CR-250 Spectroradiometer

USER GUIDE

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About this Guide

This guide provides information on instrument features, setting up the instrument, and technical specifications.

CAUTION indicates that failure to follow directions could result in damage to equipment, physical harm or injury.

WARNING! indicates that failure to follow directions could result incorrect usage or loss of information

NOTE provides important supplemental information.

TIP describes optimization of usage.

Remote Communication COMMANDS `are indicate in this font.`

Getting Started

The CR-250 is a USB 2.0 compatible device, remotely controlled by the host software from any personal computer, laptop, net book and some smartphones.

Standard Components

Each CR-250 instrument is accompanied by the following standard equipment

USB 2.0 Cable

USB to mini-USB cable is provided to connect to a PC. On request, a mini-USB to micro-USB is provided to connect to a smartphone

Universal mounting bar

The CR-250 comes with a universal mounting bar that has 3 threaded holes one inch apart with standard tripod mount ¼-20 threads. In addition, there are 4 threaded holes with M6 metric threads in two pairs 30 mm apart.

Optional Components

Detachable Viewing Systems

The CR-250 has been designed with a direct viewing system that is easily detachable from the instrument's main body (e.g., snaps in and out manually), and can be replaced with different types of viewing systems depending on user needs.

Horizontally Rotatable Viewing Systems (Patent pending): Direct viewing systems have been utilized for several decades in optical measuring instruments. Typically, the eyepiece is in a fixed location on the instrument and is otherwise non-removable. As such the viewer must align themselves with the angle of the viewing optics to use the eyepiece. This can be disadvantageous in situations where the eyepiece is in an inaccessible and/or uncomfortable spot for the viewer. The CR-250 overcomes the limitations of the typical direct viewing system by offering the horizontally rotatable viewing system VO-201.

Perpendicular Viewing System: For those cases where the CR-250 is mounted vertically on a test fixture or a robotically controlled XYZ table; the Perpendicular Viewing System VO-202 is an alternative to the rotatable viewing system.

Camera Viewing System: The VO-204 is a very compact viewing system that couples to a small C-Mount camera for positioning and monitoring the measurement spot from a robotically controlled system.

Illuminance Receptor/Cosine Receptor

The Cosine Corrected Illuminance Receptor IR-250 is designed to accurately measure Illuminance, Irradiance and chromaticity of illumination sources.

Neutral Density Filter

Neutral density (ND) filters reduce the amount of light entering the instrument, enabling measurements of brighter light sources.

An ND1 will provide 10 times attenuation while ND2 provides 100 times attenuation.

The available neutral density filters are

- ND 0.3
- ND 0.7
- ND 1
- ND 2
- ND 3

Calibration mounts

Universal mounting bracket

Dual meter mount

The dual meter mount provides an easy way to install the CR-100 and CR-250 on a common mount with the rubbers hoods aligned on the same plane. This is very useful when creating a correction matrix (profiling) for the colorimeter using the spectroradiometer.

Long reach meter mount extension bar

The extension bar is very useful when getting the meters against the display is difficult using a standard tripod.

Rubber Hood

A rubber hood with a screw-on mount, provided for contact mode measurement of displays, prevents ambient light from affecting the measurements. It is a screw-on type and can be removed to install the screw-on type filter holder.

Filter Holder

It is a screw-on type filter holder designed for 50 mm x 50 mm filters such as the Dolby 3D filters or any other filter used for R&D.

Optional Configurations

Ethernet

An optional Ethernet 10BASE-T/100BASE-TX IEEE-802.3 compliant connection can be used to control the instrument.

External Trigger

The External Trigger Port/Sync Input enables remote measurement activation from either a push button or a peripheral device, while the External Trigger Port/Sync Output allows synchronization signals to measure strobes/pulsed lights, and start/stop signals.

This option is ideal for fast temporal events that need to be precisely synchronized with the measurement or data capture.

This option, requires additional hardware that has the trigger IO circuitry. The unit doesn't get any bigger, as the additional hardware fits inside the same backend housing cover. A 3 pin trigger I/O connector comes out of the back of the unit. The pins are trigger input, trigger output and ground, input and output are 3.3 volts (Input is 5 volts tolerant).

