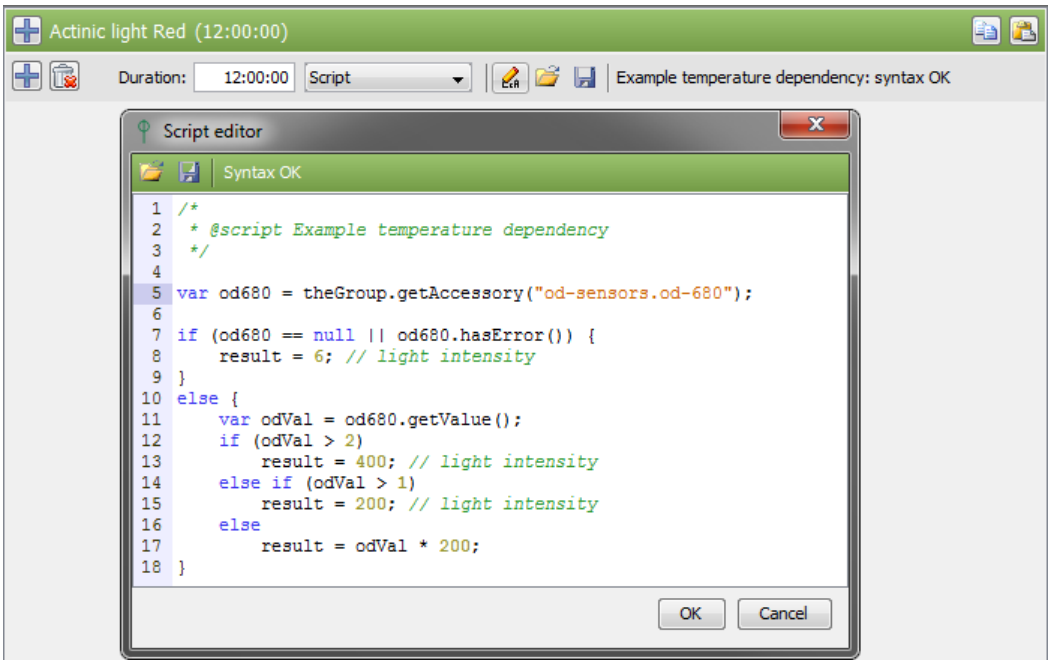

Fig. 57: Script usage in protocol

6.2 PLUGINS

Please contact the PSI support, when you plan to develop a custom functionality which should extend the Bioreactor software.

7. LICENSING

Bioreactor software can be shipped in one of two editions. Any edition must be provided with a license file, otherwise the software will not start. The license is bound to the computer hardware.

BASIC edition contains most used features:

- Online software and firmware upgrades
- Accessory calibrations
- Change protocol of running experiment
- Restore running experiments after computer reboot
- Recording of raw sensor data
- Store experiment notes and events
- Export experiment to MS Excel/LibreOffice
- Recorded experiments filtering
- Users and rights management
- Basic linear regressions in experiment graph
- OD regulator (Turbidostat) protocol support for both MC1000-OD and FMT150
- pH Regulator (Chemostat) protocol support
- External lights protocol support
- PWM pump/Stirrer protocol support
- Individual Ft/QY measuring

ADVANCED edition contains some additional features and is extra paid. In addition to BASIC edition it can do/contains:

- Email notifications
- Allow to send low level device commands
- Scripting support in protocol
- Individual measuring periods in protocol
- Protocol cycle copy/paste, protocol export/import
- Import old experiments
- Scheduled experiments
- Monitor and notify accessory value range
- Advanced regressions in experiment graph and scripting
- Additional peristaltic pumps

The devices supported by the license are configured individually per customer order:

- **Photobioreactor FMT 150**
- **MultiCultivator MC-1000**

- **Large-scale Photobioreactor devices** (bioreactor, lights, probes, fluorpen)
- **Gas Analyser** (only with ADVANCED)
- **Gas Mixer** (only with ADVANCED)
- **PeristalticPump** (connected to computer)
- **Mettler balance** (only with ADVANCED)

8. TROUBLESHOOTING AND CUSTOMER SUPPORT

In case of troubles and for customer support, please, mail to **support@psi.cz** with *Bioreactor* in subject or contact your local distributor. However, some kind of problems can be solved without contacting the support. If it seems that the Bioreactor client stopped working or is in invalid state, restart the client.

