



OWNER'S MANUAL

INSIGHT QUANTUM SPECTRORADIOMETER

Models MS-100

Rev: 12-March-2025



APOGEE INSTRUMENTS, INC. | 721 WEST 1800 NORTH, LOGAN, UTAH 84321, USA
TEL: (435) 792-4700 | FAX: (435) 787-8268 | WEB: APOGEEINSTRUMENTS.COM

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CERTIFICATE OF COMPLIANCE

EU Declaration of Conformity

This declaration of conformity is issued under the sole responsibility of the manufacturer:

Apogee Instruments, Inc.
721 W 1800 N
Logan, Utah 84321
USA

for the following product(s):

Models: MS-100
Type: Spectroradiometer

The object of the declaration described above is in conformity with the relevant Union harmonization legislation:

2014/30/EU	Electromagnetic Compatibility (EMC) Directive
2011/65/EU	Restriction of Hazardous Substances (RoHS 2) Directive
2015/863/EU	Amending Annex II to Directive 2011/65/EU (RoHS 3)

Standards referenced during compliance assessment:

EN 61326-1:2013	Electrical equipment for measurement, control, and laboratory use – EMC requirements
EN 63000:2018	Technical documentation for the assessment of electrical and electronic products with respect to the restriction of hazardous substances

Please be advised that based on the information available to us from our raw material suppliers, the products manufactured by us do not contain, as intentional additives, any of the restricted materials including lead (see note below), mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB), polybrominated diphenyls (PBDE), bis (2-ethylhexyl) phthalate (DEHP), butyl benzyl phthalate (BBP), dibutyl phthalate (DBP), and diisobutyl phthalate (DIBP). However, please note that articles containing greater than 0.1 % lead concentration are RoHS 3 compliant using exemption 6c.

Further note that Apogee Instruments does not specifically run any analysis on our raw materials or end products for the presence of these substances, but we rely on the information provided to us by our material suppliers.

Signed for and on behalf of:
Apogee Instruments, July 2024



Bruce Bugbee
President
Apogee Instruments, Inc.



CERTIFICATE OF COMPLIANCE

UK Declaration of Conformity

This declaration of conformity is issued under the sole responsibility of the manufacturer:

Apogee Instruments, Inc.
721 W 1800 N
Logan, Utah 84321
USA

for the following product(s):

Models: MS-100
Type: Spectroradiometer

The object of the declaration described above is in conformity with the relevant UK Statutory Instruments and their amendments:

2016 No. 1091	The Electromagnetic Compatibility Regulations 2016
2012 No. 3032	The Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations 2012

Standards referenced during compliance assessment:

BS EN 61326-1:2013	Electrical equipment for measurement, control, and laboratory use – EMC requirements
BS EN 63000:2018	Technical documentation for the assessment of electrical and electronic products with respect to the restriction of hazardous substances

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Signed for and on behalf of:
Apogee Instruments, July 2024



Bruce Bugbee
President
Apogee Instruments, Inc.



PACKING CONTENTS



MS-100 InSight Spectroradiometer



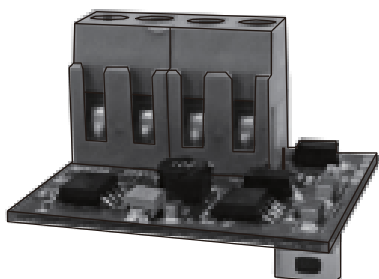
Protective Case

QUICK START GUIDE

Apogee InSight MS-100
Handheld Spectroradiometer



Quick Start Guide



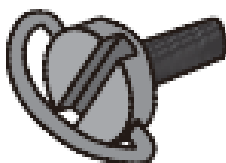
Modbus Communication Board



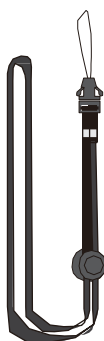
Mini-USB Cable



European or US style
Power Adapter



Neck Strap Screw



Neck Strap

INTRODUCTION

Spectral (i.e., wavelength-dependent) radiation is intensity of output from a radiation source (e.g., sun, electric lamp, reflected radiation from a surface of interest) as a function of wavelength. Radiation spectra vary for different radiation sources and conditions. Radiation spectra can be used to characterize radiation sources.

Spectrometers measure relative spectral radiation over a specified wavelength range. Spectroradiometers are spectrometers calibrated to output spectral measurements in absolute units (e.g., energy flux density in $\text{W m}^{-2} \text{nm}^{-1}$ or photon flux density in $\mu\text{mol m}^{-2} \text{s}^{-1} \text{nm}^{-1}$).

Typical applications of spectroradiometers include measurement of spectral output from radiation sources used to grow plants, algae, and corals (e.g., in greenhouses, growth chambers, and aquarium lighting), measurement of solar spectra with changing atmospheric conditions, and measurement of spectral reflectance on stationary (e.g., agricultural or ecological weather stations and flux towers) and mobile (e.g., plant phenotyping) platforms. **Please note that the meter is not waterproof.**

Apogee Instruments InSight model MS-100 (380 to 780 nm measurement range) spectroradiometers are handheld units designed for laboratory and field use. Each spectroradiometer consists of a spectrometer (slit, diffraction grating, detector array) and diffuser mounted in a small plastic housing. Each unit is calibrated to provide spectral measurements in absolute units. Onboard circuitry allows for output to a computer (via USB), handheld device (via Bluetooth), or datalogger (via ModBus).

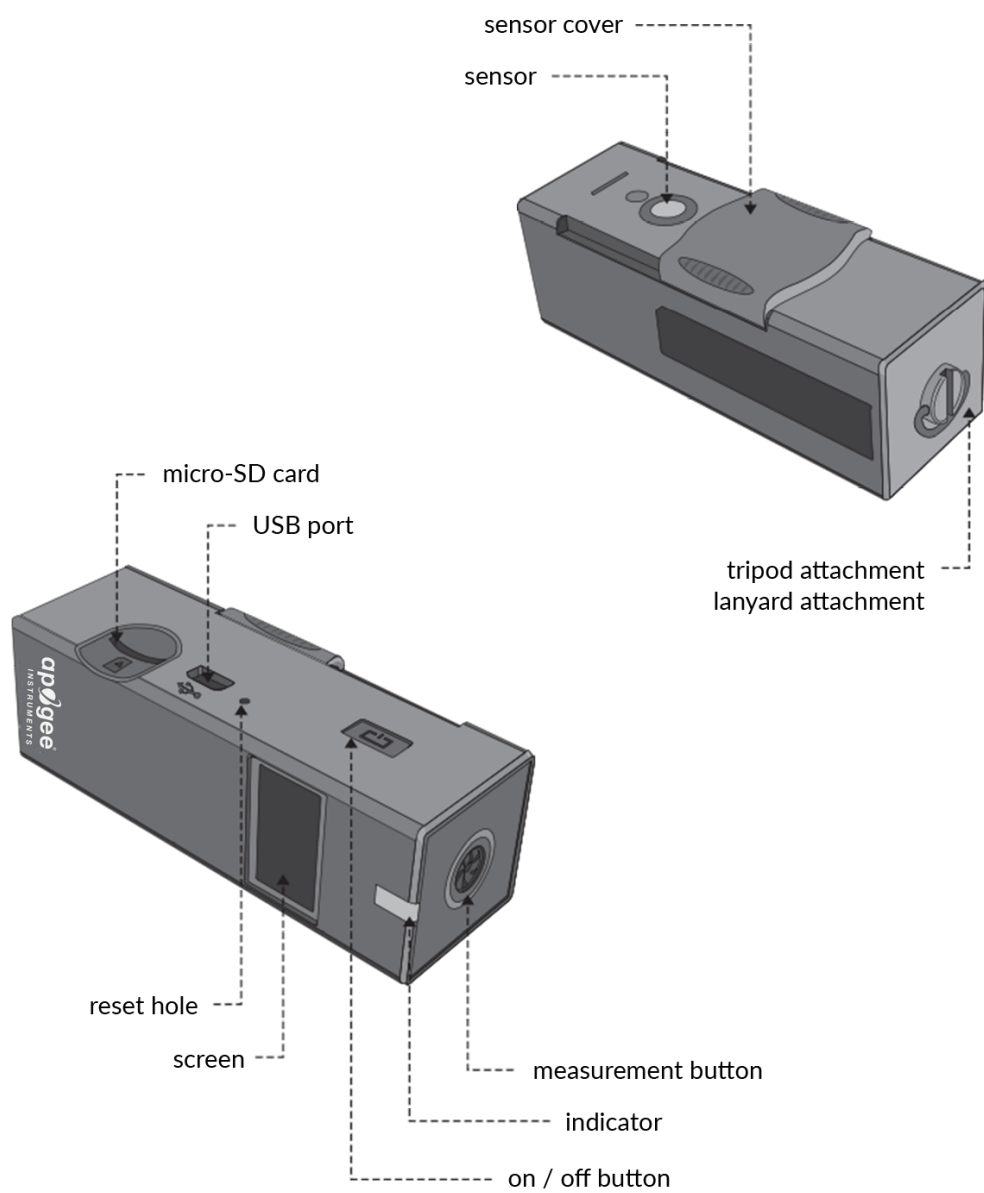
SENSOR MODELS

The Apogee InSight MS series handheld quantum spectroradiometers covered in this manual are self-contained and come complete with a handheld meter, carrying case, protective case, quick start guide, mini-USB cable, power adapter, communication board, neck strap screw, and neck strap.



Sensor model number is located on a label on the right side of the meter. The serial number is located on the same side under the bar code.

PRODUCT DIAGRAM



GETTING STARTED

Installing the SD Card

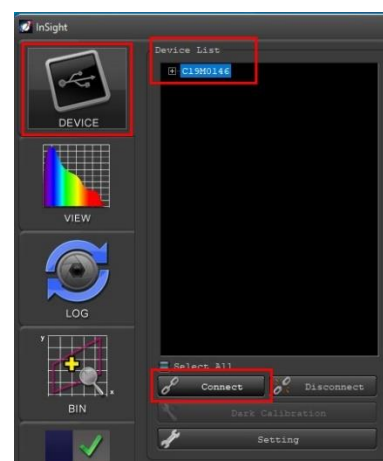
This unit writes measurement data onto a MicroSD card (1 GB to 32 GB). The SD card is not included and must be purchased separately. Insert the card into the MicroSD card slot. All captured data is written to excel files (.xls). **Note:** The MS-100 is not compatible with SDXC or SDUC standard SD cards, and it will only work with SD and SDHC standard cards.



Even without a MicroSD Card, the MS-100 can capture data.

Setting the Date/Time

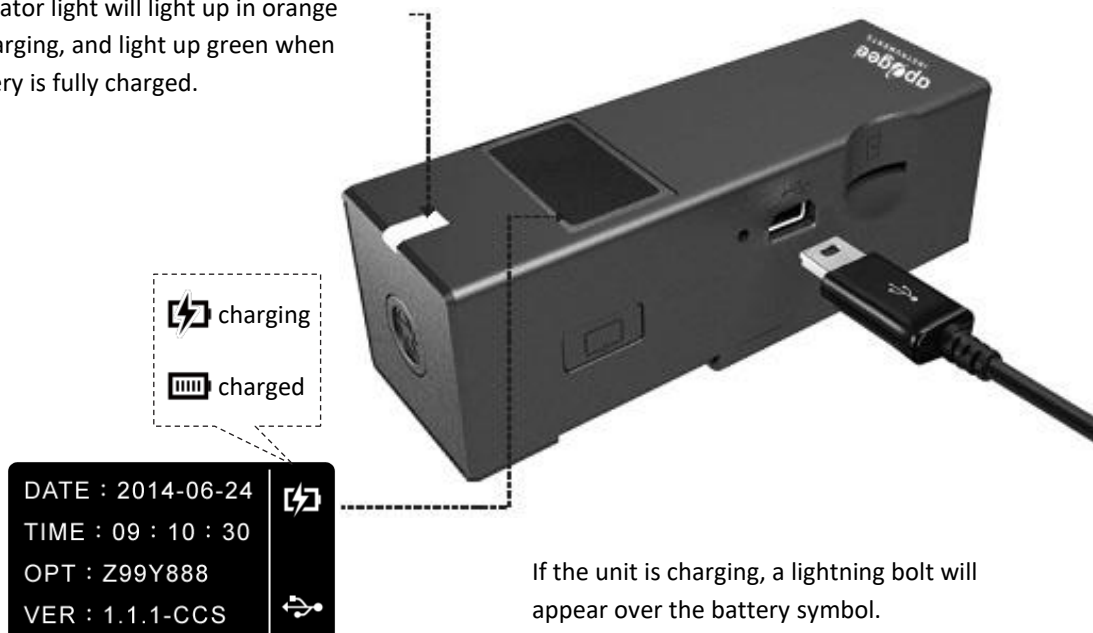
Plug your MS-100 into your PC using the included mini-USB cable. [Launch the Apogee InSight software](#). Click on "Device." Under "Device List," click on your meter and choose "Connect" to automatically sync up your device with the Date/Time on your PC.



