

FLEX-LOGIC CORRELATOR

FC

USER MANUAL

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1. INTRODUCTION

Overview

The correlator FC is a multipurpose real-time device for auto- and cross-correlation measurements built on the software-configurable flex-logic integrated circuits. A capability of further software upgrade of hardware functions is the unique feature of the FC correlator. The FC is a suitable device for photon correlation spectroscopy because it has all necessary modes of operation and is a fully hardware standalone device. Therefore, it is possible, during accumulation of the correlation function, to use the computer for other purposes (e.g. temperature control).

The FC has TTL input levels as standard. Both autocorrelation and cross-correlation functions can be measured. The living display of a probability distribution of the real input signal favors correct result making. The FC provides most efficient data collection in a wide dynamic range of the input signal.

Specifications

Hardware structure	Programmable flex-logic
Processing algorithm	Hardware, updated through software
Processing	32 bits
Input frequency	100 MHz
Capacity of each channel (hardware)	48 bits
Minimum sample time (true real-time operation)	10 ns
Input signals	TTL
Operation mode	Autocorrelation; cross-correlation
Time scale	Multiple-tau; linear
Multiple-tau scale	
Number of channels	288
Configuration	36 sections x 8 channels, factor 2
Number of monitor channels	72
Linear time-scale mode	
Number of channels	128
Number of monitor channels	3
Software dust-cutoff regime	Yes
Prescaling	Not required
Living monitor of probability distribution	Hardware
Design	USB interface
Dimensions (LxWxH)	160 x 95 x 35 mm
Power requirements	5V x 0.2A

2. INSTALLATION

System requirements

FC correlator requires the following minimum system configuration:

Microsoft Windows 2000/XP/Vista/7

PC-compatible computer
Spare USB port
30 MB free hard disk space

Installation of the FC software

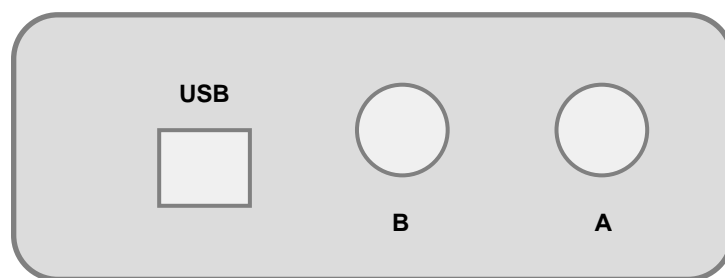
Before installing the FC correlator you need to install the FC software:

- 1) Insert Photocor CD into the CD-ROM drive.
- 2) Open the **Software** folder on the Photocor CD, double-click the **FC-6.0E.exe** file and follow the on-screen instructions to complete the installation.

Note: You must have administrative privileges in order to install FC software on Windows 2000/XP/Vista.

Important: To run DynaLS after installation you are to have Aladdin HASP key inserted in the parallel or USB port of your computer. Without HASP user may run DynaLS during evaluation period with limited number of loadable data files.

Installation of the FC correlator



Rear panel of the FC correlator

- 1) Connect the USB cable to the connector labeled **USB** on the rear panel of the FC correlator
- 2) Connect the other end of the cable to the USB port on the computer
- 3) Connect cables from photon counting system to inputs labeled **A** and **B** on the rear panel of the FC correlator (for photon counting system with single PMT module only one input **A** or **B** is connecting)
- 4) After all cables is connected additional configuration of FC correlator are required:

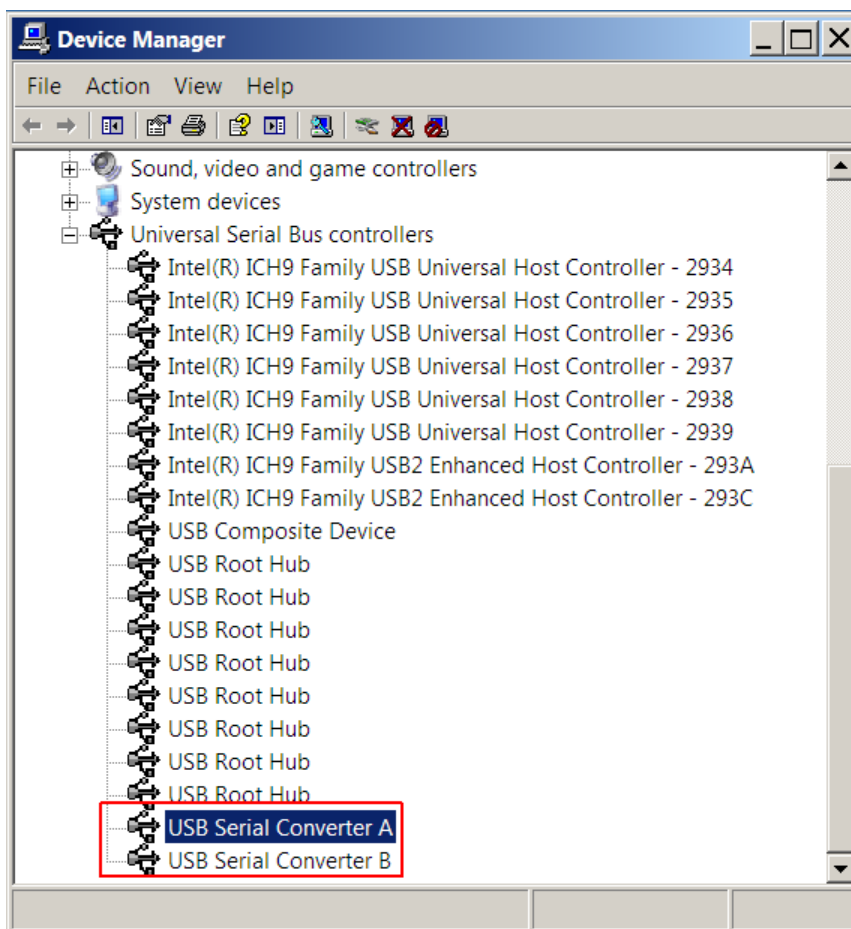
- open the **Device Manager**:

for Windows XP:

- click the **Start** button
- click the **Control Panel**
- click **Switch to Classic View** in the upper left area of the window
- click the **System** shortcut
- switch to the **Hardware** tab
- click the **Device Manager** button

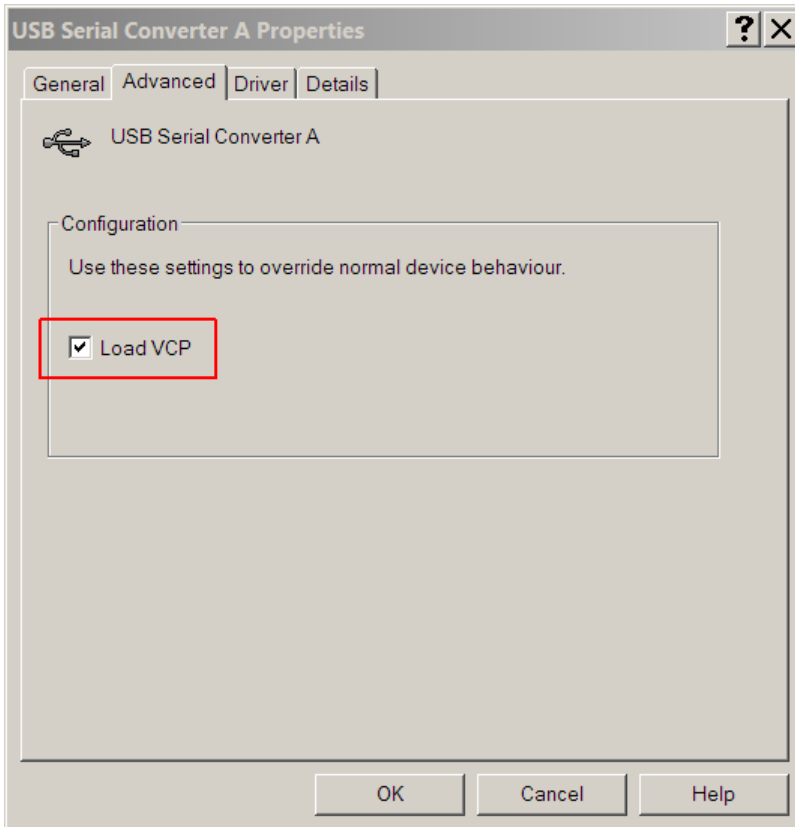
for Windows Vista/7:

