



Virtual laboratory



SCIENCE

Atomic Force Microscope

User
manual



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Terms and Definitions

The following general terms are used in the User Guide:

Virtual laboratory	Virtual laboratory "Science", "Atomic force microscope" section
Scene	A virtual three-dimensional space within which the user can interact with the Virtual laboratory objects. The concept of "scene" also includes the data of the current research (positions of objects, their parameters, etc.)
Camera	A scene tool with which the user observes everything that happens in the Virtual laboratory.
Process simulation	The process of interaction of objects in a scene modeled in the Virtual laboratory.
Click	To make a click: — when using a mouse, move the mouse pointer to the object, press and release the left mouse button without moving the pointer; — when using a touchscreen, press the object with a finger and release it without moving the finger along the screen.
Toggle-button	A button that changes its state from inactive to active and vice versa after being pressed. The state is retained until the next interaction.

1 System requirements

Minimum system requirements for the Virtual laboratory "Science", "Atomic force microscope" section are:

- **Processor:** Intel Ivy Bridge series / AMD Bulldozer series.
- **RAM:** 4 GB.
- Graphics Card:
 - Integrated: Intel HD Graphics 5000 / Intel Iris;
 - Discrete: GeForce 400 series / Radeon HD 7000 series.
- **Screen Resolution:** 1920x1080 / 1920x1200 (4K and Retina displays require a more powerful graphics card for comfortable operation).
- **Supported Browsers:** Chrome, Yandex.Browser, Opera 44+, Firefox 51+, Edge 79+, Safari 15+.
- **Supported Operating Systems:**
 - Microsoft Windows 7 (x64 versions) with WebGL 2.0 driver support,
 - MacOS X "Snow Leopard" 10.6 with WebGL 2.0 driver support,
 - Linux or Debian with WebGL 2.0 driver support.

2 Virtual laboratory interface

The virtual laboratory is a virtual three-dimensional environment for studying flat and three-dimensional images of the sample surfaces. The Virtual laboratory interface (Figure 1) includes the following elements:

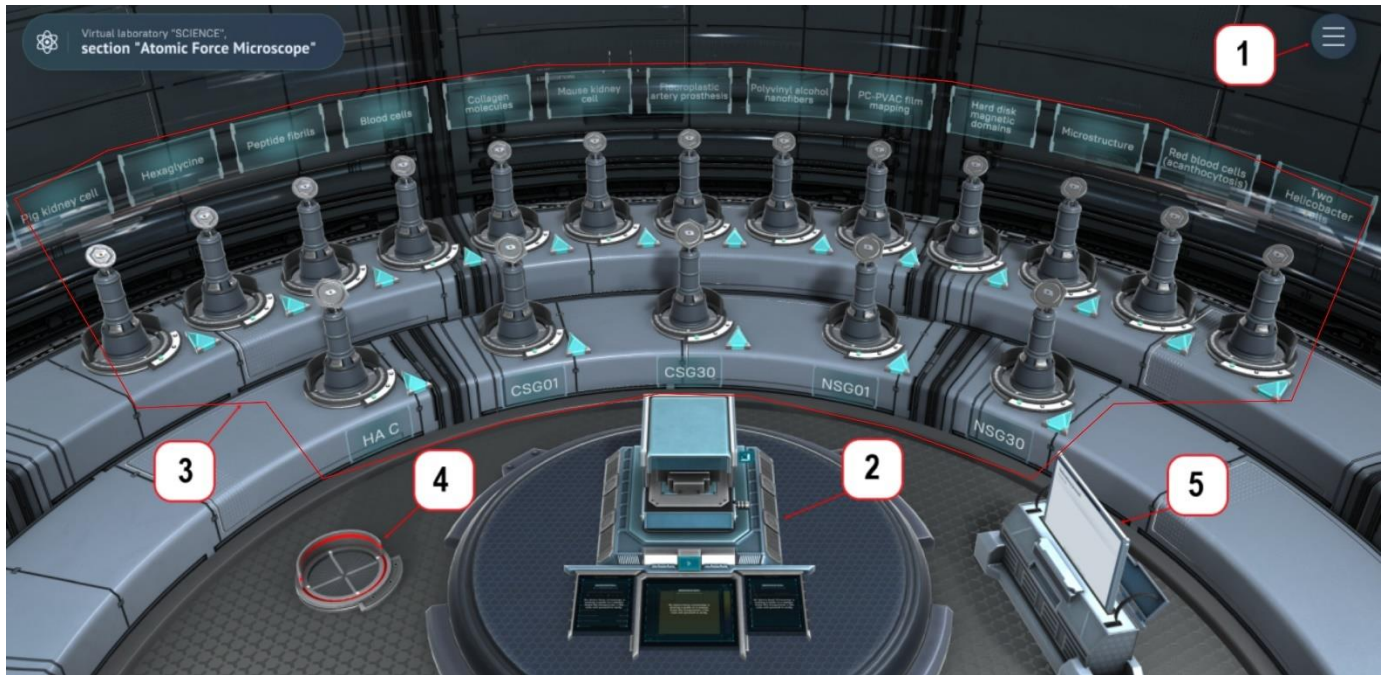


Figure 1 – Virtual laboratory "Science", "Atomic force microscope" section

- 1) **Main menu** (see [4 Main menu](#)).
- 2) **Atomic force microscope** — a three-dimensional model that imitates the structure and external properties of a real device and repeats the logic of its behavior (see [5.1 Atomic force microscope](#)).
- 3) **Gallery of samples and probes** (see [5.2 Gallery of samples and probes](#)).
- 4) **Deletion slot** (see [5.2 Gallery of samples and probes](#)).
- 5) **Laboratory journal** (see [5.3 Laboratory journal](#)).

3 Camera control

The camera is controlled using the mouse or your fingers (when working with a touch screen).