Charging the Internal Battery

Connect one end of the mini-USB charger cable to the MS-100 and the other end into a wall socket with the appropriate voltage. You can also connect the meter to a computer to charge. The indicator light will illuminate orange while it is charging. The light will turn green when fully charged. For first time use, charge the battery for at least 6 hours.

The indicator light will light up in orange while charging, and light up green when the battery is fully charged.



Using the Lanyard Strap/Tripod



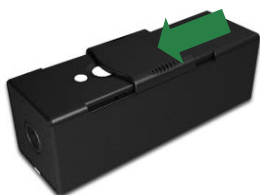
You can attach a lanyard (neck strap) onto the ring at the bottom of the MS-100.



If you detach the lanyard screw on the bottom of the MS-100, it will expose a screw hole where you can attach a tripod for hands-free LED measurements.

DARK CALIBRATION

It is good practice to perform a dark calibration every time you turn on the MS-100, whenever you move to a different temperature environment (hot to cold or cold to hot), or whenever you move to a different light intensity environment (light to dark or dark to light).



Slide the sensor cover up over the sensor lens on the back of the unit.



Press the “Measure” button at the top of the MS-100. The calibration takes approximately 6 seconds.



When Dark Calibration is complete, the screen will read “Calibration OK.”

You also can use the [InSight PC software](#) to perform a dark calibration.

TAKING A MEASUREMENT



1. Slide the sensor cover up over the sensor diffuser on the back of the unit.



2. Turn on the MS-100 by pressing the On/Off button on the left side of the unit. The indicator light on the front of the unit will illuminate green, and an Apogee splash screen will display.

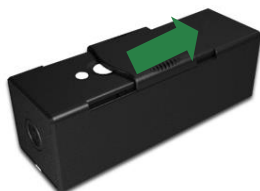
Note: If you are using a USB charger, the MS-100 will automatically turn itself on.



3. After the splash screen, a “Dark Calibration” label will display, indicating that a dark calibration is in progress.



4. When dark calibration is complete, the screen will read “Calibration OK” and then show the time, date, and software version number.



5. Slide the sensor cover down so that the sensor diffuser is visible again.



6. The first screen will display the date and time, optic number, and software version number. The battery level indicator is on the top right.



7. Hold the MS-100 as shown with the sensor facing toward the front, in the direction of a light source, and press the “measure” button on the top of the MS-100.



8. The measurement takes approximately 10 seconds to complete. The unit will beep to indicate completion. The screen will then show the wavelength spectrum. Press the On/Off button on the left side of the unit to go to the next measurement screen.

Note: See the following page for an explanation of the different measurements the MS-100 can take.



9. Continue to press the On/Off button once to go to the next screen. The following screens display the different measurements.

DATA SCREEN EXPLANATIONS

PPFD: photosynthetic photon flux density. Sum of photons between 400 and 700 nm in units of micromoles per square meter per second [$\text{mmol m}^{-2} \text{s}^{-1}$] for instantaneous measurements. PPFD is almost universally used to quantify photosynthetically active radiation (PAR), radiation driving photosynthesis.

ePPFD: extended photosynthetic photon flux density. Sum of photons between 400 and 750 nm in units of $\text{mmol m}^{-2} \text{s}^{-1}$ for instantaneous measurements. Recent research indicates PAR should be extended to include far red photons between 701 and 750 nm because these photons drive photosynthesis with similar efficiency to photons in the 400 to 700 nm range when they are acting synergistically with photons in the 400 to 700 nm range (meaning when far red photons in the 701 to 750 nm range are added to photons in the 400 to 700 nm range) (Zhen and van Iersel, 2017; Zhen et al., 2019; Zhen and Bugbee 2020a; Zhen and Bugbee 2020b; Zhen et al., 2021; Zhen et al., 2022).

YPFD: yield photon flux density. Photon flux density at each wavelength weighted by relative quantum efficiency, measured by McCree (1972a, 1972b), and summed. Quantum yield is moles of carbon fixed per mole of photosynthetic photons absorbed. Relative quantum yield data from McCree were derived from measurements made on single leaves of twenty-two species with monochromatic radiation sources over short time intervals. YPFD as measure of photosynthetically active radiation may not be appropriate for broad spectrum radiation sources over longer time intervals for whole plants and plant canopies.

TPFD: total photon flux density. Sum of photons between 380 and 780 nm in units of $\text{mmol m}^{-2} \text{s}^{-1}$ for instantaneous measurements. The range 380 to 780 nm is the entire spectral measurement range of the spectroradiometer.

PFD-UV: photon flux density in the ultraviolet (UV) range. Sum of photons between 380 and 399 nm in units of $\text{mmol m}^{-2} \text{s}^{-1}$ for instantaneous measurements. The spectroradiometer is only sensitive to UV radiation from 380 to 399 nm.

PFD-B: photon flux density in the blue (B) range. Sum of photons between 400 and 499 nm in units of $\text{mmol m}^{-2} \text{s}^{-1}$ for instantaneous measurements.

PFD-G: photon flux density in the green (G) range. Sum of photons between 500 and 599 nm in units of $\text{mmol m}^{-2} \text{s}^{-1}$ for instantaneous measurements.

PFD-R: photon flux density in the red (R) range. Sum of photons between 600 and 700 nm in units of $\text{mmol m}^{-2} \text{s}^{-1}$ for instantaneous measurements.

PFD-FR: photon flux density in the far-red (FR) range. Sum of photons between 701 and 750 nm in units of $\text{mmol m}^{-2} \text{s}^{-1}$ for instantaneous measurements.

FR F: far-red fraction. Sum of far-red photons between 701 and 750 nm divided by the sum of photons between 400 and 750 nm (ePAR range). Phytochrome is a pigment in plant leaves that mostly absorbs radiation in the red and far-red wavelength ranges. Absorption by phytochrome in these ranges influences plant perception of sunny and shaded conditions, and as a result, plant morphology. Historically, the red to far-red ratio has been used in field studies as a metric to indicate full sunlight to deep shade, where full sunlight has a red to far-red ratio near

1.1 and deep shade has a red to far-red ratio less than 0.1. However, the red to far-red ratio approaches infinity for some electric light sources. The far-red fraction is an improved metric for indicating the sun to shade environment because it ranges from 0 to 1 and is positively correlated with plant morphological responses influenced by phytochrome (Kusuma and Bugbee, 2020). A far-red fraction of 0 indicates no far-red radiation and a far-red fraction of 1 indicates only far-red radiation.

PPE: phytochrome photoequilibrium. Photon flux density at each wavelength weighted by phytochrome red state weighting factors divided by the sum of photon flux density at each wavelength weighted by phytochrome red state weighting factors and photon flux density at each wavelength weighted by phytochrome far-red state weighting factors, where the weighting factors are from Sager et al. (1988). Phytochrome photoequilibrium is a metric to quantify the sun versus shade environment of plants. It is used in a similar way to red to far-red ratio and far-red fraction, but weights spectral radiation by the photostationary states of phytochrome and therefore accounts for spectral absorptivity of phytochrome. Phytochrome photoequilibrium ranges from 0 to 1, with full sunlight about 0.7 and deep shade near 0.3.

iPPE: improved phytochrome photoequilibrium. Same as PPE, but with updated weighting factors from Kusuma and Bugbee (2021). The updated weighting factors include distortion functions that account for radiation absorption from the leaf surface to location of phytochrome within the leaf.

CFI: sometimes called color fidelity index. Relative metric quantifying the ability of a light source to accurately render colors of objects relative to the color appearance when illuminated by a reference light source, typically daylight. Similar metric to color rendering index (CRI) but updated to include more color samples to produce a more representative measurement than CRI. CRI was derived with eight color samples, Rf was derived with ninety-nine.

CRI: color rendering index. Relative metric quantifying the ability of a light source to accurately render colors of objects relative to the color appearance when illuminated by a reference light source, typically daylight. Maximum CRI is 100 and is only achieved by a light source with a spectrum identical to daylight, which would render colors the same as daylight. CRI can be negative, as with a low-pressure sodium lamp, which is about -44. Typically, CRI falls between 0 and 100. Incandescent bulbs are near 100 and most white LEDs are greater than 80.

CCT: correlated color temperature. Metric quantifying color appearance of white light sources. It is reported as an absolute temperature (in units of K) and typically ranges from 2000 to 6500 K, with lights that appear blue (cool colors) being higher numbers and lights that appear orange (warm colors) being lower numbers. For example, clear blue sky ranges from about 15000-25000 K and flame ranges from about 1700-2000 K. An incandescent bulb is about 2500 K.

LUX: lux. Illuminance in units of lumens per square meter [lm m^{-2}]. Metric that quantifies light intensity weighted by the sensitivity of the human eye, as defined by the CIE 1931 weighting factors.

ADDITIONAL MEASUREMENT INFORMATION

fc: footcandles. Illuminance in units of lumens per square foot [lm ft^{-2}]. Metric that quantifies light intensity weighted by the sensitivity of the human eye, as defined by the CIE 1931 weighting factors.

R FR R: red to far-red ratio. Sum of red photons between 650 and 670 nm divided by the sum of far-red photons between 720 and 740 nm. Metric often used in field studies to indicate plant radiation environment from full sun to deep shade. As indicated above, far-red fraction is an improved metric.

LambdaP: peak wavelength. Wavelength where maximum radiation is measured, in units of nanometers [nm].

LambdaD: dominant wavelength. Wavelength indicating perceived color of a radiation source, in units of nm. It is the wavelength within the visible range that aligns with perceived hue.

CIE 1931 x and y: chromaticity coordinates calculated from CIE 1931 color matching functions.

CIE 1976 u' and v': chromaticity coordinates calculated from CIE 1976 color matching functions.

Kusuma, P., and B. Bugbee, 2020. Far-red fraction: An improved metric for characterizing phytochrome effects on morphology. *Journal of the American Society of Horticultural Science*, doi: 10.21273/JASHS05002-20.

Kusuma, P., and B. Bugbee, 2021. Improving the predictive value of phytochrome equilibrium: Consideration of spectral distribution within a leaf. *Frontiers in Plant Science*, doi: 10.3389/fpls.2021.596943.

McCree, K. J., 1972a. The action spectrum, absorptance and quantum yield of photosynthesis in crop plants. *Agricultural Meteorology*, 9:191-216.

McCree, K. J., 1972b. Test of current definitions of photosynthetically active radiation against leaf photosynthesis data. *Agricultural Meteorology*, 10:443-453.

Sager, J. C., W. O. Smith, J. L. Edwards, and K. L. Cyr, 1988. Photosynthetic efficiency and phytochrome photoequilibria determination using spectral data. *Transactions of the ASAE* 31(6):1882-1889.

Zhen, S., and M. W. Van Iersel, 2017. Far-red light is needed for efficient photochemistry and photosynthesis. *Journal of Plant Physiology*, 209:115–122.

Zhen, S., M. Haidekker, and M. W. van Iersel, 2019. Far-red light enhances photochemical efficiency in a wavelength-dependent manner. *Physiologia Plantarum*, 167(1):21-33.

Zhen, S., and B. Bugbee, 2020a. Far-red photons have equivalent efficiency to traditional photosynthetic photons: Implications for redefining photosynthetically active radiation. *Plant Cell and Environment*, doi: 10.1111/pce.13730.

Zhen, S., and B. Bugbee, 2020b. Substituting far-red for traditionally defined photosynthetic photons results in equal canopy quantum yield for CO₂ fixation and increased photon capture during long-term studies: Implications for re-defining PAR. *Frontiers in Plant Science*, doi: 10.3389/fpls.2020.581156

Zhen, S., M. W. Van Iersel, and B. Bugbee, 2021. Why far-red photons should be included in the definition of photosynthetic photons and the measurement of horticultural fixture efficacy. *Frontiers in Plant Science*, doi: 10.3389/fpls.2021.693445.

Zhen, S., M. W. Van Iersel, and B. Bugbee, 2022. Photosynthesis in sun and shade: The surprising importance of far-red photons. *New Phytologist*, doi: 10.1111/nph.18375.