- click the **Start** button
- click the **Control Panel**
- click the **System and Security** shortcut (only for Windows 7)
- click the **Device Manager** in the category **System**



- expand the **Universal Serial Bus controllers** list

- double click the **USB Serial Converter A** device



- switch to the **Advanced** tab
- clear the **Load VCP** checkbox
- click OK
- now you need to perform the same actions for the **USB Serial Converter B** device

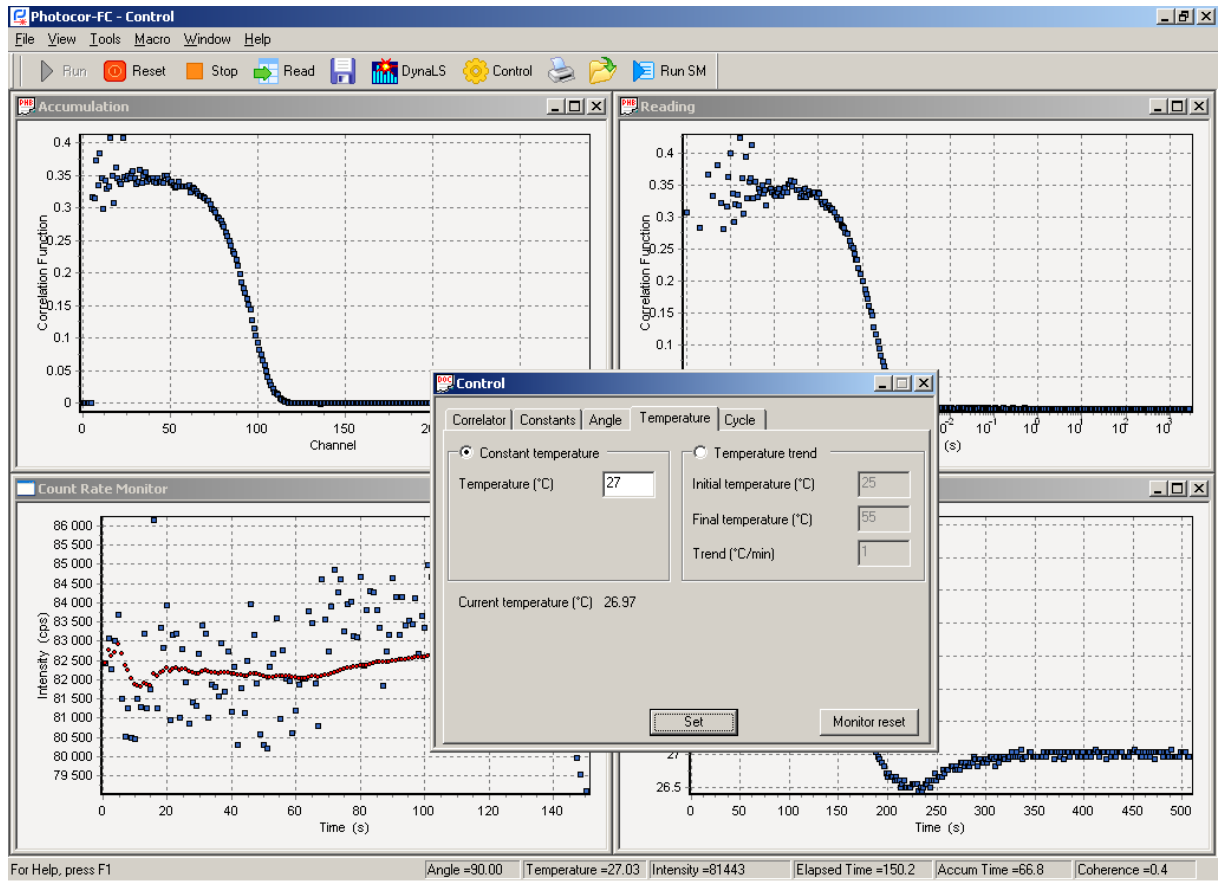
Note: In future if you connect the FC correlator to another USB port of the computer you will need to perform step 4) again.

5) Installation of the FC correlator is completed. Now you may start working with the FC software.

3. DESCRIPTION OF FC PROGRAM

Typical FC window

A user may combine a suitable configuration of the FC windows on the screen. Example of a screen is shown below:



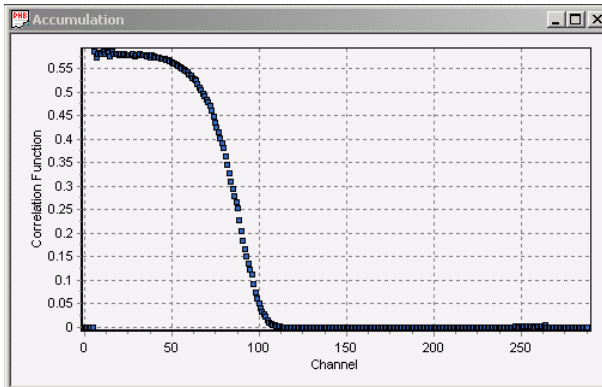
There are the following types of windows:

- 1) To display measured values: **Accumulation, Reading, Count Rate Monitor, Temperature Monitor, File** - window to show saved correlation function.
- 2) To control correlator and some functions of the BC-1 instrument: Control window with tabs, File setup.
- 3) Standard dialog boxes of Windows.

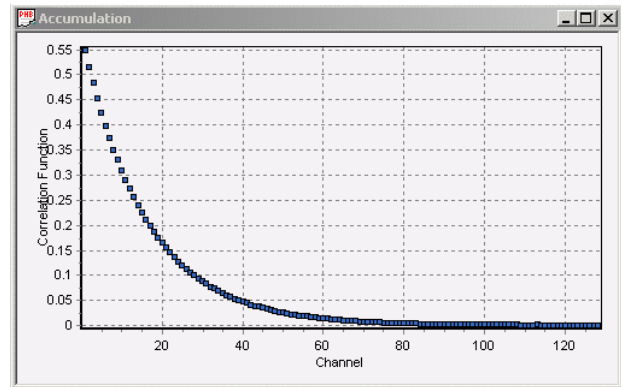
Accumulation window

Accumulation window monitors in real time the process of accumulation of the correlation function in the correlator. For activation of the window **Accumulation** it is necessary to open menu **View** and select **Accumulation**.

