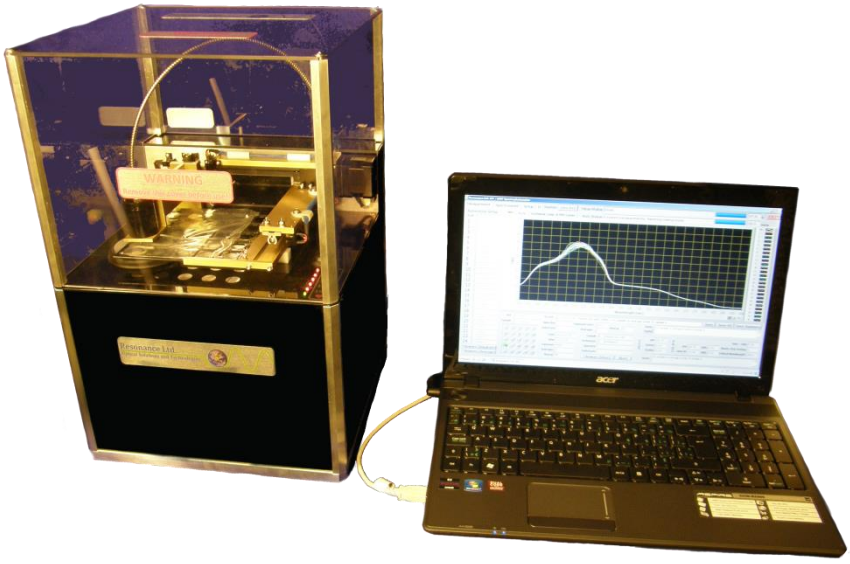
RESONANCE LTD
Optical Solutions & Technologies

S-40-SPF

Hardware Manual

REV 1.0

8/13/2014



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Overview

The S-40-SPF UV Penetration and Protection Measurement System is a solid-state ultraviolet (UV) spectrometer that utilizes new technology developed in the last decade to redefine the state-of-the-art for the measurement of sun protection factor (SPF) and other parameters for characterization of a variety of sunscreen and cosmetic products.

Covering both the UVB and UVA spectral regions, the system automatically captures spectra from 270 to 400nm with better than 1nm resolution, and automatically saves the processed data set including:

- SPF
- UPF (Ultraviolet Protection Factor)
- UVAPF (UVA Protection Factor)
- T (UVA)
- T (UVB)
- Boots Star Rating
- Critical Wavelength
- MPF (Monochromatic Protection Factor)
- Transmission Spectrum

The monochromatic protection factor is determined for each of the selected wavelengths and is used to calculate the SPF value, using solar irradiance and erythemal curves that are programmed into the software. All calculations are made according to the American Association of Textile Chemists and Colorists (AATCC) and the European Cosmetics Association (COLIPA) standards [2] [3].

This system employs a novel modulated UV light emitting diode (LED) array, which is synchronized with a charge-couple device (CCD) spectrometer. This allows real-time dark current correction which greatly improves the accuracy of SPF values. The LED light source consumes only a few watts of power and has a lifetime in excess of 300,000 sample measurements. The light source range of 270 to 400 nm is covered by 9 LEDs which can be readily replaced. Supplemental LEDs extend the range to 240 nm. These can be turned on in the control software but are not required according to the AATCC and COLIPA standards. The LEDs project into an integrating sphere to randomize and mix the various wavelength regions. The uniform beam is then directed upwards onto the motorized sample holder, which has complete X, Y, and Z motion control. A collecting optic and fibre gathers the transmitted light passed through the sample and brings it to the CCD spectrometer where the transmission spectrum can be obtained and forwarded to the software for analysis. The system also has the capability to use a reference beam from a port diametrically opposite to the sample port using a built-in fibre switch. This advanced feature provides a unique real-time correction for the sample reflectivity and LED drift. This correction is fully compliant with the AATCC [2] standard, however to conform to COLIPA [3] standards, this feature is not activated in the software. It is fully functional upon request, which requires a software update.

Features

The S-40-SPF system represents the culmination of 30 years of experience making UV light integrators with unique self-cleaning coatings and high UV reflectance. Additionally, this system reflects the development of high sensitivity CCD spectrometers for trace gas atmospheric studies. These systems incorporate features which allow the measurement of 1 part in 104 changes in absorbance to accurately compute part-per-billion (ppb) levels of gas in the atmosphere. By applying these advanced methods from related fields Resonance Ltd. has re-defined the "state-of-the-art" for UV transmission measurements.