While the application is loading, the camera is in default position — focused at the center of the table (Figure 1).

To zoom in/out, rotate the mouse wheel. When using the touch screen, touch the screen with two fingers, spreading them apart or pressing them together. To return the camera to the default position, click anywhere in the scene around the microscope.

To move the camera, hold down the right mouse button anywhere in the scene; drag the pointer in the desired direction and then release it. The camera moves no more than 5° .

To focus the camera on the microscope, click on any device or rotate the mouse wheel (pinch your fingers when using the touch screen) until the camera moves to focus on the device (Figure 2).

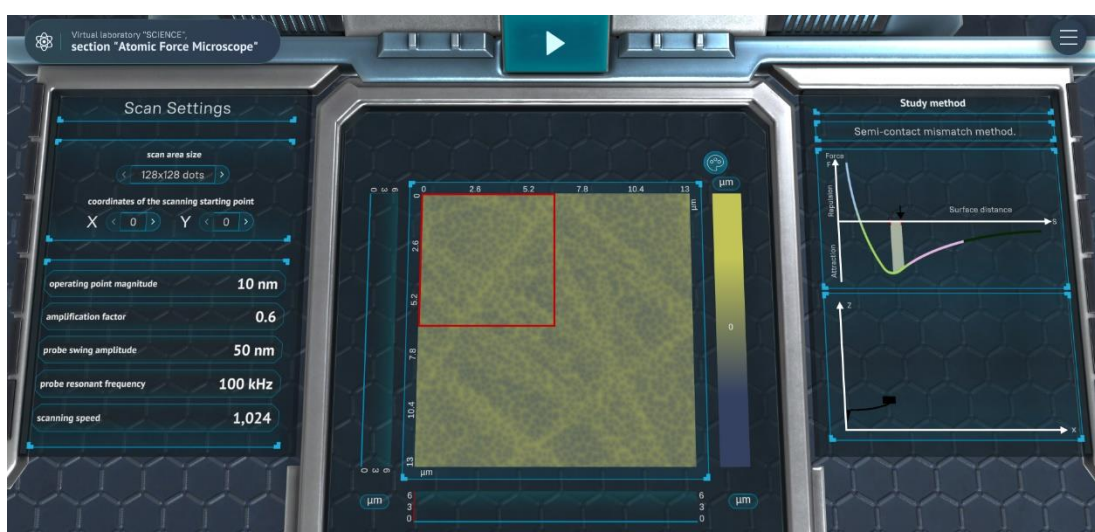


Figure 2 – Focusing the camera on the microscope

To return the camera to the default position, roll the mouse wheel or spread your fingers apart. You can also return the camera to the default position by clicking on microscope.

4 Main menu

To open the Main menu, press the  button in the upper right corner of the app (1 in Figure 1). The main menu consists of the following elements (Figure 3):

1) Set of functional buttons:

- **Instructions** button  (see [4.1 Instructions](#));
- **Tips mode** button  (see [4.2 Tips mode](#));
- **Virtual keyboard** button  (see [4.3 Virtual keyboard](#));
- **Fullscreen mode** button  (see [4.4 Fullscreen mode](#)).

2) Username display field.

3) **Scene menu** (see [4.5 Scene menu](#)).

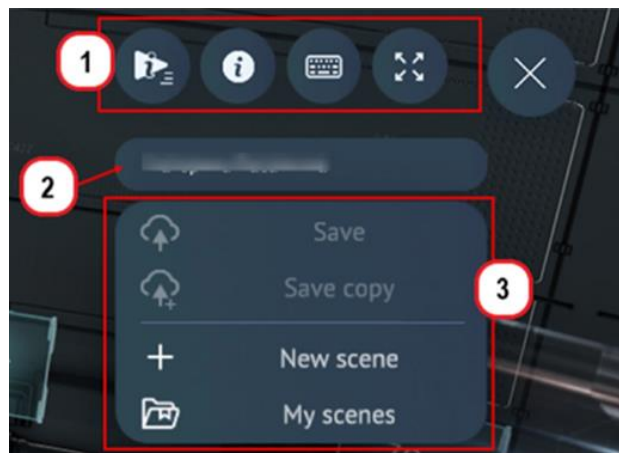


Figure 3 – Main menu

To close the **Main menu**, press the  button or click anywhere in the scene outside the menu.

4.1 Instructions

To select an instruction to view, click the **Instructions**  toggle-button in the **Main menu** (Figure 3). An instruction selection menu will open (Figure 4). Read **User manual** or watch video instructions to learn:

- how to work with the scene and equipment — "Introduction video";
- how to save created scenes and load saved scenes — "Saving and loading".

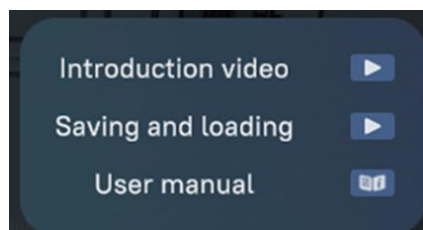


Figure 4 – Menu for selecting instructions

Click on the video title to start watching. The video will play on the screen over the scene. Control playback using the built-in player (Figure 5).



Figure 5 – Player control elements

To close the playback screen, click the **Close** button  in the top right corner of the screen.

To close the video instructions selection menu, press the  button.

4.2 Tips mode

To switch to the interactive tips mode, click the **Tips mode** toggle-button  in the **Main menu** (Figure 3). Tips points will appear next to the objects in the scene, and a description of the installation will open on the left side of the screen (Figure 6).