Depending on the hardware configuration of the correlator (multiple-tau or linear channel spacing) the correlation function shows in form a) and b) correspondingly.



a)



b)

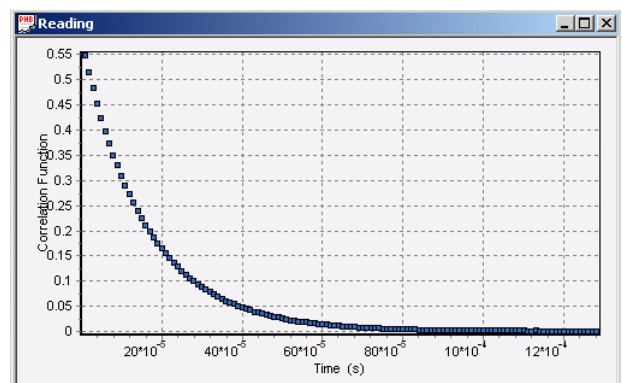
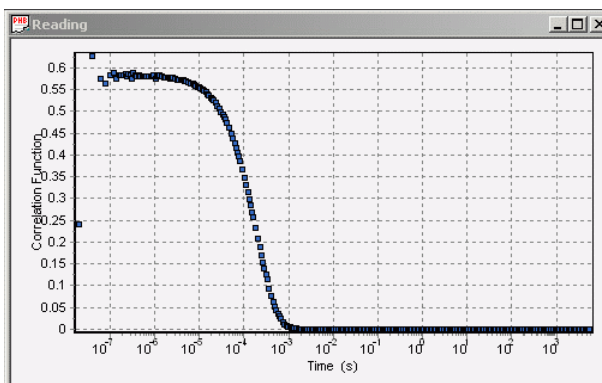
Reading window

Reading window shows the correlation function read out from the correlator to PC for fitting or saving.

To be able to perform fitting of the accumulated correlation function you should first copy it into the computer memory using the **Read** button. It is not necessary to stop the accumulation before reading of the correlation function. Therefore, you can make current estimation of the particle size during the process of accumulation.

For activation of the **Reading** window, it is necessary to open the **View** menu and select **Reading** or simply click **Read** button on the toolbar.

Examples of **Reading** windows for multiple-tau and linear hardware configurations are shown below:

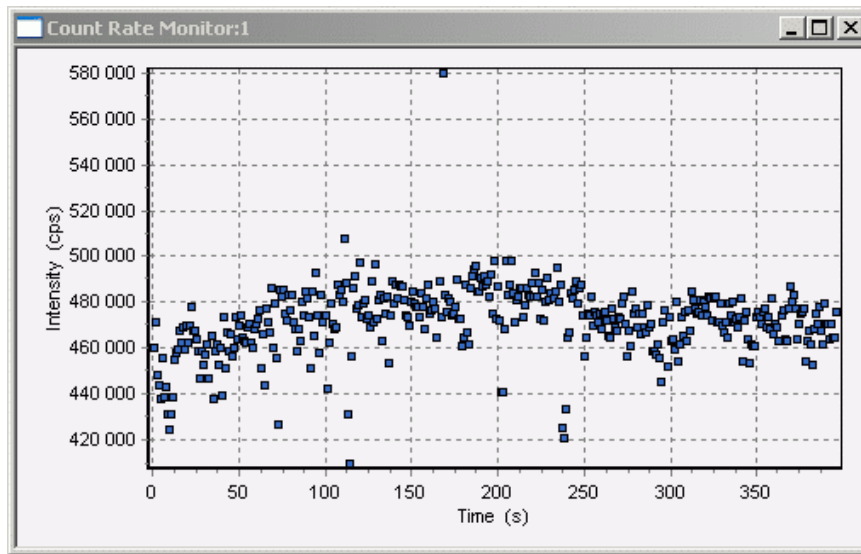


Count Rate Monitor window

Count Rate Monitor window displays current count rate of input signals of correlator coming from photon counting system.

Take into account that count rate of input signals will be measured, if the **Count Rate Monitor** window was open before **Run** of the correlator. For activation of the **Count Rate Monitor** window it is necessary to open menu **View** and click **Count Rate Monitor**.

Count rate history can be saved in common file of results by clicking button **Save**.

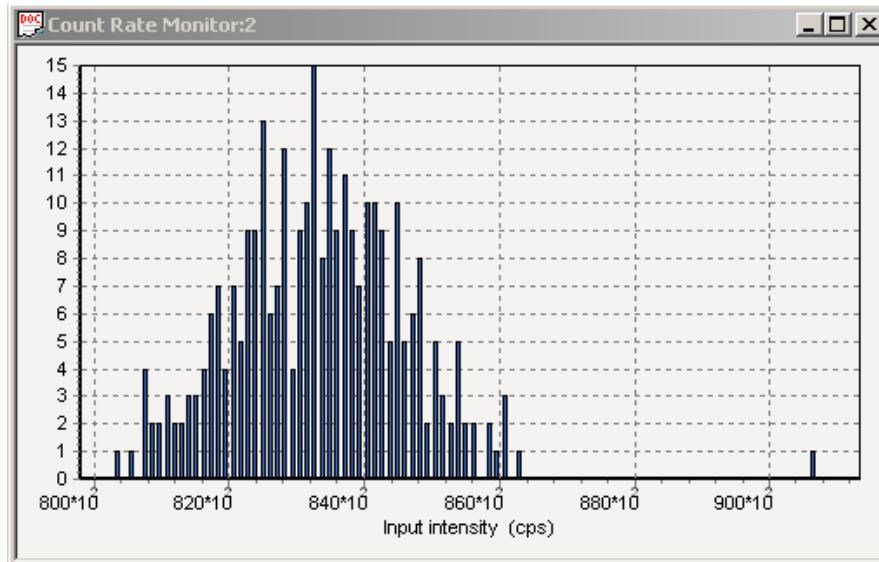


Count Rate Distribution window

Count Rate Distribution window displays current differential probability distribution of input signals of correlator coming from photon counting system.

Take into account that probability distribution of input signals will be measured, if the **Count Rate Monitor** window was open before **Run** of the correlator. For activation of the **Count Rate Distribution** window it is necessary to open menu **View** and click **Count Rate Distribution**.

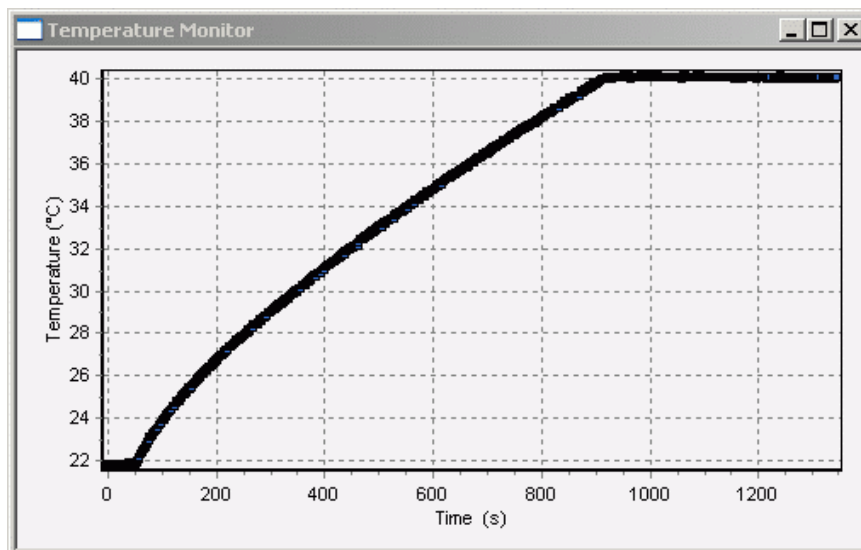
Count Rate Distribution can be saved in common file of results by clicking button **Save**.



