USER OPERATION MANUAL

SpectralLED® TUNABLE LIGHT SOURCE

MODEL: RS-7

Revision A/X1

SpectralLED – Spectral Simulation Assistant, Revision 2.18

RS-7 Firmware Revision 1.12

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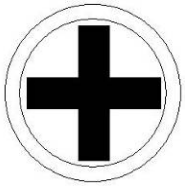
Your input is appreciated

SAFETY FIRST



Protect yourself. Follow these precautions:

- This Manual contains information about the proper procedures for preparing this product for its use and care.
- Follow the instructions of other manufacturer's equipment when used in conjunction with this product.
- Explosion Hazard. Do not use in the presence of flammable liquids, vapors, gases or dusts.
- FIRE HAZARD: DO NOT DRAPE OR COVER ANY LIGHT SOURCE WHILE IT IS OPERATING.
- Pay attention to **WARNING** statements. They point out situations that can cause injury or death.
- Pay attention to CAUTION statements. They point out situations that can cause equipment damage.
- The user of this product should be thoroughly familiar in the set-up, use, and care of this product.
- The user should carefully study this manual before using the equipment. Instructions should be followed, with special attention given to warnings, controls and user specifications. This manual should be available to the appropriate personnel.
- Before every procedure, carefully inspect the equipment to ensure it has been properly maintained and cleaned, and that it is fully functional. DO NOT use if inspection reveals anything unusual, including case damage or loose connectors.
- SAFETY PRECAUTIONS MUST ALWAYS BE EXERCISED WHEN USING ELECTRICAL EQUIPMENT TO PREVENT OPERATOR SHOCK, FIRE HAZARD OR EQUIPMENT DAMAGE.
- Don't touch any exposed wiring.
- All electrical equipment must be used with approved power cords and power plugs inserted properly into grounded AC power outlets.
- Don't plug in the power cord until directed to by the installation instructions.
- Don't bypass the power cord's ground lead with two-wire extension cords or plug adaptors.
- Don't disconnect the green and yellow safety-earth-ground wire that connects the ground lug of the power receptacle to the chassis ground terminal (marked with ⏚ or ⚠).
- To reduce the risk of fire and electric shock, do not expose electrical equipment to moisture. When cleaning, do not immerse any electrical device in liquid.
- Do not use or store liquids on or above the equipment.

- Electric shock hazard. If unit is not functioning properly, DO NOT OPEN. Please refer to the Maintenance and Troubleshooting section of this manual.
- Use only properly functioning cables that are made for system instrument connectors.
- Light sources produce high intensity light. Thermal burns can result from improper use of the light source.
- Use care not to point any operating light source directly at the eye.
- When light source is not in use, turn off the power.
- Keep any cooling vents and fans free of obstructions.

INSTRUMENT CERTIFICATION

Gamma Scientific, Inc., certifies that this instrument was thoroughly tested, inspected and found to meet its published specifications when it was shipped from the factory. Gamma Scientific, Inc., further certifies that its calibration measurements are traceable to the U. S. National Institute of Standards and Technology (NIST) formerly National Bureau of Standards to the extent permitted by the Bureau's calibration facility.

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All products manufactured by Gamma Scientific are warrantied to be free from defects in material or workmanship subject to the following terms and conditions. All other products sold by Gamma Scientific are warrantied only to the extent of that offered by the manufacturer.

(a) PERIOD OF WARRANTY:

This warranty shall terminate one year after the date of shipment.

(b) REPAIR OR REPLACEMENT:

Seller's obligations under this clause shall be limited to repair or correction of any defect of material or workmanship in any such product or to replacement of any defective product or part or unit thereof, notice of which shall have been given to Seller within the warranty period specified in subdivision (a) above.

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Since the life of such components is a function of the customer's usage of them, all electron tubes and photomultiplier tubes are warrantied only to the extent that the original manufacturer's warranty applies. Claims are limited to those presented within 30 days after occurrence of any failure.

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This warranty shall not apply if modifications not authorized in writing by Seller are made.

The warranties set forth in this clause are in lieu of any other warranties, expressed or implied, which the purchaser or others might have under or arising from this agreement, by statute, at law, in equity, or otherwise, INCLUDING ANY WARRANTY OR MERCHANTABILITY OR FITNESS. Goods sold subject to above warranty only, and Seller expressly denies any other warranties or representations, statutory, legal or equitable, expressed or implied.

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In the event the instrument does not function properly or is damaged, Gamma Scientific Inc. should be contacted with regard to the specific symptoms of the problem.

NOTE

For all service requirements, please ask for the Customer Service Department. Gamma Scientific must be contacted prior to any return shipment of equipment, and an RMA must be issued prior to returning equipment. Failure to do so will result in delayed return to the customers.

Table of Contents

SECTION 1 INTRODUCTION

1.1 General Information

Gamma Scientific's SpectralLED® Tunable LED Light Source (Model: RS-7) is a multi-channel light source capable of providing single channel illumination or broadband illumination using multiple channels. It is designed to simulate broadband illuminants or any arbitrary spectrum by precisely combining the output of its LED channels closely recreate real-world spectra. Gamma Scientific's RS-7 features near perfect linearity and uniformity over the entire intensity range, and comes with NIST-traceable absolute calibrations.

1.1.1 Features

- Multi-Channel LED Light Source covering a wavelength range from 360nm to 1000nm
- Digital Linear DC Drive Current Control
- High Dynamic Intensity Range (16 bit)
- Built-in Photodiode Feedback
- NIST Traceable Irradiance Calibration
- Long Lifetime

1.1.2 Precautions

WARNING:

Maintain ground to avoid electric shock
Disconnect power cord before replacing fuse
Replace fuse with same type and rating only

WARNING:

No user serviceable parts inside
Service by a qualified Gamma Scientific professional only
Do not open cover

1.2 System Specifications

Table 1. RS-7 System Specifications

Spectral Range	360nm-1000nm (Standard version, custom configurations available)
Spectral Output	32 discrete LED channels, 3 broadband LED channels Visible resolution ≈15nm, NIR resolution ≈50nm (typical channel spacing)
Spectral Peaks	395nm, 405nm, 420nm, 430nm, 450nm, 460nm, 475nm, 495nm, 505nm, 520nm, 525nm, 535 nm, 545nm, 590nm, 595nm, 620nm, 630nm, 637nm, 660nm, 675nm, 685nm, 700nm, 715nm, 735nm, 750nm, 760nm, 780 nm, 805nm, 850nm, 910nm, 940nm, 985nm, 2700K Warm White, 3000K Warm White, 6500K Cool White (Standard version, custom configurations available)
Spectral Bandwidth[1]	Channel dependent visible typical ≈20nm FWHM, NIR typical ≈50nm FWHM
Source Geometry	75mm diameter uniform output, Lambertian radiant source
Spatial Uniformity[2]	≥ 97%
Optical Geometry	Built-in integrating sphere, 200mm diameter (other output geometries available for projection or illuminator applications)
Radiance Range[3]	Typical maximum ≈ 7,500µW/cm²/sr Typical minimum ≈ 10µW/cm²/sr (spectrum dependent)
Luminance Range[3]	Typical maximum ≈ 15,000cd/m² Typical minimum ≈ 20cd/m² (spectrum dependent)
CCT Range	1,900K - 40,000K
SpectralLED Assistant Application Spectra	CIE Illuminants A, B, C, D50, D55, D65, D75, E, F1-F12, Macbeth®[4]/X-Rite®[4] color patches
Custom Preset Spectra	Arbitrary spectra; can be configured as presets using API. Gamma can provide factory loaded custom presets, use part number RS-7-PRE (Spectral Information must be Provided by Customer at Time of Order)
Illumination Stability	≥ 99.99% after settling (channel dependent, settling occurs after ≈50ms for radiance and ≈2000ms for color)
Illumination Accuracy	± 1% absolute NIST traceable, calibration stored internally
Spectral Accuracy	± 1nm centroid wavelength
Color Accuracy	CIE 1931 x,y = ±0.003
Linearity	< 0.1% RMS of full scale
Temperature Stability	Active thermoelectric cooler with feedback, temperature control within ± 1C°
Long Term Drift	Output: ≤ 0.2% Spectral: ≤ 1nm (typical, channel dependent)

Table 1. RS-7 System Specifications continued

Electrical Resolution	16 bit DAC for channel current drivers (32 independent DACs, 1 for each LED channel) 24 bit ADC for internal radiance monitor/feedback
Dynamic Range Adjustment	Spectrum dependent, 4-5 decades typical
LED Control	Pure DC constant current with floating differential sensing
Software	Firmware contains full spectral calibration, handles spectral fitting, preset storage, real-time optical feedback, radiometric and photometric units supported.
Interface	USB 2.0 type B connector and DB-9 connector
Interface Protocol	Simple ASCII commands with optional binary block transfer
Supported Operating Systems	USB drivers for Windows®, OSX, and Linux® via FTDI virtual COM port Legacy RS-232 serial port for integration into automated systems (no OS required)
Input Voltage	110-240 VAC, 50-60Hz
Maximum Power Consumption	600W
System Dimensions	Height: 405mm, Width: 460mm, Depth: 305mm, Weight: 25kg

1. FWHM: Full-Width Half-Maximum.
2. Uniformity measured using an 8° FOV at the output plane of the device while simulating illuminant E over a wavelength range of 380nm-1000nm. Uniformity spec measures over the entire Ø 75mm active area, when considering only the center Ø 50mm area uniformity exceeds 98%.
3. Spectra fit over a wavelength range of 380nm-780nm, maximum output is dependent on spectral content of the target spectra. Most CIE illuminants and color patches can fit to at least this level, typical spectra can far exceed this maximum however some spectra cannot achieve this maximum.
4. X-Rite, Macbeth, and ColorChecker are registered trademarks of X-Rite, Inc.

SECTION 2 OPERATING PROCEDURES

2.1 Principle of Operation

2.1.1 Overall Design

The SpectralLED® RS-7 Tunable Light Source uses light emitting diodes driven by digitally controlled constant current sources. The use of precision voltage references, along with active optical feedback, enables a stable output with extremely linear brightness adjustment. In addition, the incorporation of multiple independent spectral channels provides flexible spectral and colorimetric programmability of the output. NIST-traceable calibration of the spectral output, luminance, and uniformity, add to the reliability of the source as an optical reference tool.

2.1.2 Linear Brightness Control

The SpectralLED® RS-7 Tunable Light Source built around a 16-bit DAC controlled linear brightness adjustment circuit operating at comparatively high speeds, and exhibits excellent repeatability. An integral real-time optical feedback circuit arbitrates the brightness control circuit, resulting in the RS-7's extremely linear intensity adjustment capability. This allows the source to adjust linearly without independent monitoring by a radiometer, without the need for neutral density filters or other attenuators, and without the need for pulse width modulated intensity control, which can cause flicker.

2.1.3 Real-Time Feedback

The SpectralLED® RS-7 Tunable Light Source has a fully integrated real-time optical feedback system, which monitors the source output and constantly adjusts the brightness to maintain the selected intensity level. The RS-7 also features closed loop thermal feedback control to add another level of stability and maintain reliable operation over many years. The RS-7 can be operated reliably even in high temperature environments (up to 40°C) while retaining linearity and stability.

2.1.4 Spectral and Colorimetric Matching

The SpectralLED® RS-7 Tunable Light Source is spectrally programmable to allow for the creation of both narrowband and/or broadband spectrums with arbitrary spectral distributions. In addition, it can provide 'preset' standard illuminants and individual color components combined, simulates among other things; X-Rite Color Checker patches illuminated by standard illuminants. Each RS-7 spectral channel is individually calibrated and controlled. For colorimetric applications, the RS-7 can be used to accurately reproduce color coordinates over a much larger gamut than most any standard RGB source, while exhibiting a much smaller color error than is possible with three component RGB sources or reflective color test targets.

2.2 Hardware Configuration

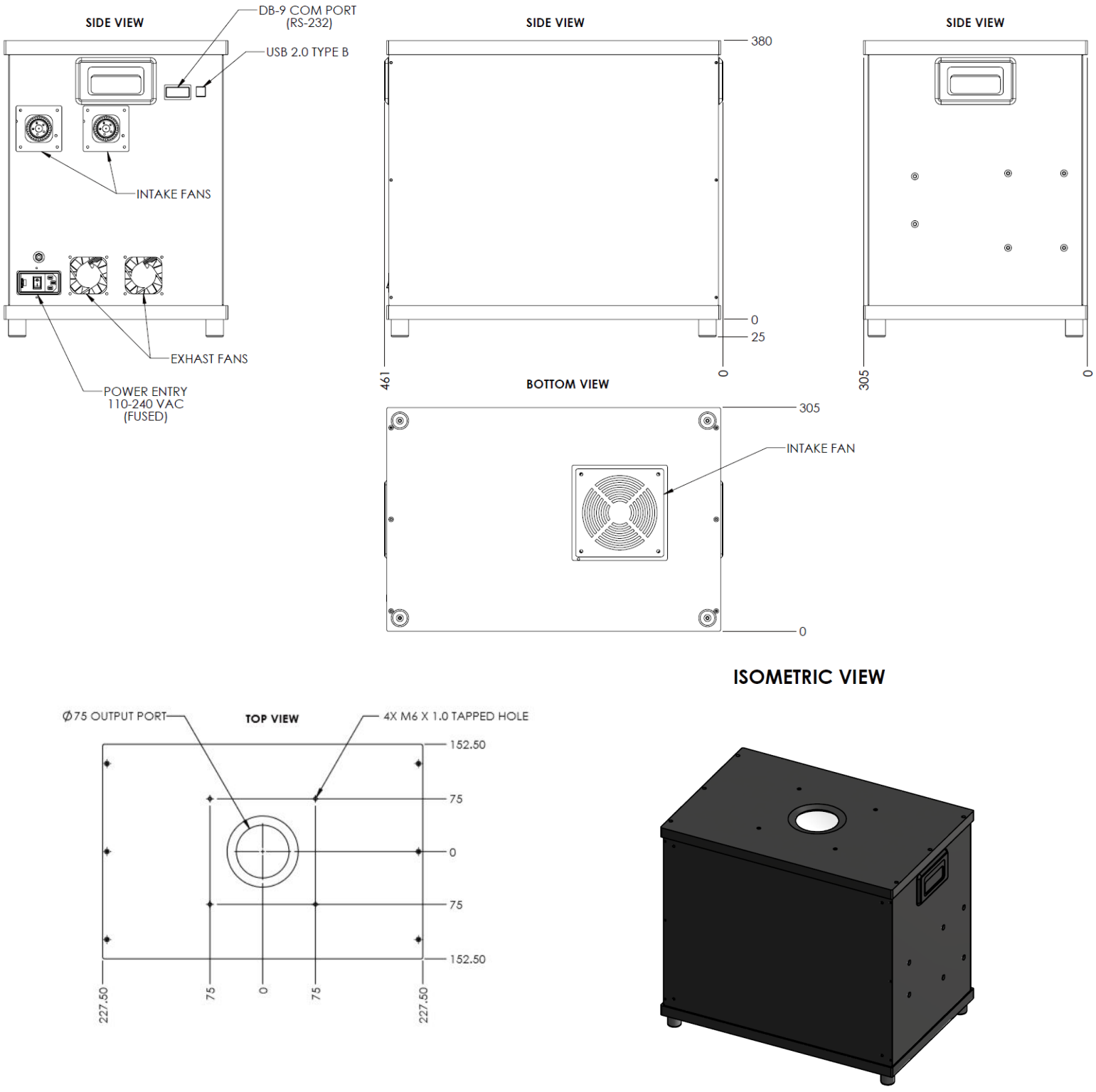


Figure 1. RS-7 Schematic – Hardware Configuration

Basic Operation

Step 1. Connect the USB and power cables to the RS-7.

Step 2. Locate the power switch on the RS-7 and turn the unit on by flipping the switch.

Step 3. Connect the USB cable to the host computer, drivers should automatically install on Windows and OSX.
   a. If drivers do not automatically install, please use the drivers provided by Gamma Scientific.

Step 4. On the host computer, determine the COM port assigned to the RS-7.
   a. In Windows, done via Device Manager.
   b. The RS-7 will appear as a USB Serial Port (virtual COM port).