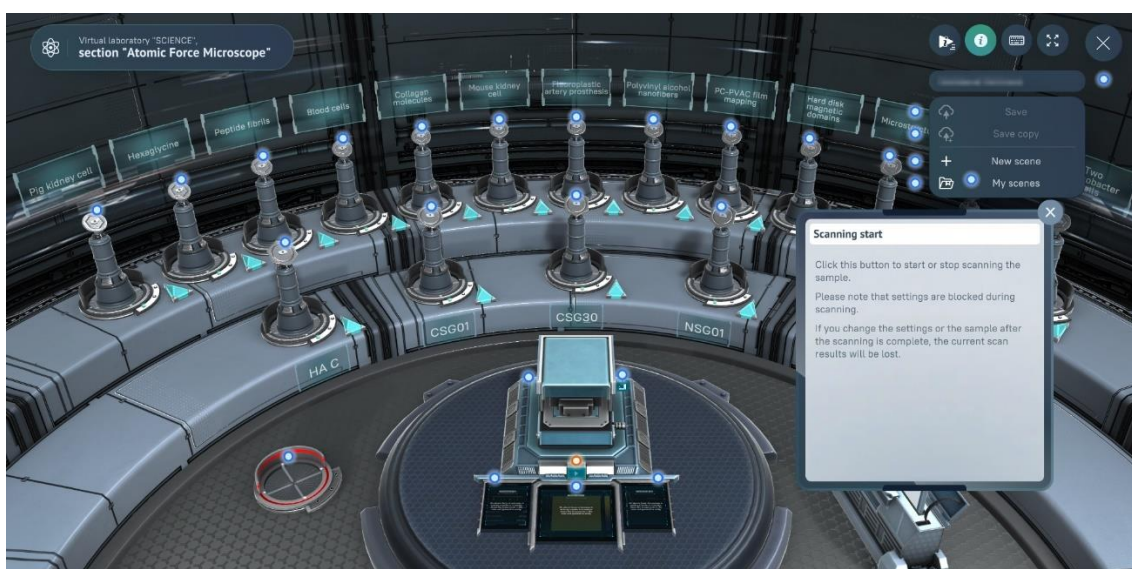


Figure 6 – Tips mode

To view a tip, press the point. To close the tip panel, press the tip point again or click on the cross in the upper right corner of the panel.

Tip points change their outline color depending on whether the user has viewed the tip or not (Figure 7):



Figure 7 – Point outline color options

- 1) Point with orange outline  — the tip is open on the screen (as in Figure 7).
- 2) If several objects have the same tooltips and one of these tooltips is currently open, then the tooltip points of other objects with the same tooltip will have a double outline: dotted gray and orange .
- 3) Point with gray outline  — the user previously viewed and closed the tip.
- 4) Point with blue outline  — the user has not yet viewed this tip.

To exit the **Tips mode**, press the  button in the **Main menu**.

4.3 Virtual keyboard

To switch to the **Virtual Keyboard mode**, press the toggle-button  in the **Main menu** (Figure 3). In this mode, a virtual keyboard will appear on the screen automatically when you start to type in any text field (Figure 8).

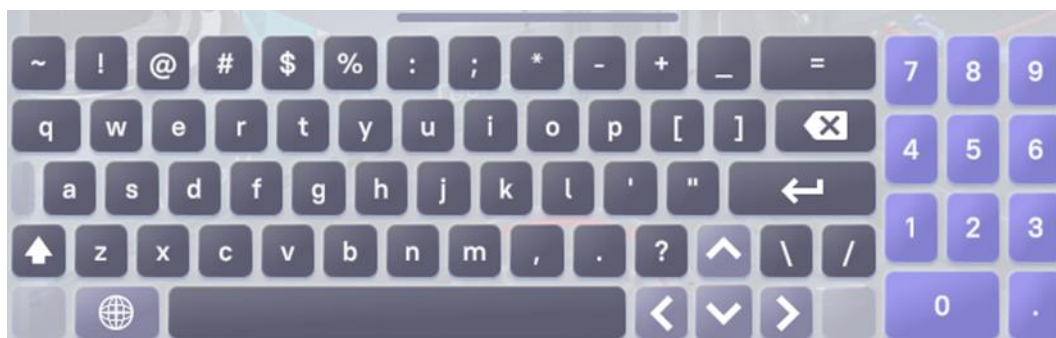


Figure 8 – Virtual keyboard

The virtual keyboard has two layouts: latin and symbolic. The layout is changed using the button  on the virtual keyboard.

To exit the virtual keyboard mode, press the button  in the **Main menu**.

4.4 Fullscreen mode

To enable full screen mode, press the **Fullscreen mode** button  in the **Main menu** (Figure 3). The application will expand to full screen, hiding the browser frame and the OS taskbar. To exit full screen mode, press the  button or the **Esc** on your keyboard.

4.5 Scene menu

Working in the Virtual Laboratory, you can:

- save the current scene (see [4.5.1 Saving a scene](#));
- save the copy of the current scene (see [4.5.2 Saving a copy of a scene](#));
- create a new scene (see [4.5.3 Creating a new scene](#));
- open the **My scenes** library (see [4.5.4 Viewing and loading user scenes](#)).

To go to one of the actions, select the desired item in the **Scene menu** (Figure 9).



Figure 9 – Scene menu

To close the **Scene menu** and the **Main menu**, press the  button or click anywhere in the scene outside the menu.

4.5.1 Saving a scene

To save the created scene in the **My scenes** library, select **Save** in the **Scene menu** (Figure 9). The scene state and laboratory journal's entries will be saved.

If the scene has already been saved, the application will overwrite the contents of the scene file. If the scene is being saved for the first time, the save scene form will open (Figure 10).

Figure 10 – Scene saving form

Enter the name of the scene to be saved (no more than 36 characters) and its description (no more than 1000 characters) in the appropriate fields of the form and click the  button.

You can use the virtual keyboard if necessary. To do so, use the  button, located to the left of the saving form. This button duplicates the  button in the **Main menu** (see [4.3 Virtual keyboard](#)): if the **Main menu** had the virtual keyboard mode enabled , then the button next to the scene saving form will also be in the active state  and vice versa.

