CONTROL UNIT

FOR OPTICAL RADIATION MEASUREMENT PROBES
PCE-LMD 100 and PCE-LMD 200

Instruction manual

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1 . CHARACTERISTICS OF INSTRUMENT

The control unit is designed to control measurement probes used for optical radiation measurement. The measurement probes are complete meters that communicate with a control unit through a digital interface with the use of the manufacturer's data transmission protocol. With the aid of the control unit you can read measurement results, average them and save them to the memory afterwards. You can also change the settings of the attached probe and calibrate it. The instrument is equipped with a micro SD card, on which the measurements results can be saved. The data on the micro SD card can be transmitted to a PC with the use of a standard memory card reader. You can also connect the unit with a PC using a micro USB cable, so in this case the card is seen as an external drive. The control unit is equipped with an inbuilt high-capacity LiION battery that can be charged with the fast charger which is an accessory to the instrument or with any other charger used for mobile phones with a micro USB connector.

measurement probe socket

USB socket

charging status LED

extension socket

SD card slot

Fig. 1.1. control unit – main view.

1.1. Equipment

1.1.1. Basic accessories:

- Mains charger.
- 1m USB (micro USBA-USBB) cable.
- 4GB memory card.
- Plastic carrying case used for transport of instruments.
- Instruction manual.

1.2.2 Input and output connectors ofcontrol unit

The instrument is equipped with the below-given elements:
- a FISHER connector that is used to connect the measurement probe to the instrument,
- a type B micro USB connector used for charging the battery and exchanging data,
- a RJ-11 connector to connect extensions and to the firmware update,
- a micro SD card slot.

The position of input and output connectors is shown in Fig. 1.1.

1.3. Technical data

- Dimensions (excluding a FISHER connector)   107 x 70 x 20mm
- Weight   150g
- Power supply
  - internal battery   Li-ION 3.6V / 1500mAh
  - charger   TC21U2 5V / 2.1A
- Environmental conditions:
  - temperature   -20°C – +50°C
  - humidity   < 90% (non-condensing)
- Time of continuous operation with a
  fully-charged battery   23h

2. CONTROL OF INSTRUMENT

The control of the instrument is possible with the use of the keyboard.

2.1. Control keys

The keyboard of the instrument consists of:
- on/off key:

- control keys:

In order to switch the instrument on, press the following key: . In order to switch the instrument off, press the same key and hold it down for 3 seconds.

To display the MENU, press the following key on the results screen (see Sec. 2.4). It is possible to enter the menu only then when the measurement procedure is stopped.

To navigate through the menu, use the following keys: . To enter numerical values, use the given keys: . The following key is used to save to a file the measured quantity that is displayed on the results screen (detailed description of measurement memory can be found in Sec. 3.7). When the results screen is displayed, the key can be used to trigger a single measurement or to start / stop a continuous measurement.

2.2. Menu

2.2.1. Zeroing

Detector – starts the procedure for determination of detector dark current. The procedure should be conducted only when the probe is covered.
System – starts the procedure for determination of measurement circuit offset voltage.

2.2.2. Memory

New file – creates a new file used for saving data.
Autosave – turns on/off the automatic saving of measurements to the memory.
Interval – sets the time interval between the subsequent auto saves.
Memory card – displays information about the installed memory card: a card type, file system, capacity and the remaining free space.

2.2.3. Measurement setup

Single – chooses a single measurement mode.
Continuous – chooses a continuous measurement mode.
Relative – chooses a relative measurement mode. When it is turned on, it is necessary to enter the reference value (the default value is the latest measured value). When the relative measurement mode is turned on, the statistics and integration are turned off.
Statistics – it is a sub-menu to change the statistics settings. The statistics option is related solely to both single and continuous measurement modes. As for the integration mode, the statistical calculations are done independently.
Statistics->Add measurement – adds the last measurement to statistics. If the statistics is turned off, it turns it on.
Statistics->Clear all – deletes and turns off the statistics.
Statistics->Auto add – turns on/off the function of the automatic adding of every measurement to statistics.
Integration – turns on/off the integration. If the statistics is turned on, it turns it off. If the relative measurement is on, it is turned off. Additionally, the autorange and continuous measurement mode are set; these settings can not be changed in the integration mode.
Delete integral – it is used to delete the integration results and statistics related to integration; it requires further confirmation.
Autorange – turns on/off the automatic change of the measurement range.
Averaging – sets the result averaging time.

Luminance – it is a sub-menu to choose a luminance measurement adapter (only when the measurement probe is equipped with that function). This option is inactive in the case of a luminance meter.

2.2.4. User setup

Contrast – adjusts the display contrast.
Brightness – adjusts the brightness of the display.
Backlight – sets the operation mode of display backlight. There are three options to choose from:
> **On** – the backlight is turned on all the time,
> **Off** – the backlight is turned off all the time,
> **Auto** – the backlight is turned on when any key is pressed and it is turned off when the set time limit passes.

Autooff – turns on/off the function of the automatic turning off of the instrument. If the function is activated, the instrument is turned off automatically after the set time of inactivity (the instrument is not turned off when the measurement runs).
Date and time – enters the current date and time.
Language – selects one of the languages of the menu.

2.2.5. Calibration

This option of the menu triggers the calibration and adjustment procedure described in Sec. 3.3.

2.2.6. Applications

This sub-menu allows you to run the advanced applications described in Sec. 4.

2.2.7. Panel info

The panel information screen shows: its type, serial number, manufacture year, firmware version, measurement module version and current battery voltage.

2.2.8. Head info

The information is displayed about the attached measurement probe showing: its type, serial number, manufacture year, firmware version and calibration factor.

2.3. Splash screen

On the splash screen there is the following data: an instrument name, firmware version and measurement module version. There is also the manufacturer's data such as their WWW address and phone number.

Pressing on the splash screen the following key or causes the display of menu command referred to as **User setup->Contrast**. This shortcut is used to set the contrast even if there is no information shown as a result of contrast setting being too high or too low. Pressing any key leads to entering the results screen. The results screen displays automatically in 30 seconds' time.