Features

- Meets FDA / UVA *in vitro* test procedure guidelines
- Motorized 2-axis sample stage (X,Y) and vertical axis (Z) collector optics for automated measurements
- Special sample holder with magnetic clips specifically designed to hold fabrics or substrates for creams / liquids
- Flexible LabVIEW™-Based Software; with intuitive and user-friendly interface
- Ability to specify exact sample locations using the XYZ stage
- Software operating modes to accommodate:
    - 24 separate measurements for up to 24 sample locations (with 1 reference)
    - multiple repeated measurements of the same sample location (automated mode)
    - Averaged result created from up to 24 measurements
- Software & system provisioned to use custom sample trays that can be manufactured for custom applications at users' request
- USB interface – only 1 port required
- Calculates and displays SPF, UPF, UVAPF, T(UVA), T(UVB), Boots Star Rating, Critical Wavelength, MPF, & transmission spectrum
- Software allows for hundreds of measurements to be taken in a given session. All data can be exported and saved at any time.
- Wavelength regions can be user-selected from 0.1 to 5 nm with CCD Spectrometer
- Efficient LED light source, high speed zero, and reference measurement ensure stability & accuracy of readings
- Self-cleaning, proprietary high-reflectance UV paint for integration sphere
- New dual beam measurement can correct for sample reflectance
- High resolution with CCD Spectrometer (< 1 nm)
- Operates on 100 to 240 V (60 / 50 Hz) power

Parts/Components (packing list)

The S-40-SPF system is shipped fully assembled and therefore requires almost no setup to reach an operational state. The components listed in table 1 below comprise the official packing list, however the sample holder is the only part not installed in the system. Each component has an identifying label with a model and serial number. When unpacking the system please ensure that all the components listed below are present.

Table 1: The included components (packing list) with model & serial numbers.

Component	Model # (MN)	Serial # (SN)
1. Spectrophotometer Sensor	S-40-SPF-S	
2. Dust Cover	S-40-SPF-c	
3. Collector Optics	S-40-SPF-co	
4. 25x25 cm Fabric Sample Holder with Magnets	S-40-SPF-sh-1x25	
5. Computer (Laptop)	S-40-SPF-PC	
6. Cable Set	S-40-SPF-cs	
7. Software & Manual	S-40-SPF-sw-man	

Interior View & Labels

The following figures show the internal workings of the S-40-SPF system. This is primarily meant for explaining the optical design of the system and is in no way meant to be taken as a repair guide.

The user should NEVER attempt to open the system without first contacting Resonance Ltd.