If you want to cancel the saving of the scene, press the  button.

4.5.2 Saving a copy of a scene

To save a copy of the scene in the **My Scenes** library, select **Save Copy** on the **Main menu** (Figure 9). This will open the form for saving a copy of the scene, which is similar to the scene saving form (Figure 10).

If the scene is being saved for the first time, you must fill in the **Scene name** (no more than 36 characters) and **Scene description** (no more than 1000 characters) fields.

If the scene has already been saved, the previously saved scene name with the copy number in brackets will be displayed in the **Scene name** field — **Scene 1(3)**. The scene name and copy number can be adjusted or left unchanged.

Click the **Save** button to save a copy of the scene.

After you have saved a copy, you will continue to work with it, and the copy of the scene you worked with before will remain in the state of its last save.

If you do not need to save the scene copy, press the **Cancel** button.

4.5.3 Creating a new scene

To create a new scene, select New scene in the **Scene menu** (Figure 9). If there are unsaved data, a window with a warning about possible data loss (Figure 11) will open.



Figure 11 –Create new scene window

To avoid losing the current data, click the **Cancel** button and continue working with the scene. If you do not need to save the data, click the **Create** button, after which all unsaved data will be lost and a new empty scene will open.

4.5.4 Viewing and loading user scenes

To view a list of scenes, select **My Scenes** in the **Main menu** (Figure 9). **My Scenes** library page (Figure 12) will open.

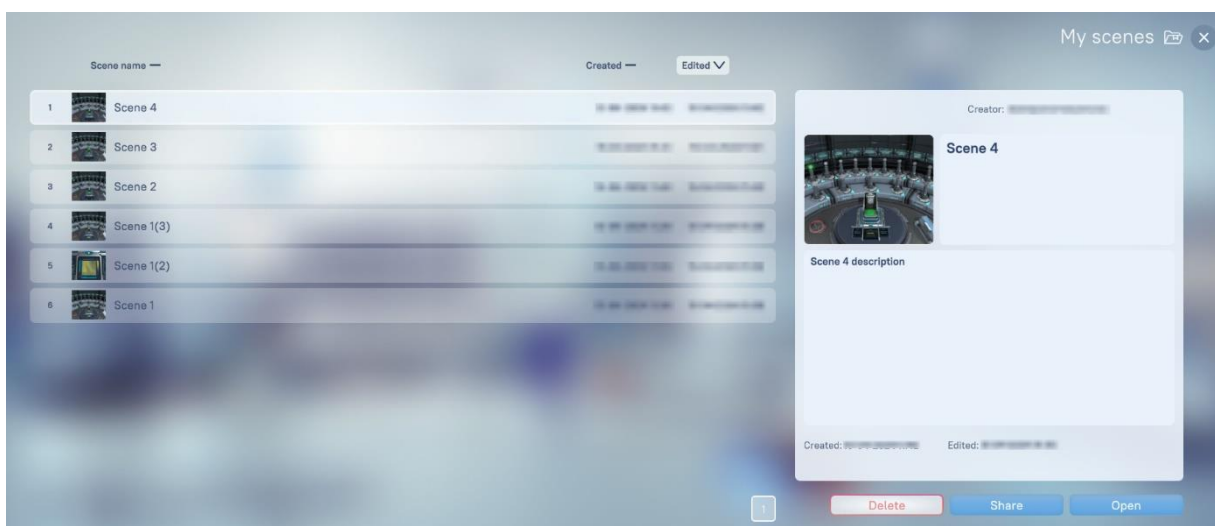


Figure 12 –My Scenes library

On the left side of the screen, a list of all saved scenes will be displayed. You can sort the data by scene name, creation date, and modification date. To sort, click on the name of the corresponding table column (Name, Created or Modified). The  icon next to the name will change to a check mark, indicating the sorting direction .

If the list of scenes does not fit on one screen, it will be split into pages. Navigation through the pages is done using a series of buttons with page numbers, located to the right under the table.

The information about the selected scene is in the scene card to the right of the table. If necessary, you can open, delete, or share the selected scene using the buttons located under the scene card.

5 Objects description

5.1 Atomic force microscope

An atomic force microscope (AFM) is a three-dimensional model that imitates the structure of a real device and repeats the logic of its behavior.

Various samples can be scanned during the research process (see [5.2 Gallery of samples and probes](#)). You can entry the results of your study into the Laboratory journal (see [5.3 Laboratory journal](#)).

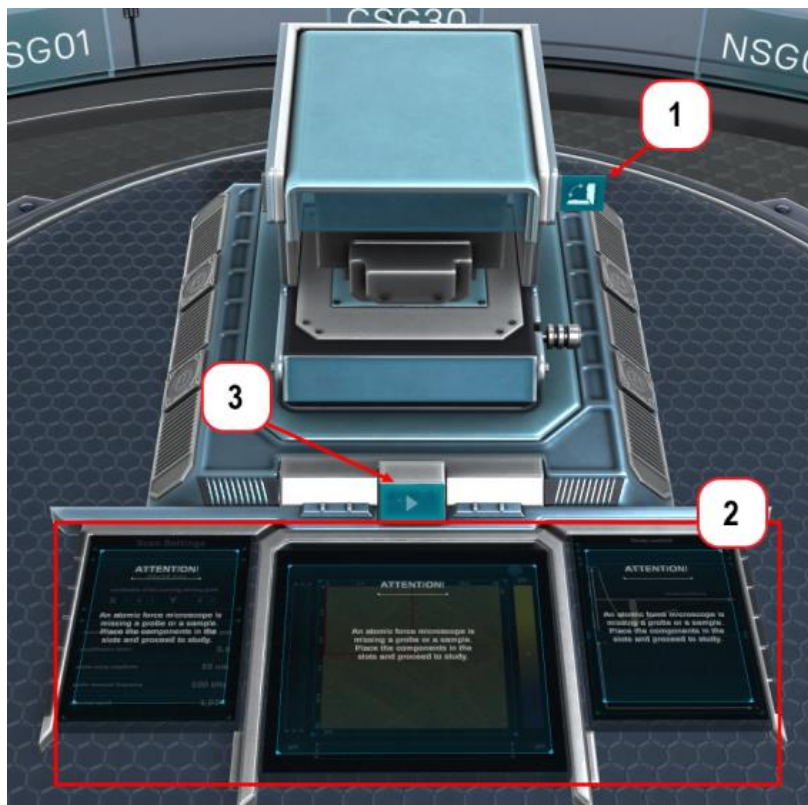


Figure 13 – Appearance of an atomic force microscope

The installation consists of the following elements (Figure 13):

- 1) button to open/close the lid;
- 2) button **Start**;
- 3) displays.