2.4 Results screen

Results screen comprises a measurement window, icon bar and a field with the current date and time. Its layout is different for every operation mode. In the below-given pictures there is the layout of results screen shown for different operation modes. The layout is refreshed every second.
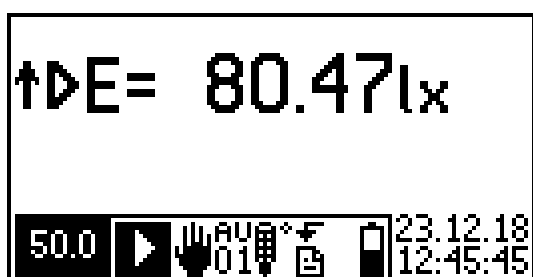
Fig. 2.2. Single measurement.
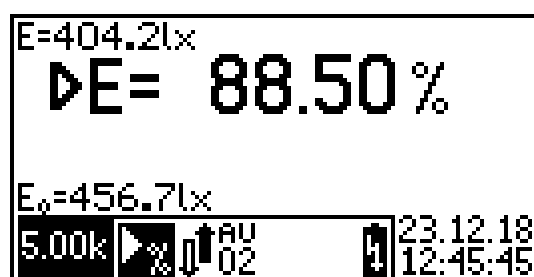
Fig. 2.3. Single relative measurement.
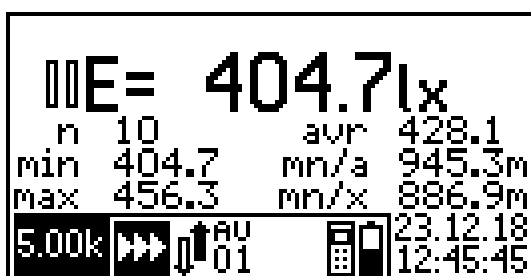
Fig. 2.4. Continuous measurement, statistics.
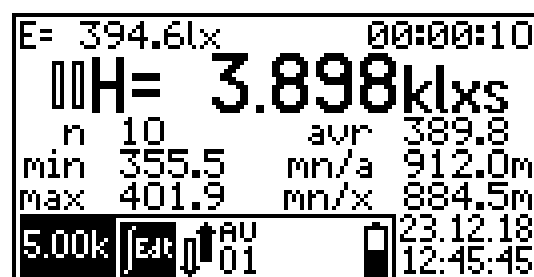
Fig. 2.5. Continuous measurement, integration.

2.4.1. Active control keys.

It enters the instrument menu. It works only when the measurement is stopped.

It starts/stops a continuous measurement, triggers a single measurement.

It changes the measurement range to a higher level (if the autorange is turned off, the change of the measurement range is possible only when the measurement is stopped).

It changes the measurement range to a lower level (if the autorange is turned off, the change of the measurement range is possible only when the measurement is stopped).

It saves the current measurement to a file.

2.4.2. Measurement window

The measurement window comprises:
- measurement status indicator:
  - ‖ pause,
  - ▷ measurement,
- ↑ indicator of measurement range exceedance,
- measured quantity indicator:
  - E= illuminance/irradiance,
  - L= luminance/radiance,
  - H= luminous/radiant exposure,
  - G= luminance/radiance dose,
- results field with the measured value,
- field of the measured value unit.

Additionally:

for relative measurement mode: the currently measured value in the top left corner of the screen and the reference value in the bottom left corner of the screen,

integration mode: the currently measured value in the bottom left corner of the screen and integration time in the top right corner of the screen according to the format of hours:minutes:seconds.

integration and statistics mode: the statistics field comprises: the number of measurements (n), the minimum value (min), the maximum value (max), the average value (avr), the quotient of the minimum and average value (mn/a), the quotient of the minimum and maximum value (mn/x).

The metric prefix can be added to the original unit of the measured quantity in accordance with the International System of Units (SI).
The used symbols are given below:

sub-multiplies			multiplies		
symbol	name	base 10	symbol	name	base 10
y	yocto	10^{-24}	k	kilo	10^{3}
z	zepto	10^{-21}	M	mega	10^{6}
a	atto	10^{-18}	G	giga	10^{9}
f	femto	10^{-15}	T	tera	10^{12}
p	piko	10^{-12}	P	peta	10^{15}
n	nano	10^{-9}	E	eksa	10^{18}
μ	mikro	10^{-6}	Z	zetta	10^{21}
m	mili	10^{-3}	Y	yotta	10^{24}

2.4.3. Measurement results format

The measurement result that is read from the probe is displayed on the result field of the measurement window with the resolution dependable on the type of the attached probe (in the case of most probes there are 4 significant digits). The position of the decimal point and multiplier of the unit are matched together in order to achieve the highest precision.

2.4.4. Icon bar

In the bottom of the screen there is an icon bar, which indicates the status of the instrument:

- **5.00k**   currently chosen measurement range,
- measurement mode:

             single measurement,

             continuous measurement,

             single relative measurement,

             continuous relative measurement,

             integration,

- mode of measurement range change

             automatic,

             manual,

- **01**   time of result average (in seconds),
-        exceedance of acceptable operation temperature range of attached probe or temperature sensor failure,
- memory saving status:

             autosave is turned on (with set time interval),

             successful data saving to memory (animation),

             unsuccessful data saving to memory (animation),

-        automatic adding of all measurements to statistics is turned on,
- state of battery:

             battery charged to 100%,

             battery charged to 80%,

             battery charged to 60%,

             battery charged to 40%,

             battery charged to 20%,

             dead battery,

             dead battery, it is possible that the instrument turns off automatically

             battery is being charged,

2.4.5. Date and time

In the bottom right corner of the screen there is the current date in the format of day, month, year and the current time in 24 hours format.

3. WORKING WITH MEASUREMENT PROBE

3.1. Connection of measurement probe

3.1.1. Elements of measurement system

- measurement probe,
- measurement module of control unit
- control unit

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3.1.2. Assembling of measurement system

The measurement probe should be attached to the socket in the control unit. After turning on the power supply of the unit there is a splash screen with the information on the installed firmware and measurement module version.

3.2. Measurement

3.2.1. Preparation for instrument operation

The measurement should be started (see Sec. 3.2.2) and the instrument readings should be checked with the covered probe. If the instrument does not read zero, the zeroing procedure should be conducted (see Sec. 3.2.1.1). After the zeroing procedure is finished, the probe should be uncovered. The instrument is ready for operation.