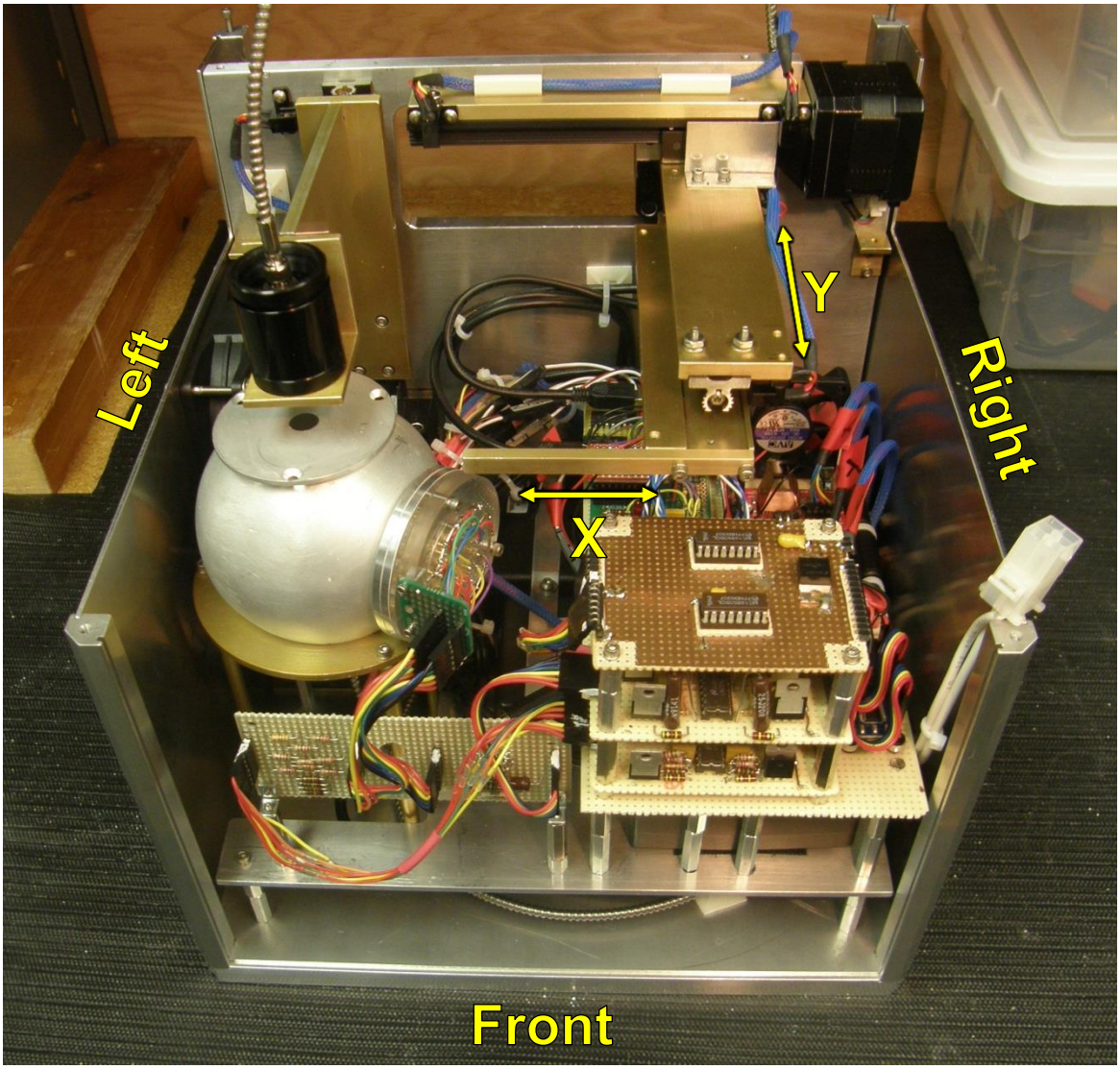

Fig. 1: The S-40-SPF system as seen from the front-above.

Interior View & Labels (continued)