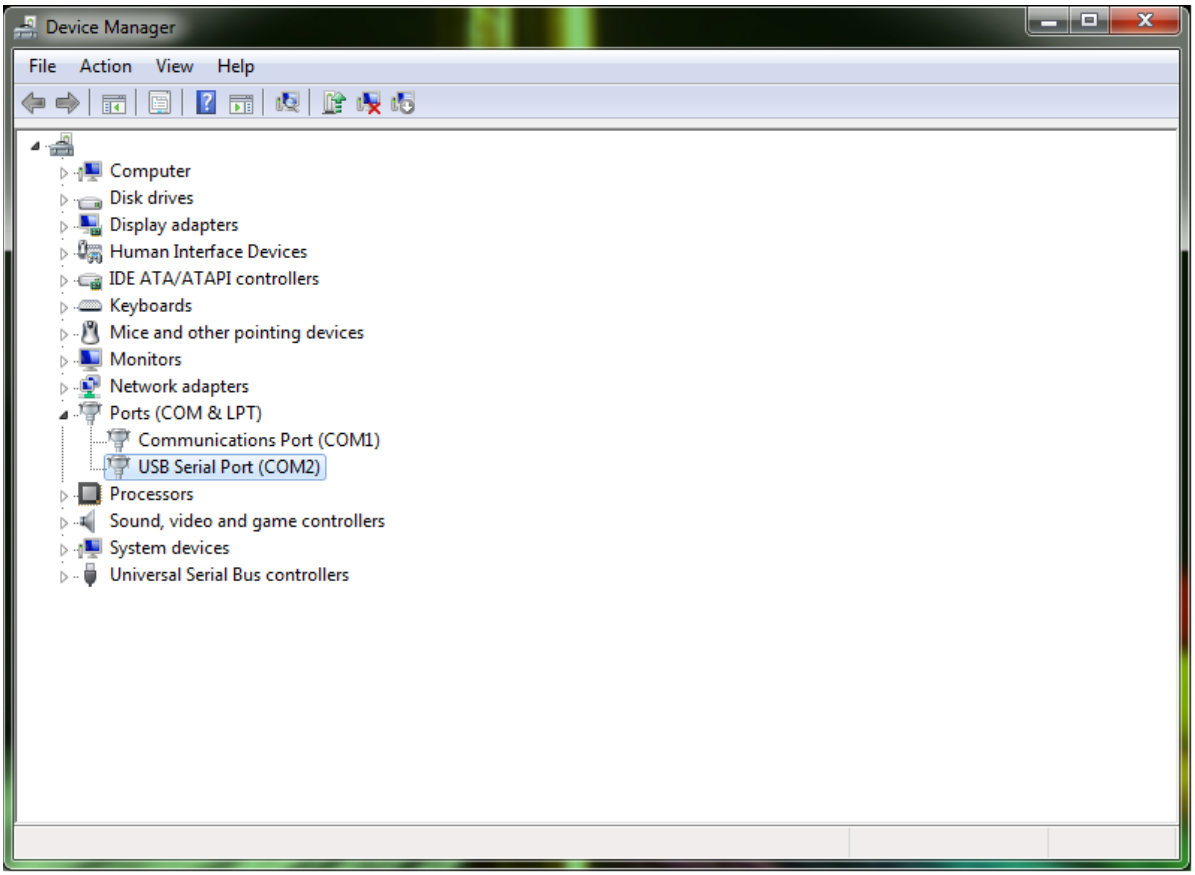


Figure 2. Device Manager

Step 5. On the host computer, start terminal emulation software of your choice, and set the following serial connection parameters (e.g. Tera Term for Windows, CoolTerm for OSX).

a. Baud rate: 460,800 (note that the RS-7 may be optionally configured for 115,200 baud operation)
b. Data bits: 8
c. Parity: None
d. Stop bits: 1
e. Flow control: None

Since the RS-7 does not echo characters as they are being typed, it is helpful to enable “Display Typed Characters Locally”. Also, the RS-7 always sends a linefeed <LF> with each carriage return <CR>, so it is not necessary to enable any kind of “Add LF to each CR” or “Implicit LF in each CR” function.

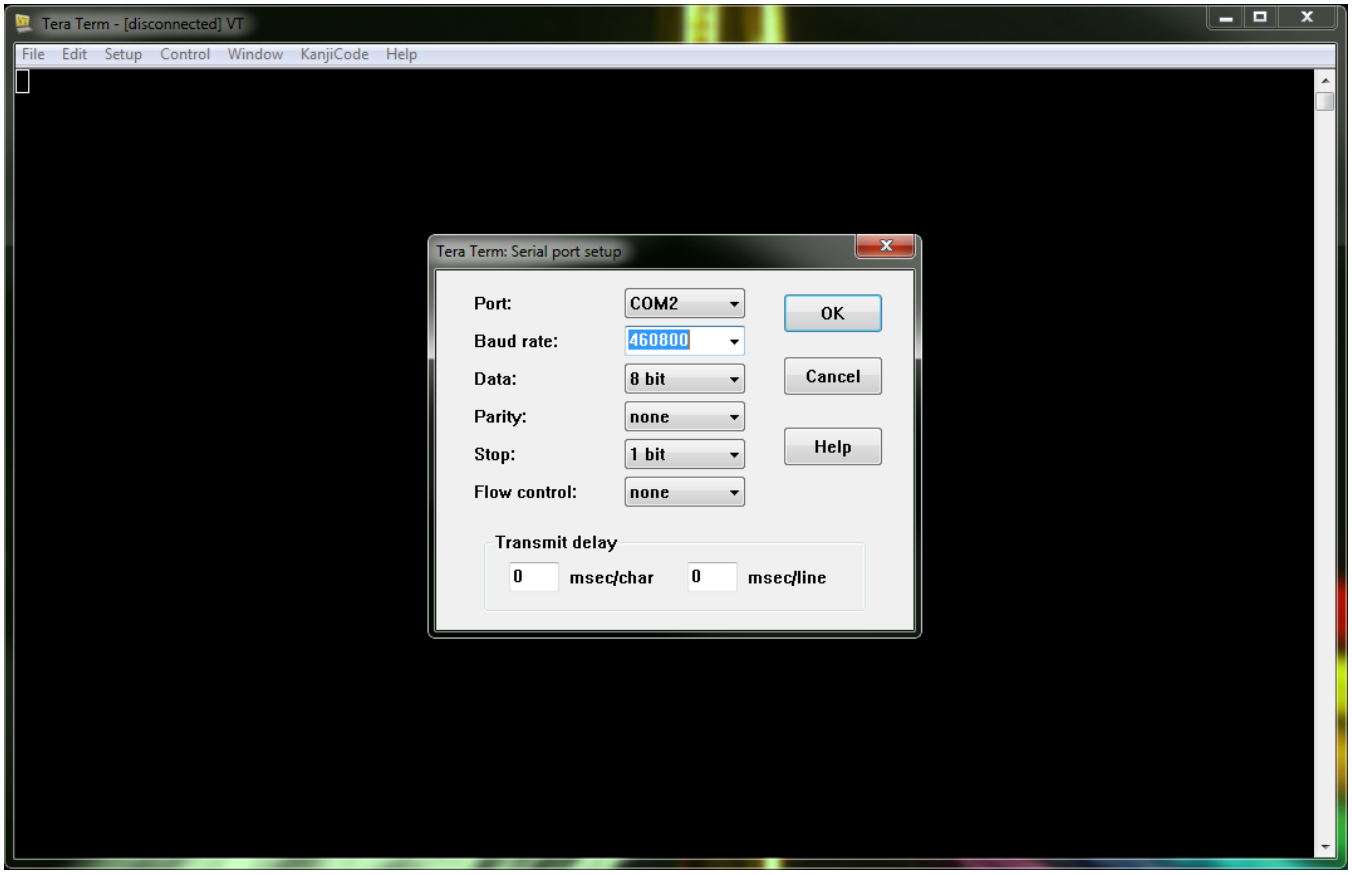


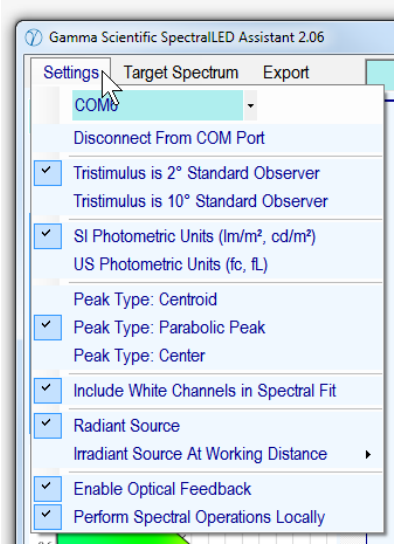
Figure 3. Tera Term: Serial port setup

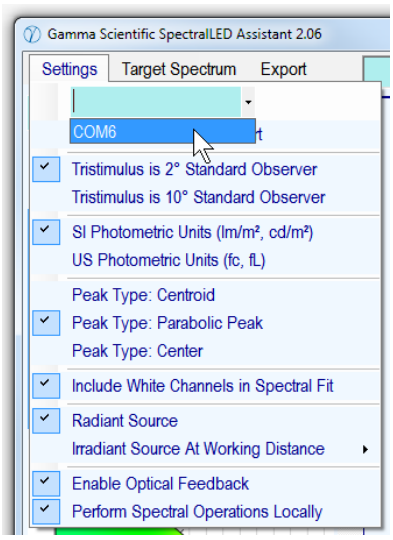
Step 6. Once the terminal connects to the RS-7, user should be able to start issuing commands as defined in the ASCII Command API, SECTION 4 below. Alternatively, the graphical user interface provided by the SpectralLED Assistant application program (MS Windows) controls the operation of the RS-7, as described in SECTION 3.

SECTION 3 SPECTRALLED - SPECTRAL SIMULATION ASSISTANT

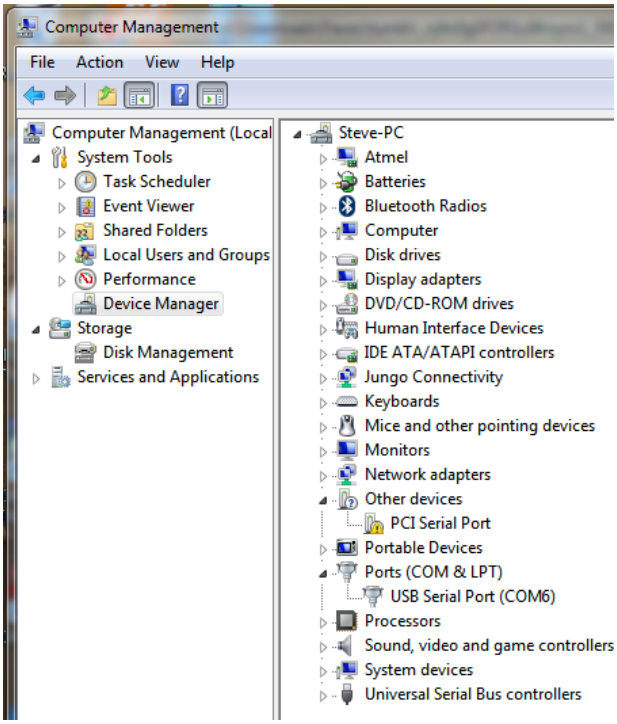
Getting Started

To connect to the RS-7, click on the **Settings** menu **(2)** and then select the a COM port by clicking on the down-arrow and selecting the appropriate COM port going to the RS-7.

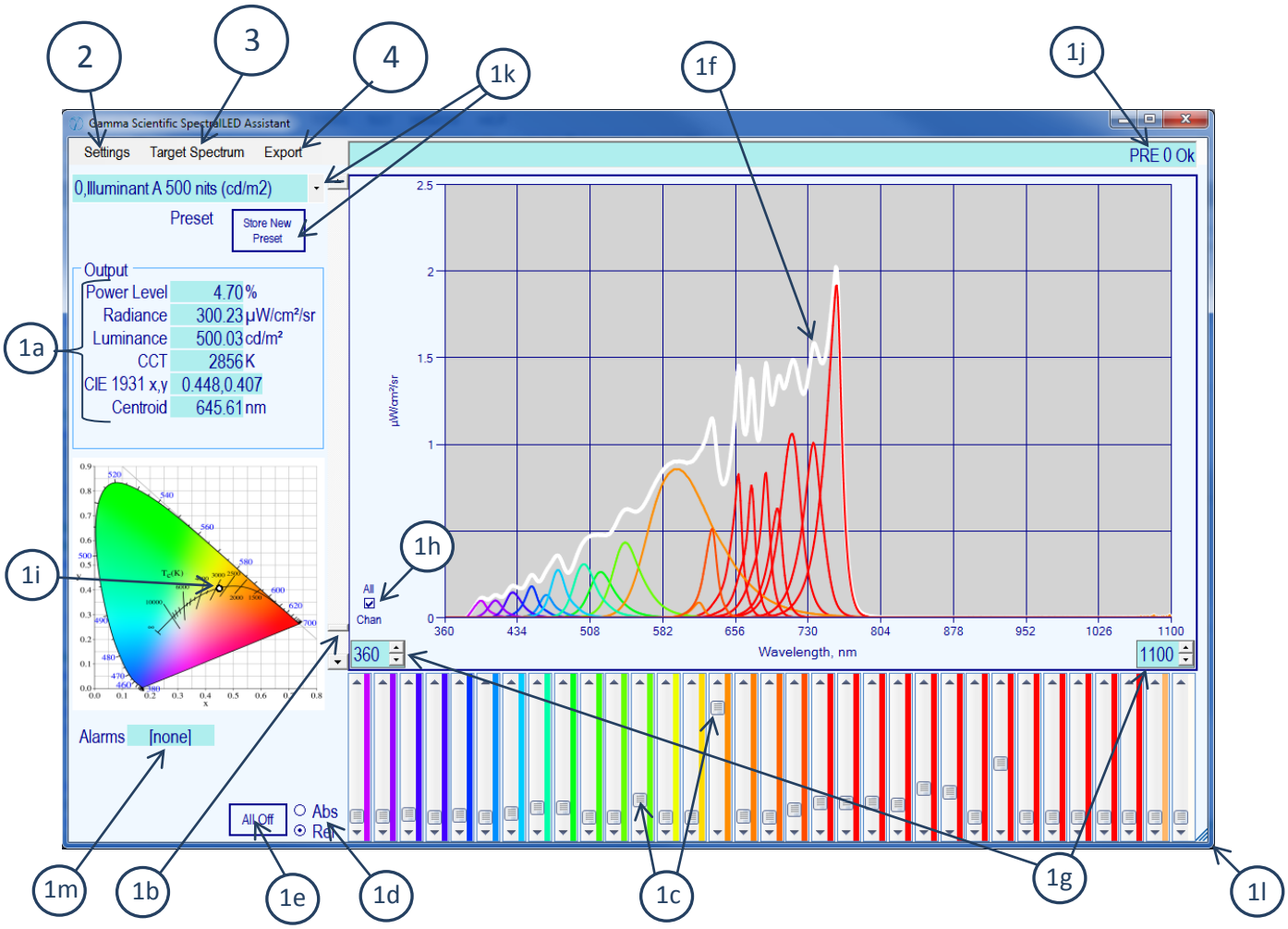




Don't know which COM port to select? Click on the Windows **Start** button, then right-click **Computer**, then click **Manage**. When the Computer Management window opens, click **Device Manager** in the left pane. Then, in the right pane, expand **Ports (COM & LPT)**. The RS-7 will appear as "USB Serial Port". In this example, the COM port is COM6.



3.1 SpectralLED Assistant Main Window



CLICK ON THE ARROW AND SELECT FROM DROP-DOWN LIST to load an existing spectral preset (**1k**).

DRAG the individual channel power controls (**1c**) up and down to manually create/modify a spectrum.

DRAG the main power level control (**1b**) up and down to change the current spectrum's overall power level.

CLICK, TYPE IN A NUMBER, and PRESS ENTER to input a specific power level, CCT, or chromaticity in the boxes (**1a**).

CLICK on the CIE 1931 x,y chromaticity diagram to modify the current spectrum's chromaticity (**1i**).

1a. Output Pane

Power Level shows the output power of the currently generated spectrum as a percentage between 0 and the RS-7's Soft Limit (see the **SLM** command, section 4.6.19) which represents the maximum possible power that can be achieved for the current spectrum. **Radiance** (or **Irradiance**)**, Luminance** (or **Illuminance**)**, CCT** (Correlated Color Temperature in degrees Kelvin)**,** and **1931 x,y chromaticity** are also reported.

Centroid shows the wavelength-weighted average of the combined spectral output power distribution; this can be configured to alternatively display **Parabolic Peak** wavelength or **Center** wavelength (**2d**). An RS-7 equipped with the optional Wavelength Monitor System has the additional capability of measuring and reporting the centroid/peak/center wavelength of a single channel in real time, and this box will continuously be updating with wavelength information whenever one and only one channel is active.

Note that all of the boxes except Centroid accept input, by **clicking on the box, typing in a new value, and pressing ENTER.** Changing the **CCT** (Correlated Color Temperature) or the **CIE 1931 x,y** chromaticity will modify the output spectrum to match the specified chromaticity using a color-matching algorithm that uses the tristimulus curves as weighting functions to add or remove energy in the three X, Y, and Z regions to arrive at the new chromaticity.

Holding down the SHIFT key when you press ENTER when typing a new level into any of the **Power Level, Radiance/Irradiance,** and **Luminance/Illuminance** boxes will cause the RS-7 to ***maintain the same chromaticity*** at the new power level. This is because LEDs tend to slightly shift in wavelength (change color) as their drive current is increased or decreased, so this option provides a way to "touch up" the spectrum at the new power level to keep chromaticity constant. You will see the **CIE 1931 x,y** box change from blue to green when the SHIFT key is being held down, as an indicator that the chromaticity is to be maintained. This also applies to the Main Power Level control (**1b**); change it while holding down the SHIFT key will keep the chromaticity constant.

(ASCII Command API reference **CCSx,y** Section 4.4.6, **OUTC** Section 4.5.3)

1b. Main Output Power Level Control

Click and drag this control up or down to change the output power of the current spectrum in real time. Holding down the SHIFT key while changing this control will cause the RS-7 to maintain the same chromaticity throughout the output power range (see the comment about ***Holding down the SHIFT key*** in the box above).