3.2.1.1. Zeroing of detector

The zeroing procedure of the detector consists in the measurement of the dark current of the measurement probe detector and its corresponding temperature (see Sec. 3.2.4). On the basis of this, the probe calculates the correction for the current operation temperature and deducts it from the result. The proper procedure is started with the use of the **Zeroing->Detector** menu command. It can be conducted only with covered the reception field of the probe. The value of the dark current and the temperature of the zeroing are saved to the memory of the measurement probe.

3.2.1.2. Zeroing of measurement system

The zeroing procedure of the measurement system consists in the direct measurement of the correction that results from the measuring circuit offset voltage (see Sec. 3.2.4), which is deducted from the result. It is automatically conducted after the probe is connected to the control unit and whenever the detector is zeroed. The User can start the procedure of the measurement system zeroing by using the **Zeroing->System** menu command. The value of the correction and the temperature of the zeroing are saved to the memory of the probe.

3.2.1.3. Automatic change of measurement range

In order to turn on/off the automatic change of the measurement range, the User should follow the **Measurement settings->Autorange** menu command. The manufacturer recommends turning on the automatic change of the measurement range. The manual control is used for checking the linearity during the calibration or in the specific conditions of the measurement when the measured value changes in time in such a way that the instrument is incapable of determining the proper measurement range.

3.2.1.4. Additional actions

If the instruction manual of the attached probe requires the conduction of any additional actions which are not included in Sec. 3.2.1, these activities should be conducted.

3.2.2. Measurement triggering

To trigger the measurement, use **Start/Stop measurement** (see Sec. 2.1) or the key which some measurement probes are equipped with. The key can also have other functions, which depends on the currently running application.
The measurement time depends on the set operation mode.

- **Single measurement mode** – the measurement lasts for the set averaging time and it stops automatically when the set time elapses.
- **Continuous measurement mode** – the measurement lasts until the key for starting the measurement is pressed once again.

In the case of controlling the measurement triggering with the use of the probe key, the measurement lasts until the key is released, but not shorter than the set averaging time. If during averaging time at least one partial result is measured when measurement range was exceeded, the measured value is considered to be erroneous and the proper icon is displayed in front of the result (see Sec. 2.4.2). The icon is turned off after the set averaging time has elapsed since the last exceedance. The measurement is stopped after the trigger key is pressed again. The result is not refreshed then.

3.2.3. Averaging of results

The measurement value displayed in the measurement window consists of many partial measurements taken from the attached probe. The displayed result is the arithmetic average of all read values within the set averaging time. The frequency of reading partial results from the probe depends on its type and is chosen so as not to omit any of them. The averaging time is set in the menu **Measurement setup->Averaging** from the 1 – 10 seconds range. The result is refreshed every second and is the moving average from N last seconds where N stands for the set averaging time.

3.2.4. Temperature compensation

The change in the temperature of the probe influences the measurement result. Due to the temperature change, the other parameters also change and they are as follows:
- detector dark current   - shift of zero indication,
- offset voltage of the measuring circuit   - shift of zero indication,
- responsivity of a detector   - change of measured quantity value,
- gain of the measuring circuit   - change of measured quantity value.

Measuring probes are equipped with the temperature sensor and functions that minimise the influence of the above-mentioned factors on the measured value. The compensation of zero indication occurs after the zeroing of the detector (see Sec. 3.2.1.1) or measuring circuit (see Sec. 3.2.1.2). Moreover, all measurement probes are equipped with the function of automatic compensation of temperature influence on the measurement result. That solution significantly expands the operating temperature range minimising the measurement uncertainty.

3.2.5. Luminance mode

Illuminance/irradiance probes with the suitable adapter attached to them become luminance/radiance meters – depending on the probe type. Each type of the measuring probe has assigned permissions to adapters, with which they can work. The choice of adapter is possible with the use of the **Measurement setup->Luminance** menu command.

3.3. Calibration and adjustment of measuring probe

Calibration and adjustment procedure is the comparison of the measured values with those of a calibration standard of known accuracy. On the basis of this comparison, the calibration factor is calculated and saved to the measuring probe. Calibration should be conducted by a competent laboratory equipped with the suitable instruments and the proper photometric/radiometric standards. The calibration procedure is started with **Calibration** menu command (see Sec. 2.2.5). In the calibration mode, the temperature

compensation of the result is turned off; the temperature, in which the adjustment is made, is measured with the probe and is the reference for the temperature compensation algorithm.

The calibration procedure starts with the display of the results screen and the measurement is started (see Fig. 3.1). After pressing the **ENTER** key, there displays a screen on which the correct value of the measured quantity is entered (see Fig. 3.2). The approval of the correct value leads to displaying the summary of the calibration. In the new window there are displayed two calibration factors: the current one that is read from the probe and the one that has just been calculated (see Fig. 3.3). The acceptance of the new calibration factor results in saving it to the probe. At the end of the procedure there is a message that informs about the success or failure of the calibration and adjustment procedure.

The reasons for failure of calibration and adjustment procedure can be the following ones:

● the exceeded range of calibration factor (the permissible range is 0.01 – 9.99),
● an error in saving the calibration factor to the measuring probe (e.g. due to disconnecting the probe before the saving process is completed).

Before the final approval of the new calibration factor with the use of the **ESC** key it is possible to go back to the previous step of the procedure.

Fig. 3.1. Calibration and adjustment procedure – results screen view.
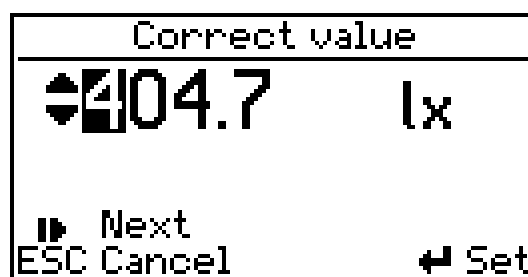
Fig. 3.2. Calibration and adjustment procedure – entering correct value.