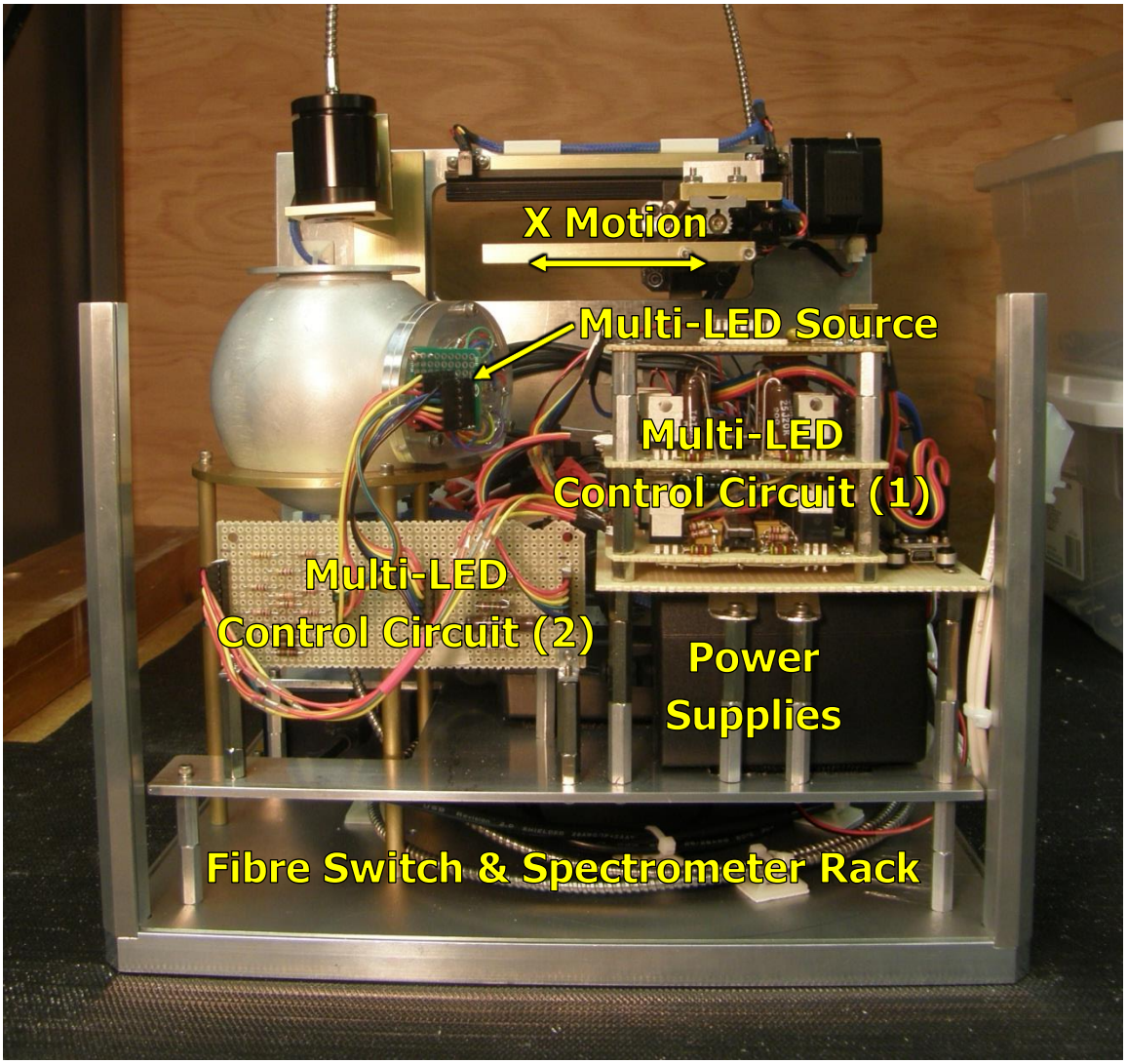

Fig. 2: The S-40-SPF system as seen from the front.

Interior Views & Labels (continued)