Temperature Monitor window

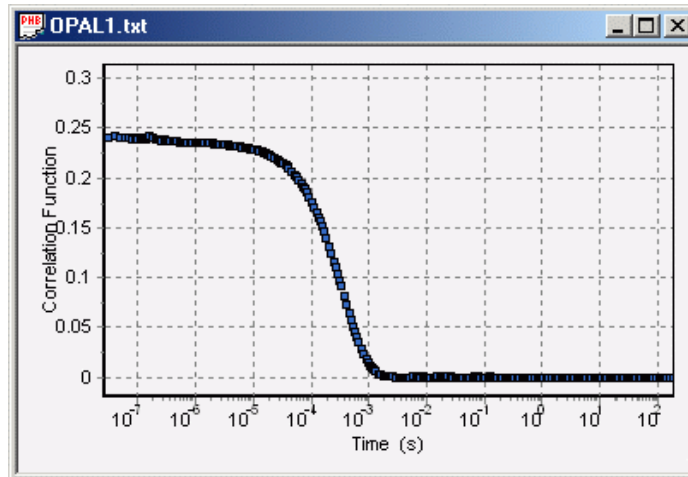
Temperature Monitor window display current temperature in graphical form.

For activation of the window **Temperature Monitor** it is necessary to open menu **View** and select **Temperature Monitor**.



Window for saved files

Saved correlation functions can be displayed in corresponding window. This window appears after open of file from menu **File** or clicking the file open button. Name of window corresponds to name of open file.



Control window

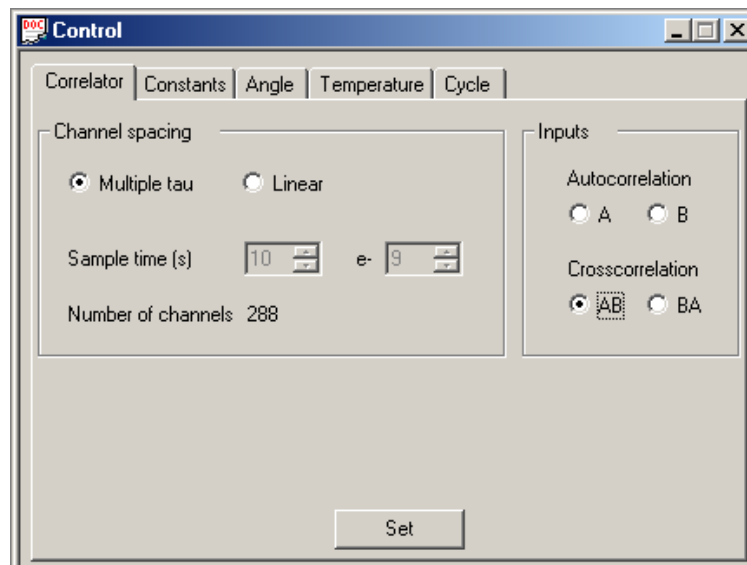
Control window is used to set parameters of experiment.

For activation of the **Control** window, it is necessary to open the **View** menu and select one of the items in the **Control** menu or simply click **Control** button on the toolbar.

Correlator tab

Channel Spacing:

Two radio buttons **Channel Spacing** serves to switch **Multiple tau** or **Linear** hardware configuration of the correlator. If **Linear** channel spacing is set, the correlation function is accumulated and displayed in the linear time-scale. If **Multiple tau** channel spacing is set, the correlation function is accumulated and displayed in the quasi-logarithmic time-scale. The change of the mode must be confirmed with clicking **Set** button.



Operation mode:

The FC correlator has two functionally equal inputs. For autocorrelation measurements input **A** or **B** can be chosen in accordance with the physically used input of the correlator. For cross-correlation **AB** or **BA** modes are available, which corresponds to (current **A** × delayed **B**) or (current **B** × delayed **A**) multiplication of signals.

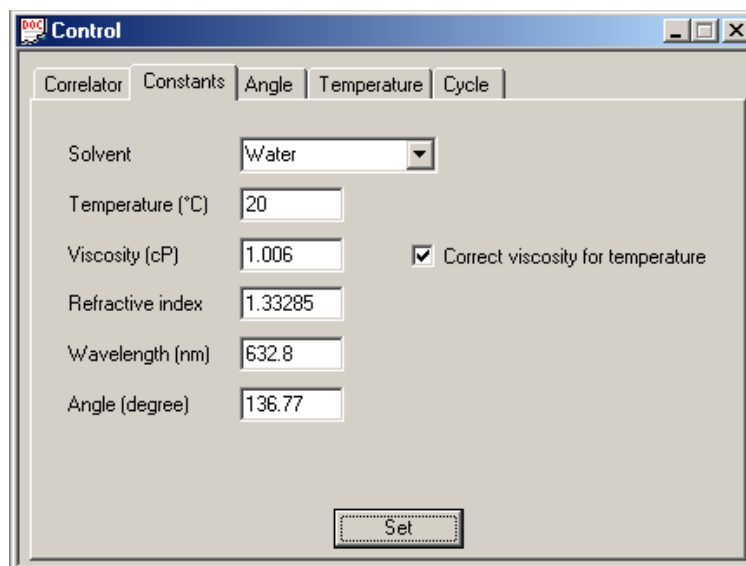
Sample-time setting:

This setting is active for **Linear** channel spacing only. Two spinner controls are used to set value of **Sample time**, one is to set mantissas, another one is to set an exponent value of **Sample Time**.

Any changes in tab **Correlator** will be activated after clicking **Set** button.

Constants tab

The edit strings: **Temperature**, **Viscosity**, **Refractive index**, **Wavelength** and **Angle** allow to set, correspondingly, the values of temperature, viscosity, refractive index of the solvent, laser wave length and scattering angle. A user can choose a solvent from the **Solvent** list box, and **Viscosity** of a solvent will be calculated automatically according to the set temperature. The data for solvents are stored in text files with **.cns** extension. These files should be in the same directory as **Photocor.exe** file. Similar files for any solvents can be created in the same manner, if necessary.



Experimental parameters setting:

Determination of a particle size from the characteristic decay time of a measured autocorrelation function is based on the Stokes-Einstein formula (*see p.21 of this Guide*). Therefore, before data processing it is necessary to let the program know the values of the experiment conditions represented in the formula. They should be set in the **Control-Constants** window. It is necessary to set four values in this menu. They are temperature, solvent viscosity, solvent refractive index, and laser wavelength.

To free the user from the searching of solvent viscosity and refractive index for the given temperature and wavelength through the books and special tables, the FC software includes corresponding files for most widely used solvents. To use this possibility, just set the appropriate solvent in the **Solvent** toggle field of the **Control-Constants** window. After that, solvent viscosity and refractive index will be determined automatically for the preset temperature. If the solvent you are using is not in the list or if you prefer to set the constants manually, just set this field to "no guess".