Maintenance Guidelines

Shock

Do not subject the instrument to strong impacts or vibrations. Even though there are no moving parts, optical elements glued together may come loose if a very sudden force is applied.

Check the calibration accuracy if the instrument is subject to a strong accidental impact.

Temperature and Humidity

Do not keep the instrument in direct sunlight or near sources of heat, such as heaters, stoves, etc. The internal temperature of the instrument can quickly rise to much higher than the ambient temperature in such cases.

Do not leave the instrument inside a vehicle or in the trunk parked in the sun. At its peak in summer under direct sunlight, the inside of the vehicle can reach extreme temperatures rapidly.

Avoid sudden temperature changes, this can cause condensation in the optical path which would in turn affect your readings.

Store at temperatures between 10°C to 40°C and at a maximum humidity of 85%. Do not store in environments subject to high temperatures, high humidity or rapid changes in temperature which can cause condensation.

It is recommended to store in room temperature with a drying agent (desiccant).

Magnetic Field

Do not use the instrument near strong electric or magnetic fields.

Dust

Do not use the instrument in environments prevalent in dust, smoke, or where chemical gases are present. This can possibly cause deterioration in performance or in some cases cause the instrument to breakdown.

Cleaning

The rubber hood has a tendency to attract dust. When dust accumulates, use a dust blower can of the type recommended for small electronics and optics.

Do not use any chemical solvents to clean.

Clean the lens with a lens cleaner and then dry.

Installation

The Colorimetry Research, Inc, software consists of the CRIApp and the Colorimeter Utility.

The instrument is detected as a serial communication device and communicates at **9600 baud rate, 8 data bits, 1 stop bit, no parity and no flow control.**

Windows

On windows the driver installation configures the instrument to work with the native windows USB-serial driver. Both 32 and 64 bit version of the drivers are available.

Tools: PuTTY, HyperTerminal

Mac

On OSX the native driver detects the instrument as a USB Modem and it will be displayed as

```
/dev/tty.usbmodemXXXX
```

Tools: screen

Linux

Tested with Ubuntu.

Under Ubuntu Linux the instrument is detected as a generic USB ACM device and will be displayed as

```
/dev/ttyACM*
```

Tools: screen

Operation

The instrument setup parameters and the corresponding remote communication commands are mentioned below.

Aperture

Displays the current `Aperture` that is configured with the instrument. This option is read-only.

Available apertures are 3°, 2°, 1°, 0.5°, 0.25° and 0.125°.

Accessory

Selects the current `Accessory` selected for capturing the light signal. This could include a luminance accessory such as the standard lens or illuminance accessories such as the illuminance receptor. This selection also indicates the units of the photometric and radiometric result displayed.

Filters

ND (Neutral Density) Filter (`Filter1`, `Filter2`, `Filter3`) used.

A maximum of **3** filters can be used simultaneously with a given Accessory.

Exposure

Specifies the exposure (msecs.) settings for the capture. The exposure range is 0.02 to 30 seconds.

Auto	`ExposureMode = 0`	Automatically selects the exposure
Fixed	`ExposureMode = 1`	The exposure time range is between 20.58 ms to 30 secs

To speed up recurring measurements of the same light source it is advised to perform an initial “learn and repeat” exposure setting. Make a test measurement and learn the exposure time using auto exposure mode and then apply this exposure time by switching to the fixed exposure mode.

Learn and Repeat

A recommended approach to all system integrators, is the “**Learn and Repeat**” method, which is as simple as the following sequence:

1. Set the CR-250 to *Exposure = Auto*.
2. Take a measurement.
3. Get the exposure time used by the meter for the measurement taken in Step 2. This information is retrieved from the CR-250 via the remote communication command (`RM Exposure`).
4. Set *Exposure = Fixed* and enter the exposure time of the previous measurement (or send it to the CR-100 via a remote communication command, `SM Exposure`).
5. Proceed to measure the same light level keeping the setting *Exposure = Fixed*.

Speed

Specifies the speed setting for the capture.

Speed = Normal is recommended for most measurements.

Set the *Speed = Slow* when measuring very low light levels.

Set the *Speed = Fast* or *Speed = 2x Fast* when measuring medium and high light levels.