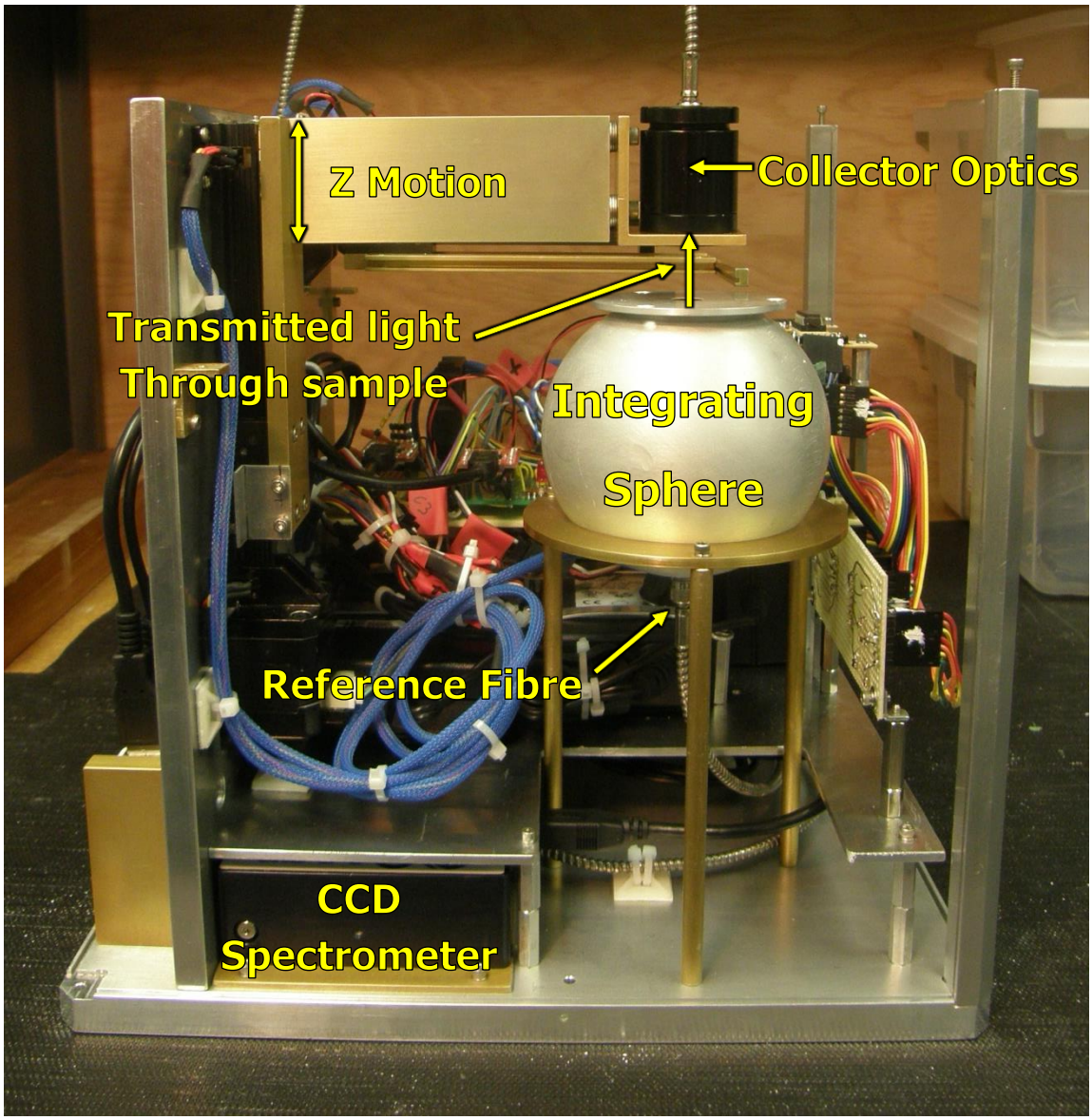

Fig. 3: The S-40-SPF system as seen from its left.

Interior Views & Labels (continued)