Solvent file creating:

You can create the corresponding file yourself. The extension of the file should be **.cns** and the file should be placed in the FC software directory. It should be an ordinary text file and you can create it with any text editor. The format of the file is very simple. An example of a table file follows (this is just the file **toluene.cns** file):

```
nD=1.4969 dn/dT=-5.67e-4 dn/dl=0.0
  T      eta
-20.0   0.989
-10.0   0.863
  0.0   0.770
 10.0   0.667
 20.0   0.584
 30.0   0.517
 40.0   0.469
 60.0   0.381
 80.0   0.318
100.0   0.269
```

The first string of the file contents the following values:

n_D is a value of refractive index at $t=20^\circ\text{C}$ and for *Na D*-line wavelength.

dn/dT is a refractive index temperature decrement ($1/^\circ\text{C}$)

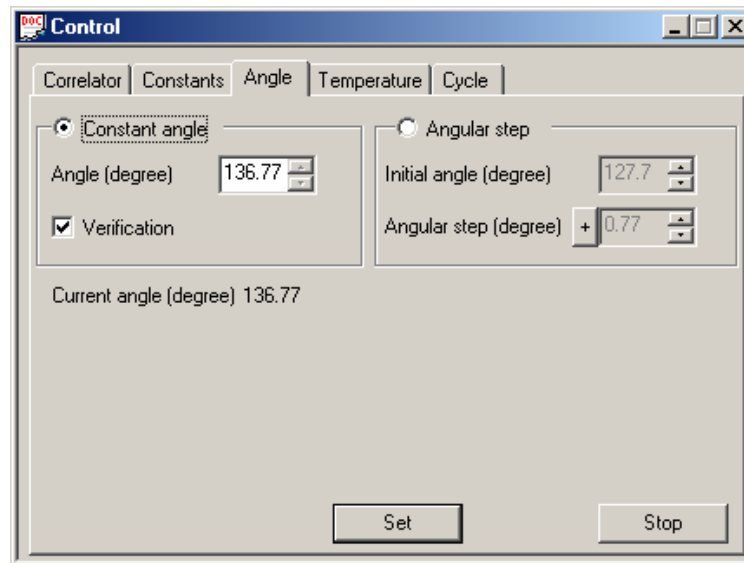
dn/dl is a refractive index wavelength decrement ($1/\text{Å}$)

All the other strings of the file are the table of temperature dependence of solvent viscosity, where T is temperature in *Celsius* and η is viscosity in *cP*. The program calculates the value of a viscosity using the linear interpolation of the closest points of the table. The points should be ordered by the increasing of a temperature. The file name will be included the corresponding list of the **Solvent** toggle.

Any changes in tab **Constants** will be activated after clicking **Set** button.

Angle tab

Stepper motor driven turntable allows automatically to set a scattering angle with resolution 0.01°.



There are two modes of turntable control:

Constant angle mode allows to write desirable value in **Angle (degree)** spinner controls. After click of **Set** button this angle will be set.

Check the box **Verification** means that each angle will be set after verification procedure, which consist in turning of arm to certain angle (150°). After that the arm of turntable will go to the chosen angle. We recommend use this procedure seldom, for example, if scattering angle was set manually with existing knob in the warm gear (in this case turntable will have wrong angle scale). After single verification procedure, please uncheck the box **Verification**.

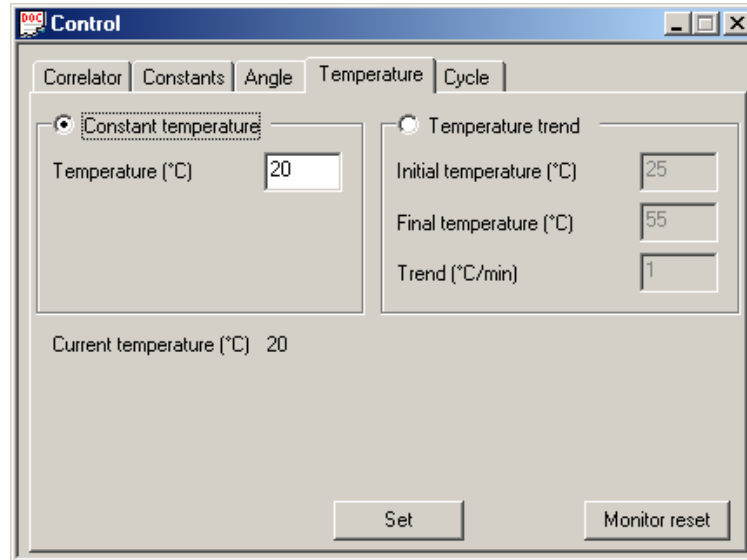
Angular step mode allows to write desirable value of angle in **Initial angle (degree)** spinner controls and desirable value of angle increment in **Angular step (degree)** spinner controls. Each click of **Set** button will change angle from initial value with angle increment equal to chosen step. Sign – (minus) corresponds to decrement of angle changing with clicking of **Set** button.

Running value of angle during turning is shown in **Current angle (degree)** string.

Clicking of **Stop** button interrupt current angle operation.

Temperature tab

Temperature tab allows to control temperature of thermostat with accuracy 0.1° C.



There are two modes of temperature control:

Constant temperature mode allows to write desirable value in **Temperature** spinner controls. After click of **Run** button the temperature will go this temperature. When thermostat reaches this temperature, it will be stabilized with accuracy 0.1° C.

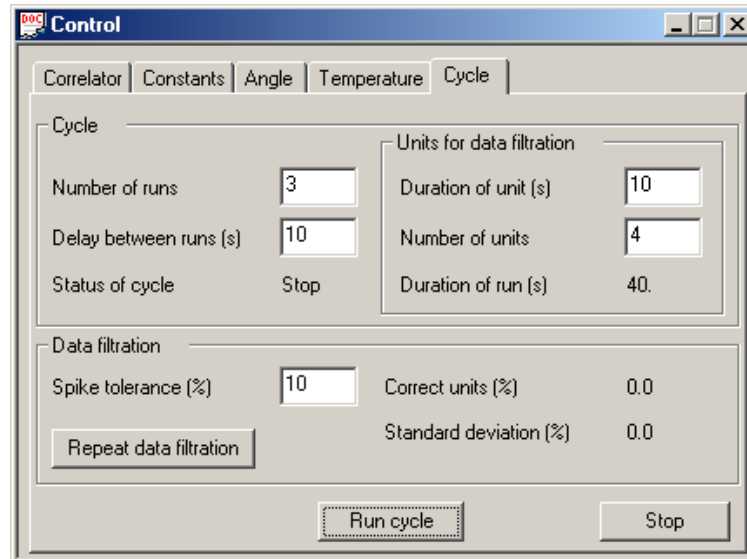
Temperature trend mode allows to assign desirable temperature trend in range of **Initial temperature** to **Final temperature** with assigned **Trend**. This operation starts after click of **Set** button

Running value of temperature is shown in **Current temperature** string.

After click of **Set** button the temperature history will shown in **Temperature monitor** window during all time. To clear **Temperature monitor** window click **Monitor reset** button.

Cycle tab

1. **Cycle** tab allows to run simple cycle of measurement. The **Number of runs** field allows to assign desirable number of measurements. Waiting time between each run is written in **Delay between runs** field. Duration of each run can be assigned in frame **Unit for data filtration**.



The user has two options to assign duration of each run:

2. To write desirable duration of measurement in the **Duration of unit** field and write 1 in the **Number of units** field. In this case duration of run will be equal to duration of unit and possible following data filtration will be not available.

Desirable duration of measurement can be divided on many short units with duration of each unit written in the **Duration of unit** field and number of these units written in the **Number of units** field. Obtained array of correlation function can be analyzed with the **Data filtration** procedure. This procedure allows indicating the "bad" units and creating the summarized correlation function without these "bad" units. Data filtration procedure based on well-known fact that light scattering intensity on seldom large particles of contaminations (dust particles) considerably increases the average light scattering. Threshold for indication of the "bad" units can be assigned in **Spike tolerance** field. Correctness of the data filtration procedure can be estimated with corresponding values shown in **Correct units** and **Standard deviation** fields. For the last run of the cycle the Data filtration procedure can be repeated many times (**Repeat data filtration** button), for example, with the various spike tolerance values. This option is suitable for fine tuning of the data filtration procedure to find the optimal spike tolerance for the certain sample under investigation.