5.1.1 Installation of samples and probes

By default, the microscope does not have an installed test sample or probe — an error message appears on the displays (2 in Figure 13). To get started, you need to place these objects in the slots of the microscope.

Press the  button (1 in Figure 13) to open the microscope and access the probe and sample slots. Place the desired sample (see [5.2 Gallery of samples and probes](#)) into the sample slot. To do this, hold down the sample with the left mouse button, drag the pointer to the slot and release it — the sample will be automatically installed in the slot. While a sample is being moved, its slot is highlighted green (Figure 23).

Install a suitable probe in the probe slot in the same way. Green indication of the probe means that it is compatible with the sample installed in the AFM (see [5.2 Gallery of samples and probes](#)).

After installing the sample and probe, press the  button again to close the lid. The names of installed objects are displayed on the cover and front panel of the device.

5.1.2 Scan settings

To set scanning parameters, place the sample and probe into the microscope and focus the camera on the device (see [3 Camera control](#)).

The display on the left (1 in Figure 14) shows the scanning settings, the display in the center (2) shows the scanning area, and the display on the right (3) shows study methods.

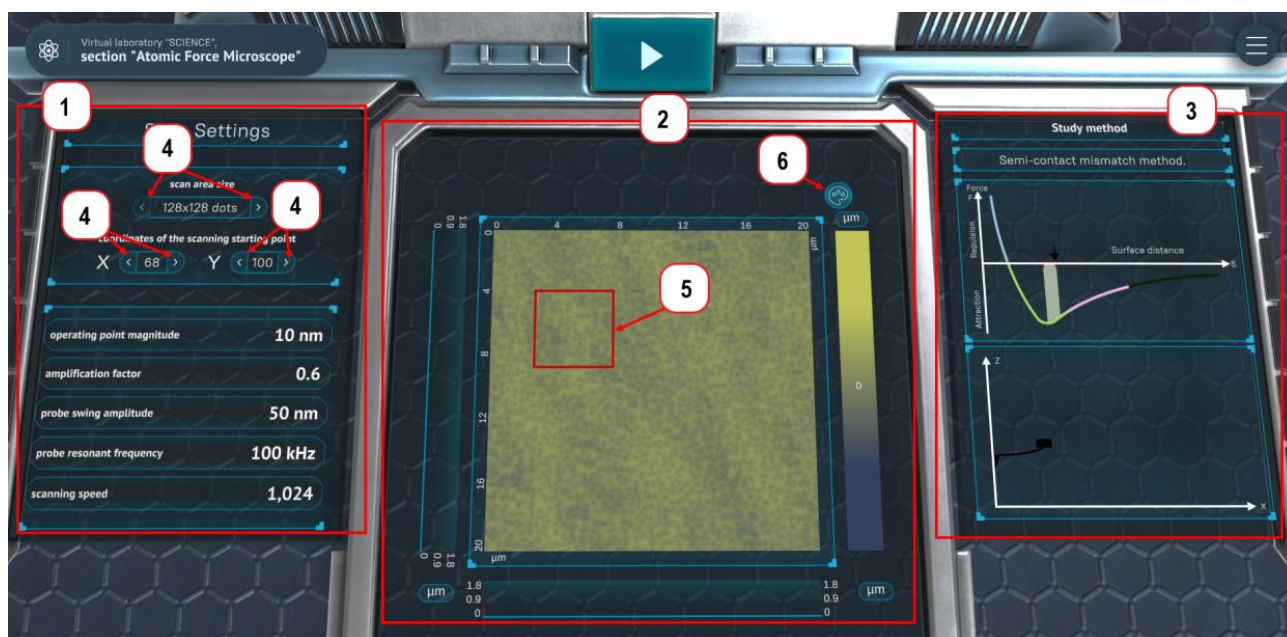


Figure 14 – Scan settings

The scanning area is indicated by a square (5 in Figure 14) on the central display. To change the size of the scanning area and the coordinates of the scanning starting point, use the  /  buttons (4).

You can also move the scanning area using the mouse: hold down the left button inside the area and drag it to the desired location.

By default, the size of the scanning area is 128x128 dots, the starting point is in the upper left corner of the scanning area, the coordinates are indicated in pixels.

Different ranges of starting point coordinates are available for different scanning areas:

- scanning area 256x256 or 512x512 (entire sample) — only (0,0);
- scanning area 128x128 or 256x256 (1/4 sample) — from (0,0) to (128,128), offset step — 4 pixels;
- scanning area 128x128 (1/16 sample) — from (0,0) to (384,384), offset step — 8 pixels.

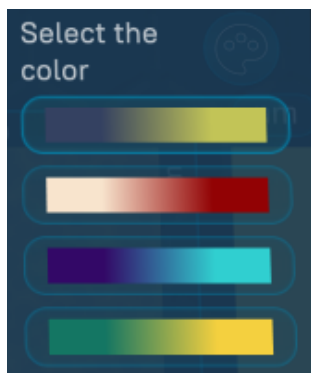


Figure 15 – Palette selection menu

To customize the height scale palette, press the  button (6 in Figure 14) on the central display and select the desired color from the menu (Figure 15). You can change the palette after scanning the sample.