- If it seems that the Bioreactor server stopped working, restart the computer or just the Bioreactor server (chapter 8.1). All recording experiments are preserved and will continue smoothly. Idle experiments are restarted and previous Idle data become inaccessible.
- If a device is reported as disconnected in Bioreactor software even if it seems that it works correctly, try to plug out and in the device-computer USB cable or switch off and on the device.
- Contact the PSI service at **support@psi.cz** or your local distributor. The customer support may require additional diagnostics information from your system. See chapters 8.2 and 8.3.

8.1 RESTART BIOREACTOR SERVER

In some cases it is necessary to restart the Bioreactor server. If root node (localhost/node with IP address) is selected from the device tree, server options view is displayed. It contains *Restart* button to enable server restart.

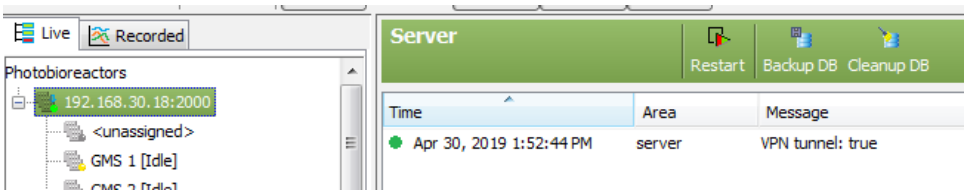

Fig. 58: Server options

Another way is to open a terminal window on the computer (by pressing Ctrl-Alt-t) or open a remote SSH connection to the computer (e.g. with putty software) and login as root.

On the command line enter the command

```
invoke-rc.d bioreactor-server restart
```

8.2 GATHER LOG FILES

If requested, send the log files to PSI support. To gather the log files you can either

- Start e.g. the WinSCP application and make SFTP connection to the computer using bio-reactor or root Linux account.
- Copy log files from */var/psi/bioreactor/server/logs* to your computer
- Pack the log files to a zip file and send by email to the support.

or

- Connect an USB flash to the computer. See chapter 9.3.6.
- Open a terminal window, see chapter 9.2

- Copy log files from computer to the USB. The USB will be typically mount to */media/usb*.
  - Enter the command

```
cp /var/psi/bioreactor/server/logs/* /media/usb
```

- Unmount the USB flash and disconnect it from computer. See chapter 9.3.6.
- Pack the log files to a zip file and send by email to the support.

8.3 GATHER SERVICE INFORMATION

The PBR server or HW device information that can help the support team to solve your issues can be displayed in PBR client. Click on the server or device node in Live tree tab and invoke the context menu (mouse right click). Choose the item *Service information*. Copy the content of the displayed dialog and send to the support.

9. APPENDIX

9.1 BIOREACTOR CLIENT HINTS

To select multiple items (in device and groups tree, recorded experiments, protocol accessories or calibration points) use the Ctrl and Shift button.

- **Ctrl** – allows you to click and select multiple items that are anywhere on the list, not necessarily next to each other.
- **Shift** – allows you to select a set of items that are contiguous (i.e. next to each other) by clicking one item, and then holding Shift and clicking the last item. All the items in between are then selected.

To display a context menu on an item (devices and groups tree node, experiment legend panel item), click the right mouse button on the item.

To display a help text on a field or label of a form, place the mouse cursor on it and wait for short time. If the field or label has a tooltip associated, it will be displayed.

9.2 LINUX TERMINAL HINTS

To open the terminal press *Ctrl-Alt-t* when logged in Linux desktop. By default the terminal is running under *bio-reactor* Linux account. The terminal can be also started from the Desktop Menu.