SPECIFICATIONS

MS-100		
	SPECTRUM	
Sensor	CMOS Linear Image Sensor	
Wavelength Range	380 to 780 nm	
Wavelength Data Increment	1 nm	
Spectral Bandwidth	Approximately 12 nm (half bandwidth)	
Wavelength Reproducibility	± 1 nm*1	
Measurement Range	PPFD: 0.1 to 3,500 μmol m ⁻² s ⁻¹ ; Lux: 5 to 190,000 lx	
Illuminance Accuracy	Illuminant A @ 2,856 K at 20,000 lx *2	± 5 %
Color Accuracy		± 0.0025 in CIE 1931 x, y
Color Repeatability		± 0.0005 in CIE 1931 x, y
CCT Accuracy		± 2 %
CRI Accuracy @ Ra	± 1.5 %	
Stray Light	-25 dB max. *3	
Integration Time Range	6 to 1,000 ms	
Digital Resolution	16 bits	

FEATURE	
Capture Function	One time
Operation Mode	Standalone Mode/Bluetooth Mode/USB Mode (PC Connection)
Integration Mode	Auto
Measuring Modes	<ol style="list-style-type: none"> 1. Spectrum Graphics 2. PPFD, ePPFD, YPFD, TPDF 3. PFD-UV, PFD-B, PFD-G, PFD-R 4. PFD-FR, FR F, PPE, iPPE 5. CFI, CRI, CCT, lux 6. fc, R F-R R, λ_p, λ_d 7. CIE 1931 x & y, CIE 1976 u' & v'
Measuring Capabilities	<ol style="list-style-type: none"> 1. Illuminance (LUX)/Foot Candle (fc) 2. Correlated Color Temperature (CCT) 3. CIE Chromaticity Coordinates <ol style="list-style-type: none"> a. CIE 1931 x, y Coordinates b. CIE 1976 u', v' Coordinates c. CIE 1931 XYZ Value 4. Dominant Wavelength (λ_d) 5. Color Fidelity Index (CFI, Ra)/R1 to R15 6. Photosynthetically Active Radiation (PAR) <ol style="list-style-type: none"> a. PPFD (400 to 700 nm) $\text{m}^{-2} \text{s}^{-1}$ b. ePPFD (400 to 750 nm) $\text{m}^{-2} \text{s}^{-1}$ c. PPF-UV (380 to 400 nm) $\text{m}^{-2} \text{s}^{-1}$ d. PPF-B (400 to 500 nm) $\text{m}^{-2} \text{s}^{-1}$ e. PPF-G (500 to 600 nm) $\text{m}^{-2} \text{s}^{-1}$

	f. PPF-R (600 to 700 nm) $\text{m}^{-2} \text{s}^{-1}$ g. PPF-NIR (700 to 780 nm) $\text{m}^{-2} \text{s}^{-1}$ 7. Percent Flicker 8. Spectral Power Distribution (SPD) mW/m^2 9. Peak Wavelength (λ_p) 10. Peak Wavelength (λ_{pV}) 11. Integration Time (I-Time)
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SYSTEM CONFIGURATIONS

Display	0.96" 128x64 mono OLED
Maximum Files	\approx 1.2 million files @ 8 GB Micro-SD card (Excel)
Battery Operation Time	\leq 3 hours/Fully charged
Battery Operation Power	USB Power; 700 mAh/3.7V Rechargeable Li-ion Battery Micro Card (SD 2.0, SDHC/up to 32G)
Data Output Interface	Mini USB port (USB 2.0) Bluetooth 3.0 and 4.0 compatible with iOS and Android
Data Format	Compatible with Microsoft Office Excel
Dimensions	90 x 30 x 32.2 mm (H x W x D)
Weight (with Battery)	70 g \pm 5 g
Operating Temperature	0 to 35°C, relative humidity 70 % or less without condensation
Storage Temperature	-10 to 40°C, relative humidity 70 % or less without condensation
Display Languages	English
Software	Apogee InSight (available for PC, iOS, and Android)
Warranty	One year

*1 : Input source must be a stable light source.

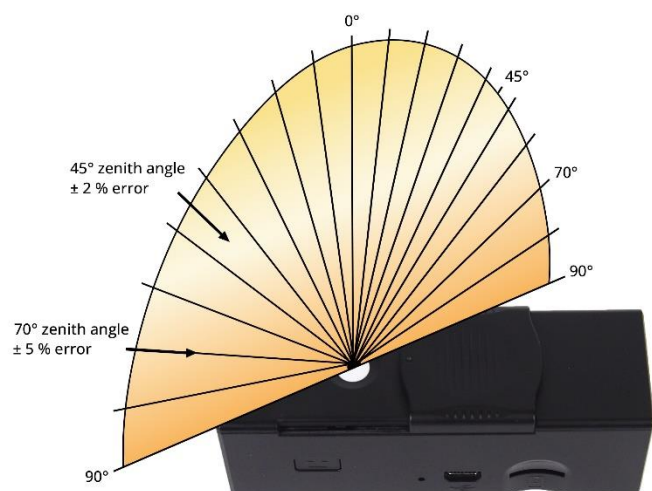
*2 : Temperature $23 \pm 2^\circ\text{C}$ and relative humidity 50% or less.

*3 : Input the 550nm monochromatic light and measure the stray light ratio at $550\text{nm} \pm 40\text{nm}$.

Calibration Traceability

Spectroradiometer calibrations are performed using a radiation source traceable to the National Institute of Standards and Technology (NIST).

COSINE CORRECTION



Directional (cosine) response is defined as the measurement error at a specific angle of radiation incidence. Error for Apogee InSight MS-100 series spectroradiometers is approximately $\pm 2\%$ and $\pm 5\%$ at solar zenith angles of 45° and 70° , respectively.

USING APOGEE INSIGHT PC SOFTWARE

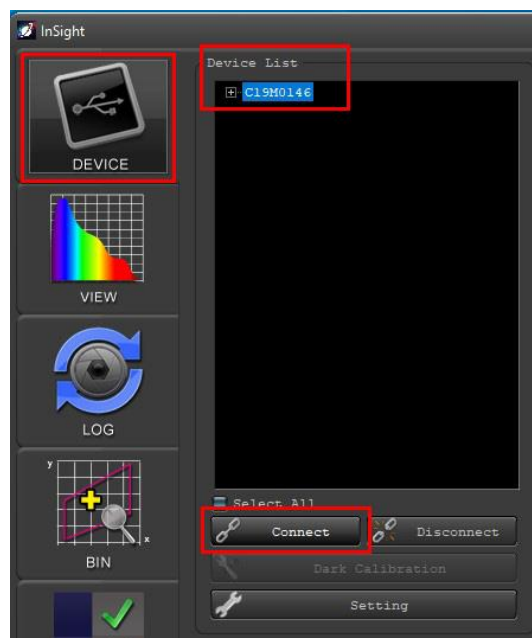


To download Apogee InSight software, go to www.apogeeinstruments.com/downloads/.

DEVICE SCREEN

Launch the Apogee InSight software. Plug your spectroradiometer into the PC using the included mini-USB cable. To connect your MS-100, click on “Device.” Under “Device List,” select on your meter and choose “Connect.” This will also automatically sync up your device with the Date/Time on your PC.

Perform a [dark calibration](#) on your meter. Once your meter is connected to the software, click the “Dark Calibration” button above the “Setting” button. The calibration takes about 4 seconds.



VIEW SCREEN



Load Data: Load previously saved data from your PC.

Save Data: Save data to your PC. Data rows can also be selected to be saved individually.

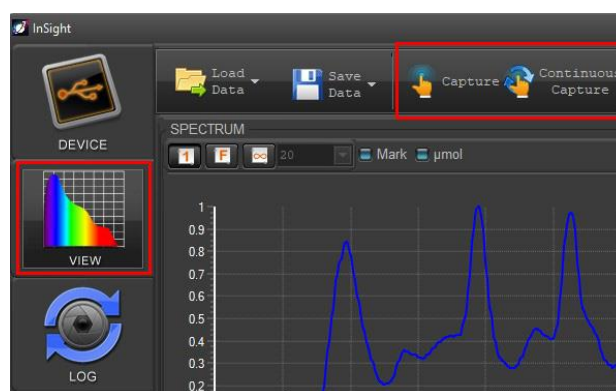
Capture: Spectroradiometer takes a light measurement.

Continuous Capture: Spectroradiometer continuously takes light measurements at short intervals (approximately every 5 seconds), allowing you to move and reposition the sensor without needing to click the “Capture” multiple times.

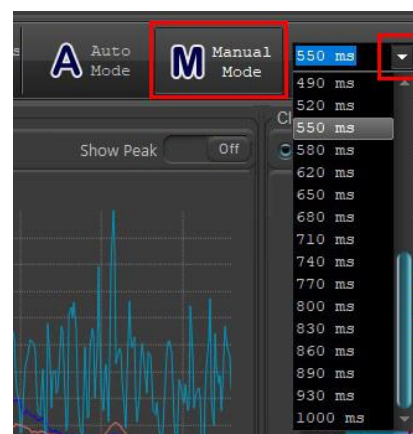
Auto Mode: Interval time for “Continuous Capture” is fixed.

Manual Mode: Manually set the interval time for “Continuous Capture.”

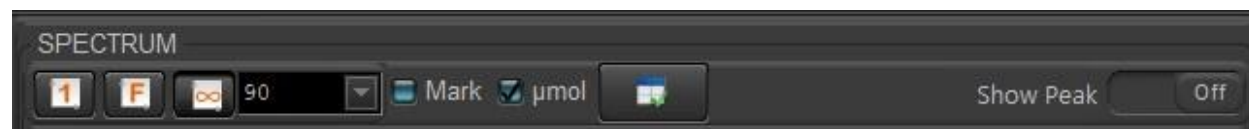
To take a measurement, click on “View.” At the top of the screen, choose “Capture” or “Continuous Capture.” “Capture” takes a single measurement, while “Continuous Capture” continues to take measurements until you stop the program. Click on the “Continuous Capture” button again to stop the automatic captures.



You can take measurements in “Auto Mode” or “Manual Mode.” In “Manual Mode,” select the drop down to select your integration time (exposure time) in milliseconds.



The “Spectrum” window graphs the wavelength spectrum of your light measurements. You can view multiple captures at the same time. The captures are tracked in the “Data” window below the graph. The x-axis represents wavelength, and the y-axis represents intensity.



1 Mode: Displays the high peak wave (λ_p) at 100% of the y-axis height.

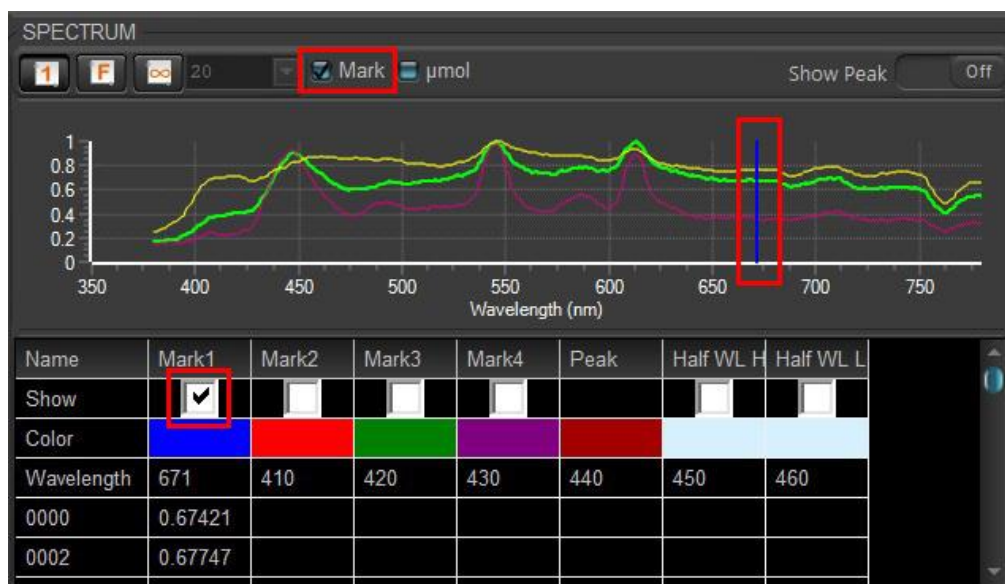
F Mode: When displaying several spectra at once, all are displayed with their relative intensities.

∞ Mode: Y-axis height is fixed and based on values in the drop-down menu or an inserted value.

Mark: Allows you to view numerical data for all measurements across a vertical cross section of the spectrum.

μmol Mode: Shows the spectral graph data in micromole units.