The remaining scan parameters are displayed for additional information and cannot be changed.

During setup, the **Study method** display (3 in Figure 14) shows:

- name of the scanning method;
- force/distance graph. It displays the dependence of the force acting on the probe from the surface, as well as its dependence on the distance between the probe and the sample;
- an empty graph displaying the operating principle of the method.

5.1.3 Sample scanning

Press the  button (3 in Figure 13), to start scanning the sample. You cannot change settings on the left display while scanning (1 in Figure 16).



Figure 16 – Sample scanning

During scanning, the central display (2) shows:

- scanning results;
- progress bar indicating the number of scanned points and the total number of points (4);
- on the graph on the left (5) — the top point of the profile of the current pass (the graph point is the maximum height of the pass);
- on the graph below (6) — the profile of the current pass (the graph point is the height of the scanning point in each pass). The schedule changes with each pass. At the end of the scan, the summary profile of all passes is displayed;

- in the color indication block (7) the height scale (taking into account all heights) and the zero value are displayed. After scanning is completed, the remaining numerical values of the heights are added.

The right display (3) shows:

- scanning method;
- force/distance graph (Figure 17). The range of probe-to-sample distances is indicated by two red lines perpendicular to the S axis, and the current tip-to-sample distance is indicated by a vertical arrow. The arrow moves evenly in the specified range from border to border. The color of the graph indicates the scanning mode range:
 - blue — contact mode;
 - green — semi-contact mode;
 - pink — non-contact mode.
- graphs of probe movement and cantilever bending conditionally reflect the principle of operation of the probe (Figure 18):
 - red line — trajectory of movement of the base of the cantilever leg attachment;
 - green line — the amount of cantilever bending;
 - white line — diagonal profile of the selected sample area.



Figure 17 – Force/distance graph

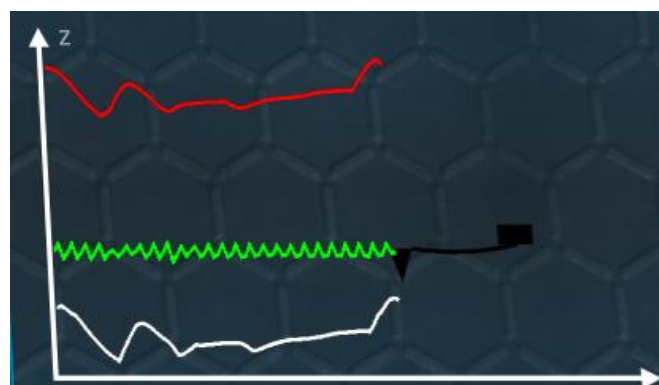


Figure 18 – Graph of probe movement and cantilever bending

To stop the scanning, press the  button above the center display. The displays will return to the setup mode (see [5.1.2 Scan settings](#)). Intermediate scan results will remain on the central display until the study parameters are changed or the sample is replaced. Changing the probe to the same new one does not reset the scan results.

To continue scanning, press the  button. If no changes are made to the study parameters after scanning is stopped, scanning will continue from the moment it was stopped. If changes have been made, the scanning will start anew.

5.1.4 Processing the scanning results

Once the scan is completed, the result is shown on the central display (Figure 19).

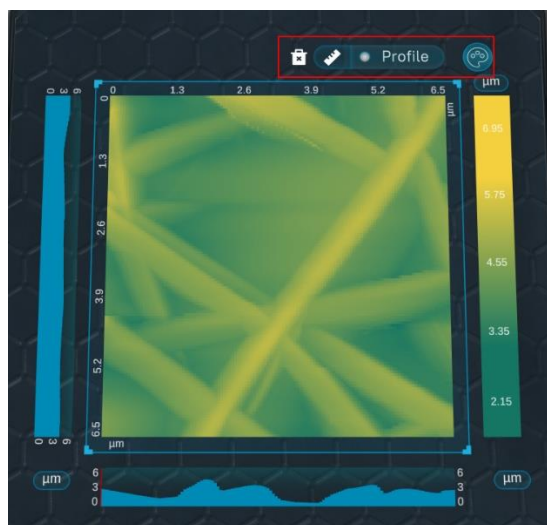


Figure 19 – Processing scan results

The graphs to the left and below the scan results display the total height profiles along the side of the sample. There is a toolbar at the top.

Click the  button to activate the ruler (Figure 19). To move the ruler, left-click a point on one of its ends , drag it to the desired location and release it. The values will be recalculated automatically. To turn off the ruler, click the  button.



button.

Press the  button to study the profile of the selected segment (Figure 20).

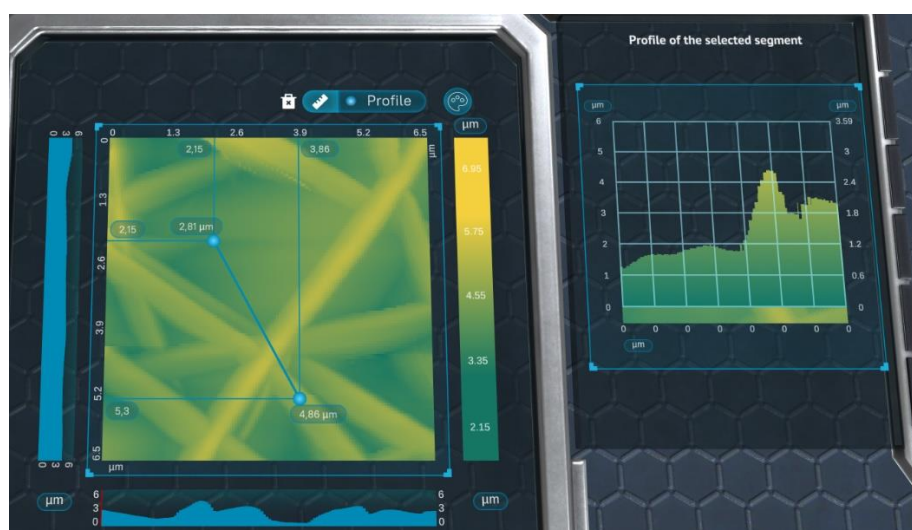


Figure 20 – Ruler in the central display and line profile in the display on the right

To close the profile viewing, click the  button again.