Some useful commands follows:

- **su** – login as administrator (*root*). The *root* password has to be entered.
- **man** <*command*> - show help on given command. E.g. *man cp*
- **cd** <*dir*> – change current directory
- **mkdir** <*dir*> – create a directory. E.g. *mkdir mydirectory*
- **ls** – list directory content
- **cp** - copy files. E.g. *cp file1 file2 /home/bio-reactor/mydirectory*
- **rm** <*files*> – delete files. E.g. *rm file1 file1*
- **<Up>/<Down>** arrows browse in command history
- **<Tab>** key performs the auto-complete functionality which e.g. fill the file name or executable name.

9.3 INSTALLATION

The PBR software is either preinstalled on a computer provided by PSI or can be installed on any computer that meets the HW requirements. The customer can perform complete installation of his own computer from the PBR SW ISO image. Note that the operating system as well as all files on such computer are **irreversibly lost** during this process. **Please do a backup before performing the installation** (See 9.3.2).

Computer HW Requirements

The minimal computer requirements are as follows:

- 2 GB RAM
- 50 GB hard drive
- free USB port
- Ethernet card supported by Linux kernel 3.16.0 (most of them)
- CPU with 2 or more cores, amd64 architecture
- optionally wireless card supported by Linux kernel 3.16.0

9.3.1 PREREQUISITES

DOWNLOAD THE ISO IMAGE

Go to the Download section on www.psi.cz/products/photobioreactors/photobioreactor-fmt-150. If you computer has 64-bit CPU or you are not sure, download the 64-bit ISO image. If you computer has 32-bit CPU, download the 32-bit ISO image.

CREATE BOOTABLE MEDIA

You can either burn the downloaded ISO image to CD or create a bootable USB flash. To burn the image to CD use a proper software e.g. *ImgBurn* at www.imgburn.com. To create bootable USB flash use e.g. the *Universal USB Installer* tool from www.pendrivelinux.com.

9.3.2 PRE-INSTALLATION STEPS

BACKUP OLD RECORDED EXPERIMENTS

If the computer contains old bioreactor software, create (e.g.) WinSCP SFTP connection and backup complete content of directory

/var/psi/services2/recorder/root/recorded

9.3.3 SYSTEM INSTALLATION

CHECK THE NETWORK

It is recommended that the computer is connected to a wired network with DHCP server during installation time. To get latest updates and synchronize time with a time server during installation, ensure that the network has Internet access.

BOOT THE COMPUTER FROM ISO IMAGE

Plug in the installation media and power on (or reboot) the computer and press a key to display boot options (the key depends on computer BIOS, usually Escape). Choose proper boot device (CD or USB flash) and confirm. Wait until the computer boots.

INSTALL THE OPERATING SYSTEM

- The initial Debian installation screen should be displayed (Fig. 59). On the screen choose "Graphical install".

Fig. 59: Debian installer initial screen

- Select you country and continue
- If requested select locales (e.g. en_US.UTF-8) and continue
- If DHCP is not detected, the installer may ask additional questions about network configuration.
- Verify that *bioreactor-small* profile is selected and *bioreactor-large* profile is deselected and continue (Fig. 60)