(ASCII Command API reference **OUT** Section 4.5.2, **OUTC** Section 4.5.3)

1c. Individual Channel Power Level Controls

Click and drag these controls up or down to change an individual channel's power level. **Hover** the mouse pointer over a control to display the channel's nominal wavelength and channel number(s). These controls can be configured to show either absolute channel power levels (0 to maximum possible), or relative power levels (relative to the channel that is set to the highest level) using the **Abs/Rel** control (**1d**).

(ASCII Command API reference **SCP** Section 4.2.1)

1d. Absolute vs. Relative Channel Output Power Level

When the Main Output Power of the RS-7 is set to very low levels, the individual Channel Power Level controls (**1c**), if they are showing absolute power levels (between 0 and the maximum possible for each channel), will barely be moving at all, and their individual contribution to the current Output Spectrum will not be obvious. By

changing to relative power levels, the controls are all scaled relative to the channel which is set to the highest output power; in this way, the actual *spectrum* as shown by the controls' relative positions to each other can be seen regardless of the RS-7's Main Output Power.

1e. All Off (Reset Spectrum To Zero)
This button will set all the channels to **OFF** (0), thus ***removing the current output spectrum completely***. If you merely want to turn the RS-7's output off but *want to maintain the spectrum,* instead use the Main Output Power Level control (**1b**) or type zero into one of the power level boxes (**1a**); in this case, the RS-7 "remembers" the current spectrum in spite of the fact that all of the Individual Channel Power Level controls (**1b**) appear to be set to OFF (in other words, using the All Off button *really* turns all the channels off, and you won't be able to set the Main Output Power Level to anything besides zero because *there is no Output Spectrum for it to use*. Move at least one Channel Power Level Control to start creating a new spectrum).

1f. Spectral Plot
The white line shows the RS-7's current Output Spectrum, and the individual channels' spectra are shown in their approximate color, with infrared channels displayed as deep reds, if Plot All (**1h**) is checked. Additionally, if the Target Spectrum is visible (**3b**), it will be shown as a blue line, with graphic brackets representing the effective Wavelength Range (**3n, 3o**) for spectral operations. The wavelength range of the Spectral Plot itself can be adjusted by changing the Start and End wavelengths (**1g**).

(ASCII Command API reference **OSP** Section 4.4.3, **TSP** Section 4.4.4, **WLR** Section 4.4.1)

1g. Spectral Plot Wavelength Range
The starting and ending wavelengths of the Spectral Plot can be changed in order to display just a portion of the spectrum.

1h. Plot All Chan
If this is not checked, only the current Output Spectrum (white line), and optionally the Target Spectrum (blue line) (see Section 3.3) will be plotted. Checking this box will include all of the individual channels' spectra in approximately the color of each channel, with infrared channels all shown in red.

1i. CIE 1931 x,y Color Chart
The chromaticity of the RS-7's current Output Spectrum is shown on the Color Chart as the little black circle. ***Note that the Color Chart also accepts input***; you can click anywhere on the chart and the RS-7 will attempt to modify the current Output Spectrum using a color-matching algorithm that uses the tristimulus curves as weighting functions to add or remove energy in the three X, Y, and Z regions to arrive at the new chromaticity.

(ASCII Command API reference **OXY** Section 4.5.6, **CCSx,y** Section 4.4.6)

1j. Command/Status Bar
ASCII Commands sent to the RS-7 over the COM port, and the responses received back from the unit, are displayed in this box. In the event there is an error, the box will briefly flash red to draw attention to what went wrong. See SECTION 4 for a description of the each of the ASCII commands used to operate the unit, and Section 4.7 for an explanation of the "?nn –" error codes at the end.

1k. Presets
The RS-7's current output state can be stored as a preset. **To load an existing preset**, click on the arrow and select a preset from the list. **To save the RS-7's current output state as a new preset**, click the Store Preset button, select the preset # where you want to store the preset by clicking on the arrow and selecting from the

list, enter a description in the Enter Description box, and click Ok. **To delete a preset**, select one of the presets from the list, and press the DELETE key. ***Note that <u>the RS-7 always loads preset #0 at power-on</u>***, so you can specify the initial power-on state of the RS-7 by merely saving the desired configuration, spectrum, & output level as preset #0.

(ASCII Command API reference **PRE** Section 4.3.1, **SPR** Section 4.3.2, **DPR** 4.3.3)

1l. Resize SpectralLED Assistant Window

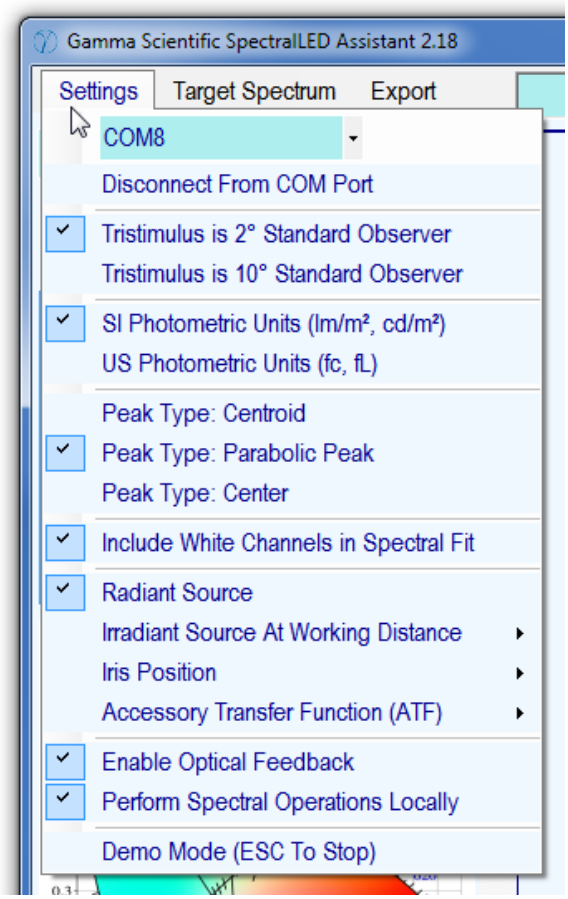
The window can be resized by dragging the corner in typical Windows fashion. A larger window can show more detail, and also shows the Individual Channel Power Level controls (**1c**) with each channel's approximate color shown immediately to the right of the control, with infrared channels shown as deep reds.

1m. Alarms

If SpectralLED Assistant detect that the RS-7 has raised on or more alarms, the alarm code(s) will be displayed here and the box will flash red until the alarm is cleared (see Section 4.7 for an explanation of the various alarm codes). Click anywhere on the box (**1m**) to clear an alarm condition.

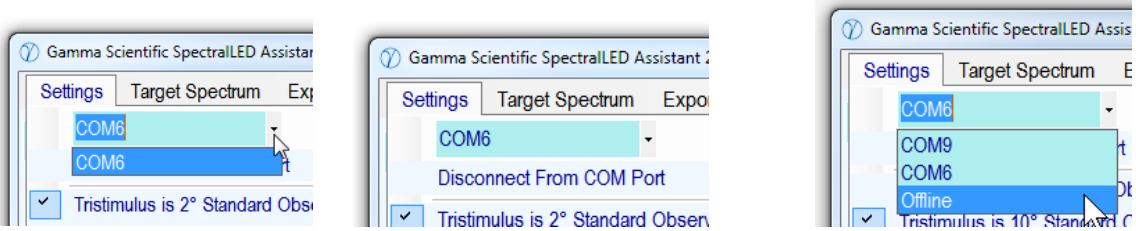
(ASCII Command API reference **ALA** Section 4.6.20)

3.2 Settings Menu



3.2.1 Select COM Port: Connects to the RS-7

Disconnect From COM Port: Disconnects to the RS-7, freeing the COM port for another program to use

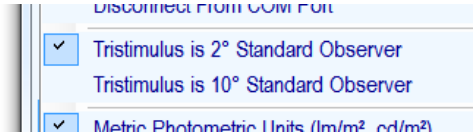


Select COM Port: Click on the arrow to display a list of available COM ports, then click on the appropriate COM port in order to connect to the RS-7. Once you have identified the COM port, SpectralLED Assistant will remember it and automatically connect to the RS-7 using the same COM port the next time SpectralLED Assistant is launched, so you don't have to select the COM port each and every time. ***Offline*** allows SpectralLED

Assistant to be operated *without an RS-7 attached;* if you select Offline, you will be prompted for the name of the **SpectralCal_HXnnnn_nnnnnnnn.bin** file (associated with a particular RS-7, generated automatically by SpectralLED Assistant during SPECTRAL CAL SYNC) you wish to use during this "simulated" operation.

Disconnect From COM Port: Click to release the COM port, in order to allow another program to access it. SpectralLED Assistant will re-connect to the RS-7 automatically whenever you perform any operation that requires SpectralLED Assistant to communicate with the unit.

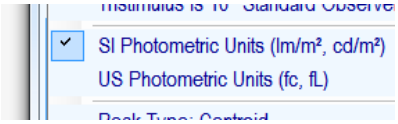
3.2.2 Tristimulus is 2° Standard Observer
Tristimulus is 10° Standard Observer



Selects the tristimulus color-matching functions to be either the CIE 1931 2° Standard Observer, or the CIE 1964 10° Standard Observer.

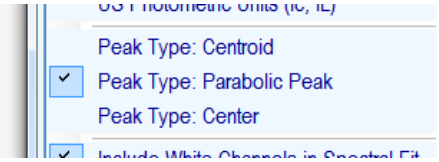
(ASCII Command API reference: **SOB** Section 4.5.5)

3.2.3 SI Photometric Units (lm/m², cd/m²)
US Photometric Units (fc, fL)



Selects between SI photometric units of
lm/m² (illuminance units of lumens per square meter, also known as **lux**)
cd/m² (luminance units of candela per square meter, also known as **nits**)
and US photometric units of
footcandles (illuminance units)
footLamberts (luminance units)

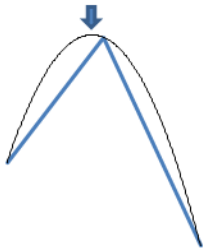
3.2.4 Peak Type



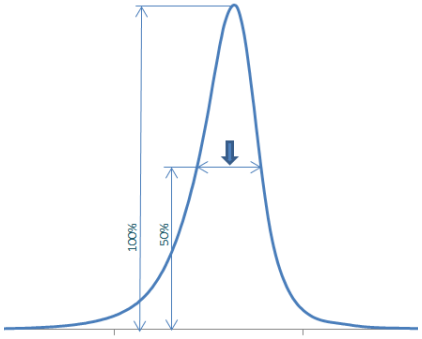
The wavelength of each of the RS-7's channels, as seen for example when one hovers the mouse pointer over one of the Individual Channel Power Level controls (**1c**), or as generated by the Export Channel List function (see Section 3.4), can be calculated in one of three ways:

Centroid, which is the amplitude-weighted average of all wavelengths of the spectrum.

Peak, which represents the peak (where 1st derivative = 0) of the parabola defined by the highest-amplitude spectral data point and its two immediate neighbors:



Center, which represents the wavelength exactly midway between the two half-power points (i.e. the midpoint of the two wavelengths that define FWHM):



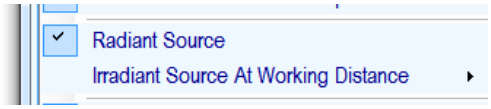
(ASCII Command API reference **PTY** Section 4.2.3)

3.2.5 Include White Channels in Spectral Fit

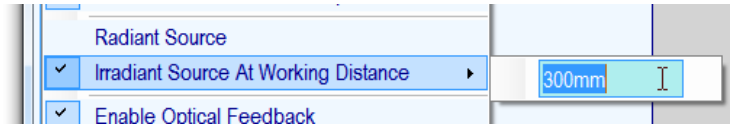
When performing a least-squares spectral fit of multiple RS-7 channels to a target spectrum (see section **3**), the RS-7 can be instructed to include *broadband white channels* as part of the solution. This may result in better spectral matches for some broadband targets, although it may also limit the maximum power level that the spectrum is capable of generating.

(ASCII Command API reference **FTS/FTSW** Section 4.4.5)

3.2.6 Radiant Source
Irradiant Source At Working Distance



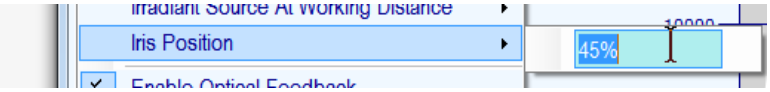
For an RS-7 with an internal integrating sphere, the unit itself is calibrated as a **Radiant** source in units of Radiance (µW/cm²/sr) and Luminance (cd/m², also called *nits*, or optionally in *footLamberts*; see **2c**). However, the RS-7 can also be operated as an **Irradiant** source, to illuminate a downrange target, in units of Irradiance (µW/cm²) and Illuminance (lm/m², also called *lux*, or optionally in *footcandles*; see **2c**). In order to operate as an Irradiant source, SpectralLED Assistant must be told the working distance from the output port plane in order to scale the irradiance units appropriately. Click on the box, type in the desired working distance in millimeters, and press ENTER.



The units will change to units of Irradiance and Illuminance, and will be properly scaled to reflect the illumination at the specified working distance from the sphere output port plane. Note that while the working distance can be specified down to 1 millimeter, ***a working distance no closer than 100mm is recommended for best accuracy.***

(ASCII Command API reference **IRR** Section 4.6.5)

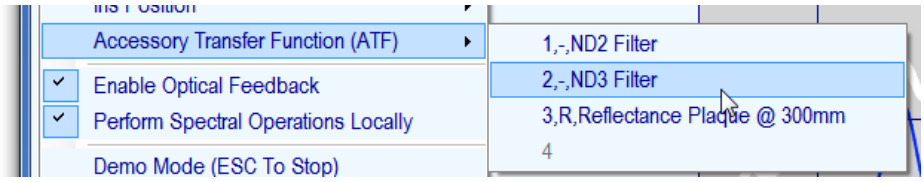
3.2.7 Set Iris Position



If the RS-7 is equipped with the optional motorized iris, its position can be set anywhere between 0% (fully open) and 100% (fully closed). Click on the box, type in the desired iris position (0 – 100), and press ENTER. If the RS-7 is configured as an Irradiant source (**2f**), the units of Irradiance (µW/cm²) and Illuminance (lm/m²) will be scaled appropriately.

(ASCII Command API reference **IRI** Section 4.6.26)

3.2.8 Accessory Transfer Function



External accessories that may be used with the RS-7, such as ND filters, polarizing filters, reflectance plaques, etc. can have associated with them an **Accessory Transfer Function**, which is a set of spectral coefficients on a per-nanometer basis that can be used to modify the RS-7's spectral calibration and therefore include the accessory (-ies) as part of the overall operation of the RS-7 as if it were present during the original calibration of the unit.

In addition to the spectral modification, an ATF can optionally change the basic units of the RS-7 from its original calibration to units of **irradiance (I), radiance (R), or total flux (F)**.

Up to four ATF's can be active at once.

(ASCII Command API reference **ATF** Section 4.6.4)

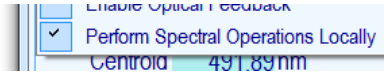
3.2.9 Enable Optical Feedback

Normally the RS-7 is operated with Optical Feedback *enabled*, such that the RS-7's internal monitor photodiode is being constantly sampled and the output power level continuously adjusted to hold the optical output power steady at the programmed level. When the Optical Feedback is disabled, the LEDs are driven at a fixed constant current. In this mode, the Output display (**1a**) will be continuously updated in real-time to show the actual

optical power level being produced at the moment.