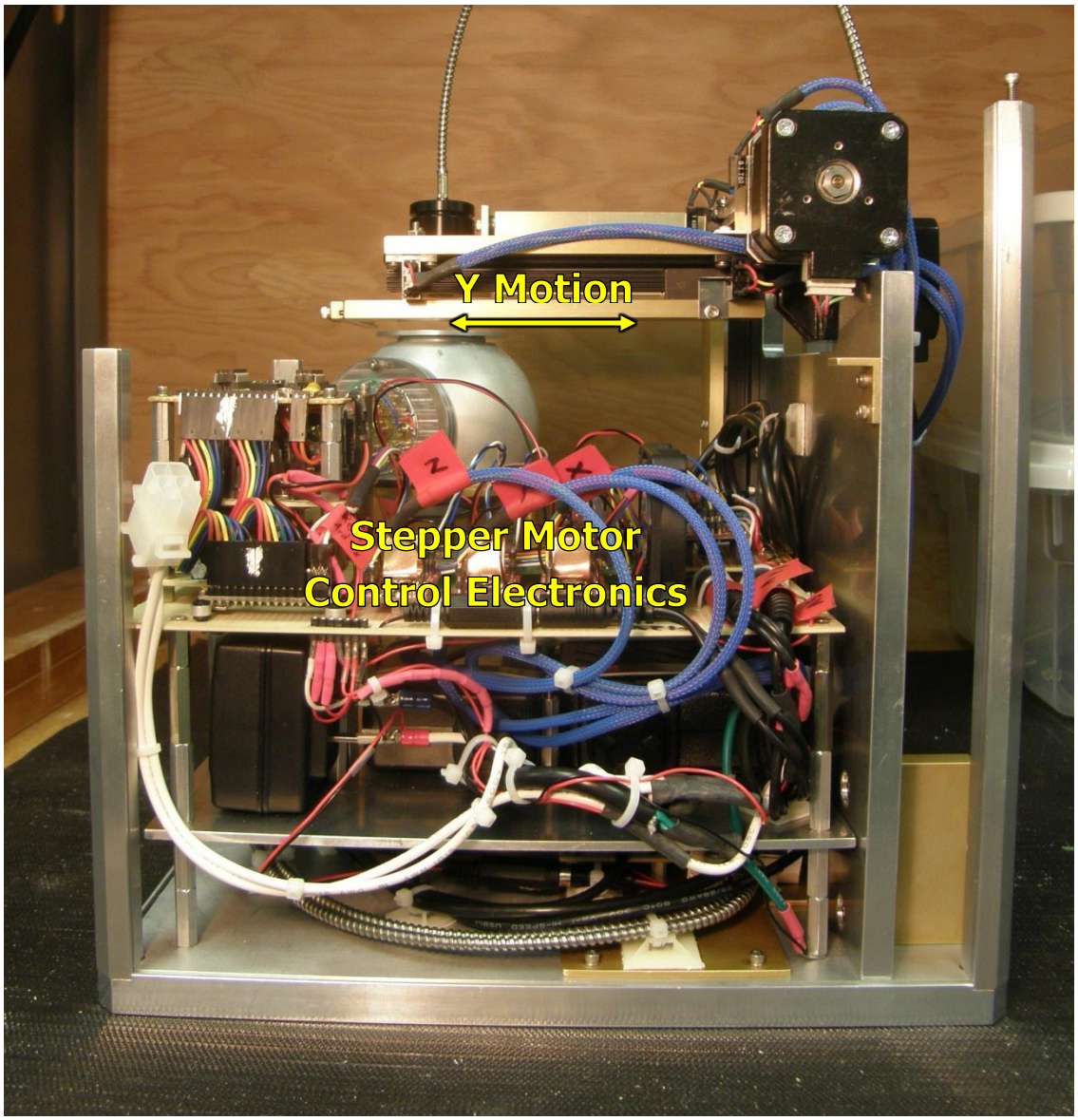

Fig. 4: The S-40-SPF system as seen from its right.

Specifications

Table 2: The specifications for the S-40-SPF system.

Electrical / Optical Specifications				
Specification	**Min**	**Type**	**Max**	**Unit**
Light source stability	-	0.01	-	% / hour
Light source spectral range	-	240 to 400	-	nm
Light source lifetime	100,000*	350,000*	1,000,000*	measurements**
Exposure time	0.5	3	10	seconds
Sample measurement cycle	4	24	80	seconds
Spectral range of spectrometer	-	235 to 450	-	nm
Spectral resolution of spectrometer	-	0.8	1	nm
Corrected linearity	-	99.8	-	%
Sample table X range	-	10	-	cm
Sample table Y range	-	10	-	cm
Sample table Z range	-	10	-	cm

Other Specifications	
Specification	**Value / Description**
Dimensions	28 (width) x 43 (height) x 28 (depth) cm with dust cover
Weight	~12 kg
Interface	Single USB cable – 1 port required
Power Requirements	100 to 240 V (60 / 50 Hz)
Software Compatibility	LabVIEW™-Based for PC running Windows XP, Vista, or 7

* Lifetime depends on the exposure time & the number of averages per measurement.

** Spectral transmittance measurement consisting of two exposures; one for a reference position and one for the sample position. All results (UPF, T (UVA), T (UVB), MPF, SPF, UVA PF, Critical Wavelength, UVA, UVB, and Boots Star Rating) are calculated from this measurement.

Initial Setup & Warnings

Once the system has been unpacked and all packing tape and plastic has been removed, the user will have to follow the steps in the next few sections in order to start taking measurements. Read all sub-sections in this section carefully, as missed information may lead to improper information which could damage the instrument.

Dust Cover

The S-40-SPF system was shipped with the acrylic plastic dust cover installed, with packing material inside to prevent the fibre and Z-axis collecting optics from colliding during shipment. This cover protects the sample area and integrating sphere window when the system is not being used. It is imperative for the user to understand that the dust cover MUST BE REMOVED before any movement of the X, Y, or Z stages is attempted, including the zeroing routine. Refer to figure 5 below for a clear view of the dust cover.