Fig. 3.3. Calibration and adjustment procedure - summary

3.4. Relative measurement

The relative measurement mode makes it possible to perform measurements whose results are presented as the percentage value of the reference value.

This mode is turned on with the use of the **Measurement setup->Relative** menu command. After choosing this option from the menu, there is a window used for entering the reference value. The default value is the recently-measured value. There is the main result expressed as a percentage displayed on the results screen. Besides, the

reference value is displayed in the bottom left corner of the screen. The value measured in the absolute units is shown in the top left corner of the screen (see Sec. 2.4).

3.5. Integration

Time integration of measurement results can be used to assess the hazards of optical radiation with the use of the suitable measurement probes.

In photometry, the time integral of illuminance or luminance has no practical use. However, the integration function can become useful in the measurement of the highly variable values. Using the integration mode, the measurement should be conducted until the average value of the measured quantity is steady. This value is the proper measurement result and is the arithmetic average measured in integrating time. When using the integration function, it is recommended to set the averaging time that amounts to 1 second. In order to turn on the integration mode, use the **Measurement setup->Integration** menu command. To turn it off, choose the single (**Measurement setup->Single)** or continuous (**Measurement setup->Continuous)** measurement mode. After the measurement is stopped, the integral and the statistics related to it can be both deleted with the use of the **Measurement setup->Delete integral** menu command.

On the result screen, the main result is the time integral of the measured quantity expressed in units that are the products of the base unit and 1 second. In the top left corner of the screen there is the currently-measured value and in the top right corner there is the integration time. Below the main result there is the measurement statistics that contains the following items:

- **n**   the number of measurements saved in statistics,
- **min**   the minimum value of result saved in statistics,
- **max**   the maximum value of result saved in statistics,
- **avr**   the average value of result saved in statistics,
- **mn/a**   the quotient of the minimum and average value,
- **mn/x**   the quotient of the minimum and maximum value.

3.6. Statistics

This function allows you to conduct simple statistical operations on the measurement results. The results may be, among others illuminance uniformity or contrast ratio. It is possible to turn on the statistics in both single and continuous measurement mode (while the integration is turned off) with the **Statistics** sub-menu. The **Statistics->Add measurement** command adds the last measurement to the statistics. If the statistics is turned off, then it is turned on. The **Statistics->Auto add** menu command turns on or off automatic adding of every measurement to the statistics. After turning on the auto add option, the statistics is turned on if it has been turned off earlier. The **Statistics->Clear all** menu command deletes all the measurement results from the statistics and it turns off this function.

On the result screen, below the main result there is the statistics that contains the following items:

- **n**   the number of measurements saved in statistics,
- **min**   the minimum value of result saved in statistics,
- **max**   the maximum value of result saved in statistics,
- **avr**   the average value of result saved in statistics,
- **mn/a**   the quotient of the minimum and average value,
- **mn/x**   the quotient of the minimum and maximum value.

3.7. Measurements memory

This function allows you to save single measurements and create automatically their history log. It saves the collected measurements to the text file which can be directly open with the use of the spreadsheet software. The file contains the name of the instrument type, its serial number, date and time of starting and ending measurement. A new file is created at the moment of the first-time saving the measurement to memory after the change of the instrument operation mode. It can also be created with the use of the **Memory->New file** menu command.

It is possible to save it automatically to the memory with the **Memory->Autosave** menu command or manually with the key ![Mem] on the results screen. In the case of the automatic saving of data, the results are saved to the file within the set time interval with the **Memory->Interval** menu instruction.

3.7.1. File name and format

The file name and its format depend on the instrument operation mode, in which it has been saved. In each case a file name consists of a prefix, type of a used instrument and starting date and time of measurements.

3.7.1.1. Absolute measurement

The file name starts with the **Meas** prefix, e.g. "Meas PCE-LMD 100 2018-01-01 12'00'26.txt". The columns in the results sheet are as follows:
- **no.**   successive measurement number,
- **over**   exceedance of measurement range,
- **result**   measured value,
- **range**   measurement range of result,
- **comment**   individual commentary on result (empty field).

3.7.1.2. Relative measurement

The file name starts with the **Rel** prefix, e.g. "Rel PCE-LMD 100 2018-05-22 12'10'48.txt". The columns in the results sheet are as follows:
- **no.**   successive measurement number,
- **reference**   reference value for relative value calculation,
- **over**   exceedance of measurement range,
- **result**   measured absolute value,
- **result %**   relative measured value,
- **comment**   individual commentary on result (empty field).

3.7.1.3. Integration

The file name starts with the **Int** prefix, e.g. "Int PCE-LMD 100 2018-05-14 09'15'53.txt". The columns in the results sheet are as follows:
- **time**   time,
- **over**   exceedance of measurement range,
- **result**   measured value of the integrated quantity,
- **integral**   value of the integral for the time from the first column,
- **quantity**   number of measurements in statistics of integration,
- **min**   minimum value of results in statistics of integration,
- **max**   maximum value of results in statistics of integration,
- **average**   average value of results in statistics of integration,
- **min/max**   quotient of minimum and maximum value,

- **min/average**   quotient of minimum and average value,
- **comment**   individual commentary on result (empty field).

3.7.1.4. Statistics

The file name starts with the prefix **Stat**, e.g. "Stat PCE-LMD 100 2018-01-01 14'01'46.txt". The columns in the results sheet are as follows:
- **no.**   successive measurement number,
- **quantity**   number of measurements in statistics
- **over**   exceedance of measurement range,
- **last result**   value of last measurement in statistics,
- **min**   minimum value of results in statistics,
- **max**   maximum value of results in statistics,
- **average**   average value of results in statistics,
- **min/max**   quotient of minimum and maximum value,
- **min/average**   quotient of minimum and average value,
- **comment**   individual commentary on result (empty field).

3.8. Connection of instrument to PC

The question about the connection to a PC is displayed after the connection of the USB cable to the instrument with the installed memory card. After choosing the **Yes** option, the connection with the PC is established. The memory card is visible as an exchangeable disc. The conduction of measurements is impossible. Choosing the **Cancel** option makes the connection not established and the attached USB port is used only for charging the battery. The instrument operates normally. At the end of the connection with the computer, it is recommended to use the "**Safely Remove Hardware**" option available in Windows.