(ASCII Command API reference **FBK** Section 4.6.17, **OUTA** Section 4.5.4)

3.2.10 Perform Spectral Operations Locally

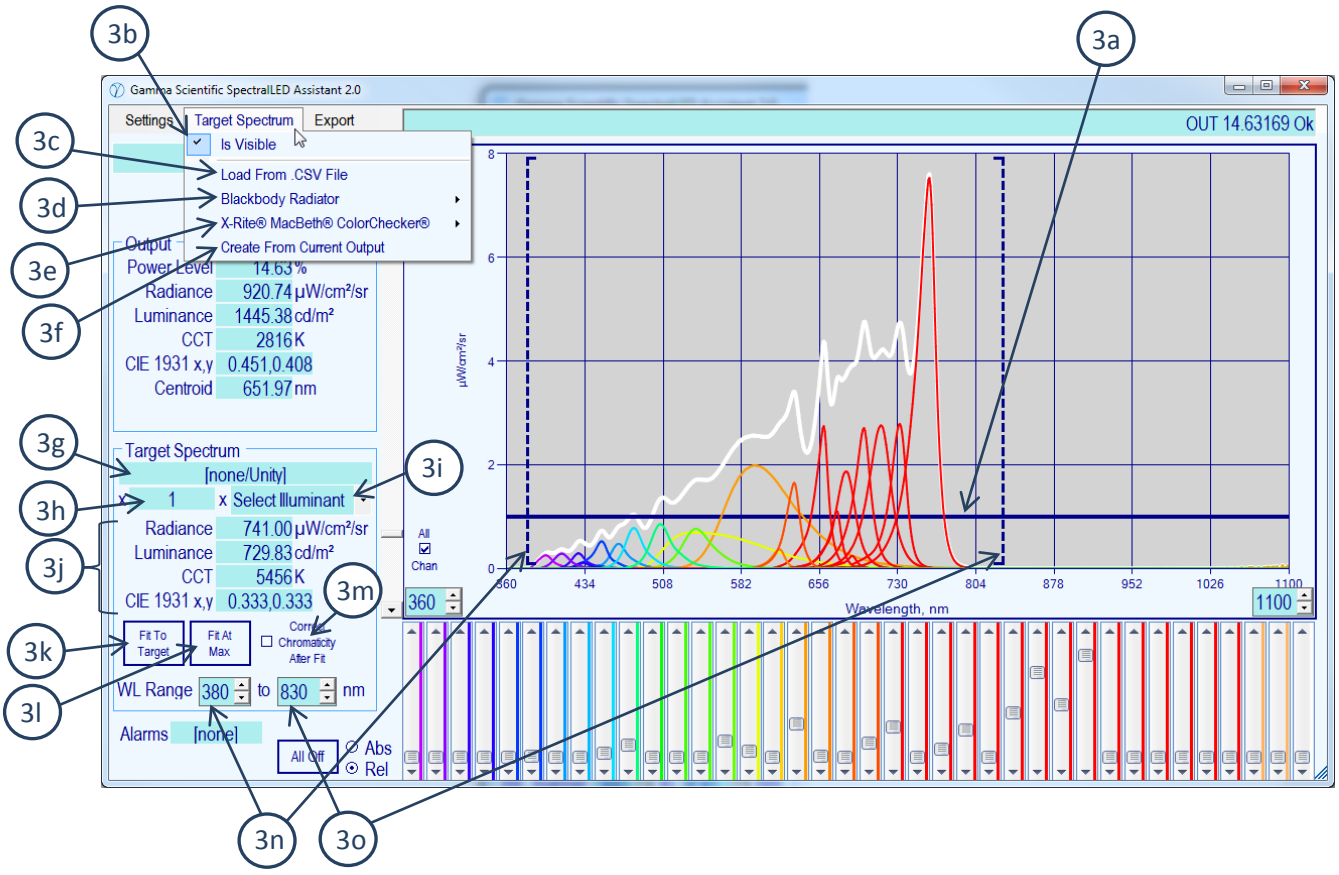


Normally SpectralLED Assistant performs all of the math-intensive calculations involved in spectral matching and colorimetric spectral modifications itself (locally), both for execution speed and to support enhanced functionality. This can be disabled, in which case the RS-7 will be commanded to perform the functions itself (remotely). The actual commands being sent can be viewed in the Command/Status bar (**1j**). A description of each of the RS-7's ASCII commands can be found SECTION 4.

3.3 Target Spectrum/Spectral Matching

The RS-7 can match any arbitrary spectrum by using a least-squares-fit algorithm to set the individual Channel Power Levels (**1c**). The spectrum the RS-7 attempts to match is called the **Target Spectrum**.

When the Target Spectrum menu is clicked, the CIE 1931 x,y chromaticity chart (**1i**) disappears and is replaced by the Target Spectrum pane (see Target Spectrum "Is Visible" **3b**), and the Target Spectrum is displayed in the spectral plot window in blue (**3a**). Here we see the initial Target Spectrum as a flat line with all spectral data points set to 1.0; this is the combination of the initial Base Target Spectrum of "none/Unity" (**3g**), multiplied by the Target Spectrum Scale Factor (**3h**), multiplied by the Illuminant (**3i**). When no Illuminant is being applied, "Select Illuminant" is displayed and the Illuminant itself has all spectral data points set to 1.0. Note that this is exactly Illuminant E, and in fact there is a selectable Illuminant called "none/Illuminant E" which is the same thing. In other words, "Select Illuminant" and "none/Illuminant E" are identical, as both represent unity at all wavelengths.



3a. Target Spectrum Spectral Plot

The Target Spectrum is shown as a blue line, and is a combination of the currently loaded Base Target Spectrum

(**3g**) multiplied by the Target Spectrum Scale Factor (**3h**) multiplied by an Illuminant (**3i**). Here it appears as a flat line (all spectral data points = 1.0) because the Base Target Spectrum (**3g**) is Unity (all Spectral Data Points = 1.0), the Target Spectrum Scale Factor (**3h**) is set to 1.0, and no Illuminant is being applied (**3i**) (meaning the effective illuminant is actually unity at all wavelengths as well.)

3b. Target Spectrum Is Visible

The Target Spectrum Spectral Plot (**3a**) and the associated Target Spectrum Pane (**3g – 3o**) are displayed when this is checked. Un-checking this will hide the Target Spectrum Pane and show instead the CIE 1931 x,y Color Chart (**1i**).

3c. Load Base Target Spectrum From .CSV File

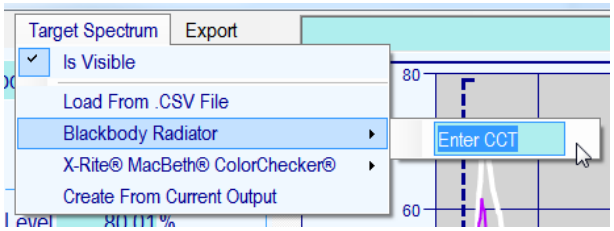
SpectralLED Assistant can read any text file which contains Target Spectrum spectral data points as simple "wavelength, amplitude" comma-separated values (one spectral data point per line). The wavelength values can be any step size, and even non-integer, as SpectralLED Assistant will interpolate the data to be 1nm increments. ***Note that there are two other ways to load the Base Target Spectrum***; you can double-click on the Base Target Spectrum box (**3g**) or drag and drop the filename into the Spectral Plot window (**1f**).

3d. Black Body Radiator

This function will generate a Black Body Radiator at a specific color temperature (degrees Kelvin) using Planck's Law:

$$B_\lambda(\lambda, T) = \frac{2hc^2}{\lambda^5} \frac{1}{e^{\frac{hc}{\lambda k_B T}} - 1}.$$

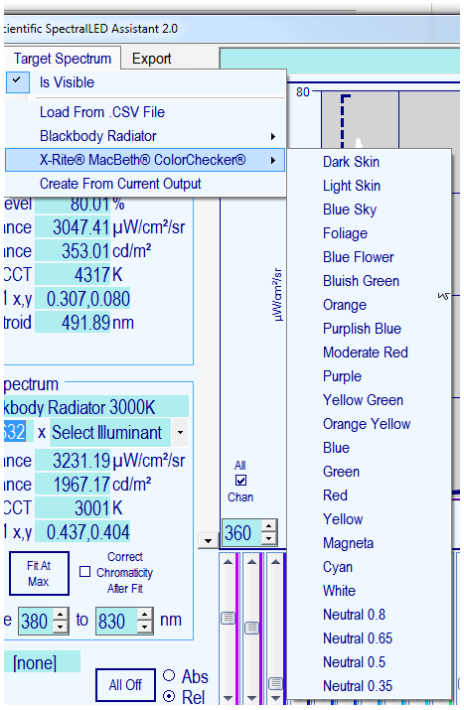
Click on the box where it says "Enter CCT", type in the desired color temperature, and press ENTER.



The resultant spectrum is normalized such that the peak value is 1.0; also, any Illuminant (**3i**) will be reset such that there is no longer an Illuminant being applied to the Base Target Spectrum.

3e. X-Rite® MacBeth® ColorChecker®[1]

This will load the illuminant-corrected spectral reflectance of one of the 24 ColorChecker® patches into the Base Target Spectrum (**3g**).



3f. Create Base Spectrum From Current Output

This will simply copy the RS-7's current Output Spectrum (**1f**) into the Base Target Spectrum (**3g**), correcting for (removing) any Target Spectrum Scale Factor (**3h**) and Illuminant (**3i**) being applied.

3g. Base Target Spectrum

This displays the name of the Base Target Spectrum that was last loaded. The final Target Spectrum (**3a**) is the combination of the Base Target Spectrum (**3g**) multiplied by the Target Spectrum Scale Factor (**3h**) multiplied by an Illuminant (**3i**). You can load your own Base Target Spectrum from a .CSV (comma-separated values) text file by either selecting from the menu (**3c**), double-clicking the Base Target Spectrum box (**3g**), or by dragging and dropping the filename into the Spectral Plot area (**1f**). ***To remove a previously loaded Base Target Spectrum, and return it to all unity, click in the Base Target Spectrum box (3g) and press the DELETE key.***

3h. Target Spectrum Scale Factor

[1] X-Rite, MacBeth, and ColorChecker are registered trademarks of X-Rite, Inc.

The value displayed in this box is used to scale the entire Target Spectrum (**3a**) up or down. Click in the box, type in a new number, and press ENTER to scale the Target Spectrum up or down as desired. The final Target Spectrum (**3a**) is the combination of the Base Target Spectrum (**3g**) multiplied by the Target Spectrum Scale Factor (**3h**) multiplied by an Illuminant (**3i**).

3i. Illuminant

Click on the down-arrow and select from the list of CIE Standard Illuminants. The final Target Spectrum (**3a**) is the combination of the Base Target Spectrum (**3g**) multiplied by the Target Spectrum Scale Factor (**3h**) multiplied by an Illuminant (**3i**). Note that "Select Illuminant" and "Illuminant E/none" are equivalent (1.0 at every wavelength, meaning no illuminant is being applied).

3j. Target Spectrum Radiance/Irradiance, Luminance/Illuminance, Correlated Color Temperature (CCT), and CIE 1931 x,y Chromaticity

In addition to displaying these various measures of the current Target Spectrum (**3a**), ***all of the boxes can accept input***, by clicking on the box, typing in a new value, and pressing ENTER. Changing the **CCT** (Correlated Color Temperature) or the **CIE 1931 x,y** chromaticity will modify the Base Target Spectrum (**3g**) to match the specified chromaticity using a color-matching algorithm that uses the tristimulus curves as weighting functions to add or remove energy in the three X, Y, and Z regions to arrive at the new chromaticity.

3k. Fit To Target Spectrum

This will perform a least-squares-fit match of the various RS-7 color channels with the current Target Spectrum (**3a**). Note that if the Correct Chromaticity After Fit checkbox is checked (**3m**), the spectrum will undergo an additional operation after the fit, in which energy will be added or removed using the three Tristimulus curves (X, Y, and Z) as weighting functions in order to obtain the same chromaticity as the Target Spectrum (this will necessarily worsen the least-squares-fit spectral match to a small degree but guarantees a perfect colorimetric match).

3l. Fit At Max

This will perform the least-squares-fit spectral matching to the Target Spectrum (**3a**) with the additional effect of adjusting the Target Spectrum Scale Factor (**3h**) such that the RS-7 will output the resultant spectrum at the maximum possible output power level as defined by the unit's currently configured Soft Limit (see the **SLM** command, Section 4.6.19). Note that if the Correct Chromaticity After Fit checkbox is checked (**3m**), the spectrum will undergo an additional operation after the fit, in which energy will be added or removed using the three Tristimulus curves (X, Y, and Z) as weighting functions in order to obtain the same chromaticity as the Target Spectrum (this will necessarily worsen the least-squares-fit spectral match to a small degree but guarantees a perfect colorimetric match).

3m. Correct Chromaticity After Fit

When the RS-7 performs a least-squares-fit spectral match of the various color channels to the Target Spectrum (**3a**), the resultant spectrum is the best possible fit of the RS-7's color channels to the Target Spectrum *spectrally*, however, this is no guarantee that the final chromaticity of the Output Spectrum matches that of the Target Spectrum as well. By checking this box (**3m**), an additional operation is always performed after the least-

squares-fit in which energy will be added or removed using the three Tristimulus curves (X, Y, and Z) as weighting functions in order to obtain the exact same chromaticity as the Target Spectrum (this will necessarily worsen the least-squares-fit spectral match to a small degree but guarantees a perfect colorimetric match).

3n, 3o. Wavelength Range For Spectral Operations

When performing the least-squares-fit spectral matching (**3k**, **3l**) to the Target Spectrum (**3a**), the beginning and ending wavelengths of the part of the spectrum you wish to match is shown here, and are also shown as graphic brackets on the Spectral Display Plot.

3.4 Export

This provides the ability to save the current Output Spectrum (**1f**) or Target Spectrum (**3a**) to a comma-separated-values (.CSV) text file.

Also, a comprehensive Channel Report can be generated, which outputs a sorted list (by increasing wavelength) of each of the RS-7's individual channels, and includes the following for each channel:

- Channel number (or numbers, for a channel group)
- Centroid, Parabolic Peak, or Center wavelength in nm (CCT in degrees K for white LEDs)
- Full-Width Half-Max (half width), in nm (shown as 0 for white LEDs)
- Minimum and maximum radiance/irradiance level
- Minimum and maximum luminance/illuminance level

Note that the radiance/irradiance levels, and luminance/illuminance levels will be adjusted to reflect the currently selected settings of SI vs. US photometric units (**2c**), and Working Distance (if the RS-7 is operating as an irradiant source) (**2f**).

SECTION 4 ASCII COMMAND API

4.1 Overview

Communication with the RS-7 is performed over an FTDI USB UART, with the nominal baud rate of 460.8K baud. The unit can be optionally configured to operate at 115.2K baud instead. UART format is 8 data bits, 1 stop bit, no parity.

Characters are not echoed as they are received by the RS-7.

DEFINITIONS

<CR>	the carriage return character, ASCII 13
<LF>	the linefeed character, ASCII 10
ACR	any boldface three-letter acronym refers to a RS-7 command & associated information

BASIC SYNTAX

Commands to the RS-7 consist of three-letter case-insensitive acronyms followed by zero or more arguments. Arguments, when specified, may be space- or comma-delimited. The command string is terminated by a single **<CR>**.

Any whitespace between the command acronym and the first argument is ignored.

In response to the complete command string, the RS-7 will immediately first and foremost transmit:

<CR><LF>

When the operation specified by the command has completed, for those commands which return no data the okay response will be transmitted:

Ok<CR><LF>

For those commands which return a single line's worth of data, the data will be transmitted in place of the "Ok" as an ASCII string terminated by **<CR><LF>**:

0.3834,0.4151<CR><LF>

For those commands which return a list (multiple lines of data), each line of the transmitted data will be terminated by **<CR><LF>** with an final additional **<CR><LF>** to terminate the list (empty line):

113.45<CR><LF>
97.511<CR><LF>
94.159<CR><LF>
91.651<CR><LF>
<CR><LF>

For a command which cannot be completed due to an error, the RS-7 will instead respond with

?nn - [Explanatory String]<CR><LF>

where nn represents an error code, and [Explanatory String] expands on the error with a human-readable explanation.

Issuing CTRL-A (ASCII code 0x01) will re-execute the previous command (“Again”)

Command List

4.2 Individual Channel Control

4.2.1 **SCP** Set Channel output Power level
4.2.2 **PUL** Pulse channel
4.2.3 **PTY** Peak Type
4.2.4 **MON** Request (optional) Wavelength Monitor System wavelength, irradiance
4.2.5 **LIN** Get LED channel Information
4.2.6 **SCA** Scan channels one at a time
4.2.7 **NPL** Set Nominal output Power Level used by **SCA, LIN**
4.2.8 **GRP** Channel Grouping disable/enable
4.2.9 **CGL** Channel Group List
4.2.10 **OCL** Offending Channels List

4.3 Presets

4.3.1 **PRE** Recall Preset
4.3.2 **SPR** Store Preset
4.3.3 **DPR** Delete Preset

4.4 Spectral Operations

4.4.1 **WLR** Wavelength Range
4.4.2 **STM** Spectrum Transfer Mode
4.4.3 **OSP** Output Spectrum
4.4.4 **TSP** Target Spectrum
4.4.5 **FTS** Fit to **TSP**
4.4.6 **CCS** Color-Correct to **TSP** or to a specific CIE 1931 x,y chromaticity
4.4.7 **RPE** Report RMS Error % **OSP** vs. **TSP**
4.4.8 **STS** Scale **TSP** to specific **UNI**

4.5 Integrated Absolute Units, Colorimetry

4.5.1 **UNI** Set Units: radiometric (µW/cm² or µW/cm²/sr), photometric (lm/m² or cd/m²), or internal units (0-100%)
4.5.2 **OUT** Integrated Output power level of **OSP** as **UNI**
4.5.3 **OUTC** Change integrated Output level of **OSP** as **UNI** while maintaining Chromaticity
4.5.4 **OUTA** Report Actual Output power level (real-time sample)
4.5.5 **SOB** CIE Tristimulus Standard Observer select, 2 degree or 10 degree
4.5.6 **OXY** Chromaticity of **OSP** as CIE 1931 x,y
4.5.7 **OXYZ** Tristimulus of **OSP** as CIE X,Y,Z
4.5.8 **TXY** Chromaticity of **TSP** as CIE 1931 x,y
4.5.9 **TXYZ** Tristimulus of **TSP** as CIE X,Y,Z
4.5.10 **CCT** Correlated Color Temperature of **OSP** in degrees K

4.6 Hardware & Housekeeping

4.6.1	**HLP**	Display help text
4.6.1	**HELP**	Synonym for above
4.6.2	**CTY**	Calibration Type, Radiant or Irradiant souce
4.6.3	**CAL**	Calibration information string
4.6.4	**ATF**	Accessory Transfer Function
4.6.5	**IRR**	Irradiance mode working distance, millimeters
4.6.6	**STP**	Output settling Threshhold, Percent
4.6.7	**LSN**	LED board Serial Number
4.6.8	**USN**	RS-7 Unit Serial Number
4.6.9	**ICK**	Integrity Check
4.6.10	**BAT**	Basic Assurance Test
4.6.11	**CPA**	Channel Power Audit
4.6.12	**PDI**	Read Photodiode(s) response
4.6.13	**PDT**	Photodiode Target
4.6.14	**SDC**	Spectral calibration Data CRC32
4.6.15	**TMP**	Read TEC(s) Temperature
4.6.16	**VER**	Firmware Version
4.6.17	**FBK**	Optical Feedback enable/disable
4.6.18	**FBG**	Query optical Feedback Gain
4.6.19	**SLM**	Soft Power Limit
4.6.20	**ALA**	Query/reset Alarms
4.6.21	**ASA**	Asynchronous Alarms enable/disable
4.6.22	**CFC**	Clear Fault Condition
4.6.23	**UDB**	User Data Block
4.6.24	**RST**	Restart unit
4.6.25	**POT**	Power-On Time
4.6.26	**IRI**	(optional) Iris control

4.2 Individual Channel Control

4.2.1 - SCP - Set Channel Power Level

Sets or reports the power level for one or more channels using the units set by **UNI**. When setting the output level, the "Ok" response will not be returned until the RS-7 output has settled to an accuracy of **STP** percent. If channel grouping has been enabled (see **GRP**), setting any channel that is a member of a group (see **CGL**) will set all channels of that group identically.