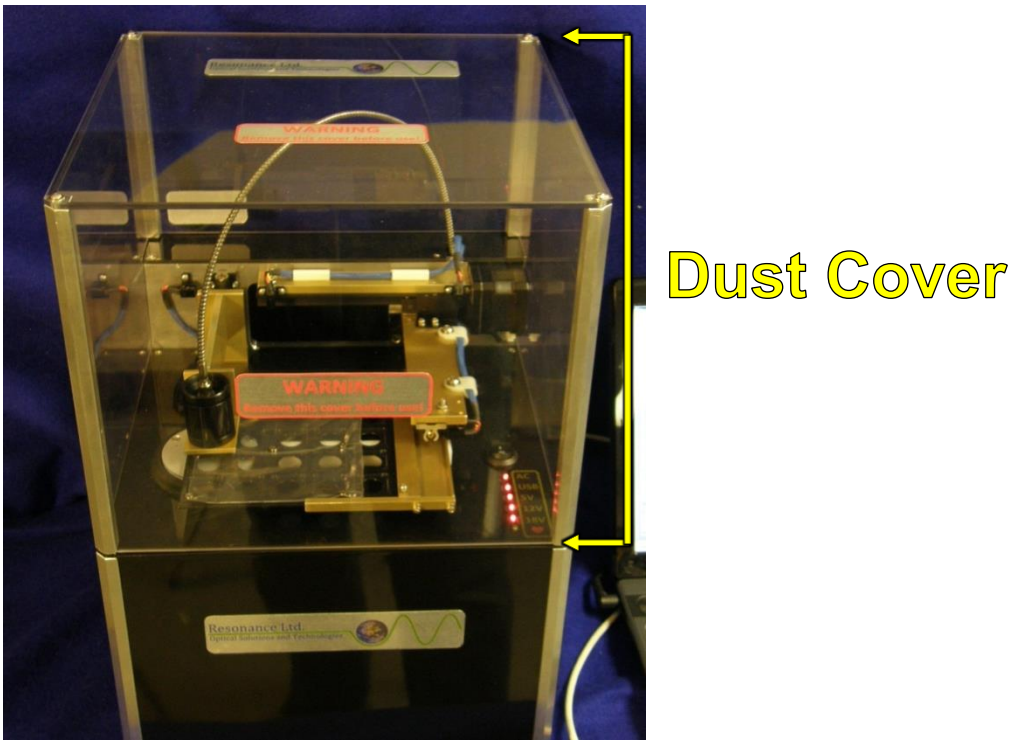

Fig. 5: The S-40-SPF system with dust cover installed & identified.

Error Log

There are 6 LEDs on the front panel just beneath the main power switch used to indicate whether the system is operating normally. There are 5 red LEDs to indicate that all power supplies are functioning, and 1 green LED that blinks when the software has successfully been started. Refer to figure 6 and table 3 below for a description of each LED and picture of the front panel.

LED	Description
AC	Indicates main power connected
USB	Indicates USB power (PC connected)
5 V	Indicates internal 5 V adapter operational
12 V	Indicates internal 12 V adapter operational
18 V	Indicates internal 18 V adapter operational
Heartbeat	Blinks when software initialized

Fig. 6 (left) & Table 3 (right): The S-40-SPF front panel LEDs & descriptions.

Zeroing

The first step to running the system is to zero it. First of all, power must be applied and some simple checks must be made. Follow the steps below to begin:

1. Plug in the AC main power cable in the back of the instrument and connect it to the main power line (mains). The first red LED labeled “AC” should light up.
2. Plug the USB cable into the back of the instrument and to a free port on the supplied laptop computer. If the laptop has not been turned on, do so now. When Windows has booted up the USB line should be powered and therefore the 2nd red LED on the front panel labeled “USB” should light up.
3. If the dust cover has not already been removed from the instrument do so now.
4. The main power switch above the indicator LEDs may now be turned on. The red LEDs labeled “5 V”, “12 V”, and “18 V” should light up.
5. The software pre-installed on the laptop should now be executed. Upon a successful start, the green LED with the heart icon to its right should turn on and off at 1 second intervals.
6. If any of the red LEDs are not illuminated, refer to the *Troubleshooting* section. If the green LED is not lit up, or a software error occurs, refer to the software manual [1] for appropriate steps to rectify the issue.
7. The system is now ready to be used, and more specifically zeroed.

DO NOT MOVE ANY STAGES UNTIL THE DUST COVER HAS BEEN REMOVED AND SET ASIDE. FAILURE TO DO THIS WILL CAUSE THE SAMPLE STAGE TO IMPACT THE DUST COVER AND DAMAGE IT AND / OR THE STEPPER DRIVE(S).

With the software open and initialized without error, you may “zero” the XYZ stage by pressing the *Zero XYZ* button (refer to figure 7 below). This is necessary to ensure that the stage knows exactly where it is every time the instrument is used to ensure repeatability, accuracy, and precision. During this process all axes will move to their inner limit and calibrate themselves. The software displays the status of the procedure in the *Meas Status* box. Figure 7 below, for example, was taken while the software was zeroing the Z axis. Note that all controls are greyed out and disabled during the process to prevent any accidental interruptions.