4. APPLICATIONS

4.1. Medical monitors

This application is intended for measuring heads that are luminance meters. It allows you to conduct tests of medical imaging monitors in accordance with the guidelines of the American Association of Physicists in Medicine (AAPM).

It allows you to conduct the following tests:
- grayscale mapping curve according to DICOM GSDF [1],
- compliance of the maximum luminance between monitors of one station,
- luminance uniformity.

Only some measurement probes have access to this application. The detailed information on the permissions to applications is included in the instruction manual of the attached instrument. The tests can be conducted for a maximum of 8 monitors in one diagnostic station. The results of all the tests can be labelled with one comment and saved to the text file which can be open directly with a spreadsheet. The collected results can also be open and pasted to the copy of the MonitorCheck.xls. spreadsheet template.

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[1] DICOM GSDF: Grayscale Standard Function according to PS 3.14-2011 Digital Imaging and Communications in Medicine (DICOM) Part 14: Grayscale Standard Display Function.

4.1.1. Operation of application

In order to run the application, use the **Applications->Medical monitors** menu command. It is then necessary to choose a number of monitors in the diagnostic station. After the confirmation of the number of monitors, there is some information displayed on the screen which contains: the number of the tested monitor, the type of currently conducted test and name of the test pattern to display (see Fig. 4.1). After pressing the **Start** key, there comes up the results screen, on which the measurement should be conducted (see Fig. 4.2).
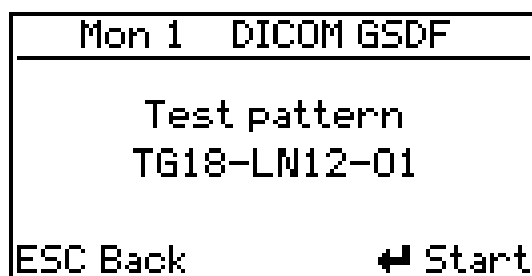

Fig. 4.1. Medical monitors – information screen.
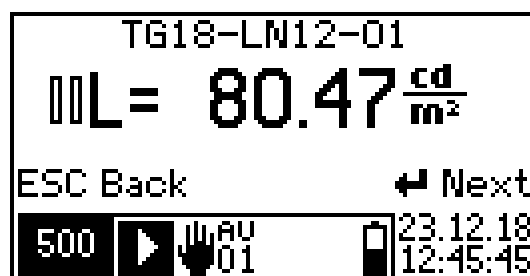
Fig. 4.2. Medical monitors – results screen.

After conducting the measurement, you can move further with the **Next** key or move back to the previous step with the use of the **Back** key

ATTENTION! The choice of Back option results in the deletion of the current step.

After all the measurements intended for the certain monitor are completed, the next monitor is chosen and another cycle of measurements starts from the beginning. After testing all the monitors it is possible to add a commentary that consists of a maximum of 16 characters. After the confirmation of the commentary the results are automatically saved to the file whose name is automatically generated (see Sec. 4.1.3). The mesurement data file is also saved after the approval of each partial result.

The application can be interrupted at any moment by holding down the **ESC** key for 3 seconds. This action results in the display of the window with the request for the confirmation of the interruption. The application is interrupted when it is confirmed.

4.1.2. Conduction of tests

In order to conduct the tests, it is necessary to have test patterns files and the possibility of displaying them on the controlled monitors. Each diagnostic station should be equipped with such test patterns. These test patterns files are published by the European Reference Organization for Quality Assured Breast Screening and Diagnostic Services (EUREF) [2].
The procedure to be followed:
- Prepare the instrument for operation in accordance with Sec. 3.1 and Sec. 3.2.
- Put the stabilising cap on the measurement probe if it is included in the set of accessories.
- Set the proper result averaging time (see Sec. 2.2.3). The more unstable in time the luminance value of the tested monitor is, the longer averaging time is.
- Run the application.
- Enter the number of tested monitors.

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[2] Source: http://www.euref.org/downloads/software-physico-technical-protocol/monitor-qc-test-patterns.

- Conduct a series of measurements.
- Enter the commentary. The data is saved to the text file.

4.1.3. Data file

The file name starts with the **MonitorCheck** prefix, starting data and time of measurements, e.g. "MonitorCheck 2018-01-01 14'01'46.txt". All data is saved in the text format and is tab-separated.

5. USAGE RECOMMENDATIONS

5.1. Internal battery

The instrument is operated normally with the use of the internal battery. It is, however, necessary to connect the charger to the instrument in order to charge the battery. The charging status is indicated with the LED placed under the micro USB connection (see Fig. 1.1). The blinking of the LED diode indicates the battery charging process. After the charging process is completed, the diode goes out. The process of charging is also signalled on the results screen (see Sec. 2.3).

If possible, the internal battery should be discharged completely (20% or less) before being recharged. It is recommended to avoid the frequent recharging of partially discharged battery because it reduces the battery life. The continuous operation with a connected charger is possible.

ATTENTION! The battery is charged, regardless of the fact whether the instrument is turned on or off!

5.3. Repairs and maintenance

The control unit **does not** require any special maintenance jobs.
All repairs of the instrument are performed by the Manufacturer.

6. CE MARKING AND WEEE DIRECTIVE

The product described in this instruction conforms to the following EU Council Directives:
2014/30/EC   Electromagnetic compatibility

The conformance of the above-mentioned requirements is confirmed by CE mark.
This product cannot be thrown away with household waste. Deposit the product in an authorized electrical and electronic waste collection area for recycling. Contact the local authorities or the nearest waste disposal company to get more detailed information.

PCE-LMD 200 (Probe)

INSTRUCTION MANUAL

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1. CHARACTERISTICS

This lux meter is designed on the basis of
the division of the meter into a measurement probe that is a complete meter and a control unit that can operate with probes that serve different metrological functions. This allows different configurations of operation depending on the needs or preferences of the User. The function of the control unit can be served by the control panel.
By the notion of metrological functions one can understand the varied assessment of optical radiation used for the measurement of:

- illuminance,
- irradiance of different actinic results,
- luminance / radiance.