Slow	`SpeedMode = 0`	Slow speed setting
Norrmal	`SpeedMode = 1`	The normal speed setting. This is the default speed mode.
Fast	`SpeedMode = 2`	The fast speed setting
2x Fast	`SpeedMode = 3`	Two times the speed of Fast

Average

The average (ExposureX) setting averages captures to the specified multiple of the exposure used.

The value ranges from *1 to 50*.

Sensor Heater

The sensor heater option allows temperature control of the light sensors when the ambient temperature is below 20° C. The sensor heater is enabled at the factory upon request only.

When the heater is ON the red LED is turned ON. The LED in the back of the instrument is a dual color LED, Green and Red.

The temperature is regulated to be between 16.5° C and 21.5° C when ambient temperature drops below 20° C.

Off	SensorHeater = 0	The heater is always off.

Auto	SensorHeater = 2	Automatically controls the heater setting based on the internal temperature of the light sensor.

Sync

The Sync option specifies the synchronization mode for the measurement capture.

None	SyncMode = 0	Not synchronized to the frequency of the light signal
Manual	SyncMode = 2	Manual sync mode allows synchronizing the capture of the light signal to a custom frequency
NTSC	SyncMode = 3	NTSC sync mode uses fixed 60 Hz frequency to synchronize the capture of the light signal
PAL	SyncMode = 4	PAL sync mode uses a fixed 50 Hz frequency to synchronize the capture of the light signal
CINEMA	SyncMode = 5	CINEMA sync mode uses a fixed 48 Hz frequency to synchronize the capture of the light signal

Sync = None

The *Sync = None* setting should be used only when the light source you are measuring does not have any AC components. This is only used when measuring constant light output with no modulation or “refresh cycles”. It should never be used when measuring/calibrating displays or projectors.

Many industrial applications use constant light output sources, for example, when measuring transmittance or reflectance of materials. Only in these cases *Sync = None* is recommended.

Sync = Manual

The Setting *Sync = Manual*, allows the user to select the frequency of the light signal in Hertz. The custom sync frequency range is 10 Hz to 10 KHz.

Several predefined Sync modes are available which automatically selects the sync frequency based on the display type, such as NTSC, PAL and CINEMA.

Custom Color Matching Functions

The CR-250 has in built CIE 1931 2° observer and CIE 1964 10° standard observer Color Matching Functions.

The CR-250 allows uploading up to three sets of custom CMFs. This “custom” CMFs can be alternate standards proposed by different organizations, such us Judd-Voss 1978 or custom CMFs a researcher may be working on.

Maintenance

Calibration

The instruments are calibrated using NIST traceable calibration standards at a color temperature of 2856°Kelvins. This is a standard calibration method used by most colorimeter manufacturers. In addition to the NIST traceable calibration standards we take pride in having developed proprietary Calibration and Quality Assurance processes that require a laboratory grade scanning double monochromator and high accuracy filters of known transmittance and chromaticity.

Essentially, no other spectroradiometers are used during manufacturing and Q.A. because none of them are as accurate as a laboratory grade scanning double monochromator.

It is recommended to verify the calibration every 1 to 2 years, this will determine if recalibration is necessary. There are many environmental factor (humidity, air pollution, etc.) that can make the measurement deviate from its factory calibration. Under normal operating condition, recalibration will be needed after 2 years, but again in some cases recalibration could be required after 1 year, thus it is important to check the calibration after 1 year.

The factory criteria to mandate a need recalibration is if either CIE x or CIE y deviates from the reference by more than ±0.001 or the luminance deviates by more than ±1.0%

This is the general criteria to provide a NIST traceable calibration certificate, but for some applications the user can decide the acceptable deviation.

Backup & Recovery

The Colorimeter Utility is used to "Backup" (download from the probe) and "Recover" (upload to the probe) all or some calibration files.

The “backup” pane lists all the available items that are available for backup. Select by checking the items that are required to be backed up and an archive will be created of the selection. The archive file will be automatically titled with the model and identifier of the probe specified within its configuration file.

The configuration is a mandatory item that is required for a valid archive.

The “recover” pane is a drop-zone that accepts a previously backed up archive file. Once an archive file is selected or dropped into the drop-zone, a list of items that can be recovered are displayed. Select by checking the items that are required to be recovered.

The probe will have to be restarted after a successful recovery.

Upgrade

The Colorimeter Utility is also used to "Upgrade" the firmware on the probe.

