PianoLab

Quick start

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Introduction

PianoLab – is the program for tuning and analysis of piano for Windows XP and above.

PianoLab simplifies a task of piano's tuning by using such means as automatic calculation of optimum frequencies of a temperament zone, visualization of a spectrum and the analysis of harmonics of the concrete note, the analysis of sound scale by the curves of *Railsback* , intervals, etc.

The basic possibilities

- The spectral analysis and display of a sound signal in a mode of real time
- Measurement of frequency of a sound to within the 100-th shares of Hz,
- Automatic calculation of the optimum plan of tuning of the piano for a temperament zone with taking into account inharmoniousness of strings,
- Granting to the user of control over results of calculation of the plan of optimum tuning of the piano,
- Displaying of the full information on a piano's sound in real time in the form of various graphics and tables: windows of the table of frequencies, the *Railsback* curves, intervals, deviations of harmonics,
- Automatic separation in a spectrum of a sound of the pressed note of its harmonics (the quantity of analyzed harmonics is adjusted by the user - from 5 to 16),
- Taking a snapshot of a spectrum of a signal for visual comparison of spectrums of two notes (for tuning of unisons),
- Saving the information on an piano sound scale in a file, loading of the information from earlier kept file,
- Others: spectrum smoothing, decimation, scaling on amplitude and frequency, etc.

It should be emphasized the presence in the program module for finding an optimal solutions for areas of temperament. The fact that the issue range on the display and recommendations for the frequencies of the idealized (without disharmony strings) – the task is not difficult. And it allows to make almost all of the hardware and software tuner type guitar. But to find the optimum for an array of frequency zones in accordance with certain restrictions, and criteria – is more difficult task and enable it do only the advanced and expensive tuners.

Hardware and software requirements

- The Operating system - Windows XP and above,
  Microsoft Net Framework 4.0 and above,
- The Processor - it is desirable not more low Intel Pentium IV (and similar AMD) and above,
- The Sound module - any, including built in (on the motherboard),
- The Microphone - any, but for full tuning of a scale is desirable a microphone c a range of frequencies of 10 Hz - 20 kHz. If Your microphone is not support the entire range, it is possible to

configure in the following way. Configure the middle part of piano with the frequency range from 200 to 2000 Hz, which usually supports any microphone, then tune the rest of the scale: use upper harmonics for the bass and lower harmonics to treble.

Program installation

Installer PianoLab can be downloaded from the website http://PianoLab.ru/ in the download section.

Run the installation file and answer standard questions.

If necessary, you can change the installation options: a folder of installation of the program and availability of labels of the program. If on the computer OS Windows 7 with activated system UAC (control of access to the user) on the screen window UAC with inquiry of the permission about entering by a fitter of the program of changes about the computer will be shown is established. For continuation of installation of the program it is necessary to resolve entering into system of changes by fitter PianoLab. On termination of program installation on a desktop and in the menu "Start-up" icons for program start will be created.

The main stages of work with the program

- start of the program;
- setting basic program options (menu options\Preferences). On the initial stage of learning of the program default settings are recommended.
- check the sound section;
- pre-setting of the sound scale, if necessary;
- tuning temperament zone in automatic mode;
- tuning the rest of the sound scale(buss and treble).

Start the program

The program will not start if you do not have Microsoft Net Framework 4.x

Usually, this applies to Windows XP or Windows 7.

In order to save computer resources, **is not allowed to start the 2nd, etc. copies of the program.**

Connect a microphone (or use the built-in) to the input of the sound module. Check the recording level for the microphone in the mixer settings of operating system.

The program does not start, if the system has no audio input device.
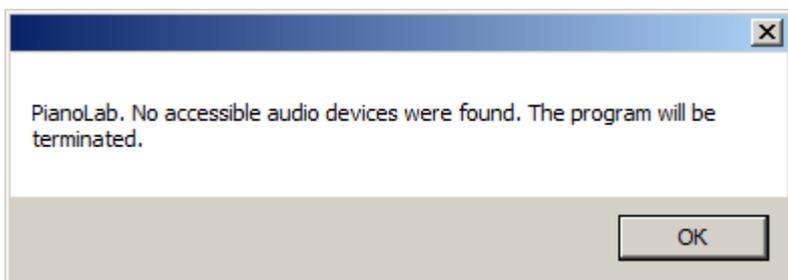
The appearance of this message means that there are no necessary drivers for the sound module, there are problems in their work or that the audio input device is disabled in the system.