The PCE-LMD 200 luxmeter is designed to measure the illuminance of natural and artificial radiation of point sources or scattered light. The connection of the proper adapter to the probe allows the User to measure luminance directly. The PCE-LMD 200 is indispensable for the measurement at workplaces and the measurement of illuminance of evacuation routes streets building sites as well as the tests on the parameters of the light sources. Every photometric laboratory should be equipped with the PCE-LMD 200 luxmeter whose greatest advantage is exceptionally good matching of the spectral sensitivity of the detector to the CIE photopic luminosity function $V(\lambda)$. The functions of the luxmeter allow the User to conduct the thorough measurement of any spectral distribution of the white light which is of great significance when you take into account the dynamic growth of lighting technology offering various sources based on modern technological solutions.

The measurement probe is equipped with the advanced functions of the processing of measurement results which virtually eliminate the influence of the environmental temperature on the measured value.

The PCE-LMD 200 luxmeter conforms to the requirements of the following standards:
- ISO/CIE 19476   Characterization of the performance of illuminance meters and luminance meters.

Owing to its technical parameters, the PCE-LMD 200 is classified as a **Class A** or **B** luxmeter, depending on the kind of the used probe according to DIN 5032-7 and TC-2.2 CIE. The PCE-LMD 200 luxmeter allows the User to make measurements conforming to the following standards:
- EN 12464-1   Light and lighting. Lighting of work places. Indoor work places.
- EN 12464-2   Light and lighting. Lighting of work places. Outdoor work places.
- EN 12665   Light and lighting. Basic terms and criteria for specifying lighting requirements.

In terms of its electromagnetic compatibility, the PCE-LMD 200 luxmeter conforms to the requirements of the following standards:
- IEC 61326-1   Electrical equipment for measurement, control and laboratory use - EMC requirements - Part 1: General requirements.
- IEC 61000-6-2   Electromagnetic compatibility (EMC) - Part 6-2: Generic standards - Immunity standard for industrial environments.
- IEC 61000-6-3   Electromagnetic compatibility (EMC) - Part 6-3: Generic standards - Emission standard for residential, commercial and light-industrial environments.

The luxmeter consists of the measurement probe that directly works with the control unit.

1.1. Equipment

1.1.1. Basic accessories

Components of set
Measurement probe
Control unit
Instruction manual
Carrying case

1.1.2. Additional accessories

- Measurement probe handle.
- Measurement probe handle used for the measurement of evacuation routes.

1.2. Configuration

The control unit can be used to control the measurement probe and read the measured values. The probe is connected directly to the control panel. The measurement probe is powered with the use of the control unit. The configuration is shown in Fig. 1.

Fig. 1. Configuration of the probe with the control unit

1.2.1. Components of lux meter

- Measurement probe
- Measurement module

Each of the above-mentioned components of the measurement system is identifiable according to the requirements of ISO/IEC 17025 standard.

1.2.2. Luminance measurement

The connection of the optional probe to the suitable adapter allows the User to measure luminance directly. At present there are the following adapters available:

Adapter type	Field aperture	Measurement type
PCE-LMD LMA1	1°	within a distance of (1m - ∞)

In combination with the luminance adaptor, the PCE-LMD 200 probe has the following measurement range:

Measurement range [cd/m^2]
PCE-LMD LMA1
0,1 - 200M

The method of setting up the luminance meter consisting of the appropriate adapter and measuring probe is described in the instruction manual of the appropriate adapter.

ATTENTION! This measurement probe has one calibration factor related to illuminance measurement. The adjustment of the luminance meter, which consists of the probe and adapter, should not be conducted because it influences the correctness of the illuminance measurement after the adapter is disconnected from the probe.

1.3. Technical data

Parameter	PCE-LMD 200 probe
Class of photometer [1]	A
Spectral sensitivity	$V(\lambda)$ CIE
Spectral matching f_1' [2]:	$\leq 2\%$
Directional characteristics:	cosine of the angle of incidence
Directional matching f_2 [2]:	$\leq 1\%$
Non-linearity f_3 [2]:	$\leq 0.3\%$
Temperature coefficient K_T:	$\leq 0.01\%/K$
Measurement ranges [3]:	50 lx 5 klx 500 klx
Measurement resolution:	0.001 lx 0.1 lx 10 lx
Total error [4]: $\quad$ +10°C − +40°C $T_{min} - T_{max}$	2.0% 2.5%
Power supply:	with control unit (5V, 5mA)
Environmental conditions - temperature ($T_{min} - T_{max}$): - relative humidity:	-20°C − +50°C < 90% (without condensation)
Dimensions: - measurement probe:	Ø44mm x 25mm
Measurement probe weight:	100g

1.3.1. Spectral characteristics

Very good spectral matching of the detector to the spectral sensitivity $V(\lambda)$ is realised with the use of the set of glass absorption filters. Such a solution guarantees high long-term and temperature stability, especially in comparison with the cheaper realisations in which interference filters are used. The quality of this kind of matching enables the correct measurement, regardless of the spectral distributions of the measured luminous flux, which in the sources of light used nowadays in the modern lighting technique differ significantly from the spectral efficiency of the calibration illuminant and are the main source of errors.