The “upgrade” pane is a drop-zone that accepts the probe operating system or firmware image. This is designated by a file with ‘cros’ extension. The utility validates the files signatures and uploads the image to the probe. Once all the steps are verified the probe is marked for installation. The installation takes place during the next power up cycle.

The probe will be prompted to be restarted for a successful upgrade to take place. The green LED will take slightly longer to turn on indicating an update is in progress. Close the Colorimeter Utility and cycle power by disconnecting the USB cable from the probe.

Control

The CR-250 comes standard with a well documented, easy to learn, pseudo english language based, command interpreter to control all aspects of its operation using a computer, tablet or a smart device, making it easy for customers to create their own software dedicated to perform specific measurement tasks or for inclusion in an Automated Test Environment using any of the modern computer development environments such as Visual Studio, Xcode, etc. For detail documentation on the remote communication refer the Remote Communications Manual.

Basics

When typing out commands on a terminal, sometimes it's hard to know what you type. To make communication intuitive the probe can be instructed to remotely echo the sent commands received back to the sender. The `E` command toggles the ECHO of characters received by the probe.

To turn on/off ECHO send the E character

`E`⏎

Result: ECHO is ON the > prompt is echoed on to the terminal. ECHO is OFF nothing is echoed on the terminal.

When communicating with an automated system ensure that the ECHO is turned OFF in order to prevent confusing the controlling software.

RC - Read Configuration commands
RS - Read Setup commands
SM - Setup Measurement commands
RM - Read Measurement commands

Identification

One of the first things to perform is to identify the model, serial number, instrument type and the version of the firmware. Communications can now be tailored efficiently to the specific mode of the instrument and target firmware.

Use the firmware version to verify supported commands

Command	Example	Description
>RC ID⏎	>RC ID OK:0:RC ID:A00102	Reads the instrument Identifier (Serial Number) from the configuration
>RC Model⏎	>RC Model OK:0:RC Model:CR-250	Reads the instrument Model from the configuration
>RC InstrumentType⏎	>RC InstrumentType OK:0:RC InstrumentType:2	Reads the instrument type from the configuration. values for instrument types are • 0: Photometer • 1: Colorimeter • 2: Spectroradiometer
>RC Firmware⏎	>RC Firmware OK:0:RC Firmware:1.32	Reports the current Firmware version,

Setup

The setup instructions are used to specify measurement and hardware (instrument) properties.

Aperture

The CR-250 is configured with one fixed aperture.

Command	Example	Description
>RC Aperture⏎	>RC Aperture OK:0:RC Aperture:1 0.5 deg	Lists the available apertures that are configured. The response returns the number of apertures in the last parameter(4th) of the first line. Every line after that lists the aperture ID and name.
>SM Aperture ***[ID]***⏎	>SM Aperture 0 OK:0:SM Aperture:No errors	Selects the aperture using its ID. This command is not required as the aperture is fixed.
>RS Aperture⏎	>RS Aperture OK:0:RS Aperture:5 deg	Retrieves the name of the current aperture.

Accessory

Command	Example	Description
>RC Accessory⏎	>RC Accessory OK:0:RC Accessory:3 0,Standard,Radiance 1,IR-100,Irradiance 2,IS-101,Rad. Flux	List the available accessories that are configured. The response returns the number of accessories in the last parameter (4th) of the first line. Every line after that lists the accessory ID, name and type. Accessory types are as follows • Radiance: Radiance • Irradiance: Irradiance • Rad. Flux: Radiant Flux • Rad. Intensity: Radiant Intensity • NA: Not applicable • Unassigned: Unassigned
>SM Accessory ***[ID]***⏎	>SM Accessory 0 OK:0:Accessory:No errors	Selects the accessory using its ID.
>RS Accessory⏎	>RS Accessory OK:0:RS Accessory:Standard	Retrieves the name of the current accessory.