After starting the program we are in the main window:
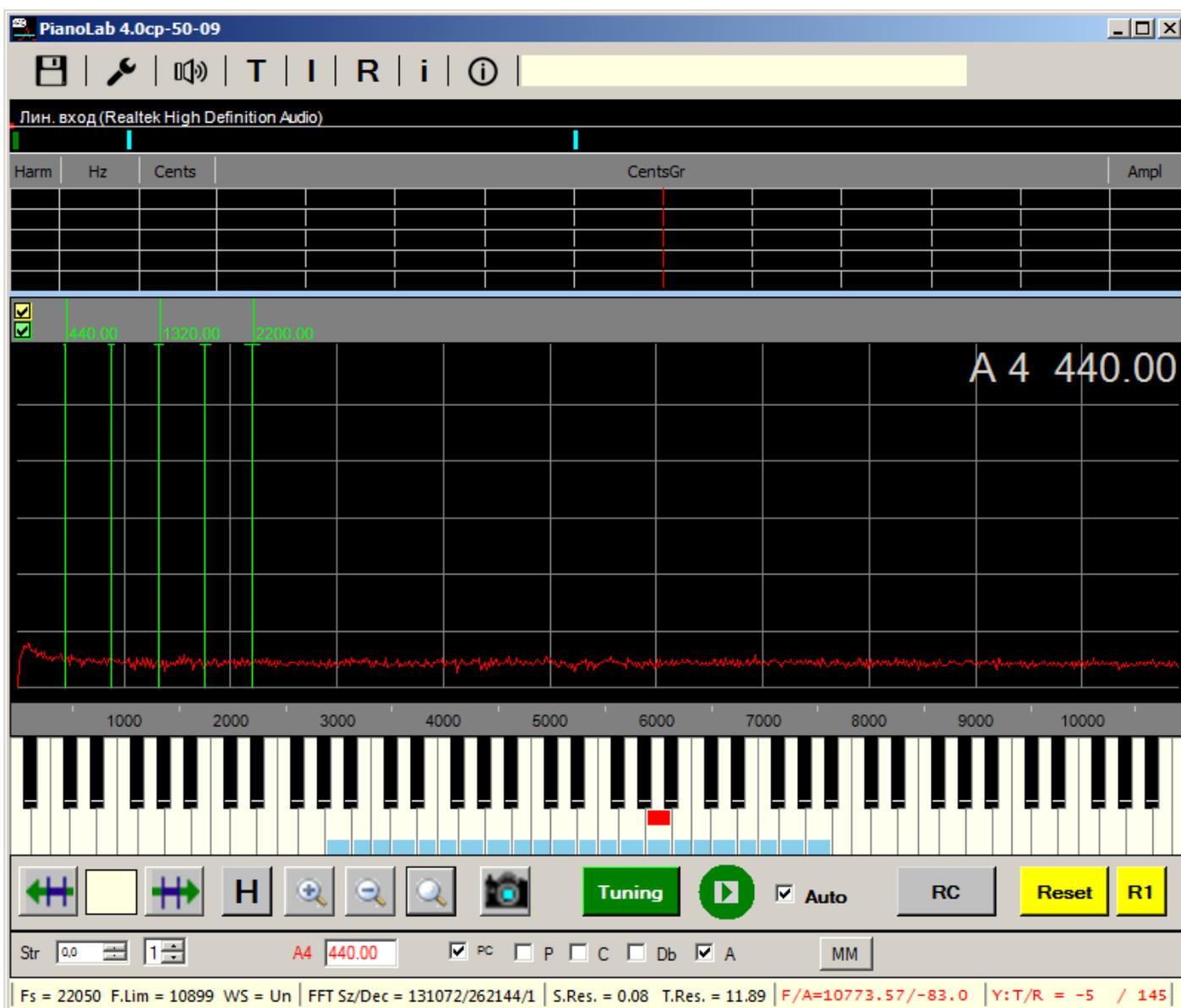
In the top line menu: file, settings, signal generator and choice of windows:

frequency table, intervals, Railsback, nonharmonicity and registration of program.

The main window is divided into three sub windows:

- window level of the input signal;
- window of values of harmonics;
- window to visualize the spectrum.

Further down, there is a piano keyboard, control panel, additional control panel(by default, it is hidden and is called from the settings menu), status bar.

For all control panel items valid contextual prompt, if to stop the mouse cursor on it.