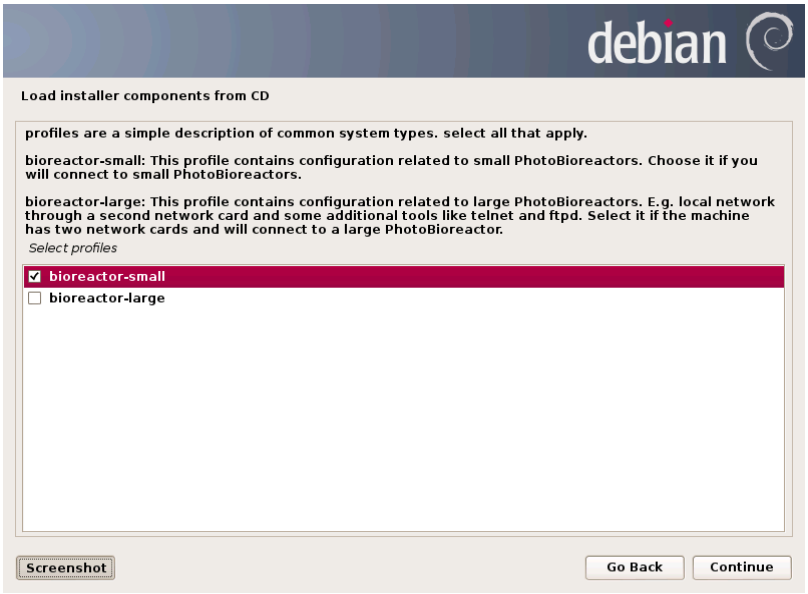

Fig. 60: Choose the bioreactor profile

- On the next screen enter your company name, email and contact person (Fig. 61). Select license type NONE. The proper license will be delivered by PSI support, see section Install the License File on page 56

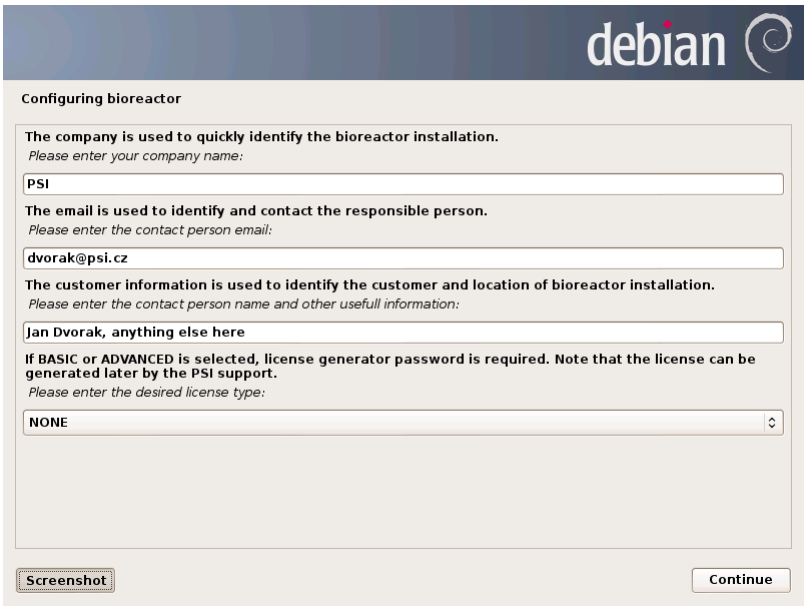

Fig. 61: Customer and license information

- Choose the debian archive mirror country (Fig. 62), server and HTTP proxy. Debian mirror is used to update installed debian system packages or install additional packages. This only works when the computer is connected to the Internet. In some cases, update fails even if internet connection is fine and valid mirror is selected. In that case, just continue with installation, update will be done later on as a background task. If HTTP proxy is used, please consult the settings with your network administrator.

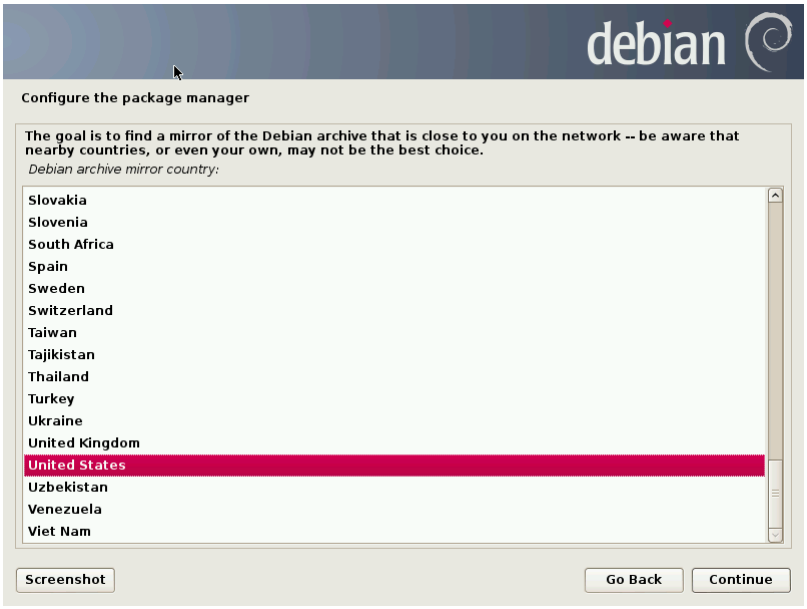

Fig. 62: Select debian package archive mirror

- Wait until the installation finishes and the computer reboots
- After successful installation the computer should boot into Bioreactor client login screen (Fig. 63)