Filters

Command	Example	Description
>RC Filter⏎	>RC Filter OK:0:RC Filter:5 3,ND-100-1,Radiance 4,ND-100-2,Radiance 5,ND-100-3,Radiance 6,ND-100-0.3,Radiance 7,ND-100-0.7,Radiance	Lists the available filters that are configured. The response returns the number of filters in the last parameter (4th) of the first line. Every line after that lists the filter ID, name and type. Filter types • Radiance: Radiance • Irradiance: Irradiance • Rad. Flux: Radiant Flux • Rad. Intensity: Radiant Intensity • NA: Not applicable • Unassigned: Unassigned
>SM Filter1 ***[ID]***⏎	>SM Filter1 3 OK:0:Filter1:No errors	Selects the 1st filter using its ID.
>SM Filter2 ***[ID]***⏎	>SM Filter2 3 OK: 0:Filter2:No errors	Selects the 2nd filter using its ID.
>SM Filter3 ***[ID]***⏎	>SM Filter3 3 OK: 0:Filter3:No errors	Selects the 3rd filter using its ID.
>RS Filter⏎	>RS Filter OK:0:RS Filter:ND-100-1,None,None	Retrieves the names of the current filters as a comma separated value.

Sync

The sync setting is a combination of the sync mode and the sync frequency. If the sync mode is manual, then the sync frequency is a pertinent setting.

Command	Example	Description
>RC SyncMode⏎	>RC SyncMode OK:0:RC SyncMode:3 0,None 1,Auto 2,Manual 3,NTSC 4,PAL 5,CINEMA	Lists the available Sync Modes configured. The response returns the number of sync modes in the last parameter (4th) of the first line. Every line after that lists the sync mode ID and name. Available Sync Modes • None: The instrument will not sync to the light source. • Auto: The instrument syncs to the light source automatically. • Manual: The instrument will sync to the frequency specified by RS SyncFreq. Additional Sync modes to allow for easy selection based on the display technology • NTSC • PAL • CINEMA
>SM SyncMode ***[ID]***⏎	>SM SyncMode 0 OK:0:SyncMode:No errors	Selects the sync mode using its ID.
>RS SyncMode⏎	>RS SyncMode OK:0:RS SyncMode:None	Retrieves the current sync mode.
>RC MinSyncFreq⏎	>RC MinSyncFreq OK:0:RC MinSyncFreq:10.00 Hz	Lower limit of the sync frequency reported in Hertz. Used in conjunction with the Manual Sync Mode.
>RC MaxSyncFreq⏎	>RC MaxSyncFreq OK:0:RC MaxSyncFreq: 10000.00 Hz	Upper limit of the sync frequency reported in Hertz. Used in conjunction with the Manual Sync Mode.
>SM SyncFreq ***[Frequency]***⏎	>SM SyncFreq 10 OK:0:SyncFreq:No errors	Selects the Sync Frequency in Hz. This is used only when the Sync Mode is set to manual.
>RS SyncFreq⏎	>RS SyncFreq OK:0:RS SyncFreq:60.00 Hz	Retrieves the current sync frequency. This is used only if the Sync Mode retrieved by RS SyncMode is Manual.

Speed

Command	Example	Description
>RC Speed⏎	>RC Speed OK:0:RC Speed:4 0,Slow 1,Normal 2,Fast 3,2x Fast	Lists the available speeds configured. The response returns the number of speeds in the last parameter (4th) of the first line. Every line after that lists the speed ID and name.
>SM Speed ***[ID]***⏎	>SM Speed 0 OK:0:Speed:No errors	Selects the speed to be used by its ID.
>RS Speed⏎	>RS Speed OK:0:RS Speed:Normal	Retrieves the name of the current speed mode.

Exposure

The exposure setting is a combination of the exposure mode and the exposure time in milli seconds.

Command	Example	Description
>RC ExposureMode⏎	>RC ExposureMode OK:0:RC ExposureMode:2 0,Auto 1,Fixed	List the available Exposure Modes configured. The response returns the number of exposure modes in the last parameter (4th) of the first line. Every line after that lists the exposure mode ID and name. Available exposure modes are • Auto • Fixed
>SM ExposureMode ***[ID]***⏎	>SM ExposureMode 0 OK:0:ExposureMode:No errors	Selects the exposure mode using its ID.
>RS ExposureMode⏎	>RS ExposureMode OK:0:RS ExposureMode:Auto	Retrieves the name of the current exposure mode.
>RC MinExposure⏎	>RC MinExposure OK:0:RC MinExposure:1.0 msec	Lower limit of the exposure reported in milliseconds. Used in conjunction with the Fixed Exposure Mode.
>RC MaxExposure⏎	>RC MaxExposure OK:0:RC MaxExposure: 500.0 msec	Upper limit of the exposure reported in milliseconds. Used in conjunction with the Fixed Exposure Mode.
>SM Exposure ***[exposure in msecs]]***⏎	>SM Exposure 10 OK:0:Exposure:No errors	Selects the exposure in milliseconds. This exposure is used only when the Exposure Mode is set to fixed.