Show Peak: When turned “On,” the high peak (λ_p) and its half bandwidth are both marked.



The “Mark” check box allows you to the numerical data from your captures across a vertical cross section of the spectrum. Select the data you want to see and drag the vertical line side to side to change the spectrum values.

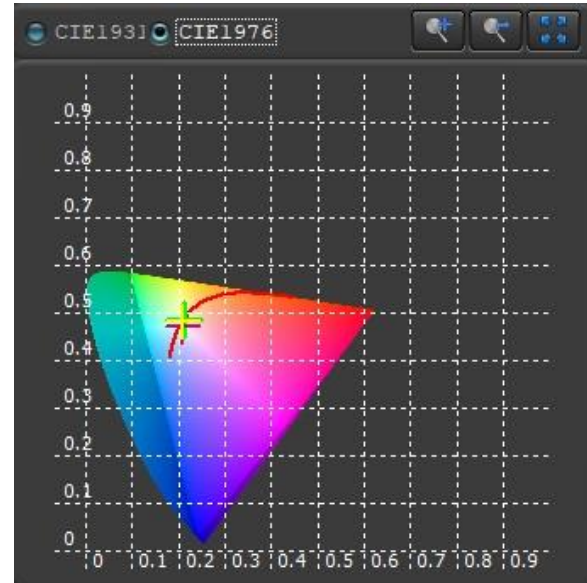
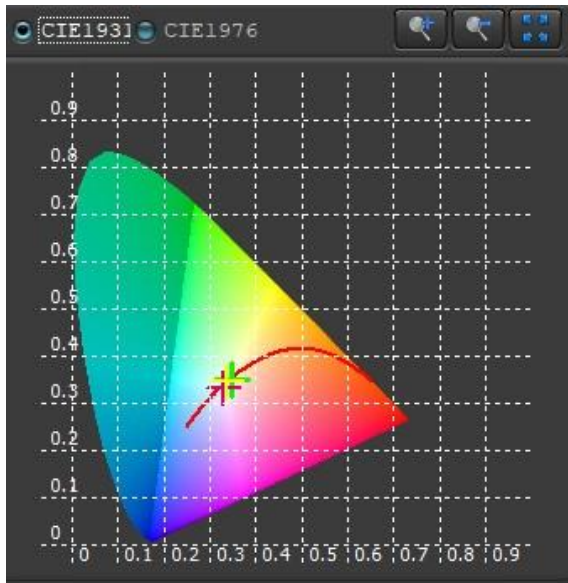
The DATA window displays a table of captures. The first four columns (State, Color, Remove, Save) are highlighted with a red box. The Remove button is also highlighted with a red box. The table contains 7 rows of data.

State	Color	Remove	Save	Saved	Type	Name	Model	SN	Time
<input type="checkbox"/>	Blue	Remove	Save	No	Data	0001	MS-100	C19M0146	2023/
<input checked="" type="checkbox"/>	Magenta	Remove	Save	No	Data	0002	MS-100	C19M0146	2023/
<input type="checkbox"/>	Yellow	Remove	Save	No	Data	0003	MS-100	C19M0146	2023/
<input checked="" type="checkbox"/>	Pink	Remove	Save	No	Data	0004	MS-100	C19M0146	2023/
<input type="checkbox"/>	Light Pink	Remove	Save	No	Data	0005	MS-100	C19M0146	2023/
<input type="checkbox"/>	Light Blue	Remove	Save	No	Data	0006	MS-100	C19M0146	2023/
<input checked="" type="checkbox"/>	Red	Remove	Save	No	Data	0007	MS-100	C19M0146	2023/

The “Data” window tracks each capture. By default, all spectral graphs overlap with one another. To view a capture individually, check the specific box under “State.” To change the color of the graph, click on a color under the “Color” category. This brings up a menu of different color options. To remove or save a capture, click the “Remove” or “Save” categories respectively.

The CIE Chart Window displays CIE 1931 or CIE 1976.

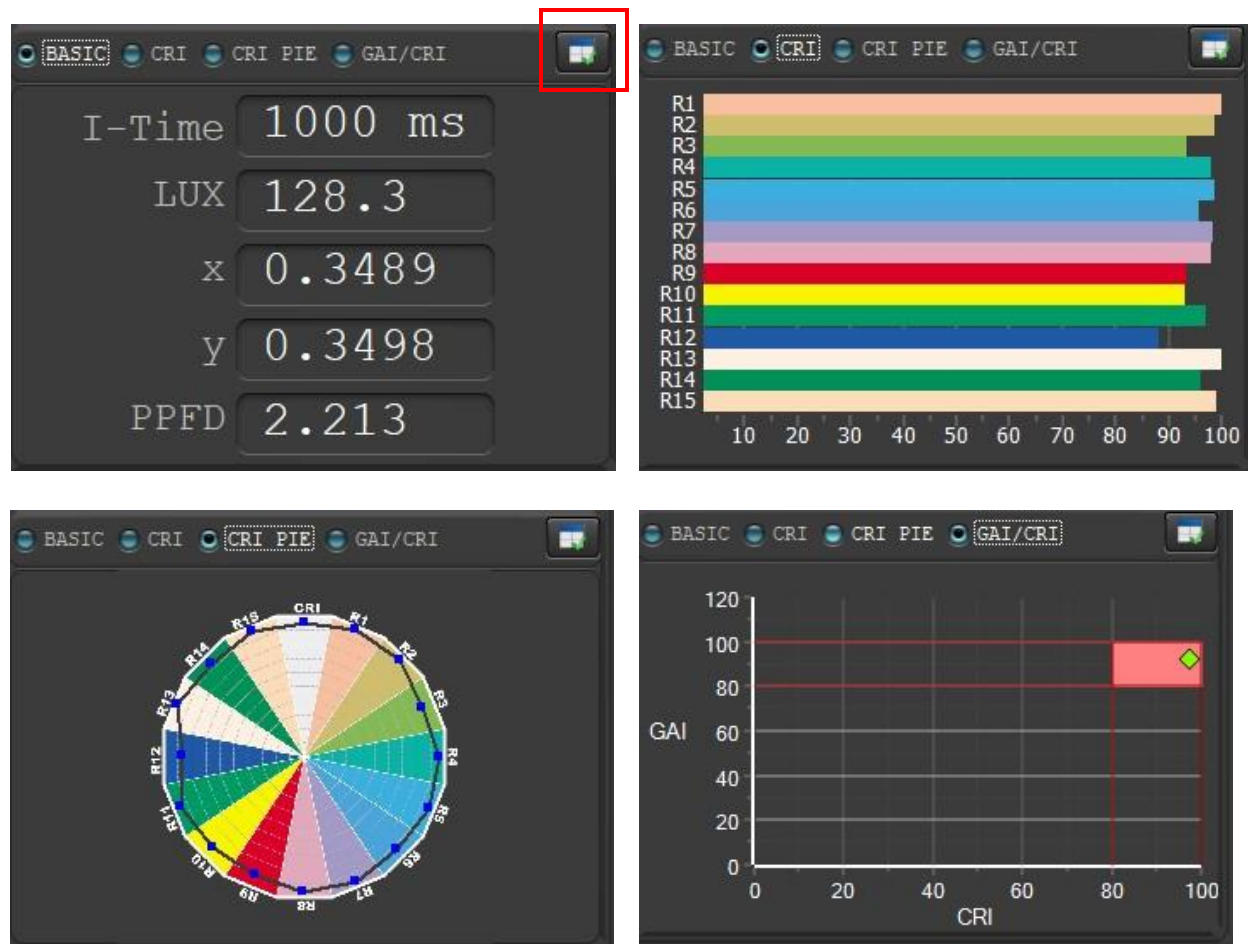
- **CIE 1931 x and y** : chromaticity coordinates calculated from CIE 1931 color matching functions.
- **CIE 1976 u' and v'** : chromaticity coordinates calculated from CIE 1976 color matching functions.



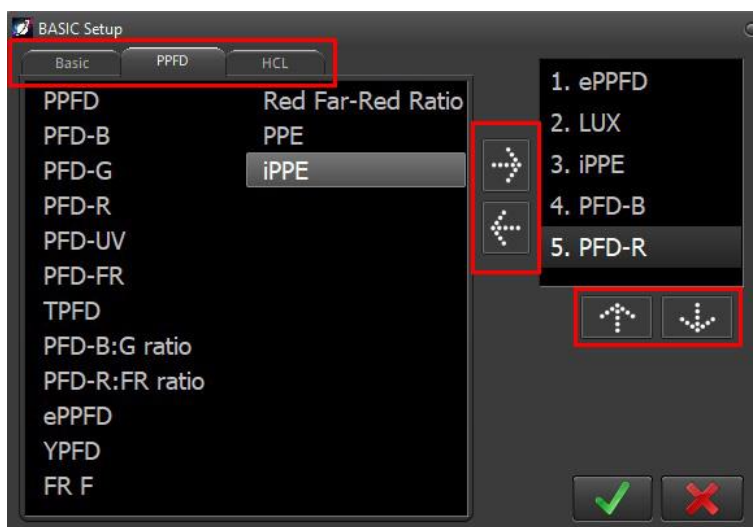
Zoom in and zoom out on the graph with the buttons in the right-hand corner.
Drag the graph to reposition it on the screen.



In the lower right-hand corner of the screen, you can choose to display the “Basic List,” “Color Rendering Index (CRI) chart,” “CRI pie chart,” or “Gamut Area Index (GAI)/CRI chart.”



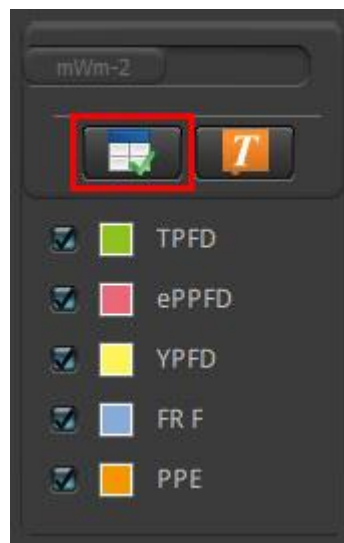
To check the measurements, select the list icon with a green check mark. Click on the measurement to the right (1-5) you want to replace. Then select your desired measurement from the three tabs at the top. Click the arrow pointing to the right to replace the measurement. To change the order of your five measurements, click on a measurement and push the up or down arrows. Press the green check mark when finished.



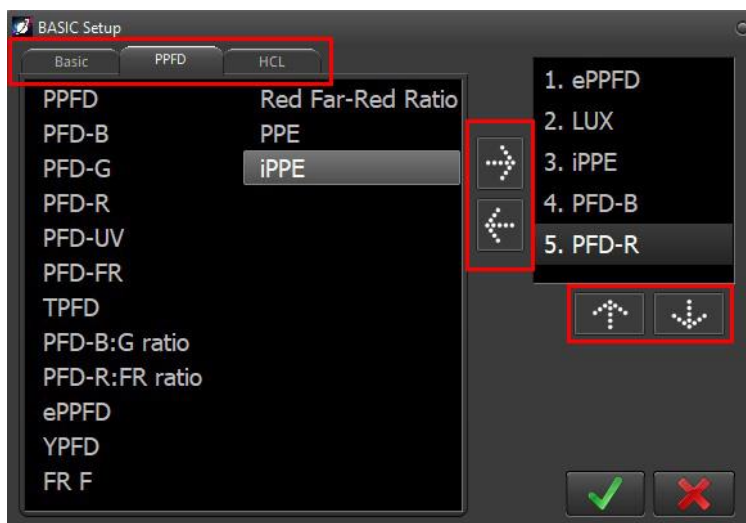
LOG SCREEN

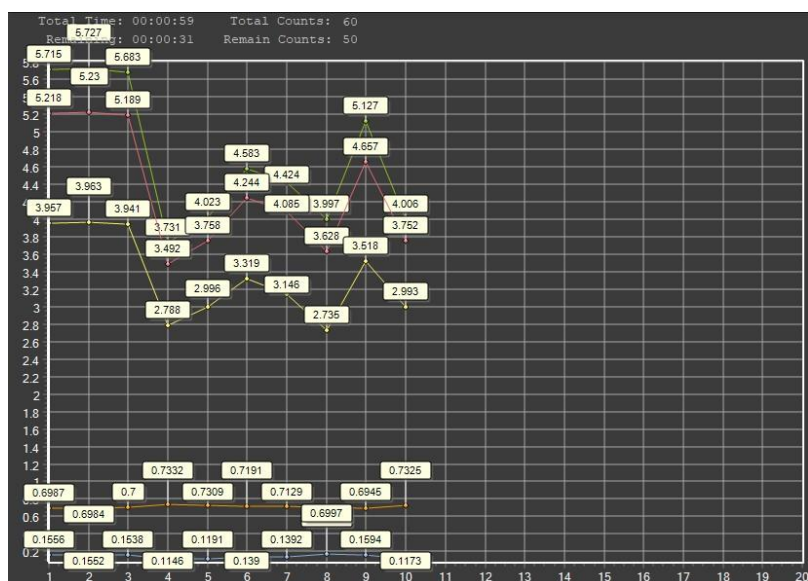
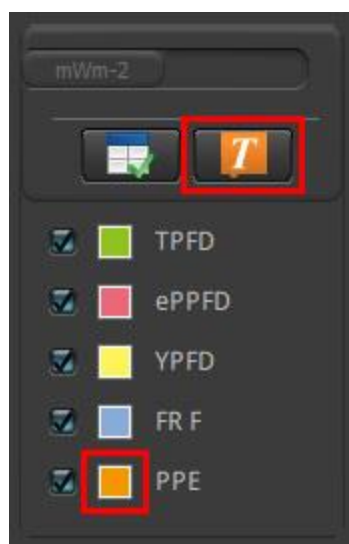
The “Log” window automatically captures and logs light measurements at certain intervals. Use the tool bar to save log data to your computer. Use the load log button to review previously saved logs.