Syntax:

SCP [chan],[power]	set [chan] output [power]
SCP 0,[power]	set all channels to output [power] (each channel individually)
SCP [chan],[power],…,[chan],[power]	set multiple [chan] to multiple [power]
SCP [chan]	report output power, channel [chan]
SCP 0	report output power, all channels (generates list)
SCP	same as SCP 0

where [chan] is an integer representing channel number 1 – 64, and [power] is a float representing the output power in the current units **UNI**.

For total integrated energy of all active channels (instead of by individual channels), use the **OUT** command.

Examples:

uni1	*select photometric units (lux/nits)*
Ok	
scp	*report individual channel power as lux/nits*
2,152.12	*only active channels (power level not zero) are displayed*
3,56.152	
5,95.811	
…	
62,4.5161	
	final <CR><LF> terminates list
uni2	*change units to internal photodiode irradiance units 0-100%*
Ok	
scp	*report individual channel power as % of maximum power*
2,65.774	
3,59.169	
5,18.834	
…	
62,65.151	
	final <CR><LF> terminates list
scp0,0,2,70	*turn all channels off, then set channel #2 to 70% power*
Ok	

uni0	*change to radiometric units µW/cm^2 or µW/cm^2/sr*
Ok	
scp2	*report power level of channel #2 in radiometric units*
68.723	
out	*report total integrated output of RS-7 in radiometric units*
68.723	*identical because there's only a single channel operating*
scp3,40	*set channel #3 to 40 µW/cm^2 or µW/cm^2/sr*
Ok	
out	*report total integrated output of RS-7 in radiometric units*
108.723	*sum of channels #2 and #3*
uni2	*change to internal photodiode units*
Ok	
scp3	*report power level of channel #3*
25.512	*40 µW/cm^2 translates to 25.512% of channel's maximum power*

4.2.2 – PUL - Pulse Channel

Pulses a specified channel for a specific duration at a specific power level (constant-current mode). During the actual pulse, the RS-7 will integrate the photodiode readings and report a normalized irradiance after the pulse has completed With the optional Wavelength Monitor System, both the centroid and normalized irradiance of the pulse will be displayed; "normalized" meaning what the steady-state irradiance would have been if the pulse were perfectly rectangular. Note that **FBK** will be disabled by this command, and must be explicitly re-enabled to resume optical-feedback mode. Also, if a channel is part of a group (see **CGL**) and channel grouping is enabled (which it is by default, see **GRP**), all channels of that group will be pulsed.

Syntax:

PUL [chan],[duration]	pulse channel [chan] for [duration] milliseconds at power level **NPL**
PUL [chan],[duration],[pwr]	pulse channel [chan] for [duration] milliseconds at power level [pwr] (0-100%)

where [chan] is an integer from 1 to 64, [duration] is an integer from 1 to 5000, and [pwr] is an ASCII float from 0 to 100.0.

Examples (no Wavelength Monitor System):

pul15,250	*pulse channel #15 for 250 ms at power level **NPL***
118.4	*steady-state irradiance/radiance for the pulse worked out to 118.4 µW/cm^2 or µW/cm^2/sr*
pul22,500,50	*pulse channel #22 for 500 ms at 50% power*
87.51	*steady-state irradiance/radiance for the pulse worked out to 87.51 µW/cm^2 or µW/cm^2/sr*

Examples (with Wavelength Monitor System):

pty0	*select peak type 0, centroid*
Ok	
pul15,250	*pulse channel #15 for 250 ms at power level **NPL***
473.4,118.4	*centroid of pulse was 473.4 nm, normalized steady-state (ir)radiance worked out to 118.4*
pul22,500,50	*pulse channel #22 for 500 ms at 50% power*

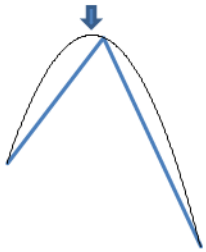
707.8,87.51 *centroid of pulse was 707.8 nm, normalized steady-state (ir)radiance worked out to 87.51*

4.2.3 – PTY - Peak type

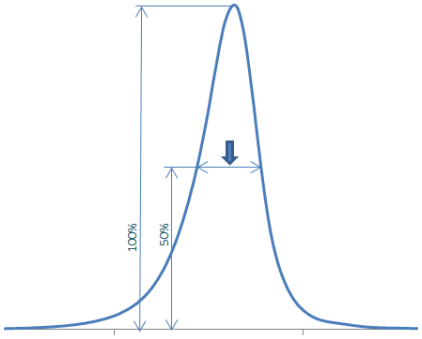
When the RS-7 reports an LED channel's wavelength (commands such as **SCA**, **LIN**, **MON**), the manner in which the wavelength is calculated can be set to one of three types:

Type 0: **Centroid**, which is the amplitude-weighted average of all wavelengths of the spectrum.

Type 1: **Peak**, which represents the peak (where 1st derivative = 0) of the parabola defined by the highest-amplitude spectral data point and its two immediate neighbors.



Type 2: **Center**, which represents the wavelength exactly midway between the two half-power points (i.e. the midpoint of the two wavelengths that define FWHM).



Syntax:

PTY report current Peak Type
PTY [0|1|2] set Peak Type to 0 (centroid), 1 (parabolic peak), or 2 (center)

Examples:

pty *request current peak type*
0 *peak type is currently set to 0, centroid*
pty1 *change peak type to 1, parabolic peak*
Ok

4.2.4 - MON – Wavelength Monitor System Query

If the RS-7 is equipped with the optional Wavelength Monitor System, this command requests centroid/peak/center wavelength (see **PTY**) and (ir)radiance of the currently active wavelength (only a single wavelength must be active).

Syntax:

MON	query Monitor System
MON C	continuous query (ESC to terminate)
MON F	fast query, executes in under 50 ms
MON CF	continuous fast query (ESC to terminate)

Examples:

scp0,0,15,70	*turn off all channels, then set channel #15 to 70% power*
Ok	
mon	*query monitor*
475.41,24.51	*monitor reports wavelength of 475.41 nm, at an (ir)radiance of 24.5*

4.2.5 - LIN - LED Channel Information

Reports centroid/peak/center wavelength (see **PTY**) & FWHM for each channel, in nanometers. Note that this information is given twice; first is a nominal wavelength & FWHM representing the channel at the current **NPL** Nominal Power Level (default: 70%), and secondly the actual wavelength and FWHM for the channel's current operating power level, reported as 0 if the channel is set to off.

Syntax:

LIN	report all channels' wavelength and FWHM
LIN [chan]	report wavelength and FWHM for channel [chan]

where [chan] is an integer between 1 and 64.

Examples:

lin	*report all channel's wavelength & FWHM*
1,546,11.452,545,11.521	*nominal wavelength (**NPL**%), nominal FWHM, actual wavelength, actual FWHM*
2,590,23.511,0,0	*channel power is set to 0 (off) so actual wavelength & FWHM reported as 0,0*
3,615,17.512,616,17.911	
…	
64,0,0,0,0	*unused channels always report 0,0,0,0*
	final extra <CR><LF> terminates list

4.2.6 - SCA - Scan Thru Individual Channels/Channel Groups by Increasing Wavelength

Activates channels one at a time at the **NPL** power in order of increasing centroid/peak/center wavelength (see **PTY**). If two or more channels share the same wavelength, then they are output in order of increasing FWHM. The currently operating channel number(s), wavelength, FWHM, and output (ir)radiance in µW/cm^2 or µW/cm^2/sr (see **CTY, IRR**) are reported each time, and are not returned until the RS-7 output has settled to an accuracy of **STP** percent. White channels will follow the monochromatic channels in order of increasing CCT.

Syntax:

SCA [startWL]	begin scan starting at channel nearest at or above wavelength [startWL]
SCAN	move to next higher wavelength
SCANR	move to next higher wavelength & wrap around to shortest wavelength after reaching the end
SCAD [delay]	execute **SCANR** repeatedly with a delay of [delay] milliseconds between commands, ESC to stop

Examples:

sca360	*begin scan at 360nm, shortest possible wavelength*
14,382.3,12.923,56.141	*RS-7 finds channel #14 is the closest at 382.3nm, and activates it at **NPL** power*
scan	*move to next higher wavelength*
8+49,387.6,14.512,49.712	*next step higher in wavelength is channels #8 & #49 (grouped) at 387.6nm*
…	
scan	*move to next higher wavelength*
51,983.4,62.512,15.633	*this would be approximately the highest wavelength found in the standard RS-7*
scan	*move to next higher wavelength*
31,2668,0,82.451	*channel #31 is a white LED with a CCT of 2668K*
scan	*move to next higher CCT*
22,6311,0,94.561	*channel #22 is a white LED with a CCT of 6311K*
scan	*move to next*
?02 – argument out of range	*error results, indicating we're past the end of the LED wavelengths/CCTs*
scanr	*move to next with repeat/wraparound*
14,382.3,12.923,56.141	*automatically wraps around back to shortest-wavelength channel*

4.2.7 NPL - Nominal Power Level

Determines the default power level (as **UNI 2**, 0 – 100% power) as used by the **SCA** (Scan Channels) command. The default **NPL** is 70%. Also, this determines the power level for which **LIN** reports a channel's nominal wavelength and FWHM.

Syntax:

NPL	report current Nominal Power Level
NPL [%]	set Nominal Power Level to [%] (0 – 100)

Examples:

npl	*query the current Nominal Power Level*
70	*Nominal Power Level is 70%*
npl90	*increase Nominal Power Level to 90%*
Ok	

4.2.8 GRP - Channel Grouping Enable/Disable

Multiple channels can be populated with the same LEDs, and operated in parallel in order to increase effective output power for certain wavelengths. Those channels that have one or more duplicates are part of a *group*, and any operation performed on one channel of a group will be performed on *all* channels of that group. This command will enable or disable the channel grouping function, and is enabled by default. A list of the channel groups can be obtained via the **CGL** (Channel Group List) command.

Syntax:

GRP	report Grouping Enable/Disable status
GRP [0|1]	disable [0] or enable [1] channel grouping

Examples:

grp	*query channel grouping status*
1	*channel grouping is enabled (default)*
grp0	*disable channel grouping*
Ok	

4.2.9 - CGL - Channel Group List

Displays a list of the channel groups. When channel grouping is enabled (see **GRP**), any action performed on any channel belonging to a group will be performed on *all* channels of that group.

Syntax:

CGL	display channel group list

Examples:

cgl	*request channel group list*
1,15,58	*channel group #1 consists of channels #15 and 58*
2,23,24,51	*channel group #2 consists of channels #23, 24, and 51*
3,27,44	*channel group #3 consists of channels #27 and 44*
	extra <CR><LF> terminates list

4.2.10 – OCL - Offending Channels List

In response to an error message such as “channel power unreachable” or “SLM exceeded”, you can ask the RS-7 for a list of those channels which were attempted to operate beyond their limits, or otherwise generated an error. The list shows each offending channel along with the requested power level (as **UNI 2**, 0 - 100%) which could not be accommodated.

Syntax:

OCL	request Offending Channels List

Examples:

uni1	*select photometric units (lux or nits, depending on **CTY & IRR**)*
Ok	
scp0,10	*set all channels to 10 lux/nits*
?06 - channel power unreachable	*one or more channels could not be set to 10 lux/nits (such as IR LEDs)*
ocl	*request offending channels*
17,154.4	*channel #17 wanted to go to 154.4% power to satisfy the request*
23,5911	*channel #23 wanted to go to 5911% power*
	extra <CR><LF> terminates list

4.3 Presets

A “preset” is defined as a complete set of all 64 channel power level settings (see the **SCP** command, Set Channel Power).

4.3.1 - PRE - Recall Preset

Loads a previously stored preset & sets the RS-7 to output the associated spectrum. When loading a preset, the “Ok” response will not be returned until the RS-7 output has settled to an accuracy of **STP** percent.

Syntax:

PRE	report currently loaded preset, returns “NONE” if no preset is currently loaded
PRE [preset]	load [preset]
PRE *	report a list of all available stored presets
PREV *	verbose version which includes radiometric and photometric power levels
PRE N	load next highest preset (for sequential operation)

where [preset] is an integer between 0 and 95.

The RS-7 will load the power level settings, and then adjust the entire LED array as required to achieve the appropriate integrated output power level.

Note that preset #0 defines the default output state of the RS-7 at power-on.

Examples:

pre3	*load preset #3*
Ok	
pre	*report currently loaded/operating preset*
3,Bob’s test spectrum	*(the ASCII name string associated with each preset is defined & stored with **SPR**)*
pre*	*list all presets*
0,sample1/D65@200lux	
1,sample1/F1@150lux	
3,Bob’s test spectrum	
4,Blackbody to 1000nm@75uW	
…	
23,Warm white LED@250lux	
	extra <CR><LF> terminates list
uni2	*select units of 0 – 100% optical output power*
Ok	
scp23,50	*change something by setting channel #23 to 50% of max optical power*
Ok	
pre	*report currently loaded/operating preset*
NONE	
pre1	*load preset #1*
Ok	

pren *load next higher preset*
3,Bob's test spectrum
pren *load next higher preset*
4,Blackbody to 1000nm@75uW

4.3.2 - SPR - Store Preset

Stores the current RS-7 output state as a preset, with an optional descriptive ASCII string attached.

Syntax:

SPR [preset],[preset name as ASCII string up to 63 characters]

where [preset] is an integer between 0 and 99, and [preset name] is a descriptive string that may include delimiters (such as spaces or commas) as this argument is treated literally and is not parsed.

Examples:

spr15,XRite moderate red under F1 @250 lux
Ok

4.3.3 - DPR - Delete Preset

Deletes a previously stored preset.

Syntax:

DPR [preset] delete preset # [preset]

where [preset] is an integer between 0 and 95,

Examples:

pre* *request list of stored presets*
0,sample1/D65@200lux
1,sample1/F1@150lux
3,Bob's test spectrum
4,Blackbody to 1100nm@75uW
…
23,Warm white LED@2500lux
extra <CR><LF> terminates list
dpr1 *delete preset #1*
Ok
dpr4 *delete preset #4*
Ok

pre* *request list of stored presets*
0,sample1/D65@200lux
3,Bob's test spectrum
…
23,Warm white LED@2500lux
extra <CR><LF> terminates list

4.4 Spectral Operations

4.4.1 - WLR - Set Wavelength Range

Sets or reports the operating wavelength range for spectral operations, including spectral data transfers to and from the RS-7.

Syntax:

WLR [startWL],[endWL]	set wavelength range [startWL] to [endWL]
WLR	report currently set wavelength range

where [startWL] and [endWL] are integers between 360 and 1100, representing nanometers, with [startWL] < [endWL].

The wavelength range is applicable for the following commands:

OSP	Output spectrum
TSP	Target spectrum
FTS	Fit to **TSP**
REP	Report RMS Error % **OSP** vs. **TSP**

Examples:

wlr	*report current operating wavelength range*
380,780	
wlr380,920	*extend wavelength range to 920 nm*
Ok	

4.4.2 - STM - Spectrum Transfer Mode

Establishes the format for spectral data transfers between the host & RS-7. Spectral data is always 1 nm-step resolution, units being µW/cm²/nm (irradiant source, see **CTY** & **IRR**) or µW/cm²/nm/sr (radiant source, see **CTY** & **IRR**) and is transferred between the host and RS-7 over the wavelength range set by **WLR**.

Syntax:

STM [0|1|2]	set spectral transfer mode to 0, 1, or 2
STM	report current spectral transfer mode

where spectral transfer mode 0 is comma-delimited ASCII data, spectral transfer mode 1 is <CR><LF> delimited ASCII data (columnar), and spectral transfer mode 2 is packed binary. The packed binary format is capable of transferring a complete set of spectral data over the full wavelength range of 380 to 1100 nm at 115,200 baud in 125 milliseconds.

When transferring in packed binary format

1. first an ASCII float representing a scale factor is sent

2. followed by a comma
3. followed by unsigned 16-bit integers as binary byte pairs, big-endian (most significant byte first), the number of byte pairs determined by the current **WLR** i.e number of byte pairs = [endWL] – [startWL] + 1
4. if the data is being transferred *to* the RS-7, the RS-7 will respond with "Ok"<CR><LF> after the final data byte has been received.