The size of the internal Windows graphics output can be changed by moving the separators (splitters). When you exit the program, all dimensions are saved.

In the window of the input signal level is also displayed and the selected input device.

Settings

Before you start working with the program need to look in Menu\Settings\Settings. Here you can configure some parameters of the processing of the input signal and visualize the spectrum. The parameters shown in the figure below, set the program default and is recommended for the initial stage of use (learning) programs, as they provide an acceptable balance between quality of the processing of the input signal and power requirements of the computer processor.

For some options, there is context sensitive help.

1. Capture device selection.
2. Parameters specifying the spectral (temporal) resolution and the number of harmonics analyzed.
   - **Sampling frequency**. The default is **22050**, which corresponds to the maximum frequency of the analyzed signal - **11000** Hz (5th harmonic of the note Do4). If you want to adjust higher notes, then you need to increase the sampling frequency. The selection of the sample rate in the program is limited to the standard values -**11025, 22050 and 44100**.
   - **The value of the block for analyzing** the Fourier transform upon recording is **262144 (256k)**. With a sample rate of **22050** and a given value of the analysis block for recording, the spectral resolution is **0.08 Hz**. This roughly corresponds to one beat in **10 seconds**. If this accuracy is not enough, then it can be increased, either by reducing the sampling frequency, or by increasing the value of the analysis block.
   - **Decimation parameter**. Removing a portion of the samples from the digitized signal, which creates the effect of reducing the **sampling frequency**. **Decimation** is used when the sound card does not support a lower **sampling frequency**.
   - **Number of harmonics**. The default is 5, the maximum is 16. The default values are sufficient for analysis of 4 types of intervals: I4, I5, I7 and I9.
3. A group of parameters that define the smoothing window and the band pass filter.
4. Type of temperament. Default equal temperament(**ET**).
   - The program has two types of temperament:
   - Standard **ET**, with an interval coefficient of $2^{1/12}$. For the temperament zone, the range [**A2**, **A5**] is taken. The range can be increased to a maximum of [**A0** , **A6**].
   - Stopper temperament (**ETs**) with an interval coefficient of $3^{1/19}$. For the zone of temperament, the range from [**D3**, **A4**] is taken.
5. Lower and upper boundaries of the temperament zone. Depends on the type of chosen temperament.

Note. For setting the program, the frequency of the base note **A4** is of great importance - by default it is equal to 440 Hz. For faster access, changing this parameter is made in the additional control panel.

The only thing that makes sense in the settings at the initial stage is the input device.

Setting a convenient scale to display the spectrum of a sound signal

Press button (**Start**), if not pressed, and check the spectrum display of the input signal.

Define a convenient scale of the spectrum display by a wheel mouse:

- **Ctrl+ Wheel** - the vertical scale,
- **Wheel** – the vertical shift.

Spectrum must respond to the microphone.

Initializing the sound scale

If the input device(microphone) all right, after starting the program initializes a sound scale from **A0** to **C8** in accordance with the principle of equal temperament, i.e. the frequencies of adjacent notes are divided or multiplied by the interval coefficient. For base note is taken **A4**.

Note. The sound scale is also initialized by pressing the button [Reset].

Definition of harmonics

In the program, one of the main concepts is the concept of **harmonic**.

- Harmonics - any complex oscillation can be represented as a sum of the simplest sinusoidal oscillations having strictly defined frequencies, amplitudes and phases (Fourier transform). These simplest oscillations are called natural frequencies. An overtone is any natural frequency above the first, lowest (**fundamental tone**), and those overtones whose frequencies refer to the fundamental frequency as **integers** are called **harmonics**, with the fundamental tone being the first harmonic. Since, in a real instrument, the frequencies of the **harmonics** can differ from the theoretical ones, we will distinguish real and theoretical (calculated) harmonics.
- **Harmonic computational** - a harmonic, the frequency of which is calculated in the program according to certain rules.
- **Harmonics real** - the harmonic of the entered note. It is sought in the spectrum as a local maximum in the vicinity of the theoretical harmonic for a given note.

The importance of this concept in the program is explained by the fact that the sound signal of a pressed piano key, which is just a complex oscillation, is converted to the sum of the simplest sinusoidal vibrations, i.e. signal spectrum. Then the harmonics are allocated in the spectrum, which are used to recognize the note.