To change the color indication of heights, click the  button and select the desired color (see [5.1.2 Scan settings](#)).

If necessary, record results in the laboratory journal (see [5.3 Laboratory journal](#)).

5.2 Gallery of samples and probes

In the gallery behind the atomic force microscope, the top shelf contains samples and the bottom shelf contains probes. The samples contain materials to be studied, and the probes contain a needle that interacts with the surface of the sample under study and is attached to the end of an elastic console called a cantilever. There are 13 samples and 5 probes available in the Virtual Laboratory. Sample and probe names are shown on the gallery cards (Figure 21).



Figure 21 – Samples and probes

To place a sample or probe into the microscope, press the  button (1 in Figure 1) — the microscope's lid will open (Figure 22). Then hold down the desired object with the left mouse button, move the pointer to the corresponding slot and release it. The slot available for placing a moved object is illuminated with a brighter light indication (Figure 23). Probes are placed in the top slot of the microscope, and samples are placed in the bottom slot.



Figure 22 – The microscope is open, slots are available for the object placement



Figure 23 – Light indication of available slot

To correctly scan a sample, it is necessary to install a probe corresponding to this sample in the microscope. After installing the sample into the microscope slot, the suitable probes will be highlighted with a green light indication (Figure 24).



Figure 24 – Light indication of the suitable probes

When placing objects that do not match each other in the microscope slots, a warning about possible damage is shown on the central display (Figure 25).

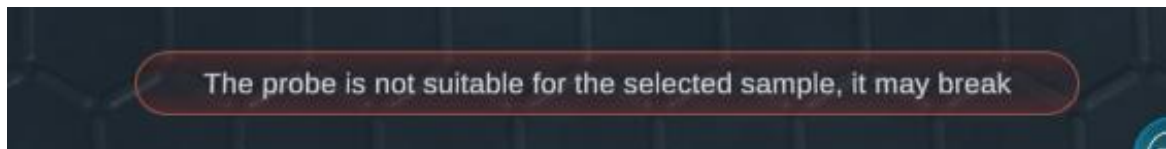


Figure 25 – Warning of possible damage

If you start scanning with a probe that does not match the sample, the probe will break and scanning of the object will be stopped. Also, the slot will fail after scanning 1,048,576 points. In both cases, failure messages will appear on the microscope displays. (Figure 26).

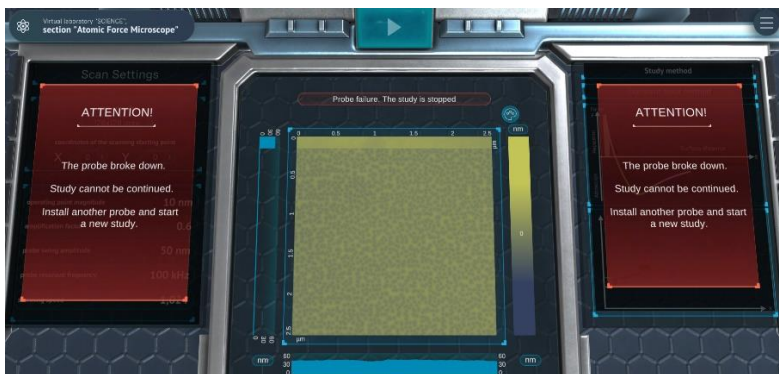


Figure 26 – Probe failure messages

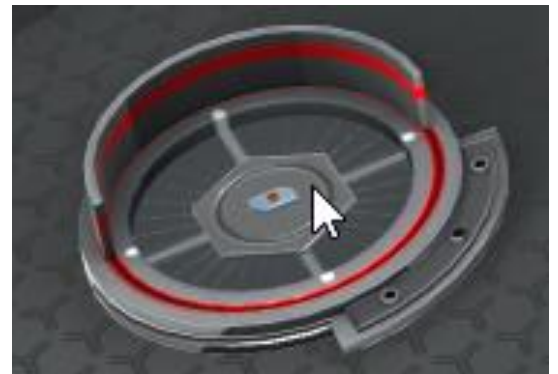


Figure 27 – Probe deleting

To continue working with a device after a probe failure, remove the faulty probe from the slot and install a new probe that matches the sample installed in the AFM.

To remove a sample or probe from the scene, hold it with the left mouse button, drag it to the deletion slot (6 in Figure 1) and release it.

5.3 Laboratory journal

Laboratory journal (5 in Figure 1) is used to record the results of scanning probes. While working with the journal, you can:

- open the journal (see [5.3.1 Opening a journal](#));
- view the list of studies and delete unnecessary ones (see [5.3.2 Viewing the list of studies](#));
- create a new study (see [5.3.3 Creating a new study](#)).

5.3.1 Opening a journal

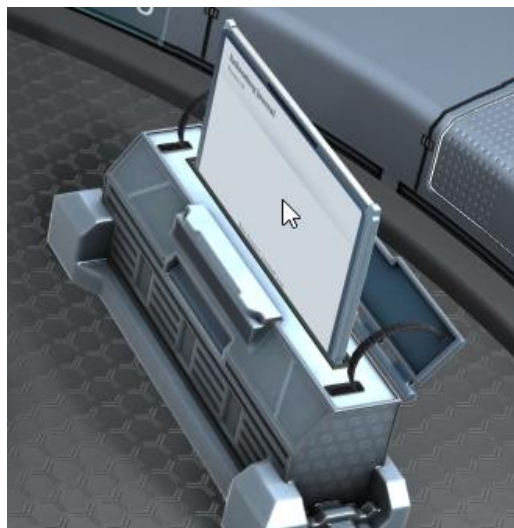


Figure 28 – Opening a journal

To open a journal, click on the journal or on its stand (Figure 28).