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[1] according to DIN 5032-7 and TC-2.2 CIE.
[2] ISO/CIE 19476 Characterization of the performance of illuminance meters and luminance meters (this standard replaces CIE publication 69/1987).
DIN 5032-7 Photometry; Classification of illuminance meters and luminance meters.
[3] The specified measuring ranges are the minimum values guaranteed by the manufacturer. The actual values depend on the sensitivity of the detector and the calibration factor and can be even twice as high.
[4] The percentage deviation of the measured value for white light sources with any spectral distribution in the given operating temperature range. It takes into account all the factors affecting the accuracy of the measurement (spectral and directional mismatch, temperature influence and others). It does not include the uncertainty of calibration.
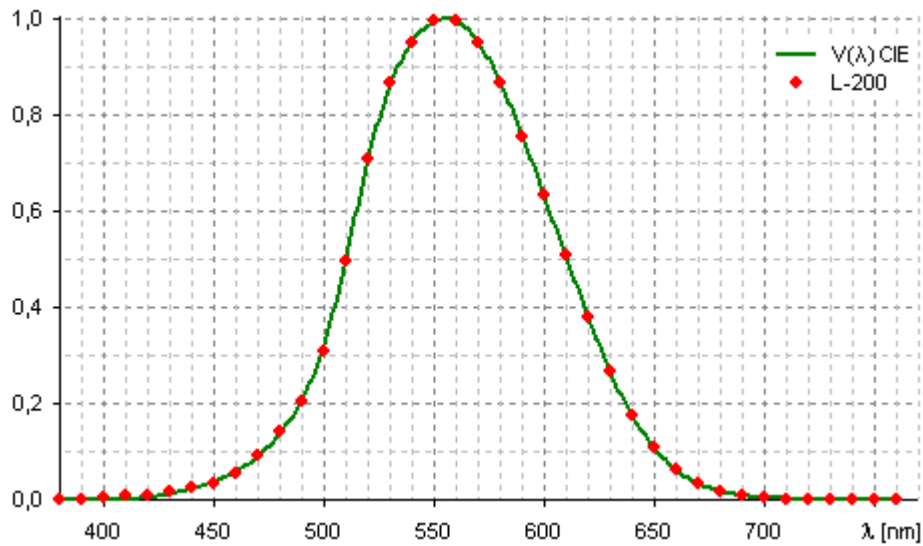
Fig. 3. Typical spectral sensitivity of the PCE-LMD 200 probe.

1.3.2. Directional characteristics

The measurement probes are equipped with the optical system that matches the directional response to the cosine function which guarantees the accuracy of illuminance measurement for point sources as well as diffuse radiation. The used set of the cosine correction which uses the high-quality diffusion materials provides the system with long-term and temperature stability especially in comparison with the cheaper realizations in which plastics are used. The standardized error of the probe response for diffuse radiation is virtually negligible.

Fig. 4. Typical directional sensitivity of the PCE-LMD 200 probe

Fig. 5. Typical error of the directional response of the PCE-LMD 200 probe in function of incident angle.

1.4. Temperature compensation

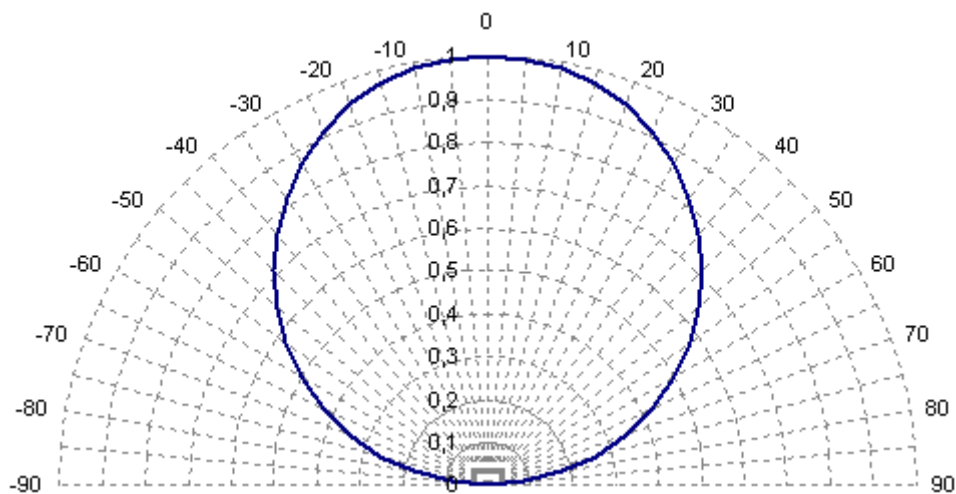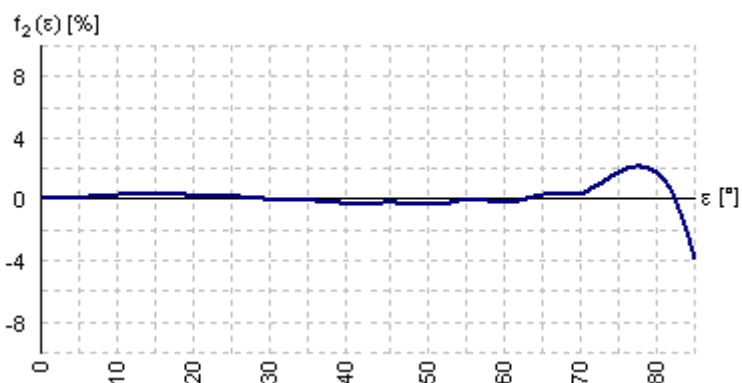The change in the temperature of the probe influences the measurement result. Due to the temperature change, the other parameters also change and they are as follows :
- detector dark current   - shift of zero indication,
- offset voltage of the measuring circuit   - shift of zero indication,
- responsivity of a detector   - change of measured quantity value,
- gain of the measuring circuit   - change of measured quantity value.

Measuring probes are equipped with the temperature sensor and functions that minimise the influence of the above-mentioned factors on the measured value.

1.4.1. Compensation of zero indication

Compensation of zero indication occurs after zeroing of the detector or the measuring circuit. It is realised with the aid of the functions which the probe is equipped with. For compensation of zero indication it is necessary to use the following commands of the control device:

- Zeroing of detector. The zeroing procedure of the detector consists in the measurement of the dark current of the measurement probe detector and its corresponding temperature. It can be conducted only with the covered reception field of the probe. The value of the dark current and the temperature of the zeroing are saved to the memory of the measurement probe.
- Zeroing of measurement system. The zeroing procedure of the measurement system consists in the direct measurement of the correction that results from the measuring circuit offset voltage which is deducted from the result. It is automatically conducted after the probe is connected to the control unit and whenever the detector is zeroed. The value of the correction and the temperature of the zeroing are saved to the memory of the probe.