Markers of calculated and real harmonics

- **The marker of the calculated harmonic** is a vertical straight line on the spectrum graph with the coordinate along the frequency axis equal to the frequency of the calculated harmonic. The default is highlighted in bright green.
- **The real harmonic marker** is a vertical straight line on the spectrum graph with the coordinate along the frequency axis equal to the frequency of the **real harmonic**. The default is highlighted in yellow.
- For all calculated harmonics of the **current note**, **markers of the calculated harmonics** are displayed in the spectrum window. At the initial stage - before the module for finding the optimal solution starts, the markers of the **calculated harmonics** exactly coincide with the values of the frequencies of the initialized scale. **Then the position of these markers can vary depending on the results of searching for the optimal solution.**
- **Markers of the calculated harmonics** are always displayed, and the **markers of real harmonics** only if the note is recognized and recognized as valid.
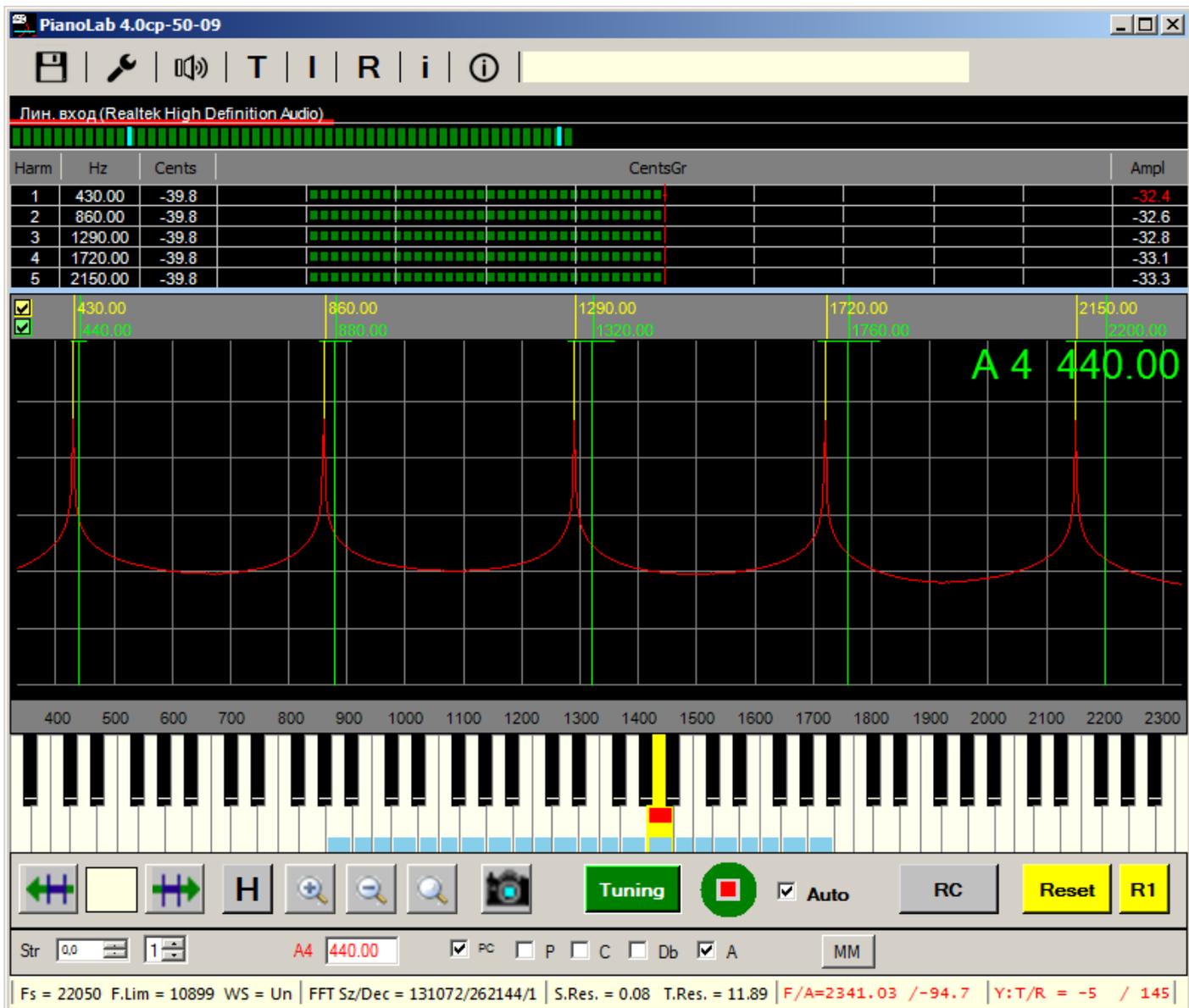
Let us consider this drawing in more detail.