You can choose which measurements you want to log. To change your selections, click on the list icon with a green check mark in the bottom right corner. To view fewer measurements on the graph, unselect the item check box.



Click on the measurement to the right (1-5) you want to replace. Then select your desired measurement from the three tabs at the top. Click the arrow pointing to the right to replace the measurement. To change the order of your five measurements, click on a measurement and push the up or down arrows. Press the green check mark when finished.



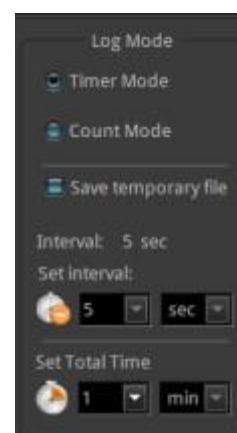


Select the orange text button to view numerical values for each point on the graph. Click the text button again to disable it. Double click the colored square next to each item to change the color of the line on the graph.

Log mode determines the intervals for automatic continuous captures. There are two modes: timer mode and count mode.

Timer Mode: Uses interval and total time as parameters. For example, the MS-100 captures data every 5 seconds for 1 minute total.

Count Mode: Uses interval and total number (counts) of captures. For example, the MS-100 captures data every 5 seconds until it reaches 10 captures.



At the bottom of the log graph, you can adjust the dimensions of the graph.

F (fit) mode adjusts the y-axis to fit all the values on the graph.

M (manual) mode allows you to manually set the y-axis minimum and maximum values.



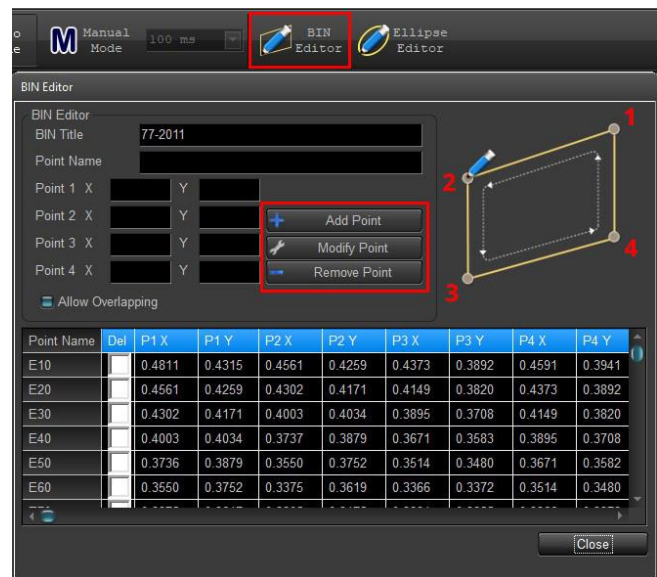
BIN SCREEN

The “Bin” feature is used to classify a light measurement within a given range of boundaries as mapped on the CIE charts.

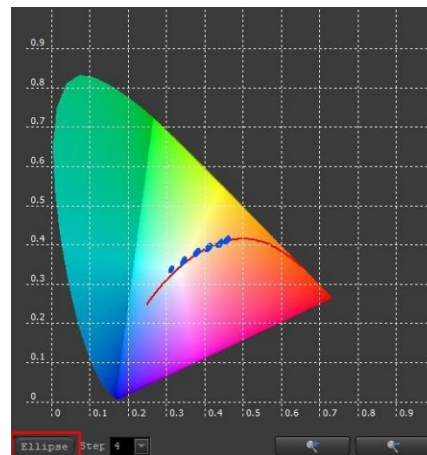
You can upload a past bin file or capture new data. A mark will show you whether the measurement is within the acceptable boundaries for the Energy Star standards. Use the zoom buttons to see the marks clearly.

You can add to or remove boundaries from the current bin chart by using the “Bin Editor.”

Enter in 4 sets of x, y coordinates for one Bin boundary and select “Add point.” You need to precede each point with a leading zero and decimal point (0.1267) for numbers less than 1. Point 1 should represent the upper left-hand corner of the boundary. Points 2, 3, and 4 should continue in counter-clockwise order. You can also modify or delete existing points.



BIN

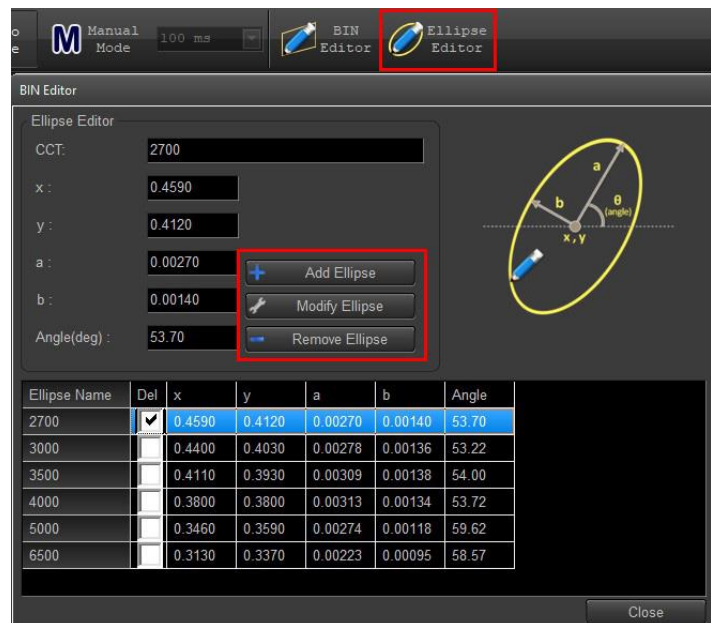


ELLIPSE

There is also an elliptical bin feature. It shows the same information as the bin feature, but the bins are elliptical in shape, as opposed to rectangular.

You can add to or remove ellipse boundaries from the current Bin chart by using the Ellipse Editor.

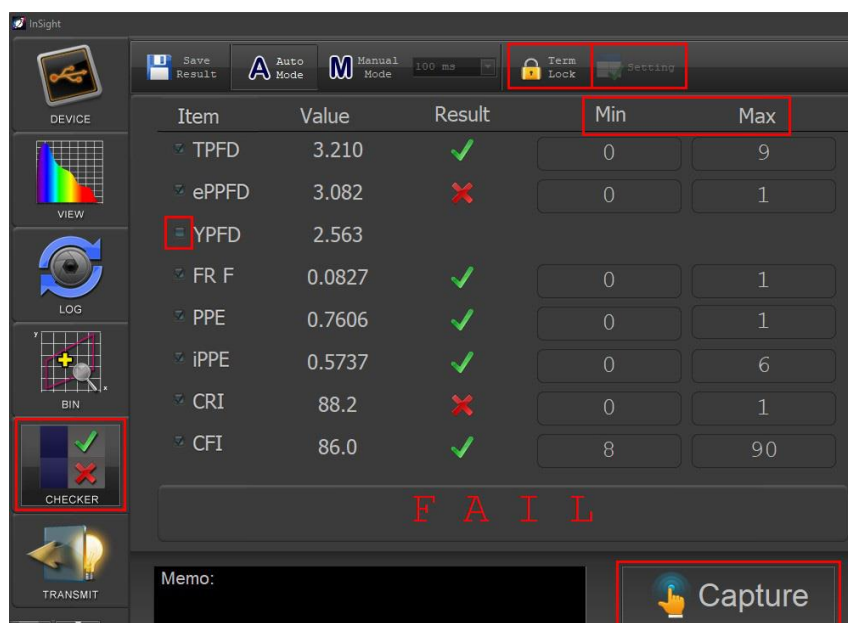
CCT is the name of the boundary and must be represented by a number between 2700-8000 (representing the CCT number). The x, y, coordinates represent the center of the ellipse. The a, b represents the half-height and half-width of the ellipse. The angle represents the slant angle of the ellipse.



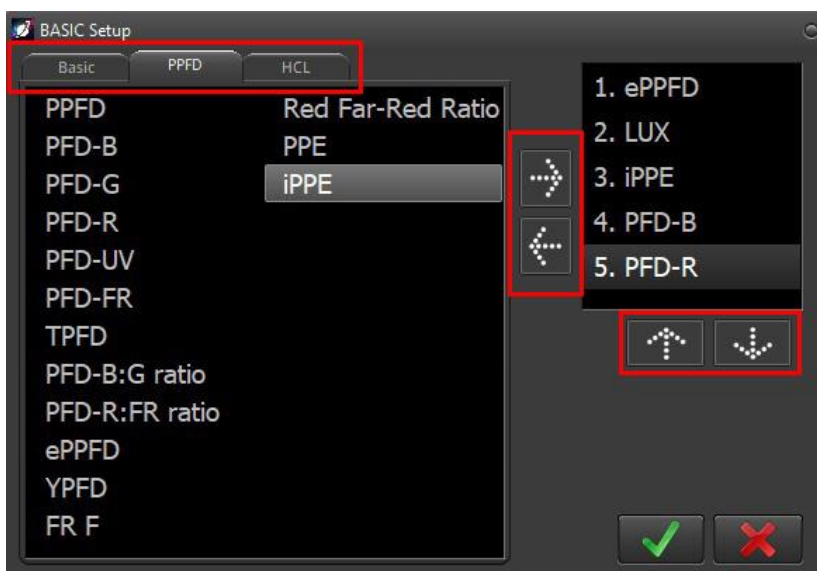
CHECKER SCREEN

On the “Checker” screen, you can test different measurement values as either a pass or fail based on your custom parameters. Green check marks mean pass and red Xs mean fail for each item.

To change your parameters, click on the “Term Lock” button and edit the “Min” and “Max” columns. Click the “Term Lock” button again before taking a capture. Unselect the checkmark on the “Item” column if you don’t want to measure that item.



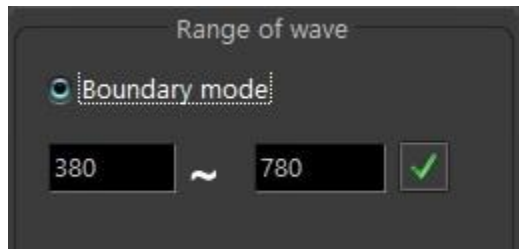
To change the “Item” column, click on the “Term Lock” button and then the “Setting” button. Click on the measurement to the right (1-8) you want to replace. Then select your desired measurement from the three tabs at the top. Click the arrow pointing to the right to replace the measurement. To change the order of your eight measurements, click on a measurement and push the up or down arrows. Press the green check mark when finished.



TRANSMIT SCREEN

The transmit function is used to measure the transmittance between the standard light and the test sample.

There are two modes: boundary mode and center mode.

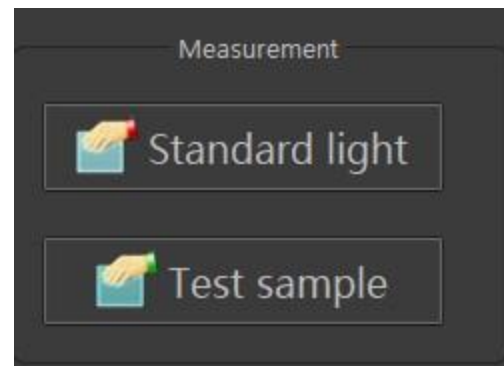


Boundary Mode: Allows you to input the minimum and maximum values to create a boundary range.