Command	Example	Description
>RS Exposure⏎	>RS Exposure OK:0:RS Exposure:1.000 msec	Retrieves the current exposure in milliseconds. This is used only if the Exposure Mode is set to fixed.

Average

Command	Example	Description
>RC MinExposureX⏎	>RC MinExposureX OK:0:RC MinExposureX:1	The lower limit of the exposure multiplier.
>RC MaxExposureX⏎	>RC MaxExposureX OK:0:RC MaxExposureX: 50	The upper limit of the exposure multiplier.
>SM ExposureX ***[exposure multiplier]***⏎	>SM ExposureX 1 OK:0:ExposureX:No errors	Selects the exposure multiplier. RC MinExposureX and RC MaxExposureX provides the range of values that can be set.
>RS ExposureX⏎	>RS ExposureX OK:0:RS ExposureX:1	Retrieves the current exposure multiplier.

CMF

Custom color matching functions are loaded using the Colorimeter Utility. The CMF commands only allow the selection of the CMFs which are loaded in the instrument

Command	Example	Description
>SM CMF [index]⏎	>SM CMF 1 OK:0:CMF:No errors	Selects the Color Matching Function to be used for the measurement calculations.
>SC CMF [index]⏎	>SC CMF 0 OK:0:SC CMF:No errors	Selects the Color Matching Function table index. This command also recalculates and modifies the current measurement.
>RS CMF⏎	>RS CMF OK:0:RS CMF:0	Retrieves the current Color Matching Function Index.

Measure

Command	Example	Description
>M⏎	>M OK:0:M:No errors >M ER:-305:M:Light intensity too low or unmeasurable	Capture a measurement and returns after the measurement is completed or an error has occurred.
>MT⏎		Trigger a measurement and returns immediately without waiting for the response. This is used for asynchronous capture of measurements.

Command	Example	Description
>MA↵		Aborts a measurement in progress. This is used for asynchronous capture of measurements.
>MF↵		Measures the sync frequency of the light source.

Reading

The RM commands retrieves parameters stored as part of the measurement data during the previous measurement command.

Command	Example	Description
>RM ID↵	>RM ID OK:0:RM ID:A00102	Retrieves the instrument identifier (Serial Number).
>RM Model↵	>RM Model OK:0:RM Model:CR-100	Retrieves the instrument model.
>RM Time↵		Retrieves the date and time stamp of measurement
>RM Aperture↵	>RC Aperture OK:0:RC Aperture:1 0,5 deg	Retrieves the name of the aperture.
>RM Accessory↵	>RM Accessory OK:0:RM Accessory:Standard	Retrieves the name of the accessory
>RM Filter↵	>RM Filter OK:0:RM Filter:None >RM Filter OK:0:RM Filter:ND-250-1,ND-250-3	Retrieves the names of the filters
>RM SyncMode↵	>RM SyncMode OK:0:RM SyncMode:None	Retrieves the name of the sync mode
>RM SyncFreq↵	>RM SyncFreq OK:0:RM SyncFreq:0.00 Hz	Retrieves the sync frequency
>RM ExposureMode↵	>RM ExposureMode OK:0:RM ExposureMode:Auto	Retrieves the name of the exposure mode
>RM Exposure↵	>RM Exposure OK:0:RM Exposure: 111.622 msec	Retrieves the exposure time in milliseconds
>RM ExposureX↵	>RM ExposureX OK:0:RM ExposureX:1	Retrieves the exposure multiplier