Parameters in the settings were taken by default. The frequency of the base note **A4** - 440 Hz. (Seen from the additional control panel)

The initialization of the scale after the program was launched was carried out at this frequency.

As a current note, the note **A4** is taken.

The markers of the calculated harmonics for **A4** (lines of bright green flowers) are displayed by the program at frequencies of 440, 880, etc. Hz. (I recall that these frequencies were calculated during initialization with respect to the base note frequency)

Then, an audible signal with harmonics frequencies was input: 430, 860, 1290, 1720 and 2150 Hz. These frequencies mimic the signal of the idealized note **A4**, which is omitted relative to the standard one at 10 Hz. The figure shows the spectrum of this introduced note **A4** (red). That is, this entered note is considered real and the markers of real harmonics are yellow lines, are displayed by the program at frequencies of 430, 860, 1290, 1720 and 2150 Hz.

The signal of the idealized note **A4** is taken from the signal generator to make the picture look simpler, since when you enter a note from a real instrument in the spectrum, there would be a lot of unnecessary information.

Presetting the sound scale (if necessary)

The initialized frequencies of the sound scale may not match the frequencies of the scale of a real equally tempering configured piano, as it does not take into account the specifics of the instrument (disharmony of specific strings, especially decks, etc.), but this standard system can be used as a first approximation.

If the temperament is raised in several approaches, gradually coming to the desired temperament, then this is accomplished in the program by changing the frequency base notes **A4** and pressing the button

 , that leads to the initialization of the sound scale at a set frequency. And enough to raise a temperament in accordance with the initialized frequencies, not achieving a particular accuracy.

That is, pull up each note so that its real marker of the 1st harmonic more or less coincides with the calculated marker of the 1st harmonic.

Features entering notes

Scheme analysis and recording of the note to be input

In the 5th version the scheme of analysis of the entered notes was modified

- In ”**Auto**” mode the beginning of the analysis starts by exceeding the level of the input signal above a certain threshold value(the right blue bar in the window of the input signal level -- call it the **MAXs**). The end of the analysis occurs when the signal level falls below a certain minimum(left blue bar in the window level of the input signal - let's call her **MINs**).
  Therefore, the level of the input signal at the initial moment of pressing the keys of the piano must be exceed the **MAXs**, and in the silence needs to be less than **MINs**. Changing the input level is done in system preferences sound control devices. To simplify calling these settings, additional control panel introduced button **MM**.
  The position of the dash **MAXs** in the window of signal level you can change the grip and mouse movement. It is sometimes useful, when increasing the force of impact by pressing or the change of the signal level in the system settings has no effect.
  In a noisy room, to reduce the likelihood of false positives when determining the notes in the “**Auto**” mode, the search can be conducted only among adjacent notes in relation to the current one note to the left or right. For this in the additional settings panel you want to disable the flag “**A**”.

- **In manual mode(the Auto checkbox is disabled)**, analysis and recognition of notes begins after the current level signal exceeds the **MINs**, but only in case of coincidence of the current notes and recognized in the input signal, the note is considered valid and allowed her entry.

What happens when a note is recognized

During signal analysis, the current state of recognized notes is maintained. The window of harmonic values is filled in, the color of the name of the note in the spectrum window becomes bright green and the

markers of **real harmonics** (yellow verticals) corresponding to the maxima of the harmonics amplitudes of the recognized note are highlighted. And, in the "**Auto**" mode, the current note automatically switches to the recognized one.

Only after the note has been recognized is it possible to record a note in the computer's memory. The process of inputting a note for individual harmonics is conveniently controlled in the window of harmonic values. You can also analyze the harmonics in the spectrum window by selecting the scale - "**H**" (all harmonics) or by selecting one of the harmonics using the buttons , .
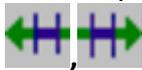
What to do if a key is not entered in "Auto" mode

- Check if the level of the input signal exceeds the **MAXs** level when the piano key is pressed.
- The end of the note input occurs when the input signal level becomes less than **MINs**. If in silence mode, the signal level exceeds **MINs**, then it should be reduced in system settings.

Recording notes

A note can be recorded in the computer's memory only when the mode is on.