Center Mode: Allows you to input the central value and its respective width.

Select the “Standard Light” button to test your reference.

Select the “Test Sample” button to measure your light.



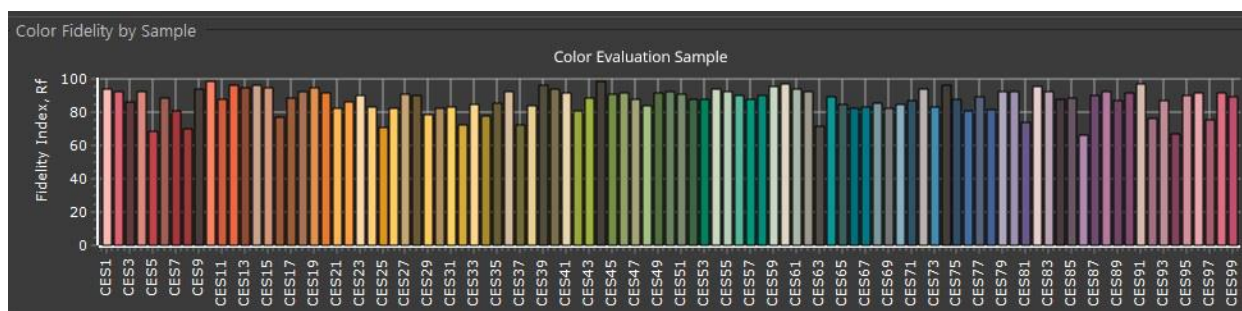
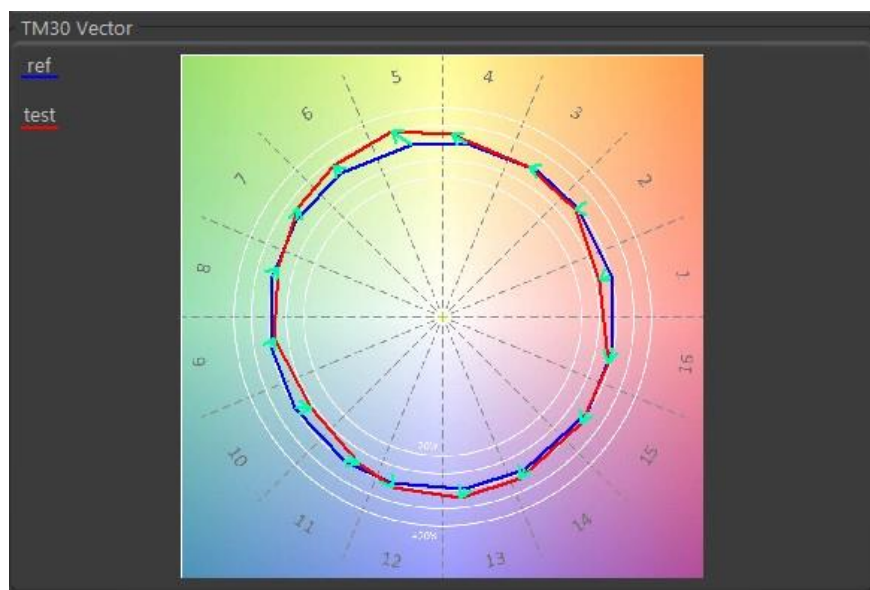
TM-30 SCREEN

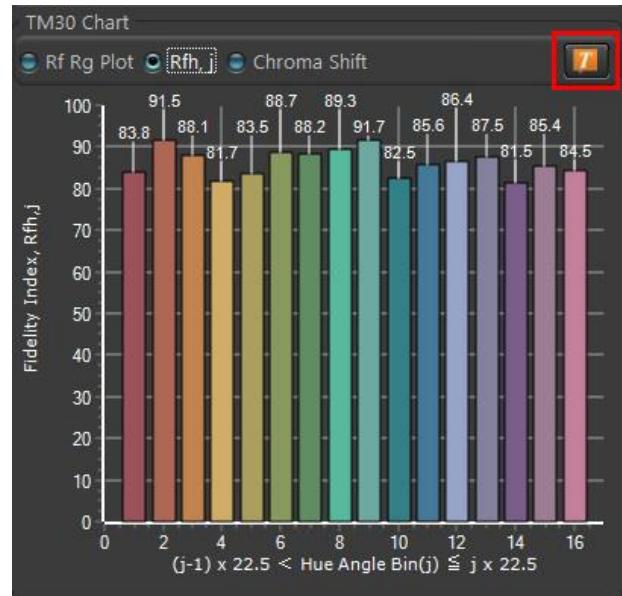
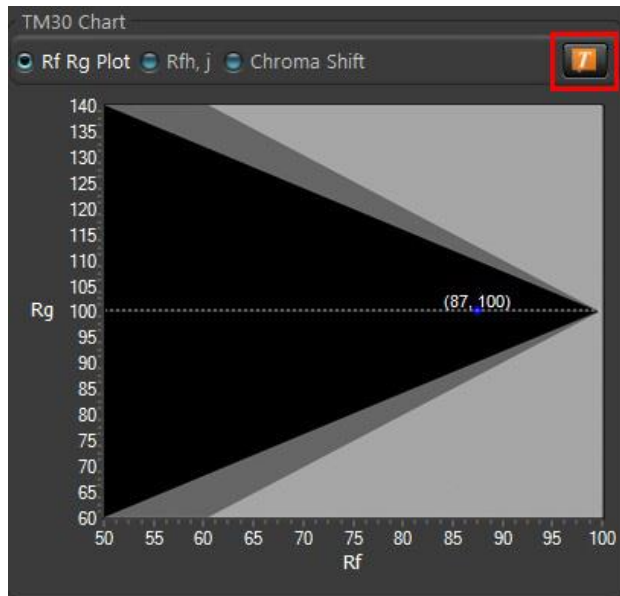
TM-30-15 is a relatively new color rendering index system published by IES (Illuminating Engineering Society). A color rendering index system indicates how well a light, when shining on an object, can reproduce the object's color accurately (compared to a black body radiator – e.g., the sun).

The **CFI metric** stands for color fidelity index. It is a relative metric quantifying the ability of a light source to accurately render colors of objects relative to the color appearance when illuminated by a reference light source, typically daylight. It is a similar metric to color rendering index (CRI), but it has been updated to include more color samples to produce a more representative measurement than CRI. CRI was derived with eight color samples, Rf was derived with ninety-nine. The differences are judged on a 100-point score, with higher numbers meaning the test light can generate accurate colors closer to sunlight's results (see the "Color Fidelity by Sample" graph below).

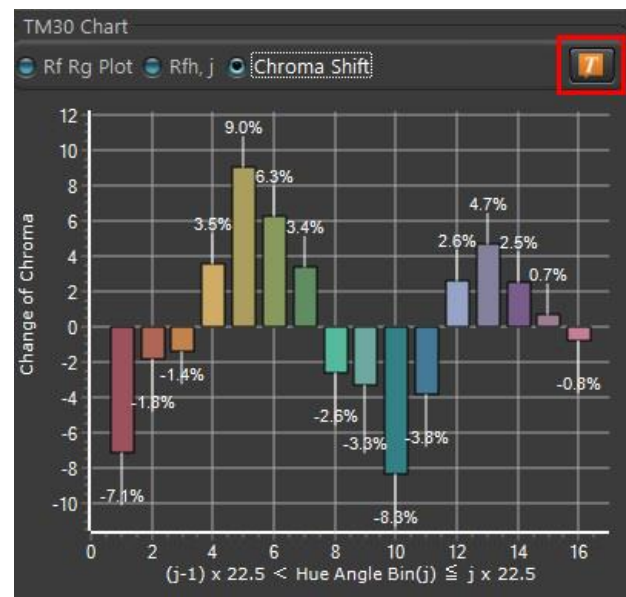
The **Rg metric** represents the other important factor for human perception of color: saturation. It also provides an average of the disparities between a test light and sunlight. It is based on a baseline score of 100; scores that are higher (100-140) indicate higher saturation (on average) and lower scores (60-99) indicate undersaturation.

The Rg metric is a number that reflects overall under or over-saturation, but it doesn't indicate which color areas are problematic. The TM-30-15 remedies this with a superimposed circular vector graph over a color space, representing where color saturation anomalies occur.



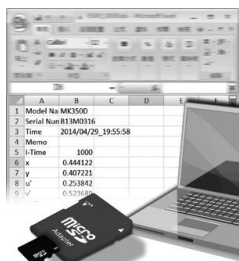


In the bottom right corner of the screen, you can select the TM30 Chart you want to view: Rf Rg Plot (upper left); Rfh, j (upper right); or Chroma Shift (lower right). Select the orange text button to view numerical values for each point on the graph.



DOWNLOADING DATA

You can read the data via a micro-SD card reader and find the data on the SD Card under the “Data” directory. There will be subdirectories marked with a sequential number “e.g. 0001”. Each directory can hold up to 100 capture files, after which the next sequential subdirectory will be created (e.g. 0002).



Each capture will be contained in its own Excel file with a naming convention of ESPD_XXXX, where XXXX is a sequential number (e.g. 0001, 0002).

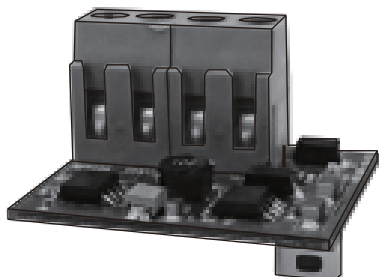
Additional data such as Integration Time, R1-R15, LambdaPV, and all the intensity data for each wavelength in the Wavelength Spectrum are all available in the file.

The MS-100 can also interface with a PC using the Apogee InSight PC Software, which provides a much richer functional and visual environment,



Connection to Apogee InSight

USING MODBUS



The MS-100 comes with a Modbus communication board to plug into the device.

Here is an example code for getting data from the Apogee Instruments MS-100 with the Modbus hardware add on.

- Due to limitation with either CRbasic or CR-loggers, the 2nd byte of the last float value in each raw data subset is missed.
- The device will need a dark calibration at least once before capturing for accurate data and wait for dark to finish.
- The device will need to be written with function 10, address 0xA1 (write multiple registers) to take a measurement.
- After measurement command, the device will need to be polled of job status and wait until job status returns Success.
- Please use datasheet for specific Modbus registers and addresses.
- This example is only for taking a measurement, waiting until device success, and grabbing one data set into a public variable array.

Public PTemp, Batt_volt,

'will need to copy this for each raw data set, address registers (380nm-429nm, 430nm-479nm, 480nm-529nm, 530nm-579nm, 580nm-629nm, 630nm-679nm, 680nm-729nm, 730nm-780nm)

Dim response2(100)As Long, error2

Public ShiftedValues(100) As String *5

Public colorResponse(100) As Float

Dim i,k As Long

Dim CaptureCommand(2) As Long, CaptureIsOkayError as long

Dim CaptureError As Long, CaptureIsOkay As Long

Dim exitloop As Long

'Public response1 As Long, error1

'because limitations of the logger/crbasic, Modbus picks up the length byte as the first byte of the data

'So this function does some shifting of data to arrange data from long to string to float
'returns rearranged value(in string format) to represent ABCD IEEE float value

```
Function shifting(x As String,y As String,z As String) As String
    Dim a As String,b As String,c As String,d As String,e As String,f As String
    f = x&y&z
    a = Right(y,2)
    b = Left(z,2)
    c = Right(x,2)
    d = Left(y,2)
    e = a&b&c&d
    Return e
EndFunction
```

'Define Data Tables.