The journal will open on the left side of the screen (Figure 29). If journal entries have already been made in the current scene, they will be displayed in the open journal. If there were no entries, an empty journal will open.

To collapse an open journal, click on its stand or hold down the journal with the left mouse button and drag it off the screen border on the left.



Figure 29 – Lab journal

5.3.2 Viewing the list of studies

The list of studies is a set of cards (Figure 30), each of which contains data about the study: number, time and date of creation, name of the study, the sample and the probe used and the number of records about the results of the study.

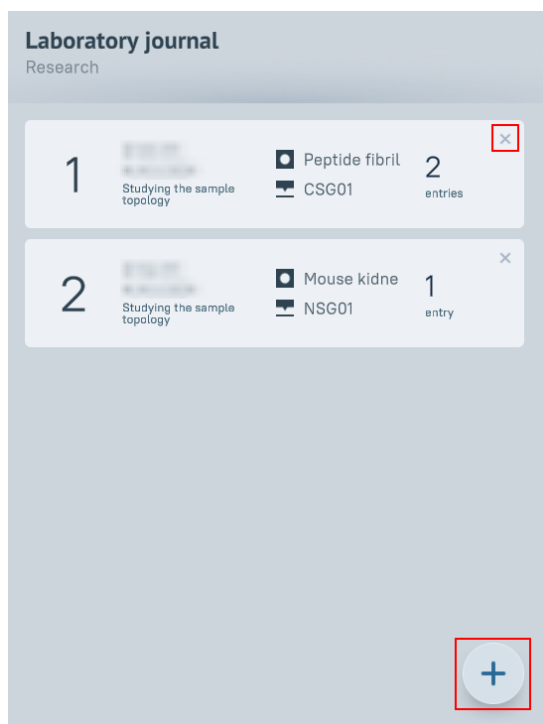


Figure 30 – The list of studies

5.3.3 Creating a new study

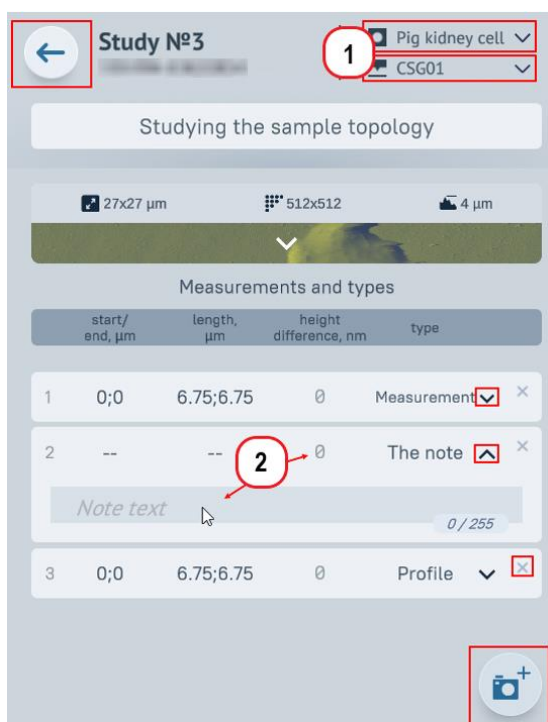


Figure 31 – The entry page

To open a study card, left-click on it.

To create a new study, press the  button in the lower right corner of the journal (Figure 30).

To delete a study, press the  button in the upper right corner of the study card.

If the list of studies does not fit on the screen, a scroll bar will appear to the right of the list. To view the list, hover your mouse over the journal and roll the mouse wheel or drag the scroll bar up or down. When using the touch screen, scroll through the list with your finger.

To create a new study, click the  button in the lower right corner of the journal (Figure 30) — the entry page will open.

To add an entry line, click the  button in the lower right corner of the page (Figure 31) and select the entry type in the opening menu (Figure 33). **Measurement** and **Profile** records are only available after the sample has been scanned.

To collapse/expand an entry or a scan result, click the  /  buttons (Figure 31).

To add the name of the sample and probe used in the study, click on the corresponding button in the upper right corner (1 in Figure 31) and select your option in the opening menu (Figure 33).

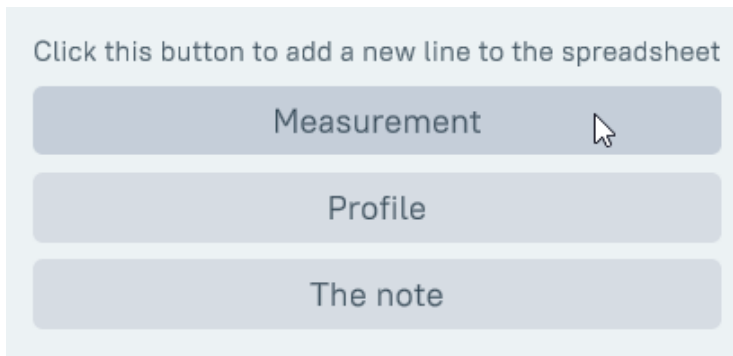


Figure 32 – Selecting an entry type



Figure 33 – Probe selection

To enter data obtained as a result of the study, click on the corresponding input field (2 in Figure 31) and enter the value using the keyboard of your device or the virtual keyboard (see [4.3 Virtual keyboard](#)). Some fields are filled in automatically.

To delete a line of entries, press the  button in the upper right corner of the line. To return to the list of studies in the journal, press the  button in the upper left corner of the page.