Command	Example	Description
>RM Speed⏎	>RM Speed OK:0:RM Speed:Normal	Retrieves the name of the speed mode
>RM Warnings⏎	>RM Warnings OK:0:RM Warnings:0	Retrieves the measurement warnings reported during the last capture. The warnings are reset after each capture.
>RM Spectrum⏎	>RM Spectrum OK:0:RM Spectrum: 380.0,780.0,2.0,201 2.119e-24 1.913e-24 . . .	Retrieves the spectral measurement. If a valid spectral reading is present the first line will indicate start, end, delta wavelengths and the number of points. Followed by a spectral point on each line.
>RM X⏎	>RM X OK:0:RM X:1.737e+00 4.3.1.22	Retrieves the (2°) tristimulus X data by default or using the selected CMF
>RM Y⏎	>RM Y OK:0:RM Y:1.685e+00	Retrieves the (2°) tristimulus Y data
>RM Z⏎	>RM Z OK:0:RM Z:1.830e+00	Retrieves the (2°) tristimulus Z data
>RM XYZ⏎	>RM XYZ OK:0:RM XYZ: 1.737e+00,1.685e+00,1.830e+00	Retrieves the (2°) tristimulus XYZ data of the last capture as comma separated values.
>RM X10⏎	>RM X10 OK:0:RM X10:1.737e+00	Retrieves the (10°) tristimulus X data
>RM Y10⏎	>RM Y10 OK:0:RM Y10:1.685e+00 4.3.1.25	Retrieves the (10°) tristimulus Y data
>RM Z10⏎	>RM Z10 OK:0:RM Z10:1.830e+00	Retrieves the (10°) tristimulus Z data
>RM XYZ10⏎	>RM XYZ10 OK:0:RM XYZ10:1.737e+00,1.685e+00,1.830e+00	Retrieves the (10°) tristimulus XYZ data of the last capture as comma separated values.
>RM xy⏎	Examples >RM xy OK:0:RM xy:0.3308,0.3208	Retrieves the CIE 1931 xy data (2°) by default or using the selected CMF
>RM xy10⏎	>RM xy10 OK:0:RM xy10:0.3308,0.3208	Retrieves the CIE 1964 xy data (10°) of the last capture as comma separated values
>RM uv⏎	>RM uv OK:0:RM uv:0.2138,0.3110	Retrieves the CIE 1960 uv data of the last capture as comma separated values.

Command	Example	Description
>RM upvp⏎	>RM upvp OK:0:RM upvp: 0.2138,0.4666	Retrieves the CIE 1976 u'v' data of the last capture as comma separated values.
>RM CCT⏎	>RM CCT OK:0:RM CCT: 5577,-0.0100	Retrieves the correlated color temperature (CCT) in °Kelvin and the uv deviation from the Planck's Locus of the last capture as comma separated values.
>RM Yv⏎	>RM Yv OK:0:RM Yv:0	Retrieves the scotopic Luminance
>RM CMF⏎	>RM CMF OK:0:RM CMF:0	Retrieves the Color Matching Function used for calculations.
>RM Radiomnetric⏎	>RM Radiometric OK:0:RM Radiometric: 0,3.209e-01,8.835e+17	Retrieves the Units of radiometric data, Radiometric power and Photon Radiometric power. Values for radiometric types are • 0: Radiance • 1: Irradiance • 2: Radiant Intensity • 3: Radiant Flux

Response Codes

Following is a comprehensive list of response codes and their description.

Negative numbers are errors while positive numbers indicate warnings. 0 indicates no errors.
300 range is measurement errors.
500 range is general command errors

Error/Warning Code	Description
100	Light intensity too low for automatic sync
101	Cannot sync to constant light source
102	Cannot find sync, max limit selected
103	Sync level too low for reliable sync
-300	Invalid Sync mode
-301	Invalid Sync period
-302	Can not sync to light

Error/Warning Code	Description
-303	Light intensity is fluctuating
-304	Light intensity too low for range
-305	Light intensity too low or unmeasurable
-306	Light intensity too high for range
-331	Hardware malfunction
-334	Uninitialized CIE tables
-335	Uninitialized CMF tables
-500	Invalid command
-505	Duplicate Filter selection
-506	Index doesn’t select an Accessory
-507	Index doesn’t select a Filter
-508	Index not valid for Accessory
-509	Index not valid for Filter
-510	Index not valid for Filter
-511	Index not valid for Filter
-514	Invalid Exposure Multiplier
-515	Index doesn’t select an Aperture
-518	Invalid Exposure Mode
-519	Invalid Exposure value
-521	Invalid Sync Mode
-522	Invalid User Sync Frequency