In order to pack the spectral data into 16-bit integers, the data are first normalized such that the peak value is set to maximum (0xFFFF), thus one is required to multiply each integer by the scale factor once the transfer is complete in order to re-establish the proper absolute magnitude of the data.

Example of spectral transfer mode 0:

stm0 *set **STM** mode 0 (not required if mode has been previously been set to 0)*
Ok
osp *request current output spectrum*
5.939613,4.743708,7.146379,35.52672,28.65044,39.23233,2440.087,519.4869,712.7541,2044.095,281.0387,202.69,4.539907,6.31384,46.78853,…,23.9096,32.474,1409.227,738.4146,1017.761,2020,391.4333,280.5293<CR><LF>

Example of spectral transfer mode 1:

stm1 *set **STM** mode 1 (not required if mode has been previously been set to 1)*
Ok
osp *request current output spectrum*
0.220141008 *data for [startWL] (see **WLR**)*
0.221931979
0.216851279
0.219466045
0.217012778
0.215644792
0.217881665
0.216041222
0.216353044
0.215767771
…
0.011663915
0.006427045
0.010699615
0.008136001
0.010370667 *data for [endWL] (see **WLR**)*
*final extra <CR><LF> terminates list (although list length is known via **WLR**)*

Example of spectral transfer mode 2:

stm2 *set **STM** mode 2 (not required if mode has been previously been set to 2)*
Ok
osp *request current output spectrum*

1.4857E-6,G7as87GH&s8c9Hjh(*89dhv8duov8d9vy8D7igvIUG(7fgt79T3rgi93h8f8(*Hvp8H#g8h#hf78f6<CR><LF>
…scale factor, followed by comma, followed by [endWL] – [startWL] + 1 byte pairs
with a final <CR><LF> at the end
tsp1.5893e-3,^%!7Ybd7Pdp9fTP(D7tfgp9DfPDTfp…DFDFp9YP(YyP(FY(DYFDFFYY*(FydDuhDUHDHG&a *set **TSP***
Ok *…scale factor, followed by comma, followed by [endWL] – [startWL] + 1 byte pairs*

4.4.3 - OSP - Output Spectrum

Outputs the spectral data of the current RS-7 output spectrum, either the combined total spectrum or the spectrum of an individual channel. The data are transmitted in the format specified by **STM** over the wavelength range specified by **WLR**.

Syntax:

OSP	*transmit the output spectrum to host*
OSP 0	*identical to **OSP***
OSP [chan]	*transmit the spectrum of a single channel [chan]*

where [chan] is an integer representing channel number 1 – 64.

Examples:

wlr500,510	*severely restrict wavelength range for purposes of this example*
Ok	
stm1	*select spectral transfer mode 1 (columnar data)*
Ok	
osp12	*transmit the spectrum for channel #12*
0.220141008	*data for 500 nm*
0.221931979	
0.216851279	
0.219466045	
0.217012778	
0.215644792	
0.217881665	
0.220141008	
0.221931979	
0.216851279	
0.219466045	*data for 510 nm*
	final extra <CR><LF> terminates list

4.4.4 - TSP - Target Spectrum

Sets or reads back the current target spectrum. The target spectrum is stored by the RS-7 as a reference spectrum, to which one can perform a least-squared spectral fit (**FTS**) & colorimetric correction (**CCS**) in order to arrive at the final RS-7 output (**OSP**). The target spectrum may be scaled up or down in absolute magnitude via

STS. The data are sent from/to the RS-7 in the format specified by **STM** over the wavelength range specified by **WLR.** When sending a target spectrum to the RS-7, data points outside the **WLR** are set to 0.

Syntax:

TSP	*transmit the current target spectrum to host*
TSP [data],[data],…,[data]	*send target spectrum to RS-7 using **STM** 0*
TSP [data]	*send target spectrum to RS-7 using **STM** 1*
[data]	
…	
[data]	
TSP&	*alternative format to send target spectrum to RS-7 using **STM** 1*
[data]	
[data]	
[data]	
…	
[data]	

where [data] is an ASCII float and the number of data points is set by **WLR** ([endWL] – [startWL] + 1)

Examples:

stm0	*set **STM** mode 0 (not required if mode has already been set to 0)*
Ok	
tsp0.1941,0.298,0.4059,0.5991,…,0.09919	
Ok	

4.4.5 - FTS - Fit to TSP

Performs a least-squares arithmetic fit to the target spectrum **TSP** over the wavelength range **WLR** and sets the RS-7 output **OSP** to the resultant spectrum. Only channels with wavelengths within the **WLR** +/- 5nm will be utilized (meaning channels as far as 5nm outside **WLR** will be utilized). The addition of the **W** suffix to the **FTS** command will also include broadband white channels as part of the solution.

Syntax:

FTS	fit to target spectrum using only the monochromatic channels (white channels not included)
FTS W	fit to target spectrum using all channels, including white channels
FTS M	fit to target spectrum at maximum possible output power as set by **SLM** (target spectrum **TSP** will be scaled accordingly)

The RS-7 will attempt to fit the currently defined target spectrum **TSP.**

Examples:

stm0	*set spectral transfer mode 0*

Ok
wlr380,650 *set wavelength range 380 – 650nm*
Ok
tsp1.129,1.38,2.2818,…,0.084 *send the target spectrum*
Ok
uni1 *select photometric units (lux or nits)*
Ok
sts2000 *scale target spectrum to 2000 lux/nits*
Ok
fts *perform the fit*
Ok
rep *report the spectral mismatch error between **TSP** and **OSP** as %RMS*
3.481
osp *get the final resultant output spectrum*
5.939613,4.743708,7.146379,35.52672,28.65044,39.23233,2440.087,519.4869,712.7541,2044.095,281.0387,202.69,4.539907,6.31384,46.78853,…,23.9096,32.474,1409.227,738.4146,1017.761,2020,391.4333,280.5293<CR><LF>
spr55,patch#24 under D65 @2000lux *save the result as a preset, name it "patch#24 under D65 @2000lux*"
Ok

4.4.6 - CCS - Color-correct to TSP or to a specific chromaticity

Modifies the current output spectrum **OSP** to exactly match the chromaticity of the target spectrum **TSP**, or to exactly match a specified chromaticity passed as arguments to the **CCS** command.

Syntax:

CCS color-correct to target spectrum
CCS [CIEx],[CIEy] color-correct to a specific CIE 1931 x,y

Examples:

fts *fit to current target spectrum **TSP***
Ok
rep *report the spectral mismatch error as %RMS*
2.581
txy *report chromaticity of target spectrum **TSP***
0.2771,0.3971
oxy *report chromaticity of output spectrum **OSP***
0.2798,0.3944
ccs *color-correct the output spectrum **OSP***
Ok
rpe *report the spectral mismatch error as %RMS*
2.971 (*necessarily worse to get the color perfect)*
oxy *report chromaticity of output spectrum **OSP***
0.2771,0.3971 *chromaticity now matches target spectrum **TSP***

ccs0.2750,0.4044	*modify chromaticity to CIE xy of (0.2750,0.4044)*
Ok	
oxy	*report final chromaticity*
0.2750,0.4044	

4.4.7 - RPE - Report RMS Error % OSP vs. TSP

Reports the spectral mismatch as the RMS of the deltas between the target spectrum **TSP** and the output spectrum **OSP** divided by the mean of the target spectrum **TSP**, over the wavelength range **WLR**.

Syntax:

RPE	report spectral mismatch as RMS% error

returns an ASCII float indicating percent RMS error.

Examples:

rpe	*report RMS% error*
4.188	
scp12,100	*turn channel #12 all the way on to increase mismatch*
Ok	
rpe	*report RMS% error*
23.582	*substantially worse*

4.4.8 - STS - Scale TSP to specific UNI

Scales the current target spectrum **TSP** to an absolute power level (radiometric or photometric) as defined by the current units **UNI**.

Syntax:

STS	report current **TSP** power level in units of **UNI**
STS [level]	scale target spectrum **TSP** to new power level [level]

Examples:

stm0	*set spectral transfer mode **STM** 0*
Ok	
wlr380,650	*set wavelength range **WLR** 380 – 650nm*
Ok	
tsp1.129,1.38,2.2818,…,0.084	*send a target spectrum **TSP** of arbitrary absolute magnitude*
Ok	
uni1	*set the integrated absolute units mode **UNI** to photometric units of lux/nits*
Ok	
sts150	*scale target spectrum **TSP** to 150 lux/nits*

Ok
fts *perform the fit*
Ok
ccs *color-correct for perfect color match*
Ok
spr23,Light Skin under D50 @150lux *save the result as preset #23*
Ok

4.5 Integrated Absolute Units, Colorimetry

4.5.1 UNI – Set Units:

Radiometric (irradiance or radiance, µW/cm² or µW/cm²/sr),
Photometric (illuminance or luminance, lm/m² [lux] or cd/m² [nits]),
or Internal Units (0-100%)

Selects between radiometric (irradiance, radiance), photometric (illuminance, luminance), and internal (0-100%) as units of integrated energy. The internal units (**UNI** = 2) represent the dimensionless irradiance response of the monitor photodiode, scaled as 0% (off) to 100% (matched to the maximum drive current as configured for each channel). Note that the unit's calibration type, **CTY**, and irradiance mode setting, **IRR**, can be queried to determine whether the units are for a Radiant source (µW/cm²/sr, cd/m²) or an Irradiant source (µW/cm², lm/m²).

Syntax:

UNI [0|1|2]	set units to radiometic (0), photometric (1), or internal 0-100% (2)

Examples:

uni	*report current units setting*
1	*units are photometric (lux or nits)*
out	*report current output level in photometric units*
351.24	
uni0	*change units to radiometric (µW/cm² or µW/cm²/sr)*
Ok	
out	*report current output level in radiometric units*
185.96	
uni2	*change units to internal photodiode*
Ok	
out	*report current output level 0-100%*
75.15	*this figure represents the channel which is operating at the highest power level*

4.5.2 - OUT - Integrated output power level of OSP as UNI

Sets or reports the RS-7 integrated (sum of all active channels) output level using the units set by **UNI**. When setting the output level, the "Ok" response will not be returned until the RS-7 has settled to an accuracy of **STP** percent.

Syntax:

OUT	report current output level in **UNI** units
OUT [level]	set the output level to **UNI** units

where [level] is an ASCII float.

Examples:

cty	*request current calibration type*
I	*RS-7 is operating as an Irradiant source*
uni0	*set units **UNI** to irradiance/radiance*
Ok	
out	*report current output level*
272.12	*µW/cm² or µW/cm²/sr*
uni1	*set units **UNI** to illuminance/luminance*
Ok	
out	
519.852	*lm/m² (lux) or cd/m² (nits)*
out300	*set output to 300 lux (lm/m²)*
Ok	

Note that changing the output level using **OUT** can result in a chromaticity shift in the final output spectrum **OSP**, as **OUT** merely adjusts all channels' power level to match the requested setting without regard to any wavelength shift caused by the change in drive current. To maintain the current chromaticity, use **OUTC** instead.

4.5.3 - OUTC - Adjust integrated output power level of OSP as UNI while maintaining chromaticity

Adjusts the RS-7's integrated output power level using the units set by **UNI**, while compensating for the LED's wavelength shift at the different drive current by adjusting the spectrum to maintain the same chromaticity. When setting the output level, the "Ok" response will not be returned until the RS-7 has settled to an accuracy of **STP** percent.

Syntax:

OUTC [level]	set the output level to **UNI** units while maintaining chromaticity

Examples:

oxy	*report current output spectrum **OSP** chromaticity*
0.4481,0.4077	*chromaticity is (0.4481,0.4077)*
uni1	*select photometric units*
Ok	
out	*report current output power in photometric units*
7858.5	*unit is outputting 7858.5 lm/m² or cd/m²*
out4000	*change output level to 4000 without regard to chromaticity shift*
Ok	
oxy	*get chromaticity at the new power level*
0.4494,0.4078	*it has changed because of LED wavelength shift at the new power level*
outc4000	*this time ask it to maintain chromaticity*
Ok	
oxy	*get chromaticity again*

0.4481,0.4077 *chromaticity is now unchanged from the original*

4.5.4 - OUTA - Report Actual (sampled) Output power level as UNI

While the **OUT** command is used to set & report the nominal, or intended optica output power level, one can read the RS-7's actual power level, as sampled by the unit's internal monitor photodiode, in units of **UNI**, at any time. Normally, with optical feedback enabled (see **FBK**), the RS-7's output power is being continuously adjusted such that the actual output level is maintained accurately at the proper requested output level, so that the radiometric and photometric levels reported by **OUT** and **OUTA** will always be very nearly identical. With optical feedback disabled (**FBK 0**), the **OUTA** command can be used to get an accurate reading of the RS-7's output power level, in real time, since the output level is no longer being maintained and the LED channels are instead being driven with a static constant-current.

Syntax:

OUTA sample photodiode and report output power level in units UNI

Examples:

fbk	*query the current state of optical feedback*
1	*unit reports optical feedback is enabled*
pre2	*load preset #2*
Ok	
uni1	*select photometric units (lm/m^2 or cd/m^2)*
Ok	
out	*request current (nominal) output power*
7858.5	*unit reports 7858.5 lm/m^2 or cd/m^2*
outa	*request current actual output power*
7858.5	*identical because optical feedback is maintaining the output power level in real time*
out2000	*set output level to 2000 lm/m^2 or cd/m^2*
Ok	
out	*request current (nominal) output power*
2000	*unit reports 2000 lm/m^2 or cd/m^2*
outa	*request current actual output power*
2000.2	*again, it matches because optical feedback maintains the output at the request level*
fbk0	*disable optical feedback*
Ok	
out8000	*set output level to 8000 lm/m^2 or cd/m^2*
Ok	
out	*request current (nominal) output power*
7999.6	*this is what it was set to (nominally)*
outa	*request current actual output power*
7984	*this is the power level that is actually being output*
outa	
7952.3	*it continues to drop as the LEDs warm up*
outa	

7920.6
outa
7891.9

4.5.5 - SOB - Standard observer select, 2 degree or 10 degree

Sets or reports the current CIE Tristimulus Standard Observer Included Angle as 2 degrees or 10 degrees. The default at power-on is always 2 degrees.

Syntax:

SOB [2|10]	set standard observer to 2 or 10 degrees
SOB	report current Standard Observer

Examples:

SOB	*report current Standard Observer setting*
10	
SOB 2	*change Standard Observer to 2 degrees*
Ok	

4.5.6 - OXY - Chromaticity of OSP as CIE 1931 x,y

Reports the chromaticity of the current output spectrum **OSP** using the 2 or 10 degree Standard Observer Included Angle as set by **SOB**.

Syntax:

OXY	report output spectrum **OSP** chromaticity

Returns two ASCII floats separated by a comma indicating the (x,y) coordinate on the 1931 CIE chromaticity chart.

Examples:

sob2	*select 2 degree Standard Observer (not required if 2 degree has been previously set)*
Ok	
oxy	*report chromaticity of output spectrum **OSP***
0.3333,0.3333	

4.5.7 - OXYZ - Tristimulus of OSP as CIE X,Y,Z

Reports the tristimulus of the current output spectrum **OSP** using the the 2 or 10 degree Standard Observer Included Angle as set by **SOB**. Note that for 2 degree observer, the tristimulus Y value will represent the output

power level in photometric units (lm/m^2, cd/m^2), identical to what the **OUT** command would report when **UNI** = 1.

Syntax:

OXYZ report output spectrum **OSP** tristimulus

Returns three ASCII floats separated by a comma indicating the (X, Y, Z) tristimulus.

Examples:

oxyz *report tristimulus of current output spectrum **OSP***
678.5079,683.7131,518.6062 *tristimulus X, Y, and Z*

4.5.8 - TXY - Chromaticity of TSP as CIE 1931 x,y

Reports the chromaticity of the current target spectrum **TSP** using the 2 or 10 degree Standard Observer Included Angle as set by **SOB**.

Syntax:

TXY report target spectrum **TSP** chromaticity

Returns two ASCII floats separated by a comma indicating the (x,y) coordinate on the 1931 CIE chromaticity chart.

Examples:

sob2 *select 2 degree Standard Observer (not required if 2 degree has been previously set)*
Ok
txy *report chromaticity of target spectrum **TSP***
0.2581,0.3511

4.5.9 - TXYZ - Tristimulus of TSP as CIE X,Y,Z

Reports the tristimulus of the current output spectrum **TSP** using the the 2 or 10 degree Standard Observer Included Angle as set by **SOB**. Note that for 2 degree observer, the tristimulus Y value will represent the power level in photometric units (lm/m^2, cd/m^2), identical to what **STS** would report with **UNI** = 1.

Syntax:

TXYZ report target spectrum **TSP** tristimulus

Returns three ASCII floats separated by a comma indicating the (X, Y, Z) tristimulus.

Examples:

txyz	*report tristimulus of target spectrum **TSP***
678.5079,683.7131,518.6062	*tristimulus X, Y, and Z*

4.5.10 - CCT - Correlated Color Temperature of OSP in degrees Kelvin

Reports the Correlated Color Temperature of the current output spectrum **OSP** in degrees Kelvin.