And depends on the state of the flag "**Auto**":

- If the "**Auto**" checkbox is enabled, the record notes in the program memory automatically at the end of the analysis notes. Selection of notes to record among the saved state is determined by the maximum sum of the weighted amplitudes of the harmonics.
- If the "**Auto**" checkbox is turned off, i.e. set to manual mode recording is by pressing the button (Stop). The time of pressing is determined by the tuner.

Note input in automatic mode

The flag "**Auto**" and the mode is enabled.

Using this mode it make easier to enter notes. In this case, you do not need to select the note from the keyboard program. Also automatically the recording of notes is performed.

1. Press button (**Start**).
2. Toggle state of the button to .
3. Press on the piano any key. Further, the analysis notes. When the analysis notes starts, it filled a window of the values of the harmonics and color of the names of the notes becomes bright green to indicate that the note is recognized. At the end of analysis notes when the input signal level falls below **MINs**, automatically record a note in the program memory. If the save of note went fine, issued by a short beep.

4. The next key press, when the spectrum is cleared from the signal of the previous notes.

Note input in manual mode

The flag "**Auto**" is **off** and the mode [Record] is enabled.

1. Press button [▶] (**Start**).
2. Toggle state of the button [Tuning] to [Record].
3. Select the desired note in the keyboard sub window.
4. Press the corresponding key on the piano. The recorded sound is analyzed in the program and if it is possible to determine the current note, then values of the harmonics of notes, deviations from the calculated in cents and amplitude, and the color names of the notes becomes bright green displayed. In the spectrum window displayed **markers of real harmonics** (yellow vertical).
5. Once the note is recognized, you can press the button [■] (**Stop**) (ex [▶] (**Start**).
   By pressing this button stops the audio input, and display information on the screen. Then the frequency of the selected note is saved. If retaining the note was okay, it issued a short beep.
   Thus, **deciding when to record notes rests with the tuner**.

The reset notes

If you find that some note have been carried out incorrectly, then it can be reset(initialized) by setting the keyboard programs the note and click [R1].

Reset (initializing the entire scale) - pressing the button [Reset]. **In this case, all the information entered will be lost.**

Tuning mode

In the tuning mode **Tuning**, **on the markers of real and calculated harmonics**, it is possible to make a decision - to tighten or loosen the string, trying to combine the markers. Since the spectrum update occurs quite often, the change in string tension is quickly reflected in the spectrum. As soon as you bring the real marker to the optimal one, you can move on to the next note.

Sometimes certain harmonics (typically the first harmonic) in the spectrum may have smeared the tip, due to the irregular shape of the hammer.

To avoid the influence of irregular shape of the hammers, you can change the character entry notes replacement of impact the hammer on the string to pinch the strings while pressing a damper pedal. But since the main input notes are still pressing the keys and thus the blow of the hammer, then, after recording the notes, it is recommended to check and disharmony entered the notes and whether all entered notes do introduced. This can be seen in the "piano Keyboard " or in the "frequency table" – entered notes are marked with a green stripe.
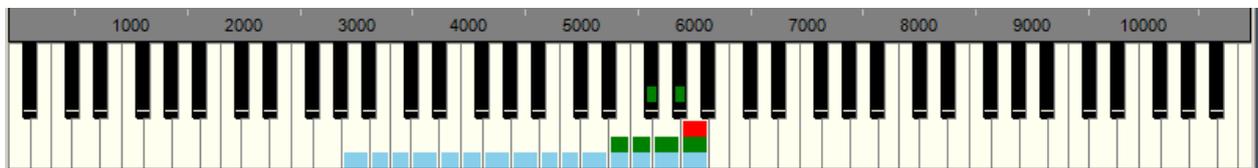
Frequencies table