FC title bar

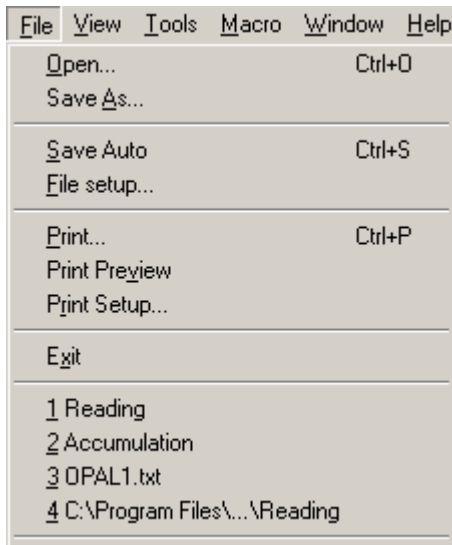


The title bar displays the name of the application and current active window.

FC menu bar



File menu



Open

Opens an existing file. Use this command to show and fit the saved correlation function again.

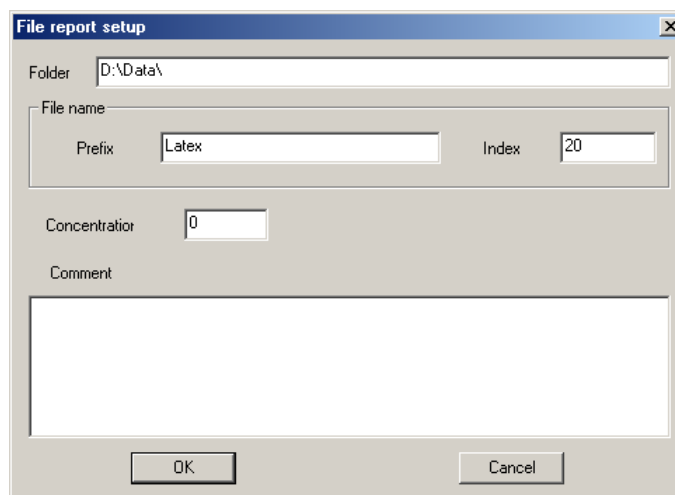
Save As

Save the current file to a specified file name.

Save Auto

Save with auto-indexation.

File Setup



FC allows assigning file names automatically. To adjust the auto-indexation mode, follow the steps:

1. Open **File** menu and select **File setup**. **File report setup** window will appear.
2. Specify a new file name into **Prefix** edit string. Specify the starting index into the **Index** edit string. The index is automatically incremented after each saving of the file. The name of the file is a combination of a prefix and an index.
3. Folder for saving is specified in **Folder** edit string.

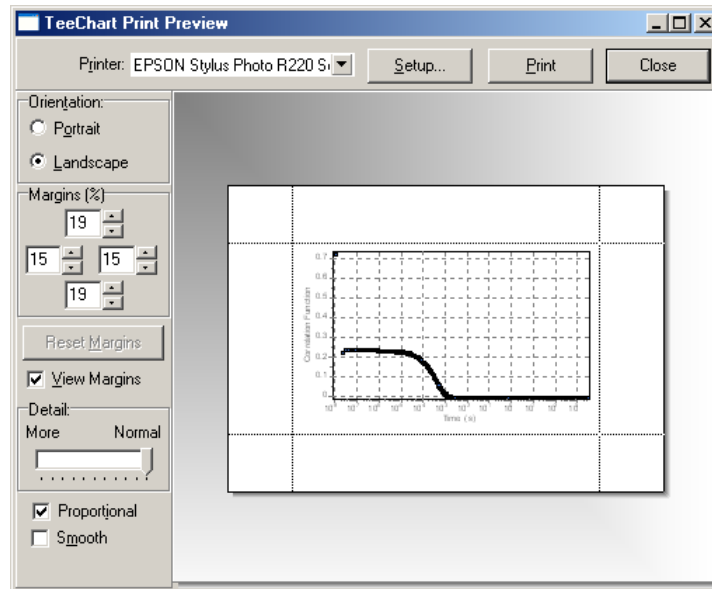
4. Click **OK**.

After auto-indexation has been adjusted, to save a protocol file simply open **File** menu and choose **Save Auto**, or click **Save** on the toolbar.

Print

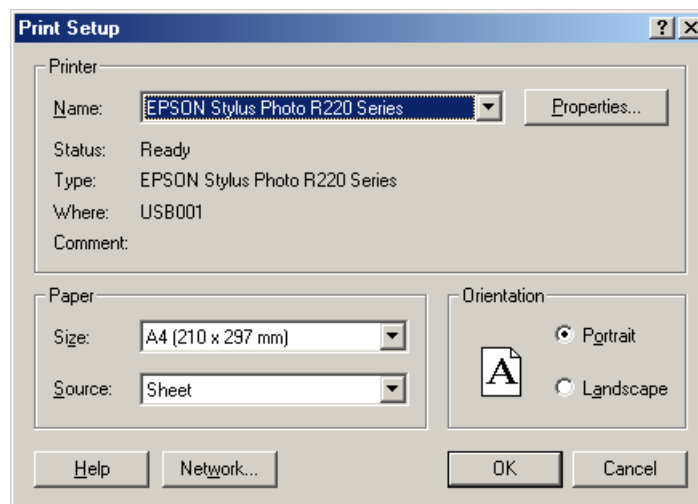
Prints a document.

Print Preview



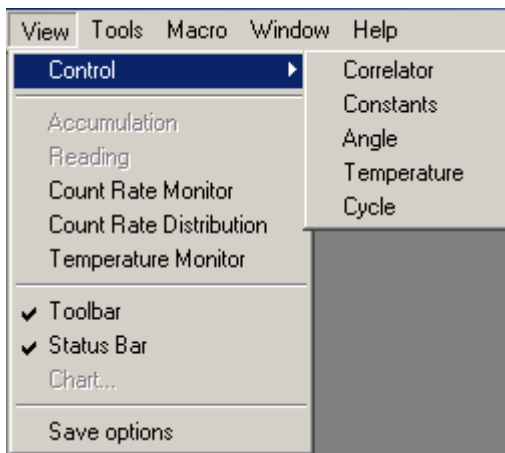
After all settings are completed, check how the data is arranged on pages before printing. For this purpose open **File** menu and select **Print Preview**. Your file will be displayed on the screen in the way, as it will be printed. Click **Print** in **TeeChart Print Preview** window.

Print Setup



Before printing, make sure that parameters of pages are set correctly. For this purpose open **File** menu and select **Print Setup**. An appropriate window will appear.

View menu



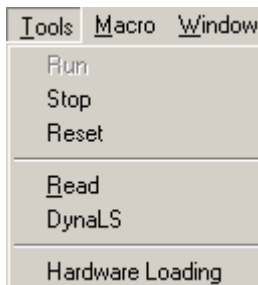
Control

Opens **Control** window in appropriate tab.

Accumulation, Reading, Count Rate Monitor, Count Rate Distribution, Temperature Monitor

Opens appropriate window.

Tools menu



Run starts the process of accumulation of the correlation function in the correlator.

Stop stops the process of accumulation of the correlation function.