Syntax:

CCT	report output spectrum **OSP** correlated color temperature

Examples:

cct	*report CCT of current output spectrum OSP*
2850	*color temperature is 2850K*

4.6 Hardware & Housekeeping

4.6.1 - HLP or HELP - Display Help text

Displays a brief listing of the RS-7's command set.

Syntax:

HLP	*display help text*
HELP	*synonym*

4.6.2 - CTY - Calibration Type, Radiant, Irradiant, or total Flux source

This command is used to query the RS-7 as to the type of native calibration the unit originally received, either as Irradiance (absolute units of $\mu W/cm^2$ and lm/m^2 [lux]), Radiance (absolute units of $\mu W/cm^2/sr$ and cd/m^2 [nits]), or Total Flux (units of Watts and lumens). The RS-7 returns either an "I" for an Irradiant source, "R" for a Radiant source, or "F" for a total Flux source. Note that **CTY** will not change even if **IRR** (Irradiance Mode Override, see **IRR**) and/or one or more **ATF**'s that modify the native units (Accessory Transfer Function, see **ATF**) are active.

Syntax:

CTY	report current calibration type

Examples:

cty	*request calibration type*
R	*calibration is for a Radiant source, units are $\mu W/cm^2/sr$ (**UNI** = 0) and cd/m^2 (**UNI** = 1)*

4.6.3 - CAL - Calibration Information string

When the RS-7 receives its spectral calibration, information such as the calibration date and CRC (see **SDC**) of the spectral data are stored here.

Syntax:

CAL	report calibration information string

Examples:

cal	*request calibration information*
2016-06-04 CRC32=DAB0FEA1	*calibration date & CRC32 of the spectral calibration data*

4.6.4 - ATF - Accessory Transfer Function

The RS-7 can be configured for multiple output configurations. The Accessory Transfer Function is a modifier of the RS-7's spectral calibration, which adjusts the calibration to match the new configuration when particular accessory (-ies) are being used with the RS-7 (such as ND filters, reflectance plaques, polarizers, etc.). Up to four individual Accessory Transfer Functions can be enabled at once. Also, an **ATF** can modify the unit's spectral calibration type to switch to one of radiance, irradiance, or total flux, shown in the **ATF*** list as either

R to convert to a Radiant source,
I to convert to an Irradiant source,
F to convert to a Total Flux source, or
- no modification.

Syntax:

ATF *	show a list of stored Accessory Transfer Functions
ATF	report all active Accessory Transfer Functions
ATF 0	disable all Accessory Transfer Functions (return to base spectral calibration & **CTY**)
ATF [1-4],[1-4]…	enable one or more Accessory Transfer Functions

Examples:

atf	*request currently active **ATF**'s*
NONE	*no **ATF**'s are currently active*
atf*	*request a list of available **ATF**'s*
1,-,ND2 Filter	#1 *compensates for the presence of an ND2 filter*
2,-,ND3 Filter	#2 *compensates for the presence of an ND3 filter*
3,R,Reflectance Plaque @ 300mm	*#3 adjusts for reflection off of a reflectance plaque at 300mm distance, and also changes the base units to radiance*
oxyz	*request current output spectrum's tristimulus*
583.6659,999.7614,510.304	*response is 583.6659,999.7614,510.304*
atf1	*enable **ATF** #1*
Ok	
oxyz	*request current output spectrum's tristimulus again*
6.26366,11.20109,6.274338	*response reflects output as now viewed through the ND2 filter*
atf1,3	*enable **ATF**'s #1 and #3*
Ok	
atf	*request currently active **ATF**'s*
1,3	*Accessory Transfer Functions 1 and 3 are now active*
atf0	*turn off all **ATF**'s*
Ok	

4.6.5 - IRR - Irradiance mode working distance, millimeters

The Standard Model RS-7 with internal integrating sphere (and optional motorized iris) is factory-calibrated with a Radiance calibration (**CTY** type "R", see **CTY** command), in units of µW/cm²/sr and cd/m² (nits). However, the

RS-7 can also be operated as an Irradiant source, with units of µW/cm² and lm/m^2 (lux). The **IRR** command is used to specify the working distance, in millimeters, from the outer face of the RS-7 to the target under illumination. The irradiance units will automatically be scaled based on the specified working distance (and also the iris position, for RS-7's equipped with the optional motorized iris, see the **IRI** command). Specifying a working distance of 0 millimeters returns the RS-7 to its base Radiance mode. Note that that calibration type (see **CTY**) will not change from "R" to "I" even when the unit is operating in Irradiance mode (**IRR** > 0).

Syntax:

IRR	report current working distance in millimeters
IRR [mm]	specify new working distance as [mm] millimeters
IRR 0	return RS-7 to its base Radiance mode calibration & Radiance units

Examples:

irr	*request current working distance*
0	*working distance of 0 indicates RS-7 is operating as Radiant source*
uni0	*select radiometric units (radiance, µW/cm²/sr)*
Ok	
out	*request RS-7's current output level*
451.34	*radiance 451.34 µW/cm²/sr*
irr300	*change to Irradiant source at 300mm working distance*
Ok	
out	*request RS-7's current output level*
27.051	*irradiance at 300mm from output port is 27.051 µW/cm²*

4.6.6 - STP - Output settling threshhold, percent

Sets or reports the required RS-7 output settling accuracy. Default is 0.25%.

Syntax:

STP [percent]	set settling threshhold to [percent]%
STP	report current settling threshhold

Where [percent] is a float between 0 and 100%.

Examples:

stp1	*set settling threshhold to 1%*
stp	*report current settling threshhold*
1	

4.6.7 - LSN - LED board serial number

Reports the serial number as stored in the LED board's on-board read-only-memory. This serial number cannot be altered.

Syntax:

LSN report LED board serial number

Example:

lsn
LHX0152

4.6.8 - USN - RS-7 unit serial number

Reports the serial number as stored in the RS-7 non-volatile memory. This serial number cannot be altered.

Syntax:

USN report RS-7 unit serial number

Example:

usn
HX2855

4.6.9 – ICK - Integrity Check

Performs an internal check of all RS-7 parameters and calibration data, and verifies that

a) all monitored internal power supply rail voltages are within tolerance
b) all parameters are within range & structures are intact
c) stored calibration data matches the serial number of the LED board for which they were generated
d) all structures have a valid CRC (CRC32)

If all goes well, only "Ok" is reported. If there are problems, each is reported with a line starting with "ERROR/" followed by a description. The following is a list of the possible ERROR/ codes:

ERROR/VOLTAGE RAIL: [expected]V measures at [observed]V
ERROR/UNIT STORED PARAMETERS: CRC or structure error
ERROR/UNIT STORED PARAMETERS: appear uninitialized
ERROR/LED BOARD STORED PARAMETERS: CRC or structure error
ERROR/LED BOARD STORED PARAMETERS: appear uninitialized
CH#x ERROR/CALIBRATION DATA: CRC or structure error
CH#x ERROR/CALIBRATION DATA: missing calibration data
CH#x ERROR/CALIBRATION DATA: LED board S/N mismatch

Syntax:

ICK	perform integrity check
ICK V	perform integrity check, verbose mode (reports all operations step-by-step)

4.6.10 - BAT - Basic assurance test

This will cause the RS-7 to rapidly sequence through all channels in order to verify basic functionality. This is intended to execute as quickly as possible and is not intended as a comprehensive audit of each channel's performance. The test criteria is that each channel, set at 50% of maximum power, demonstrates output power of at least 90% of the expected value.

Syntax:

BAT	perform basic assurance test
BAT V	verbose version, shows percentage deviation from each channel's expected power level

Examples:

bat	*perform BAT*
Ok	*all channels functional results in standard "Ok" response*
bat	*perform BAT*
?CH18 fail	*channel failure*
?CH44 fail	*channel failure*
	extra final <CR><LF> terminates listing

Note that in the case of one or more channels failing, there is no "Ok" response; in response to encountering one or more "?fail" messages, you should instead wait for the final <CR><LF> that signals the end of the list of failures.

4.6.11 - CPA - Channel Power Audit

This command is used to track LED aging, and is invoked during maintenance cycles. Each channel is individually powered on, and once the output has stabilized, the resultant output power is compared to the original channel condition when the RS-7 was last calibrated. Any discrepancies are noted and are subsequently applied as corrective coefficients on an ongoing basis in order to maintain calibration. Each channel's CPA coefficient is represented as the percentage deviation from the nominal/calibrated output power level.

Syntax:

CPA	report latest channel power audit results
CPA P	perform channel power audit and store the resultant corrective coefficients
CPA Q	"quick" power audit, which runs somewhat faster and does not store the new coefficients
CPA RESET	reset all channel coefficients to 1.0; **CPA** will then report 0.00% deviation for each channel

Examples:

cpa *report latest channel power audit results*
1,-1.4 *channel power level relative to calibrated/expected level, as percentages*
2,-0.3
3,+0.31
4,-2.94
…
62,-.04
Final *extra <CR><LF> terminates list*

4.6.12 - PDI - Read photodiode(s) response

Reads the output of the A/D converter monitoring the internal photodiode. The results are displayed as a 24-bit signed integer (range: -8,388,608 - +8,388,607).

Syntax:

PDI read photodiode response

Examples:

pdi
1207471

4.6.13 - PDT - Photodiode target

Reports the target photodiode response used by the realtime optical feedback (see **FBK, FBG**), as well as the acceptable delta as configured via **STP**. The optical feedback is continuously comparing the actual photodiode response to this number, and adjusting the entire LED array as a whole to maintain this target with **STP** percent. If the optical feedback ever fails to maintain output lock within **STP** percent on any of its attempts, an alarm is issued (typically Alarm 4, “optical feedback lock lost”).

Syntax:

PDT report photodiode target

Examples:

pdt *request photodiode target*
2784834,2784.83 *for the current RS-7 output state, photodiode should maintain 2784834 +/-2784*
pdi *request actual photodiode reading*
2783978 *realtime adjustments are being made by the optical feedback*
pdi

2784021
pdi
2784421

4.6.14 - SDC - Spectral calibration data CRC32

Calculates the CRC32 of the currently stored LED spectral calibration, and the CRC32 of the currently stored Wavelength Monitor System spectral calibration. These can be compared to the CRC32 values stored in the Calibration Information String (see **CAL**).

Examples:

sdc	*request CRC32 values*
D1FA6541,81EE80FB	*LED spectral calibration CRC32, Wavelength Monitor spectral calibration CRC32*

4.6.15 - TMP - Read TEC(s) temperature

Reads the temperature of the two temperature-stabilized TEC blocks, returned in degrees Celcius. Nominal setpoint is 25 degrees. There will two temperatures displayed; the LED board TEC block, and the (optional) Wavelength Monitor System TEC block.

Syntax:

TMP	read TEC block temperatures

Examples:

tmp	
25.42C,24.99C	*LED TEC block is at 25.42C, Wavelength Monitor TEC block is at 24.99C*

4.6.16 - VER - Firmware version

Returns the current RS-7 firmware version.

Syntax:

VER	report firmware version

Examples:

ver
1.04

4.6.17 - FBK - Optical feedback enable/disable

Enables or disables the real-time optical feedback. Normally enabled by default, the feedback can be disabled in order to provide direct control over the constant-current sources driving each channel.

Syntax:

FBK report feedback setting
FBK [0|1] disable [0] or enable [1] feedback

Examples:

fbk *query feedback setting*
1
fbk0 *disable optical feedback (channels will be operated fixed constant-current only)*
Ok

4.6.18 - FBG - Query optical feedback gain

Reports the latest optical feedback gain coefficient that is being applied to the entire LED array as a whole, which is nominally 1.0 in the ideal situation in which all LEDs are generating precisely their calibrated level of luminous output. Note that this coefficient continues to be updated in real time, even if optical feedback has been disabled via **FBK**; in this case, the feedback gain figure represents the gain that *would* be applied to the LED array, were the RS-7 permitted to be making the adjustments.

Syntax:

FBG report optical feedback gain coefficient

Examples:

fbg *request current feedback gain coefficient*
1.034

4.6.19 - SLM - Soft power limit

Reports or sets the maximum *permissible* channel operating power, as a percentage (up to 100%) of the RS-7's *actual* capability. Attempts to command the RS-7 to drive channels beyond this limit will result in an error. Note that channel power level adjustments being made via **CPA** coefficients and by the realtime optical feedback (see **FBK**) are not subject to this limit (they are permitted to use the headroom explicitly provided by this soft power limit)**.** The default **SLM** is 90%.

Syntax:

SLM report current channel soft limit

SLM [limit] set soft limit to [limit] %, where [limit] is an integer between 0 and 100

Examples:

slm *query soft limit*
90
slm80 *decrease soft limit to 80%*
Ok

4.6.20 - ALA - Query/reset alarms

Reports the presence of an alarm condition, or resets (clears) the alarm (if possible). A description of the various alarms can be found in Section 4.7.2. Note that if the condition which created the alarm still exists, clearing the alarm will cause the unit to immediately issue the alarm again. Also, alarms can be either asynchronous, meaning that the unit will transmit the alarm string immediately when the alarm condition first arises, or polled, in that one must issue the **ALA** command regularly to see if an alarm condition has arisen. The choice between polled and asynchronous alarms is configured with the **ASA** command.

Syntax:

ALA report current alarm state
ALAR reset alarm
ALAC clear alarm (identical to reset alarm)

Examples:

ala *query current alarm state*
NONE *no alarm condition*
…
…
?A1 – channel power limit *alarm indicating optical feedback is trying to drive a channel past 100%*
ala *query alarm state*
?A1 – channel power limit
alac *try to clear the alarm*
Ok
?A1 – channel power limit *fault condition still exists*
pre0 *load preset #0*
Ok
ala *query alarm state*
NONE *RS-7 is properly outputting preset #0*

4.6.21 - ASA - Asynchronous Alarm

This command configures whether or not an alarm condition is issued by the unit asynchronously, meaning that it will transmit the alarm string immediately upon encountering an alarm condition. If is not desirable that the

unit can send strings of its own volition at any time, asynchronous alarms may be disabled. Note that detecting an alarm condition in this mode requires that the user poll the unit regularly via the **ALA** command.

Syntax:

ASA 0	disable asynchronous alarms, operate in polled mode only (via **ALA** command).
ASA 1	enable asynchronous alarms

Examples:

asa0	disable asynchronous alarms
Ok	

4.6.22 - CFC - Clear Fault Condition

If the RS-7 encounters a serious operational problem, such as corrupted data structures, invalid calibration information, or an internal hardware failure, it will enter a fault mode which none of the commands will function; instead, a fault message such as

?F1 - initialization fault

will be the only response to any command issued to the RS-7.

The three exceptions are the commands **CFC**, **ICK** (Integrity Check), and **RST** (Restart). Issuing **CFC** to the RS-7 will clear the fault condition and once again allow the unit to accept commands; however, continuing to operate the unit after having to clear a fault condition means it may not be functioning properly and cannot be trusted for accuracy.

Syntax:

CFC	clear fault condition

Examples:

pre12	*attempt to load preset #12*
?F1 - initialization fault	*command not accepted, unit is in fault mode*
out	*request current output level*
?F1 - initialization fault	*command not accepted, unit is in fault mode*
rst	*restart unit to see what errors occur during initialization*
CH14 ERROR/CALIBRATION DATA: CRC or structure error	*channel #14's calibration appears corrupt*
Gamma Scientific RS-7	
Firmware Version 1.07	
Ok	
pre12	*attempt preset #12 again*
?F1 - initialization fault	*still won't function because of the initialization error*
cfc	*clear the fault condition*
Ok	
pre12	*attempt preset #12 again*

Ok *operation permitted although channel #14 is suspect*

4.6.23 - UDB - User Data Block

Reads or writes a user block of binary data from/to internal EEPROM. The data is accessed as one of 20 4K blocks, providing 80K bytes total user storage. The data is transferred as 4096 bytes of binary data.

Syntax:

UDBR [block] read 4K user data block [block]
UDBW [block],[bdata..] write 4K user data block [block]

Examples:

UDBR 14 *read 4K user data block #14*
jnqf98y3rwvh29gh123fuiownvonvowv…..weiuvhwf230guw8gh<CR><LF>
…4096 data bytes are sent from the RS-7, with a final <CR><LF> at the end
UDBW0 *write 4K user data block #0*
6yb948ygkh gi yt ego8g ag9bea…7itrv34878f7wfg8wf 8wfgw4
Ok …4096 data bytes are sent to the RS-7, with the RS-7 responding with Ok<CR><LF>
upon receipt of the final data byte

4.6.24 - RST - Restart Unit

This command will restart the RS-7 and return it to the state as if it were just powered on.

4.6.25 - POT - Power-on time

Reports the elapsed time since the unit was last powered on or restarted (see **RST** command).

Syntax:

POT report Power On Time

Examples:

pot *request time since power-up or last reset*
0D 02:09:28.736 *unit has been operating for zero days, 2 hours, 9 minutes, and 28.736 seconds*

4.6.26 - IRI - Iris control

If the RS-7 has been equipped with the optional motorized iris, this command is used to set its position, as a percentage of fully closed (0% - Fully Open, 100% - Fully Closed). When used in conjuction with the Irradiance

mode command (**IRR**), the absolute units of irradiance (**UNI** 0, µW/cm², and **UNI** 1, lm/m²) will be automatically scaled to reflect the proper irradiance at the target (at the working distance of **IRR** millimeters) accordingly.