DataTable (test,1,-1) 'Set table size to # of records, or -1 to autoallocate.

```
    DataInterval (0,60,Sec,10)
    Minimum (1,Batt_volt,FP2,False,False)
    Sample (1,PTemp,FP2)
    'i = 1
    'For i = 1 To 50
    ' Sample (1,colorResponse(i),IEEE4)
    'Next i
```

EndTable

'Define Subroutines

```
'Sub
    'EnterSub instructions here
'EndSub
```

'Main Program

```
BeginProg
    CaptureCommand(1) = &h03e8 'exposure time as long
    CaptureCommand(2) = &h0101 'include CRI or not, Auto exposure time or not
    SW12(1)
    Scan (20,Sec,0,0)
    SerialOpen (Com1,19200,0,1000,100,1)
    'ModbusMaster (error1,Com1,19200,1,3,response1,17,1,1,300,3)
    ModbusMaster (CaptureError,Com1,19200,1,16,CaptureCommand(),162,2,1,100,3)
    Do
        exitloop = 1
        ModbusMaster (CaptureIsOkayError,Com1,19200,1,3,CaptureIsOkay,164,1,1,100,3)
        If CaptureIsOkay = 32768
            Exit Do
        EndIf
```

```

Delay (0,500,mSec)
exitloop = exitloop + 1
If exitloop >= 20
Exit Do
EndIf
Loop

```

'example on pulling the raw data from address 0x34 or in decimal:52

'will need to copy this for each raw data set, address registers (380nm-429nm, 430nm-479nm, 480nm-529nm, 530nm-579nm, 580nm-629nm, 630nm-679nm, 680nm-729nm, 730nm-780nm)

```

ModbusMaster (error2,Com1,19200,1,3,response2()),53,100,1,300,3)
i = 1
For i = 1 To 100
ShiftedValues(i) = Hex(response2(i))
If Len(ShiftedValues(i)) = 3 Then
ShiftedValues(i) = "0" & ShiftedValues(i)
ElseIf Len(ShiftedValues(i)) = 2 Then
ShiftedValues(i) = "00" & ShiftedValues(i)
ElseIf Len(ShiftedValues(i)) = 1 Then
ShiftedValues(i) = "000" & ShiftedValues(i)
ElseIf Len(ShiftedValues(i)) = 0 Then
ShiftedValues(i) = "0000"
EndIf
Next i
i = 1
k = 1
For i = 1 To 49 'limitations of crbasic/logger comms, 50th value is not accurate
MoveBytes(colorResponse(i),0,HexToDec(shifting(ShiftedValues(k), ShiftedValues(k+1), ShiftedValues(k+2))),
0,4,0) 'uses function to shift some bytes, can probably do it within builtin: movebytes
k = k + 2
Next i

```

```

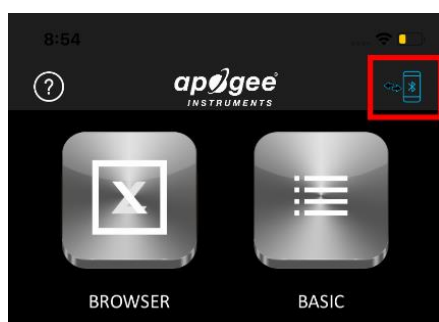
'Enter other measurement instructions
'Call Output Tables
'Example:
CallTable Test
NextScan
EndProg

```

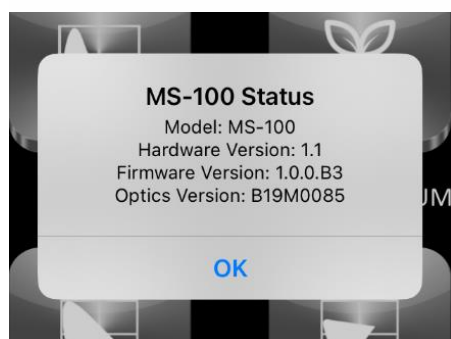
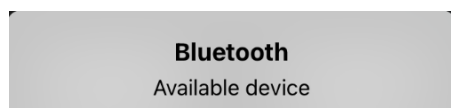
USING THE APOGEE INSIGHT APP



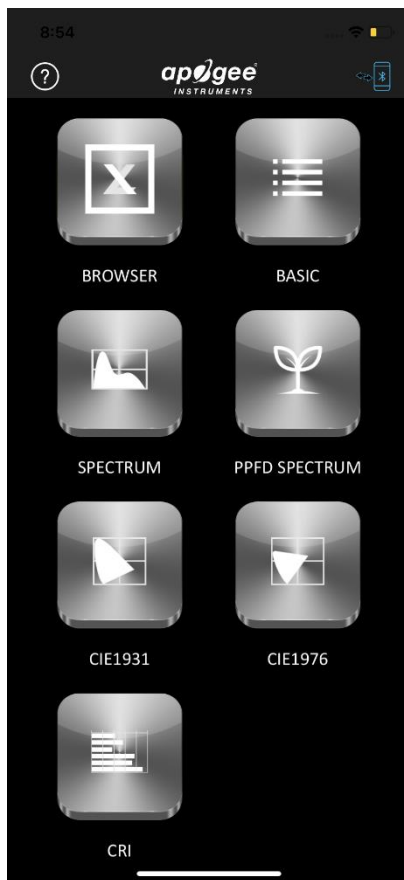
To download the Apogee InSight app, go to www.apogeeinstruments.com/downloads/ or search on the Apple or Google Play store.



To connect your MS-100 unit to the app via Bluetooth, click on the Bluetooth icon in the top right corner. Make sure the unit is powered on.

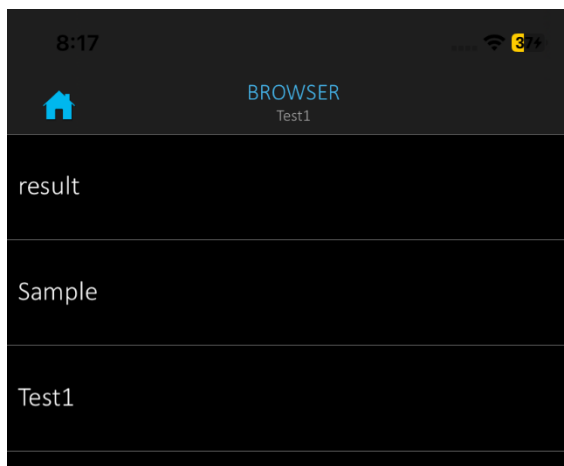


Select "Yes" when asked to reset the Bluetooth connection. Select the device that pops up under "Available Device." When the device has connected, it will show the "MS-100 Status."

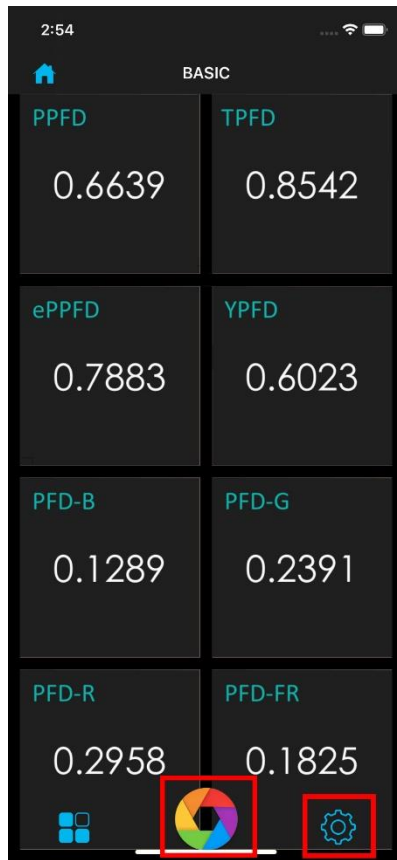


Apogee InSight has 8 screen options:

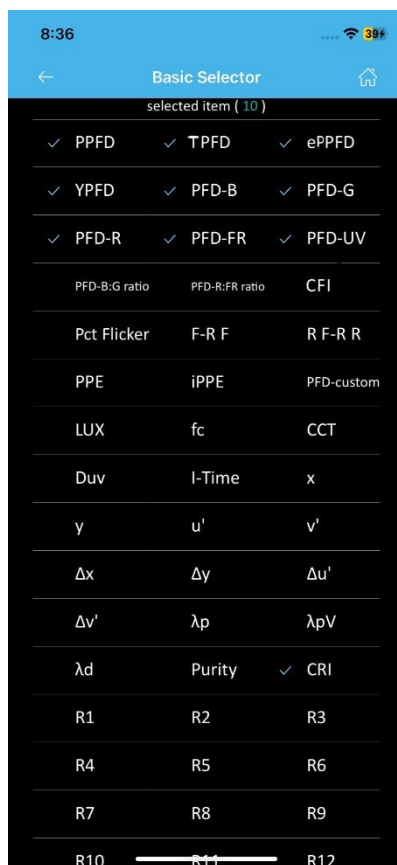
1. Browser
2. Basic
3. Spectrum
4. PPFD Spectrum
5. CIE1931
6. CIE1976
7. CRI
8. Settings (secondary page)



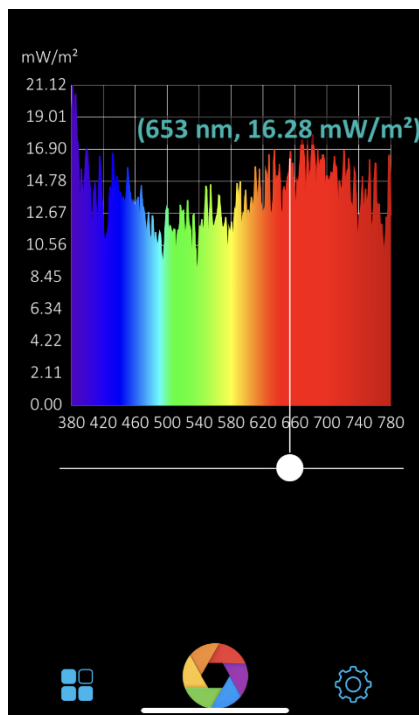
The "Browser" screen allows you to choose past measurements.



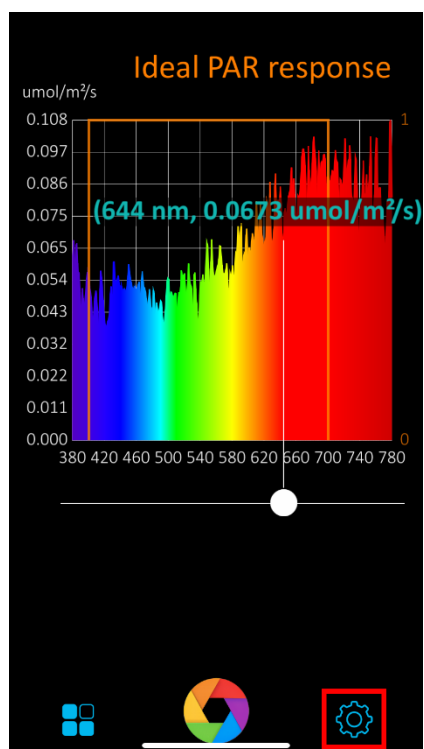
On the “Basic” screen, you can select measurements to test. Click the rainbow measurement button at the bottom of the screen to take a measurement. Scroll up and down the screen to view each measurement. To change your selected measurements, click the gear icon in the bottom right of the screen.



After selecting the gear icon, select the “Basic Selector” setting. By default, 10 measurements are displayed on the “Basic” screen, but you can select as many measurements as you need. Select the measurements you want and return to the “Basic” screen to capture data.

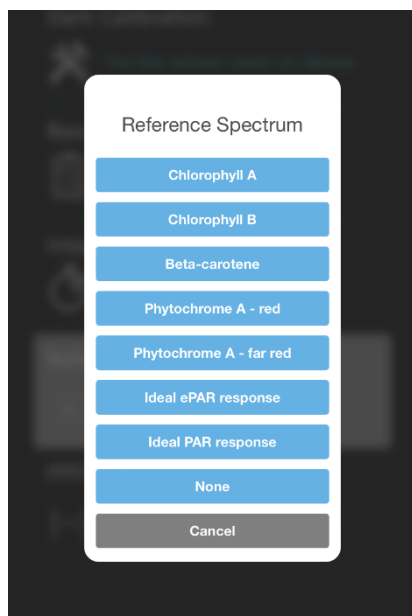


On the “Spectrum” screen, you can view a spectrum graph of your measurement. Drag the white marker left and right to view the exact measurement data.

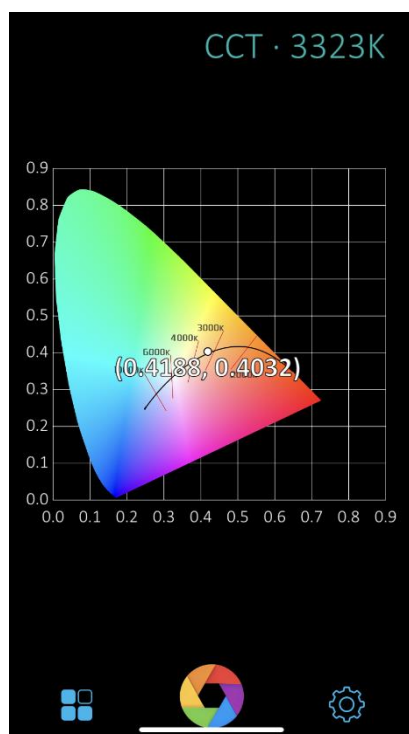


On the “PPFD Spectrum” screen, you can view a spectrum graph of your measurement. Drag the white marker left and right to view the exact measurement data.