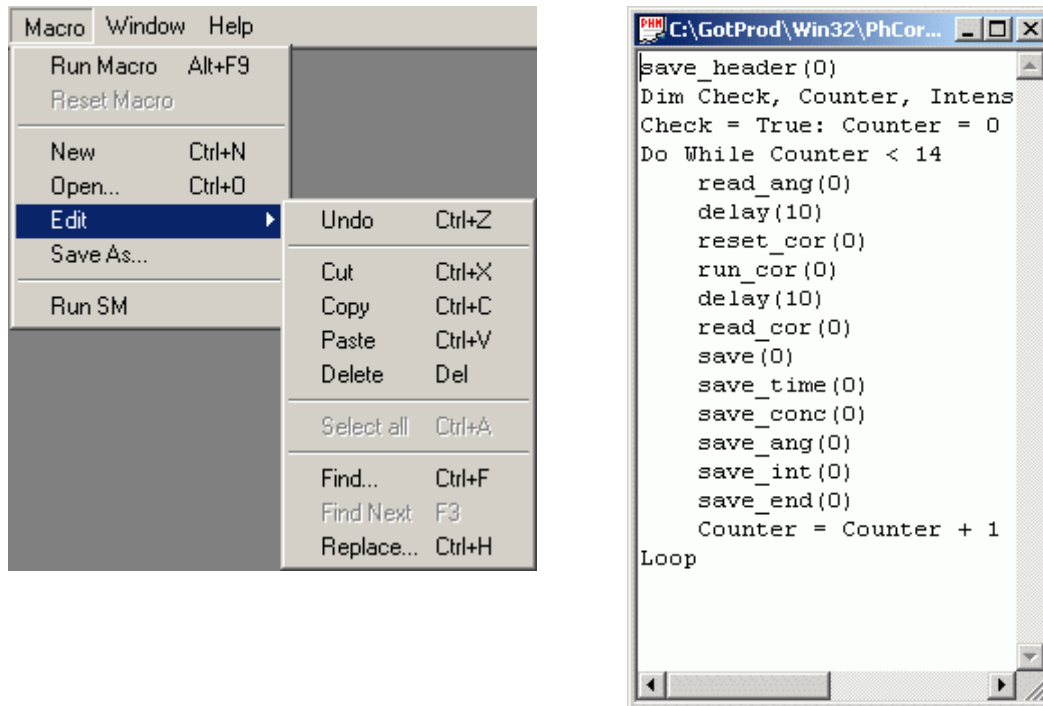
Reset resets the correlator, i.e. sets all channels of the correlator to zero. Thus, the correlator is ready for a new measurement. If the data accumulated was not preliminary saved before **Reset**, it will be completely lost.

Read reads out the current value of the correlation function into the computer. This correlation function may be fitted, saved and so forth. Reading-out of the correlation function into the computer does not interfere into the accumulation process. Therefore, repeated reading of the correlation function without stopping the process of accumulation is available.

DynaLS export measured correlation function to DynaLS software.

Macro menu

FC software supports Microsoft Visual Basic Scripting. This means you can write powerful macros that automate your measurements. Macro program examples can be found in **Macro** subdirectory of the main application. (**C:\Program Files\FC\Macro** by default)



The FC macro functions on the **Macro** menu allow one to create, save, and execute a macro file. A macro file contains the FC macro language commands that instruct the FC correlator in accordance with the desirable consequence of steps. These commands can cause a message to be displayed, control and start sub-processes, set global variables, etc. All manual operations, which are available to a user, can be performed by executing the appropriate macro command or running the macro file.

Macro functions of the FC program

Note: Argument of function must be a needed variable inside the parenthesis. For functions without variables, argument must be (0). Argument of function can be the integer (N) or the real (R). For some functions the variables N or R have restricted range.

Main functions for measurement control

run_cor(0)

start the correlation function accumulation
(the **Accumulation** window will be active after executing these command)

read_cor(0)

read the correlation function from correlator to computer
(the **Reading** window will be active after executing these command)

stop_cor(0)

stop the correlation function accumulation
(the **Accumulation** window will be active after executing these command)

reset_cor(0)

reset of the correlator

(the **Accumulation** window will be active after executing these command)

delay(N)

delay for N seconds. If **N=-1** the function will wait for **run_cycle(0)** command to be complete

update(0)

updating the data on the **Constants** tab in the **Control** window

* **run_cycle(0)**

start the cycle with parameters defined on the **Cycle** tab in the **Control** window. After finish of the cycle procedure the **Data filtration** performs. Then the results are saved in the file with **.txt** extension. The file name/index defined in the **File report setup** window.

After execution of this command the value of the file index in the **Index** field in **File report setup** window will be increased by 1.

Functions for the correlator setting.

* **set_spacing(N)**

if **N** is **0**, the linear mode set;

if **N** is **1**, the **Multiple tau** set.

* **get_st(0)**

return the current value of the **Sample time**

usage example:

set_spacing(0)

a=get_st(0)

MsgBox "Sample time: " & a

* **set_stm(N)**

set the the **Sample time** mantissa in the **Correlator** tab of the **Control** window.

It is necessary to switch correlator to the linear mode before using this command.

Range of N values is 1 to 99.

* **set_ste(N)**

set the **Sample time** order of magnitude in the **Correlator** tab of the **Control** window.

It is necessary to switch correlator to the linear mode before using this command.

Range of N values is -9 to -1.

read_st(0)

read the **SetTime.txt** file from the folder where the **Photocor.exe** file located. At every command execution the next line from the **SetTime.txt** file will be read. Then the value from this string will be entered to the **Sample time** field on the **Correlator** tab in the **Control** window.

usage example: see **Macro\st1.phm** file.

Using this command it is impossible to read any string from the **SetTime.txt** file.

Before using this command it is necessary to switch the correlator to the linear mode.

Functions for the turntable control

* **set_angle(R)**
set the angle on the turntable

wset_angle(N)
the checking procedure of the angle setup finishing will be performed for the **N** seconds.
If the angle setup is finished before **N** seconds, the next command of the macro file will be executed immediately

read_ang(0)
read the **Setangle.txt** file from the folder, where the **Photocor.exe** file located. At every command execution the next line from the **Setangle.txt** file will be read. Then the value from this string will be entered to the **Angle** field on the **Angle** tab in the **Control** window. After that the angle will be set on the turntable.

usage example: see **Macro\Indik1.phm** file

Using this command impossible to read any string from the **Setangle.txt** file.

Functions for temperature control

set_temp(R)
set the temperature in the **Temperature** filed on the **Temperature** tab in the **Control** window.
The process of temperature control starts immediately.

read_tx(0)
read the **SetTemperature.txt** file from the folder where the **Photocor.exe** file located. At every command execution the next line from the **SetTemperature.txt** file will be read. Then the value from this string will be entered to the **Temperature** field on the **Temperature** tab in the **Control** window and temperature control starting.

usage example: see **Macro\termo1.phm** file

Using this command it is impossible to read any string from the **SetTemperature.txt** file.

Main functions to work with the measurement file

open_win_file_conf(0)
open the **File report setup** window

set_file_index(N)
set the file index in the **Index** field in **File report setup** window.
Take into account that file index while saving to the disk of the computer will be converted to five-digit format, i.e. if you enter 1 as file index, file name will be: **Test00001.txt**

save(0)
save the standard file of the measurement with **.txt** extension. File name and file index correspond to the name, assigned in the **File report setup** window.
After execution of this command the value of the file index in the **Index** field in **File report setup** window will be increased by 1.
Take into account that before saving the data to files it is necessary to read the correlation function to the computer using the following command:

read_cor(0)

Additional functions to work with the measurement file

These functions allows to create file with custom-selected data

save_header(0)

Create file with **.pcs** extension which defined in the **File report setup** window. In this case the file index, entered in the corresponding filed in the **File report setup** window, will be ignored and the 000 always used as file index for the **.pcs** files. Impossible to assign a custom file index for the **.pcs** files.