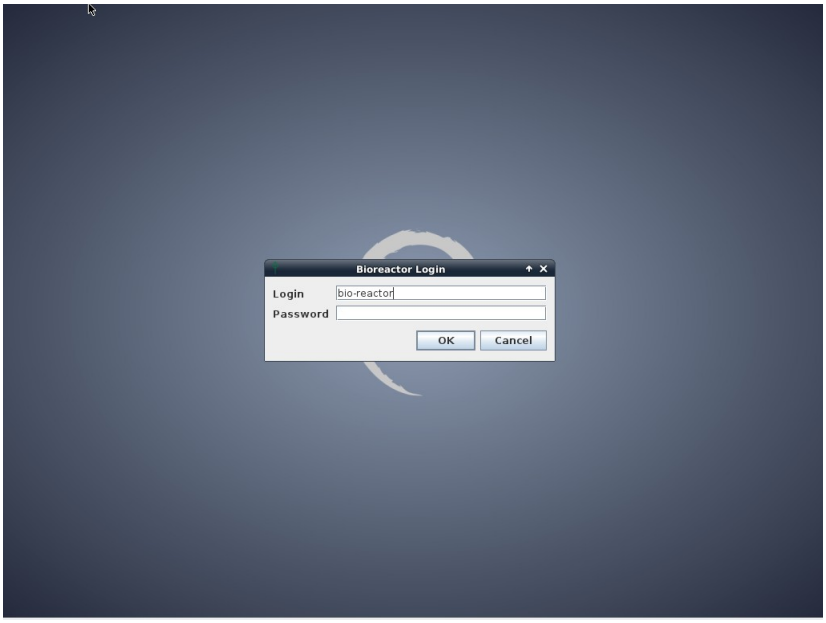

Fig. 63: Debian desktop with bioreactor GUI login

- If you have already installed the Bioreactor license file, enter the user and password (see 5.5) and the Bioreactor client application should be displayed. If you did not obtain the license file yet, continue with the post installation steps in section Install the License File in chapter 9.3.4.

9.3.4 POST-INSTALLATION STEPS

INSTALL THE LICENSE FILE

Before the Bioreactor software can be used, a valid license file must be provided. See the chapter 7 to understand licensing and Bioreactor software editions. You will need the the root account password which can be obtained from from PSI support.

First email the initial license file */var/psi/bioreactor/server/license.config* created by the Debian installer to the PSI support (support@psi.cz) with *Bioreactor* in subject and you will receive the full license file named *bioreactor-server.license* in reply. Copy this file as *root* back to original location at the computer (overwrite the old one if any) so the full license file path is

/var/psi/bioreactor/server/bioreactor-server.license

Then restart the Bioreactor server (chapter 8.1) or the computer and verify the software edition in Bioreactor client Service information (Fig. 64).

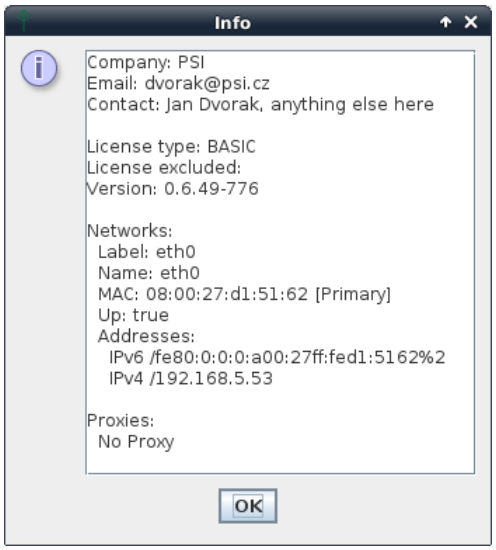

Fig. 64: Server service information with license type

UPDATE DEVICES FIRMWARE

To be able to connect a device with the PBR software, the device firmware must be up to date. The minimal recommended firmware version for software 0.8.x are mentioned below. If in doubt, please consult the recommended firmware versions of supported device types with the PSI support (support@psi.cz).