To change the reference graph spectrum, click the gear icon in the bottom right of the screen.

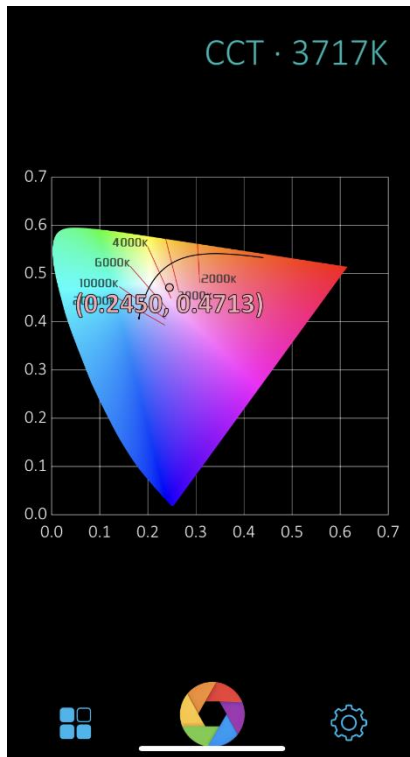


After selecting the gear icon, select the “Reference Spectrum” setting. You can choose which reference spectrum you want to measure against on the “PPFD Spectrum” page.



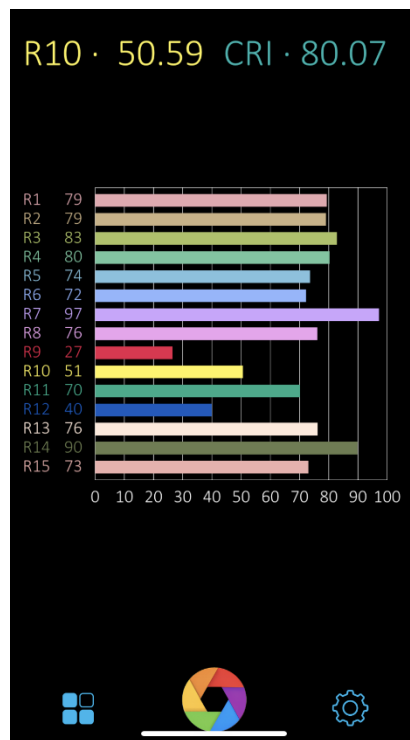
On the “CIE1931” screen, you can view the CIE1931 graph of your measurement.

CIE 1931 x and y: chromaticity coordinates calculated from CIE 1931 color matching functions.



On the “CIE1976” screen, you can view the CIE1976 graph of your measurement.

CIE 1976 u' and v' : chromaticity coordinates calculated from CIE 1976 color matching functions.

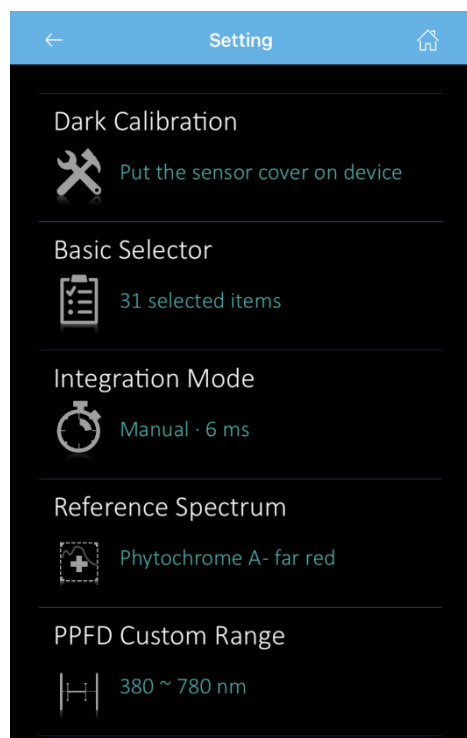


On the “CRI” screen, you can view a color rendering index graph of your measurement.

CRI: color rendering index. Relative metric quantifying the ability of a light source to accurately render colors of objects relative to the color appearance when illuminated by a reference light source, typically daylight. Maximum CRI is 100 and is only achieved by a light source with a spectrum identical to daylight, which would render colors the same as daylight. CRI can be negative, as with a low-pressure sodium lamp, which is about -44. Typically, CRI falls between 0 and 100. Incandescent bulbs are near 100 and most white LEDs are greater than 80.



To access the “Setting” page from the home screen, click on any of the “Basic,” “Spectrum,” “PPFD Spectrum,” “CIE1931,” “CIE1976,” or “CRI” options. Click on the gear setting icon in the lower right corner of these screens.



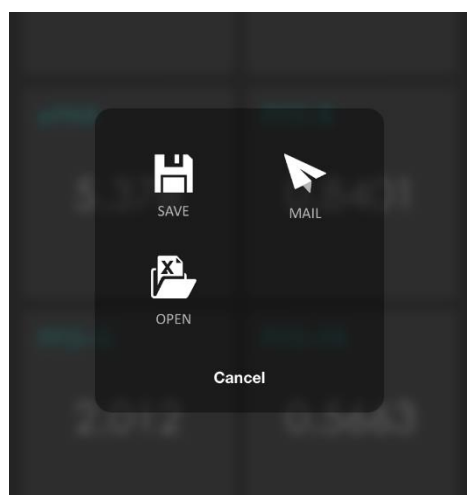
To perform a dark calibration, click on the “Dark Calibration” option. The calibration takes approximately 5 seconds.

Use the “Basic Selector” option to select the measurements you want to test on the “Basic” screen.

Use the “Integration Mode” option to change the interval of your measurements.

Use the “Reference Spectrum” option to choose which reference spectrum you want to measure against on the “PPFD Spectrum” screen.

Use the “PPFD Custom Range” option to choose a custom spectral range for your measurements.



To save, export, or open past measurements, click on any of the “Basic,” “Spectrum,” “PPFD Spectrum,” “CIE1931,” “CIE1976,” or “CRI” options. Click on the four squares icon in the lower left corner of these screens.

MAINTENANCE AND RECALIBRATION

This product is a high-precision measurement device with sensitive components. Although the meter is very stable, nominal accuracy drift is normal for all research-grade sensors. To ensure maximum accuracy, we generally recommend units are sent in for recalibration every year, although you can often wait longer according to your particular tolerances.

To determine if a specific sensor needs recalibration, the Clear Sky Calculator (www.clearskycalculator.com) website and/or smartphone app can be used to indicate PPFD incident on a horizontal surface at any time of day at any location in the world. It is most accurate when used near solar noon in spring and summer months, where accuracy over multiple clear and unpolluted days is estimated to be $\pm 4\%$ in all climates and locations around the world. For best accuracy, the sky must be completely clear, as reflected radiation from clouds causes incoming radiation to increase above the value predicted by the clear sky calculator. Measured PPFD can exceed PPFD predicted by the Clear Sky Calculator due to reflection from thin, high clouds and edges of clouds, which enhances incident PPFD. The influence of high clouds typically shows up as spikes above clear sky values, not a constant offset greater than clear sky values.

To determine recalibration need, input site conditions into the calculator and compare PPFD measurements to calculated PPFD for a clear sky. If sensor PPFD measurements over multiple days near solar noon are consistently different than calculated PPFD (by more than 6 %), the sensor should be cleaned and re-leveled. If measurements are still different after a second test, email calibration@apogeeinstruments.com to discuss test results and possible return of sensor(s).

TROUBLESHOOTING AND CUSTOMER SUPPORT

Verify Functionality

Pressing the power button should activate the LCD and provide a real-time PPFD reading. Direct the sensor head toward a light source and verify the PPFD reading responds. Increase and decrease the distance from the sensor to the light source to verify that the reading changes proportionally (decreasing PPFD with increasing distance and increasing PPFD with decreasing distance). Blocking all radiation from the sensor should force the PPFD reading to zero.

Battery Life

When the meter is maintained properly the battery should last for many years, even after continuous use. To charge the battery, connect one end of the mini-USB charger cable to the MS-100 and the other end into a wall socket with the appropriate voltage. You can also connect the meter to a computer to charge. The indicator light will illuminate orange while it is charging. The light will turn green when fully charged. For first time use, charge the battery for at least 6 hours.

Master Reset



If for any reason you need to perform a system reset, you can use a pointer to press into the reset hole as shown.

RETURN AND WARRANTY POLICY

RETURN POLICY

Apogee Instruments will accept returns within 30 days of purchase as long as the product is in new condition (to be determined by Apogee). Returns are subject to a 10 % restocking fee.

WARRANTY POLICY

What is Covered

This product is warranted to be free from defects in materials and craftsmanship for a period of one (1) year from the date of shipment from our factory. To be considered for warranty coverage an item must be evaluated by Apogee.

What is Not Covered

The customer is responsible for all costs associated with the removal, reinstallation, and shipping of suspected warranty items to our factory.

The warranty does not cover equipment that has been damaged due to the following conditions:

1. Improper installation, use, or abuse.
2. Operation of the instrument outside of its specified operating range.
3. Natural occurrences such as lightning, fire, etc.
4. Unauthorized modification.
5. Improper or unauthorized repair.

Please note that nominal accuracy drift is normal over time. Routine recalibration of sensors/meters is considered part of proper maintenance and is not covered under warranty.

Who is Covered

This warranty covers the original purchaser of the product or another party who may own it during the warranty period.

What Apogee Will Do

At no charge Apogee will:

1. Either repair or replace (at our discretion) the item under warranty.
2. Ship the item back to the customer by the carrier of our choice.

Different or expedited shipping methods will be at the customer's expense.

How to Return an Item

1. Please do not send any products back to Apogee Instruments until you have received a Return Merchandise Authorization (RMA) number from our technical support department by submitting an online RMA form at www.apogeeinstruments.com/tech-support-recalibration-repairs/. We will use your RMA number for tracking of the service item. Call (435) 245-8012 or email techsupport@apogeeinstruments.com with questions.
2. For warranty evaluations, send all RMA sensors and meters back in the following condition: Clean the sensor's exterior and cord. Do not modify the sensors or wires, including splicing, cutting wire leads, etc. If a connector has been attached to the cable end, please include the mating connector – otherwise the sensor connector will be removed in order to complete the repair/recalibration. **Note:** *When sending back sensors for routine calibration that have Apogee's standard stainless-steel connectors, you only need to send the sensor with the 30 cm section of cable and one-half of the connector. We have mating connectors at our factory that can be used for calibrating the sensor.*
3. Please write the RMA number on the outside of the shipping container.
4. Return the item with freight pre-paid and fully insured to our factory address shown below. We are not responsible for any costs associated with the transportation of products across international borders.

Apogee Instruments, Inc.
721 West 1800 North Logan, UT
84321, USA

5. Upon receipt, Apogee Instruments will determine the cause of failure. If the product is found to be defective in terms of operation to the published specifications due to a failure of product materials or craftsmanship, Apogee Instruments will repair or replace the items free of charge. If it is determined that your product is not covered under warranty, you will be informed and given an estimated repair/replacement cost.

PRODUCTS BEYOND THE WARRANTY PERIOD

For issues with sensors beyond the warranty period, please contact Apogee at techsupport@apogeeinstruments.com to discuss repair or replacement options.

OTHER TERMS

The available remedy of defects under this warranty is for the repair or replacement of the original product, and Apogee Instruments is not responsible for any direct, indirect, incidental, or consequential damages, including but not limited to loss of income, loss of revenue, loss of profit, loss of data, loss of wages, loss of time, loss of sales, accrual of debts or expenses, injury to personal property, or injury to any person or any other type of damage or loss.

This limited warranty and any disputes arising out of or in connection with this limited warranty ("Disputes") shall be governed by the laws of the State of Utah, USA, excluding conflicts of law principles and excluding the Convention for the International Sale of Goods. The courts located in the State of Utah, USA, shall have exclusive jurisdiction over any Disputes.

This limited warranty gives you specific legal rights, and you may also have other rights, which vary from state to state and jurisdiction to jurisdiction, and which shall not be affected by this limited warranty. This warranty extends only to you and cannot be transferred or assigned. If any provision of this limited warranty is unlawful, void, or unenforceable, that provision shall be deemed severable and shall not affect any remaining provisions. In case of any inconsistency between the English and other versions of this limited warranty, the English version shall prevail.

This warranty cannot be changed, assumed, or amended by any other person or agreement.

APOGEE INSTRUMENTS, INC. | 721 WEST 1800 NORTH, LOGAN, UTAH 84321, USA
 TEL: (435) 792-4700 | FAX: (435) 787-8268 | WEB: APOGEEINSTRUMENTS.COM