Shifts in frequencies	Harm. 1	Shift 1	Harm. 2	Shift 2	Harm. 3	Shift 3	Harm. 4	Shift 4	Harm. 5	Shift 5	Real I4	Opt.
42. D# 4	311.13	0.00	622.25	0.00	933.38	0.00	1244.51	0.00	1555.63	0.00	15.93	
43. E 4	330.38	-0.75	660.76	-1.50	991.14	-2.26	1321.52	-3.01	1651.90	-3.76	13.10	
44. F 4	350.02	-0.79	700.04	-1.58	1050.06	-2.37	1400.08	-3.17	1750.10	-3.96	13.90	
45. F# 4	370.84	-0.85	741.68	-1.69	1112.52	-2.53	1483.36	-3.38	1854.20	-4.22	10.45	
46. G 4	392.89	-0.89	785.78	-1.79	1178.67	-2.68	1571.56	-3.57	1964.45	-4.47	11.08	
47. G# 4	416.25	-0.95	832.50	-1.89	1248.75	-2.83	1665.00	-3.78	2081.25	-4.72	11.75	
▷ 48. A 4	441.00	-1.00	882.00	-2.00	1323.00	-3.00	1764.00	-4.00	2205.00	-5.00	12.46	
49. A# 4	466.16	0.00	932.33	0.00	1398.49	0.00	1864.66	0.00	2330.82	0.00	18.50	
50. B 4	493.88	0.00	987.77	0.00	1481.65	0.00	1975.53	0.00	2469.42	0.00	19.60	
51. C 5	523.25	0.00	1046.50	0.00	1569.75	0.00	2093.00	0.00	2616.26	0.00	20.76	
52. C# 5	554.37	0.00	1108.73	0.00	1663.10	0.00	2217.46	0.00	2771.83	0.00	22.00	
53. D 5	587.33	0.00	1174.66	0.00	1761.99	0.00	2349.32	0.00	2936.65	0.00	23.31	
54. D# 5	622.25	0.00	1244.51	0.00	1866.76	0.00	2489.02	0.00	3111.27	0.00	24.69	
55. E 5	659.26	0.00	1318.51	0.00	1977.77	0.00	2637.02	0.00	3296.28	0.00	26.16	

The tuning of temperament zone with the use of automatic search of the tuning plan

The tuning procedure using automatic plan roadmap is as follows:

1. Select the type of temperament: standard equal **ET** or **ETs** by the Stopper.
2. Check the frequency of the base note **A4**, typically, this frequency is **440 Hz**. If changed

   this value, reset the scale by pressing the [Reset] button.

3. Toggle state of the button [Tuning] to [Record].
4. Enter all notes of a zone of a temperament, the default is the range from **A2** to **A5** inclusive, for the standard **ET** (**ETs** by the Stopper **D3 – A4**). Notes area temperament is marked with a blue strip in the keyboard sub window. Then start the process of finding a solution - **button "RC"**.
5. If a solution exists, **markers of calculated harmonics** for the notes of a temperament zone are found to correspond to the tuning plan.
6. It now remains only, to each note of a zone on set an **calculated marker**. For greater accuracy, adjust the notes best not for the first harmonic, and second or higher.

Note1. The solution is sought so that the beats in quarts, quanta's, thirds and sixths fall into a certain interval, and the difference between the 2nd harmonic of the **A3** and the 1st harmonic **A4** would be minimal (for RT on the Stopper one minimizes the difference between the 3rd harmonic of **D3** and the 1st harmonic **A4**). If a solution exists, then the Message is issued the line that the solution has been found, indicating the frequency of the lower note areas of temperament and value of the improvement ratio from **0 to 1**. The smaller the coefficient, the better the decision. For example, if the value is 0.5, it means that the total deviation of the beats in all 4 intervals (thirds, quarts, fifths and sixths) for the found solution is less than twice than the total deviation of the beat for the music.

If a solution exists, then the Message is given a string of this type:

```
DONE: 108,56 ; Q=1 ; kS=181,2/642,7
```

This means that a solution is found. Specifies the frequency of the lower note areas of the temperament and two numbers separated by a slash line. The first number represents the total deviation of the beats in all 4 intervals (thirds, quarts, fifths and sixths) to the found solution, and the second is the total deviation of the beating for the entered notes. The smaller the ratio of the 1st number to the second, the better solution found.

Note2. Zone length temperament for equal temperament(**ET**) default is **[A2:A5]**. This range can be increased to **[A0:A6]**. However, as shown, for such a long range there may not always be the optimal solution. Good results are obtained for a zone of a temperament by default **[A2:A5]**.

Note3. The solution may not exist in case when one or several notes are significantly different in frequency from the initialized values of the sound scale.

The comparison of spectra. Configuring unison. Configure the rest of the scale

Tuning of bass and treble are made by already tuned notes in temperament zone with use of a snapshot of the spectrum of the corresponding note areas of the temperament zone.