Small devices:

- Bioreactor FMT-150 – 3.0.4.2
- Thermoregulator – 3.0.0.8
- Multicultivator MC-1000 – 1.0.3.8

Large scale devices:

- Photobioreactor 100 ND – 1.0.1.0
- Thermoregulator TR-2025/ TR-20SL – 3.0.0.3
- BRLight – 1.0.1.0
- PMaster PM100 – 1.0.1.2
- FluorPen – 2.2.1.1

Other devices:

- Peristaltic Pump PP-500 /PP-550 – 2.0.2.1
- Peristaltic Pump PP-600 – 1.0.1.1
- Gas Mixer GMS-150/GMS150_P – 1.0.2.6
- Gas Analyzer GAS-150/ GAS150_N/GAS150_SL – 1.0.2.3

UPGRADE LICENSE TO ADVANCED

If your Bioreactor software is BASIC edition and you have purchased the ADVANCED edition, send the current license file to PSI support (support@psi.cz) with *Bioreactor* in subject and follow the steps in section Install the License File.

Import Old Recorded Experiments

The ADVANCED edition supports import of old experiments. Copy the backed-up old experiments folder to */var/psi/bioreactor/server/recorded* so the directory structure looks like:

```
/var
  /psi
    /bioreactor
      /server
        /recorded
          /0
          /1
          /2
```

Restart the Bioreactor server (chapter 8.1) or the computer and let the import process finish – it can take several minutes. The imported experiments should be displayed in *Recorded* tab after pressing <Enter> in its search field. See section Recorded Experiments in chapter 2.3 for details on recorded experiments view.

9.3.5 INSTALLATION TROUBLESHOOTING

If anything went wrong during computer installation, report the problem directly to PSI support (support@psi.cz) with *Bioreactor* in subject.

9.3.6 USB DRIVES

When the Linux desktop is displayed, the connected USB drives are visible on the desktop as icons. When an USB drive is plugged in, it is automatically mounted to a sub folder of */media* folder.

Only FAT32 USB drives are correctly mounted. NTFS USB drives are not supported at the moment.

Before plugging out, it is necessary to safely remove the drive. Open the context menu of the USB drive icon by right mouse click and select the *unmount* action.

Alphabetical Index

Accessory.....6p., 12p., 15pp., 22p., 26p., 33p., 42, 45, 48, 64

Actinic light.....6p., 21, 27, 29, 33, 42, 45, 64

API.....45, 64

Backup.....2, 39, 41, 51p.

Calibrations.....2, 8, 12, 16pp., 23pp., 29, 41p., 44, 48, 51, 62

Chemostat.....48, 64

Client.....2p., 5, 11, 13, 15, 26, 30pp., 37pp., 42, 45, 50p., 56p., 63p.

CO2.....6, 8, 22p., 26, 29, 64

Computer.....4p., 28, 30, 32, 39p., 42, 45, 48pp., 54, 56pp., 63p.

Context menu.....5, 8p., 15p., 24, 30, 32, 37p., 42, 45, 50p., 58, 62p.

CSV.....13, 35

Database.....2, 6, 9, 11, 16, 26, 34, 36p., 39, 43, 64

Device.....2pp., 10pp., 16, 18pp., 24, 26pp., 32, 41p., 45, 48pp., 57, 62pp.

Device commander.....2, 20, 43p., 62

Email.....22, 38, 42pp., 48, 50, 53, 57, 63

Events and notes.....10pp., 17p., 36, 42, 44, 48, 62

Experiment.....2, 4pp., 8pp., 23pp., 33p., 36p., 39, 42pp., 48, 50pp., 58, 62pp.

Experiment idle mode.....6, 11, 16, 33, 36, 39, 41, 50

External light.....21, 24, 48

Firmware.....3, 21, 24, 41p., 48, 57, 63p.