Syntax:

IRI	report current iris position as percentage of closed (0 – 100%)
IRI [%]	set iris position as percentage closed (0 – 100%)
IRI H	home iris to the fully open position, and set the iris position to 0 (always done at power-up/**RST**)

Examples:

iri	*request current iris position*
65	*iris is 65% closed*
iri30	*open iris up to the 30% closed position*
Ok	

4.7 Error Codes and Alarm Messages

4.7.1 Error Codes:

?01 - missing argument

?02 - argument out of range

?03 - unrecognized command

?04 - buffer overflow

Exceeded the RS-7 input buffer size of 8192 bytes when a command is being received

?05 - LSQ fault

FTS failed to find a solution

?06 - channel power unreachable

Attempt made to command one or more channels to >100% power

?07 - channel CPA*power unreachable

The requested RS-7 output would have been reachable, except the CPA coefficients pushed one or more channels >100% power

?08 - channel CPA*FBG*power unreachable

The requested RS-7 output would have been reachable even with the CPA coefficients applied, except the initial attempt to set the output power level resulted in the optical feedback pushing one or more channels >100% power before a stable output state within STP% of PDT could be reached

?09 - channel power ADP limit

The requested RS-7 output is attempting to drive one or more channels past the allowable deviation from nominal of ADP%

?10 - channel power SLM soft limit

Attempt made to command one or more channels past the soft limit SLM%

?11 - excessive feedback correction indicated

While attempting to output the requested RS-7 output, an excessively out-of-range photodiode response was encountered

?12 - data ended unexpectedly early

When transferring target spectrum (TSP) spectral data to the RS-7, the host did not provide the expected number of spectral data points

?13 - tristimulus will not converge

CCS failed to find a solution

?14 - invalid units, must be radiometric (0) or photometric (1)

STS cannot use UNI = 2

?15 - TSP is zero

Attempt made to scale target spectrum TSP via STS command, when target spectrum is all

zeros

?16 - OSP is zero

Attempt made to change RS-7 output level via OUT command, when all channels are set to zero

?17 - preset not found

Attempt made to load a nonexistent preset (available presets can be queried via PRE*)

?18 - output level lock timeout

The RS-7 failed to achieve the requested RS-7 output within STP percent after ½ second has elapsed

?19 - missing calibration

Attempt to operate one or more channels in absolute units (UNI=1 or 2) without spectral calibration data stored

?20 - requested output level too low

The optical feedback requires a minimum level of LED output energy to function properly, an attempt was made to command the RS-7 to an output level below this threshhold

?21 - channel is not active

Attempt made to command an unpopulated channel (no LEDs)

?22 - EEPROM write verification failed

An attempt to store nonvolatile parameters, spectral data, user data, etc. to EEPROM failed to read back correctly during verification

?23 - missing power<->current information

The channel cannot be operated as power (0 – 100%) because the table used to convert power to drive current has not been constructed (calibration required)

?24 - requested output level too high

The irradiance of the requested output power will over-range the optical feedback system

?25 - passcode must be entered first

Certain commands which control core features of the RS-7, set the unit serial number (USN), etc. are passcode protected in order to prevent inadvertant changes

?26 - monitor use invalid with more than one wavelength active

The System Monitor cannot distinguish among multiple wavelengths; only one wavelength should be active during a monitor request (MON)

?27 - monitor reports irradiance that exceeds calibration data

The System Monitor is reporting an irradiance that exceeds the output power that the active wavelength should be able to generate (fault condition)

?28 - monitor unable to resolve wavelength

The System Monitor is seeing a detector differential that exceeds computable limits

4.7.2 Alarm Codes:

?A1 - channel power limit

The realtime optical feedback wants to drive one or more channels past 100% power in an attempt to maintain RS-7 output optical lock within STP% of PDT

?A2 - channel power ADP limit

The realtime optical feedback wants to drive one or more channels past ADP% allowable power deviation

?A3 - excessive feedback correction indicated

While the realtime feedback was operating, an excessively out-of-range photodiode response was encountered indicating a severe problem (RS-7 output power is suddenly less than ½, or more than twice what it should be)

?A4 - optical feedback lock lost

During an iteration of the realtime optical feedback, the RS-7 output as reported by the photodiode was outside the permissible range (STP% of PDT)

?A5 – LED TEC temperature lock lost

The TEC temperature-stabilized LED block reported a temperature beyond +/1C of the setpoint (25C)

?A6 – LED TEC overtemperature shutdown

The TEC temperature-stabilized LED block is reporting a temperature in excess of 40C, the LEDs will be automatically turned off & the unit will not function until the temperature drops back below 40C

?A7 – LED TEC undertemperature shutdown (thermistor unresponsive)

The TEC temperature-stabilized LED block has been reporting a temperature of less than 19.5C for longer than 15 seconds. Since the thermoelectric temperature control should easily be able to raise the TEC block temperature to 25C, this is considered a fault condition (a possible cause is that the thermistor used to monitor the LED block temperature is unplugged)

?A8 – MS TEC temperature lock lost

The TEC temperature-stabilized Wavelength Monitor System reported a temperature beyond +/-1C of the setpoint (25C)

?A9 – MS TEC out of lock timeout/shutdown

The TEC temperature-stabilized Wavelength Monitor System has reported a temperature beyond +/-1C of the setpoint (25C) for longer than 30 seconds

4.7.3 Fault Codes:

?F1 – initialization fault

A critical problem such as corrupted data, invalid calibration, or an internal hardware failure was detected during initialization. The unit will refuse all future commands except RST, ICK, and CFC. The CFC command can be used to forcibly clear the fault and allow the RS-7 to continue operating (albeit in a compromised/unknown state).

SECTION 5 GLOSSARY

< >	Symbols used to indicate a key on the keyboard.
ASCII	ASCII stands for American Standard Code for Information Interchange. ASCII code is the numerical representation of a character such as 'a' or '@' or an action of some sort.
Bandwidth (BW)	Bandwidth: (Full width - half maximum) A measure of the optical power resolution function (optical width) of a spectrometer system (in nanometers) given by the difference between the two extreme values of the independent variable (wavelength) of which the dependent variable (optical power) is equal to half of its maximum value.
Big-endian	Big-endian is an order in which the "big end" (most significant value in the sequence) is stored first (at the lowest storage address).
Blackbody (Full Radiator)	An ideal body completely absorbs all incident radiation and reflects none, therefore appearing perfectly black at all wavelengths.
cd	Candela: The SI unit of luminous intensity defined as 1/60 the normal intensity of one square centimeter of a blackbody at the solidification temperature of platinum.
$cd*m^{-2}$	Candelas per meter squared.
Centroid	The weighted central wavelength of a given spectral power distribution.
Chromaticity	Properties of light having to do with hue and saturation, but not luminance (brightness).
CIE	Commission Internationale de l'Eclairage (International Commission on Illumination).
Colorimetric	Measurements as related to the visual interpretation of color.
Colorimetry	The science of color measurement.
.CVS	Comma Separated Values: The .CSV file format is useable by the Microsoft Excel spreadsheet application to import or export data.
CCT	Correlated Color Temperature: Temperature (usually expressed in Kelvins) of a blackbody radiator produces the chromaticity nearest to that emitted by the light test source.
FWHM	Full width at half maximum (FWHM) is an expression of the extent of a function given by the difference between the two extreme values of the independent variable at which the dependent variable is equal to half of its maximum value.
Illuminance	Luminous flux incident per unit area of a surface (lumens per square area).
Illuminant	A luminous flux, specified by its spectral distribution, used, in principle, to illuminate, but may be defined for computational purposes and may not correspond to a real source.
Irradiance	Radiant flux incident per unit area of a surface.
LED	Light Emitting Diode: A P-N junction device that gives off light radiation when

	forward biased.
Light	Electromagnetic radiant energy that is visually detectable by the normal human observer, radiant energy having wavelengths from about 380nm to about 780nm.
Linearity	Refers to a mathematical relationship or function that graphically represents as a straight line, as in two quantities that are directly proportional to each other, such as voltage and current in an RLC circuit, or the mass and weight of an object.
Luminance	Luminance is a photometric measure of the luminous intensity per unit area of light travelling in a given direction. It describes the amount of light passes through is emitted or reflected from a particular area, and falls within a given solid angle. The SI unit for luminance is candela per square meter (cd/m^2).
LUX (lx)	Lux: Illuminance corresponding to a luminous flux density of one lumen per square meter. SI unit of illuminance.
Menu	A set of commands, parameters, or submenus grouped in a pop down menu listed in the menu bar. A pop down menu displays when it selects from the menu bar by using a mouse, the key letter, or the cursor keys and <Enter>.
	A list of options within a program activate routines at the time of selection.
	Menu Bar: The bar at the top of the screen that lists the pop down menus that are available.
Mode	Identifies the type of data in a file (i.e. Reflectance, Transmittance, other).
nm	Nanometer: Unit of length equal to 10-9 meters commonly used for identifying wavelengths of the visible portion of the electromagnetic spectrum.
NIST	U. S. National Institute of Standards and Technology
nits	In lighting, the nit is a unit of visible-light intensity, commonly used to specify the brightness of a cathode ray tube or liquid crystal display computer display. One nit is equivalent to one candela per square meter.
Optical Geometry	Geometrical optics, or ray optics, describes light propagation in terms of rays. The ray in geometric optics is an abstraction, or instrument, useful in approximating the paths along which light propagates in certain classes of circumstances.
Optical Reference Tool	The technique of establishing precise reference lines and planes by means of telescopic sights, especially for aligning machinery, machine-shop work.
Photodiode	A photodiode is a semiconductor device that converts light into current. The current generates when photons are absorbed in the photodiode. A small amount of current also produces when no light is present. Photodiodes may contain optical filters, built-in lenses, and may have large or small surface areas.
Photometric	Pertaining to the measurement of the intensity of light.
Radiance	Radiant power per unit source area per unit solid angle. Usually expressed in watts*m^{-2} *$steradian^{-1}$ (watts per steradian per meter squared).
Radiometer	Processes the signals emitted by the detector into a linear form.
Radiometric	Pertaining to the measurement of radiation (optical power).
Root-mean Square (RMS)	The square root of the arithmetic mean of the squares of a set of values, used as a measure of the typical magnitude of a set of numbers, regardless of their sign.

Routine	A series of actions allowing data to be calculated or manipulated. Operations controlled by menu selection.
Source	An object that produces light or other radiant flux.
Spectral Range	Spectral Range is the spacing in optical frequency or wavelength between two successive reflected or transmitted optical intensity maxima or minima of an interferometer or diffractive optical element.
Spectral Output	Spectral output defined as intensity of light at each wavelength over the range of wavelengths emitted by the lamp. For the most effective cure, this pattern of output matched to the pattern of absorption of the photo initiator in the product.
Spectral Peaks	Maximum (peak) energy density in the spectrum.
Spectral Bandwidth	Defined as the width of the band of light at one-half the peak maximum, (or full width at half maximum [FWHM]) and is represented.
Standard Observer	An ideal observer having visual response described by the CIE tristimulus functions.
TEC	Thermoelectric cooling (TEC) is the cooling effect that occurs as a result of current flowing between two different conductors or semiconductors; heat is produced at one juncture and a cooling effect at another juncture, creating a temperature differential.
Tristimulus	Percentage amounts of the three standard or matching stimuli designated as S, Y, and Z necessary in a three additive mixture required for matching a color.
USB	A Universal Serial Bus (USB) is a common interface that enables communication between devices and a host controller such as a personal computer (PC).
UART	A UART (Universal Asynchronous Receiver/Transmitter) is the microchip with programming that controls a computer's interface to its attached serial devices.
Wavelength	Of an electromagnetic wave, the distance, along the direction of propagation, between nearest points in an electromagnetic wave for which the electric field has the same phase. The unit generally used in spectrophotometry/spectroradiometry related to colorimetry is the nanometer (nm). Unless otherwise stated, values of wavelength are generally those in the air.
Wavelength, Peak	The wavelength at which the radiant intensity is maximum.

SECTION 6 EUROPEAN DECLARATION OF CONFORMITY

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EUROPEAN DECLARATION OF CONFORMITY

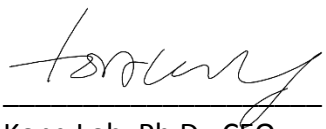
Product Family:	SpectralLED® RS-7 Series Products
Manufacturer:	Gamma Scientific 9925 Carroll Canyon Road San Diego, California 92131 United States of America
Object of Declaration:	Conformity with Relevant Standards Used

EN 61010-1:2010	Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use.
CISPR 11:2009	Industrial, Scientific and Medical Equipment – Radio-frequency Disturbance Characteristics – Limits and Methods of Measurement
IEC 61000-4-2:2001	Electrostatic Discharge Immunity
IEC 61000-4-3:2010	Radiated Electromagnetic Field Immunity
IEC 61000-4-4:2012	Electrical Fast Transient Burst Immunity
IEC 61000-4-6:2013	Radio Frequency Common Mode Immunity
IEC 61000-4-8:2009	Power Frequency Magnetic Field Immunity
EN 61326-1:2006	Electrical Equipment for Measurement, Control and Laboratory Use. EMC Requirements, General Requirements

In Accordance with the provisions of:

2006/95/EC	EU Low Voltage Directive
2004/108/EC	EU Electromagnetic Compatibility Directive

The undersigned hereby declares, on behalf of Gamma Scientific of San Diego, California, that the above-referenced product, to which this declaration relates, is in conformity with the provisions shown.

Signed: 

Kong Loh, Ph.D. CEO

25 January 2016
Date

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United States of America

RoHS CERTIFICATE

Product Family:	SpectralLED® RS-7 Series Products
Manufacturer:	Gamma Scientific 9925 Carroll Canyon Road San Diego, California 92131 United States of America
Object of Declaration:	Conformity with Relevant Standards Used

2000/53/EC End of Life Vehicle (ELV)
2000/53/EC Amendment (2002/525/EC) of Annex II of ELV
2011/65/EU Restriction of the use of Hazardous Substances in EEE (RoHS)
Administrative measures on the Control of Pollution Caused by Electronic Information Products ("China RoHS")
2015/863/EU Change of Annex II from 2011/65/EU

The product family complies with the following European and Chinese directives. These products do not contain any of the following substances in more than the following concentrations in any of the homogeneous materials:

Cadmium	0.01% in weight
Chromium VI	0.1% in weight
Mercury	0.1% in weight
Lead	0.1% in weight
Polybrominated biphenyls (PBB)	0.1% in weight
Polybrominated diphenyl ethers (PBDE)	0.1% in weight
Bis(2-ethylhexyl)phthalate	0.1% in weight
Butyl benzyl phthalate (BBP)	0.1% in weight
Dibutyl phthalate (DBP)	0.1% in weight
Diisobutyl phthalate (DIBP)	0.1% in weight

No technology exemptions are applicable for these products. The EFUP (Environmental Friendly User Period) for China RoHS is not applicable. The data provided is correct to the best of our knowledge.

Signed: _____

Kong Loh, Ph.D. CEO

25 January 2016
Date

SECTION 7 REVISION HISTORY

Revision	Brief Description of Change	Effective Date	ECN #
X1	Initial draft - preliminary	01/21/2016	
X2	Updated throughout, added sections	2/29/2016	
X3	Added GUI operation procedure section and update document format	3/24/2016	
X4	Updated Top View on 0.	5/11/2016	
X5	Updated section 2.4, added note about revision number.	5/19/2016	
X6	Update Software API, merged changed throughout	7/19/2016	
X7	Update Software API, update to SpectralLEDAssist. V2.x	10/14/2016	
X8	Update Software API, general clean-up	11/30/2016	
A	Added CE Declaration of Conformity and RoHS	11/28/2017	
A/X1	Update SpectralLED Assistant, Software API	5/10/2018	

API REVISIONS

Changes for X2:

- Add GRP (Channel Grouping Disable/Enable) command
- Add CGL (Channel Group List) command
- Add PRE N (Preset Next) command
- Add OCL (Offending Channels List) command
- Add HLP & HELP command

Changes for X6:

- Add CTY (Calibration Type) command
- Add CAL (Calibration Information) command
- Add ATF (Accessory Transfer Function) command
- Add RST (Restart) command
- Add OXYZ (Output Tristimulus) command
- Add TXYZ (Target spectrum Tristimulus) command
- Add CCT (Correlated Color Temperature) command
- Add OUTC (Change Integrated Output Power with Constant Chromaticity) command
- Add CCSx,y (Color-Correct Output Spectrum to explicit CIE 1931 x,y) command
- Remove ADP (Allowable Drive Percentage) command
- Remove SCC (Set Channel Current) command

Changes for X7:

- Add PUL (Pulse) command
- Add ICK (Integrity Check) command
- Add RST (Restart) command
- Add OPD (Output Port Differential) command
- Add MON (Monitor System Query) command
- Add PTY (Peak Type) command
- Add BAT V (Basic Assurance Test – Verbose) command
- Add SCANR (Scan Next Repeatedly) command
- Add SCAD (Scan Demo) command
- Add SDC (Spectral Calibration Data CRC32) command
- Add IRI (Iris) command
- Add POT (Power-On Time) command
- Add ASA (Asynchronous Alarms) command
- Add SDC (Spectral Data CRC32) command
- Add IRI (Iris) command

Changes for X8:

- Add IRR (Irradiance mode) command
- Add CFC (Clear Fault Condition) command

Changes for A/X1:

- Incorporate updates for CTY, IRR, ATF