Button ![camera] snapshot the spectrum in the main window is used for fixation on the screen of the current spectrum. This recorded spectrum can be used for comparison with subsequent spectra.
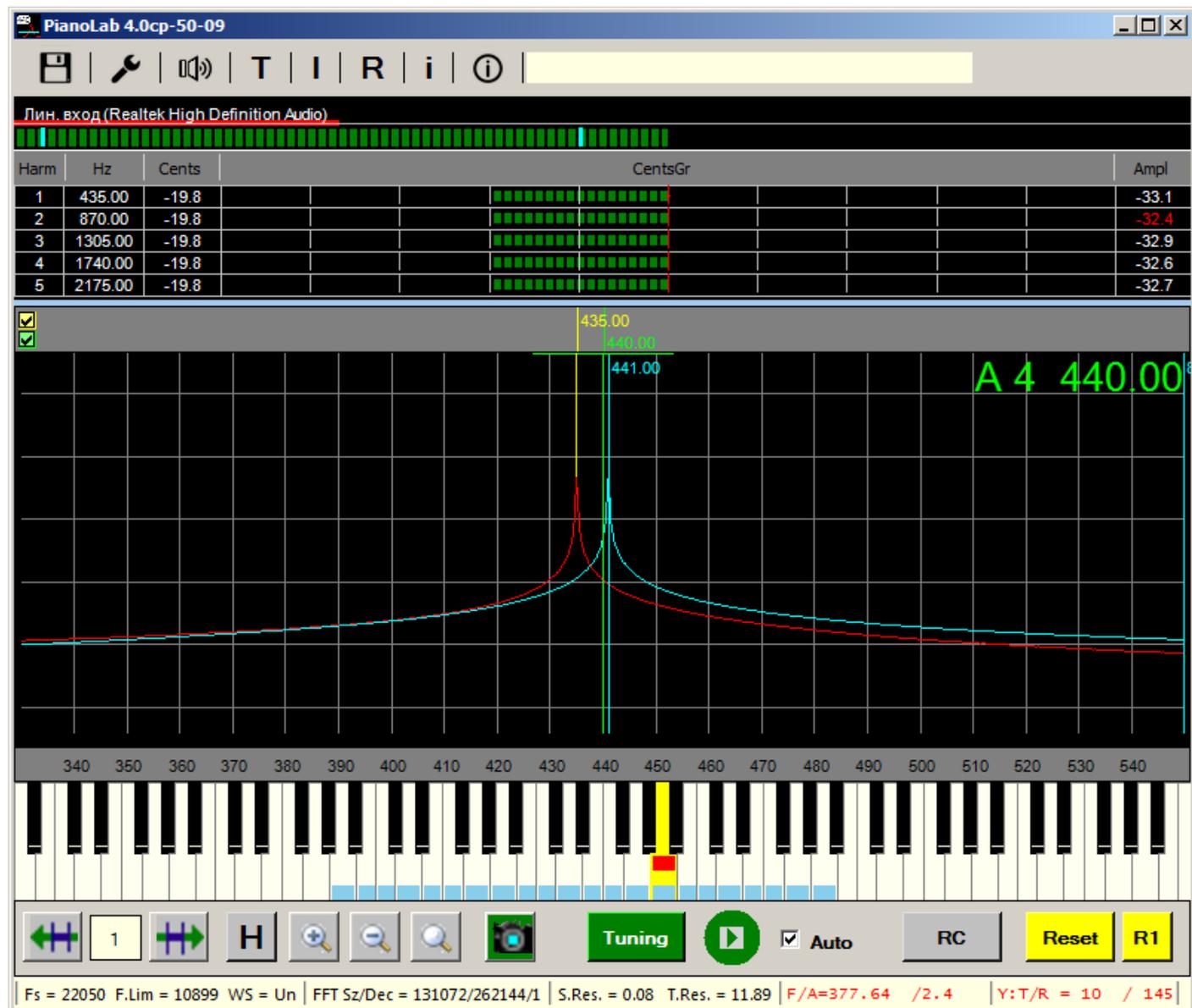
The figure shows two spectra: the spectrum of blue color is the snapshot spectrum and red is the current one.

The comparison of spectra can be used, for example, to configure the unisons.

So, to adjust the rest of the sound scale, you need to go through all the notes of the temperament zone in turn. Make a Snapshot for each note and adjust it in unison with the corresponding note from the next octave. This, of course, does not cancel control thirds, quarts, fifths and sixths and **audio control**.

The fact is that the nonharmonicity of strings can manifest itself in different ways and it is not always possible to equalize all the matching harmonics of the interval.

Pressing the button again resets the snapshot.