Fitting/regression.....15p., 18, 48, 62

Fluorescence.....22, 29

FMT-150.....2, 4p., 21pp., 28, 32, 41, 57, 64

Ft.....6p., 22pp., 29, 48, 64

Gas analyzer.....2, 4, 27, 32p., 41p., 58, 63p.

Gas mixer.....2, 4, 26p., 32p., 42, 49, 58, 62pp.

Group.....2, 5p., 8, 23, 29, 32p., 36p., 41p., 45, 51, 63p.

GUI.....5, 30, 56, 63

IP address.....30, 32

ISO image.....51p., 64

JavaScript.....7, 45, 64

Legend panel.....5pp., 12, 14pp., 24, 42, 51, 62

LibreOffice/Excel.....13, 35, 48, 63

Linux.....2pp., 32, 39p., 43p., 50pp., 58

Linux terminal window.....3, 32, 39p., 43, 50p.

Live tree.....5, 41, 45, 50

Login and password.....2, 30, 37pp., 42pp., 50p., 56p., 63p.

Multi-Cultivator.....2, 4, 27, 32, 41, 48, 57, 64

Network.....52pp.

O2.....5p., 8, 24pp., 29, 62

OD.....4, 6, 8, 21pp., 27pp., 45, 48, 62pp.

Peristaltic Pump.....2, 4, 6, 21pp., 28, 41, 48p., 58, 62, 64

PH.....5pp., 21pp., 28p., 48, 64

Plugin.....3, 45, 47, 64

Protocol.....2, 4, 6pp., 11p., 14, 21pp., 26pp., 33pp., 39, 43pp., 47p., 51, 62pp.

Pump.....2, 4, 6, 21pp., 27pp., 48p., 58, 62, 64

PWM.....23, 48, 62

QY.....6p., 22pp., 29, 48, 64

Raw signal.....8, 24, 26

Regulator.....5pp., 14p., 21p., 28, 42, 48, 57, 62pp.

Role.....38, 43p.

Root.....40, 43, 50pp., 57

Script.....3, 7, 23, 30, 37, 45, 47p., 63p.

Sensor.....4pp., 14p., 17, 21, 24, 26, 28p., 42, 45, 48, 64

Server.....2p., 5p., 9, 11, 18, 22, 27pp., 32pp., 36pp., 42p., 45, 50, 52, 54, 57p., 63p.

SMTP.....43

Software license.....43, 48, 53p., 56pp., 63p.

Software upgrade.....3, 39pp., 43p., 48, 58

SSH/WinSCP/putty.....39, 50, 52

Stirrer.....4p., 23

Temperature.....4, 6p., 21, 24pp., 33, 42, 45, 62, 64

Turbidostat.....5, 21, 28p., 48, 64

URL.....30

USB.....2, 4, 28, 32, 40, 50pp., 58

Users.....2pp., 12pp., 19, 27, 30, 36pp., 42pp., 48, 56, 63p.