1.4.2. Temperature compensation of the result

Alongside the use of the high-class elements in the design of the meter the probe is equipped with the automatic compensation system of the influence of the environmental temperature on the measurement value. The temperature in which the calibration is conducted is the reference to the correction factor being then calculated for the current temperature. The influence of the ambient temperature on the measurement value is virtually possible to be omitted for typical usage.
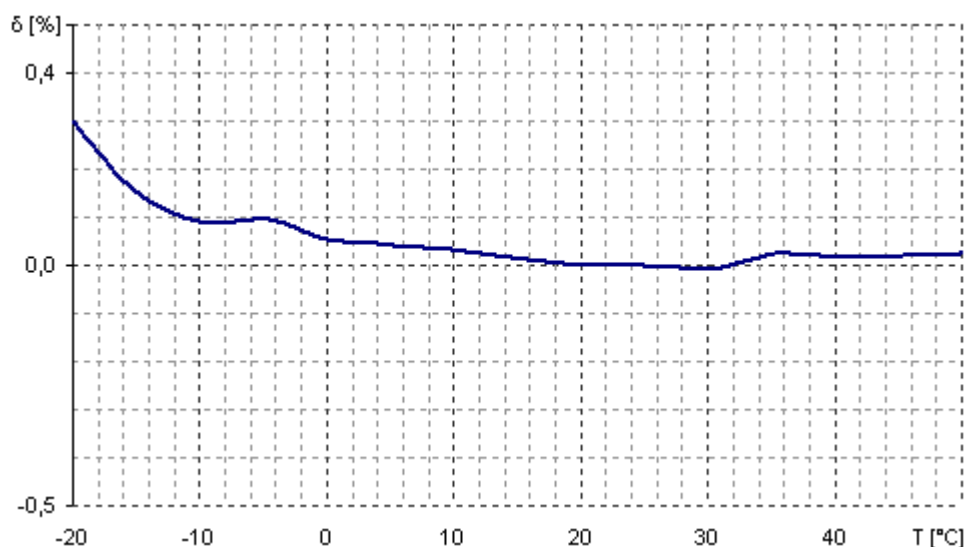

Fig. 6. Typical error of the probe response in function of the ambient temperature.

2. THE PCE-LMD 200 METER OPERATION

2.1. Preparations

- Connect the probe to the control unit according to its instruction manual.
- Start the measurement.
- Check the zero indication with the covered reception field of the probe and alternatively, conduct zeroing of the detector.
- Remove the cap from the probe. The instrument is ready to operate.

2.2. Measurement

- Set the result averaging time in the control unit. The more unstable in time the value of the measured quantity is, the longer the time should be. In most applications the sufficient averaging time amounts to 1s.
- Choose the automatic or manual change of the measurement range. It is recommended by the manufacturer to turn on the automatic change of the range. The manual control is intended for the procedures of checking linearity during calibration or in specific conditions of measurement when the value of the measured quantity changes in time to such an extent that the control unit cannot determine the proper measurement range.
- Choose the single or continuous measurement mode.
- Set the probe in the measurement field to avoid its disturbances that might be caused by the person operating the meter. It is recommended to use the photometric probe handle that is an additional accessory to the meter.
- Trigger the measurement with the key on the probe provided that it is equipped with such a key or with the certain key on the control unit.

3. BASIC FUNCTIONS OF CONTROL UNIT

The basic functions of the control unit are the following ones:

- Zeroing of the detector.
- Zeroing of the measurement system.
- Manual or automatic choice of the measurement range.
- Choice of the single or continuous measurement mode.
- Choice of the averaging time in range from at least 1-10s [5]. The measurement result is the moving average that is refreshed every 1s.
- Triggering and stopping the measurement.
- Presentation of the measurement result.
- Calibration and adjustment of the meter.

All the detailed information is included in the instruction manuals for the control units.

4. EXTENDED FUNCTIONS OF CONTROL UNIT

The control devices are equipped with applications or functions that extend the range of the probe usage. All the applications have the possibility of archiving of the

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[5] The range of values of the result averaging time depends on the control unit.

measurements results to a microSD card . The data is saved in text files
where tabs are separation signs. Such a file format enables the User to open it directly
with the help of the spreadsheet. The access rights to the certain application depend on
the type of the attached measurement probe.

4.1. Application: Measurements memory

The control units are used to archive the measurements conducted with the use of the PCE-
LMD 200 probe. It is possible to save one single measurement or chosen measurements as
well as to create the measurement history log within any time interval.

All the detailed information is included in the instruction manuals for the control units.

4.2. Application: Advanced

4.2.1. Relative measurement

The control units enable to conduct and archive the measurements whose results are expressed as a percentage of any reference. It is possible to save one single measurement or chosen measurements as well as to create the measurement history log within any time interval.

All the detailed information is included in the instruction manuals for the control units.

4.2.2. Integration

The control units are used to conduct and archive the measurements which are the time integral of the partial results. The last result or the whole measurement history log can be saved to the memory.

All the detailed information is included in the instruction manuals for the control units.

4.2.3. Statistics

The control units enable to conduct and archive the measurements as well as to make simple statistical operations on the results. The last result or the whole measurement history log can be saved to the memory.

All the detailed information is included in the instruction manuals for the control units.

5. CALIBRATION AND ADJUSTMENT

Calibration is the comparison of the measured values with those of a calibration standard of known accuracy. On the basis of this comparisonP the calibration factor is calculated and saved to the measuring probe. The control units allow the User to conduct the adjustment procedure of the measurement probe. The procedure should be conducted by a competent laboratory equipped with the suitable instruments and the proper photometric standards that are indispensable for setting the reference illuminance in the reception field of the probe. It is necessary to take into account the fact that adjustment is related to all the components of the meter specified in Sec. 1.2.1.

All the detailed information is included in the instruction manuals for the control units.

6. MAINTENANCE RECOMMENDATIONS

- The measurement probe must be connected only to the devices described in the instruction manual.
- The device should not be exposed to falls shocks or any other factors which can cause mechanical damage.
- It is necessary to protect the optical element of the reception field from dirt.
- The probe cap should be removed only during the measurement.
- The probe should be removed and put on while turning it right clockwise, which prevents it from being untwisted by accident.
- The instrument should be kept and transported only in the carrying case provided by the manufacturer.
- All repairs of the instrument are performed by the manufacturer.

7. CE MARKING AND WEEE DIRECTIVE

The product described in the instruction conforms to the following EU Council Directives:
2014/30/EC   Electromagnetic compatibility

$C\!\!\in$ The conformance of the above-mentioned requirements is confirmed by CE mark.

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