Important: this command is required to use other commands from the following list.

save_time(0)

write the system time when the correlation function was red from correlator to the memory of computer

save_temp(0)

write the latest temperature read from the temperature controller, or the **Temperature** string from **Constants** tab in **Control** window if controller are switched on.

save_int(0)

write the current measured intensity and the current value of coherence to the file with **.pcs** extension. For crosscorrelation mode (**AB** or **BA** is selected) the sum of the intensities from the both channels will be saved.

save_coherence(0)

write the current coherence to the file with **.pcs** extension

save_conc(0)

write the value of **Concentration** in the **File report setup** window to the file with **.pcs** extension

save_phd(0)

write the value of intensity monitor to the file with **.pcs** extension (only if intensity monitor switched on)

save_ang(0)

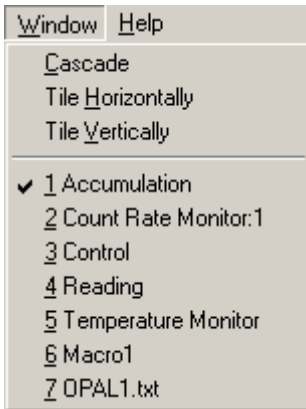
write the value of the **Angle** from **Angle** tab in the **Control** window to the file with **.pcs** extension

save_end(0)

write the end-of-line symbol to the file with **.pcs** extension. Used for **.pcs** file formatting.

* - function in non-active, if **Control** window is closed.

Window menu



Cascade

Arranges windows in an overlapped fashion.

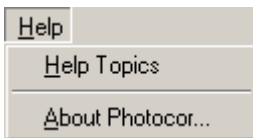
Tile Horizontally, Tile Vertically

Arranges windows in non-overlapped tiles.

1, 2, 3, ...

Goes to specified window.

Help menu



Help Topics

Displays the help file.

About FC

Displays the version number of application.

FC toolbar

The toolbar is placed on the main FC window. It duplicates executing some functions of the menu bar. To execute a required operation or to choose any option, simply click the necessary button.



Open opens the **Open** dialog box for opening a saved FC file. The button executes the same command as **Open** from the **File** menu.

Save saves the current results into a file with presetting made in the **File setup** window. The button executes the same command as **Save Auto** from **File** menu.

Print opens the **Report Printing** window for printing a hard copy of the measurement protocol. The button executes the same command as **Print** from menu **File**.

Run starts the process of accumulation of the correlation function in the correlator. The button executes the same command as **Run** from menu **Tools**.

Stop stops the process of accumulation of the correlation function. The button executes the same command as **Stop** from menu **Tools**.

Reset resets the correlator, i.e. sets all channels of the correlator to zero. Thus, the correlator is ready for a new measurement. If the data accumulated was not preliminary saved before **Reset**, it will be completely lost. The button executes the same command as **Reset** from menu **Tools**.

Read reads out the current value of the correlation function into the computer. This correlation function may be fitted, saved and so forth. Reading-out of the correlation function into the computer does not interfere into the accumulation process. Therefore, repeated reading of the correlation function without stopping the process of accumulation is available. The button executes the same command as **Read** from menu **Tools**.

DynaLS export measured correlation function to DynaLS software.

Control activates **Control** window. The button executes the same command as Control from menu View.

FC status bar

The status bar of the program is placed in the bottom of the main FC window. The status bar contains six *indicators*:

Angle =134.38	Temperature =17.88	Intensity =0	Elapsed Time =1680.0	Accum Time =0.0	Coherence =1.0
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Angle – shows current angle;

Temperature – shows current temperature;

Intensity - shows the current average intensity during accumulation;

Elapsed Time - time elapse since run;

Accumulation time - shows effective time of accumulation of the correlation function;

Coherence - shows a ratio of the maximum ordinate of the exponential correlation function to the base-line value.

APPENDIX A

DYNAMIC LIGHT SCATTERING (PHOTON CORRELATION SPECTROSCOPY)

Basic ideas of a correlator

The FC correlator is a powerful device for the measurements of time-dependent correlation functions. The cross-correlation function G_{12} of two signals (light-scattering intensity, for example) $I_1(t)$ and $I_2(t)$ describes the similarity of the signals in the time domain. This function is defined as

$$G_{12}(\tau) = \langle I_1(t) \cdot I_2(t+\tau) \rangle$$

where τ is delay time and the angle brackets denote an average over the time t . The autocorrelation function describes the correlation between a signal and a delayed version of itself of a signal $I_1(t)$:

$$G_{11}(\tau) = \langle I_1(t) \cdot I_1(t+\tau) \rangle$$

The correlator's algorithm consists of a multiplication of one signal with another that has been shifted (delayed) in time and then taking the integral of the product over time.

The FC is designed for operation with the photon correlation spectroscopy (PCS) technique. Briefly, it can be explained as follows: the laser beam is scattered by the particles or macromolecules suspended in a liquid and undergoing Brownian motion. The scattered light spectrum is broadened due to the various phase shifts. The half width of the scattered light spectrum is given by the formula:

$$\Gamma = Dq^2$$

where D is the linear diffusion coefficient of the Brownian particles and q is the modulus of the scattering wave vector. For a monodisperse suspension, the diffusion coefficient D is related to the particle hydrodynamic radius R by the Stokes-Einstein equation:

$$D = kT / 6\pi\eta R$$

where k is the Boltzman constant, T is the absolute temperature, η is the shear viscosity of the solvent. The autocorrelation function of the scattered-light field in a normalized form is

$$g_1(\tau) = e^{-\Gamma\tau}$$

The autocorrelation function of the light-scattering intensity is the fold of the Fourier transform of the spectrum with itself and has the normalized form:

$$g_2(\tau) = 1 + |g_1(\tau)|^2 = 1 + e^{-2\Gamma\tau}$$

The decay time is determined by the particle size. In the case of a mixture of particles with different sizes, one can obtain:

$$g_1(\tau) = \int G(\Gamma) e^{-\Gamma\tau} d\Gamma$$

The scattered light is received by a photodetector and the output signal of the detector is processed by the digital correlator to obtain the autocorrelation function. A computer calculates the mean size or

size distribution of the suspended particles from the autocorrelation function by inversion of the relation given above.

RECOMMENDED LITERATURE

B. Chu. Laser Light Scattering. Academic Press, N.Y., 1974

H.Z. Cummins and E.R. Pike eds. Photon Correlation and Light Beating Spectroscopy. Plenum Press, N.Y., 1974

B.J. Berne and R. Pecora. Dynamic Light Scattering with Applications to Chemistry, Biology and Physics. Willey-Interscience, N.Y., 1976

H.Z. Cummins and E.R. Pike eds. Photon Correlation Spectroscopy and Velocimetry. Plenum Press, N.Y., 1977

V. Degiorgio, M. Corti and M. Giglio eds. Light Scattering in Liquids and Macromolecular Solutions. Plenum Press, N.Y., 1980

S.H. Chen, B. Chu and R. Nossal eds. Scattering Techniques Applied to Supramolecular and Nonequilibrium Systems. Plenum Press, N.Y., 1981

B.E. Dahneke ed. Measurement of Suspended Particles by Quasi-Elastic Light Scattering. John Wiley & Sons, N.Y., 1983

R. Pecora ed. Dynamic Light Scattering - Applications of Photon Correlation Spectroscopy. Plenum Press, N.Y., 1985

K.S. Schmitz. An Introduction to Dynamic Light Scattering by Macromolecules. Academic, 1990

W. Brown ed. Dynamic Light Scattering: the Method and Some Applications. Clarendon Press, Oxford, 1993

E.R. Pike and J.B. Abbiss eds. Light Scattering and Photon Correlation Spectroscopy. Kluwer Academic Publishers, 1997

I.K. Yudin, M.A. Anisimov, V.A. Agayan, V.I. Kosov, G.L. Nikolaenko, J. Sengers. A compact photon-correlation spectrometer for research and education. Int. J. Thermophys., 18, pp.1237-1248, 1997