Valve.....7, 22pp., 26

Vessel.....4, 6, 8, 23pp., 27p., 64

XML.....13, 34, 36p., 42

List of Figures

Fig. 1: Unassigned devices....5

Fig. 2: Protocol legend panel....7

Fig. 3: Protocol panel....8

Fig. 4: Experiment legend context menu....9

Fig. 5: Recorded experiments view....9

Fig. 6: Experiment filter dialog....10

Fig. 7: Recorded experiments sort dialog....10

Fig. 8: Experiment delete confirmation....11

Fig. 9: Recorded experiments view....11

Fig. 10: Protocol history panel....12

Fig. 11: Experiment events....12

Fig. 12: Experiment event dialog....12

Fig. 13: Experiment properties panel....13

Fig. 14: Experiment export dialog....14

Fig. 15: Experiment graph toolbar....14

Fig. 16: Regression options dialog....15

Fig. 17: Linear regression in graph....16

Fig. 18: Calibration control panel....16

Fig. 19: Calibration action selection step....17

Fig. 20: Start calibration step....17

Fig. 21: Calibration points step....18

Fig. 22: Fitting function and constants step....18

Fig. 23: Enter constants step....19

Fig. 24: Import calibration from DB....19

Fig. 25: Import calibration from file....20

Fig. 26: Device commander....20

Fig. 27: OD regulator control panel....21

Fig. 28: Peristaltic pump control panel....23

Fig. 29: PWM control panel....23

Fig. 30: O2 temperature levels step....26

Fig. 31: Start experiment step....26

Fig. 32: Gas Mixer control panel....27

Fig. 33: Gas Mixer protocol in percent mode....27

Fig. 34: Gas Mixer protocol in absolute mode....27

Fig. 35: OD regulator control panel for MC....28

Fig. 36: Client login dialog....31

Fig. 37: Start Bioreactor client remotely....32

Fig. 38: Open Java Web Start Launcher file....32

Fig. 39: Java Web Start security questions....33

Fig. 40: Group with FMT150, Mixer and Analyzer....34

Fig. 41: Experiment start dialog....34

Fig. 42: Protocol panel toolbar....35

Fig. 43: Protocol update dialog....35

Fig. 44: Protocol cycle pasted from a sheet....36

Fig. 45: Sample Excel protocol cycle definition....36

Fig. 46: Save protocol dialog....37

Fig. 47: Saved protocols dialog....38

Fig. 48: Server node context menu....39

Fig. 49: Add or modify user dialog....39

Fig. 50: Server control panel....41

Fig. 51: Server shutdown notification....41

Fig. 52: Device firmware update available....42

Fig. 53: Choose firmware to upload....42

Fig. 54: Confirm firmware upload....43

Fig. 55: Firmware upload progress and status....43

Fig. 56: Outgoing email server configuration....44

Fig. 57: Script usage in protocol....47

Fig. 58: Server options....50

Fig. 59: Debian installer initial screen....54

Fig. 60: Choose the bioreactor profile....54

Fig. 61: Customer and license information....55

Fig. 62: Select debian package archive mirror....55

Fig. 63: Debian desktop with bioreactor GUI login....56

Fig. 64: Server service information with license type....57

Terms and Abbreviations

- **computer** – a computer delivered within the Bioreactor bundle, if ordered.
- **Bioreactor software** – software installed on the computer that controls the connected devices and records experiment data.
- **Bioreactor license** – a digitally signed file that defines available features of Bioreactor software. It must be presented in Bioreactor server directory otherwise the server will not start.
- **Device firmware** – software running in the HW device
- **Bioreactor server** – server part of the Bioreactor software running permanently on computer and communicating with devices and clients.
- **Bioreactor client** – client part of the Bioreactor software running either on computer or remotely from user computer and communicating with Bioreactor server.
- **Device** – a hardware box that can be controlled by Bioreactor server and is physically connected to the computer. For example FMT-150, Gas Mixer and Gas Analyzer, Multi-Cultivator.
- **Accessory** – part of the device that provides either measuring or regulation functionality, e.g. pH probe, CO2 probe, actinic light, target temperature, OD regulator
- **Sensor** – accessory that provides measuring, e.g. pH probe, CO2 probe, current temperature, Ft, QY
- **Regulator** – accessory that provides regulation, e.g. actinic light, target temperature, OD regulator, Peristaltic pump
- **Chemostat** – a software module controlling pH in the cultivation vessel. It consists of pH acid and pH base regulators.

- **Turbidostat** – a software module controlling optical density in the cultivation vessel. It consists of OD regulator.
- **OD** – optical density
- **Group** – set of devices included in an experiment
- **Experiment** – a time course, in which the accessory data are displayed on client and recorded to the database
- **Protocol** – set of rules controlling the experiment accessories
- **Device** – representation of a HW device in the Bioreactor client.
- **Bioreactor account** – credentials that allow to login to the Bioreactor client+ additional configuration data.
- **User** – a person having Bioreactor account assigned.
- **Java Web Start** – a technology that enables running Java applications remotely
- **JavaScript** – scripting language used in Bioreactor software
- **ISO** – Operating system installation image format
- **Bioreactor software API** – subset of Bioreactor software functionality available for scripting an plugins.