Zeroing (continued)

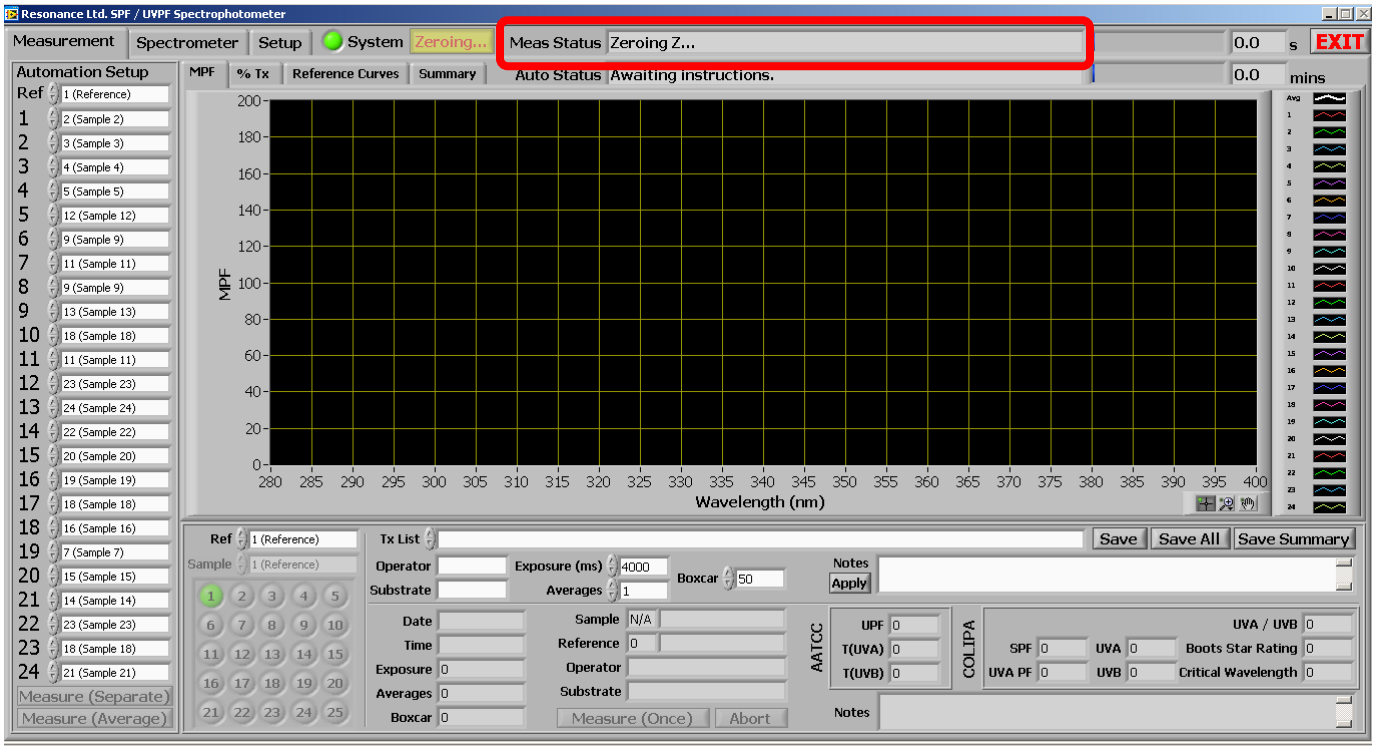

Fig. 7: The software during the "zeroing" routine. Note the *Meas Status* box.

Once the zeroing routine has completed the software is ready to be used for measurements.

Sample Tray Overview

The sample loading system designed for the S-40-SPF is very flexible and unique compared to any other system in the industry. It is designed to handle both fabrics for the AATCC guidelines [2], and also substrates for creams and liquids for COLIPA [3] and other standards. The tray by default carries 25 sample positions with 14 mm diameter openings. There are places for 4 magnets per sample positions to hold fabric across the open hole, or to hold a glass substrate in place. These magnets are tiny yet very strong due to their rare earth composition. They allow samples to be quickly loaded and positioned and can also be easily cleaned if necessary. Applying the magnets is done with a special magnetic cylinder included with the system, where the user can simply use the larger magnet to pull the smaller ones off the stainless steel sample tray. Figure 8 below shows the sample tray, taken from the 3D model.

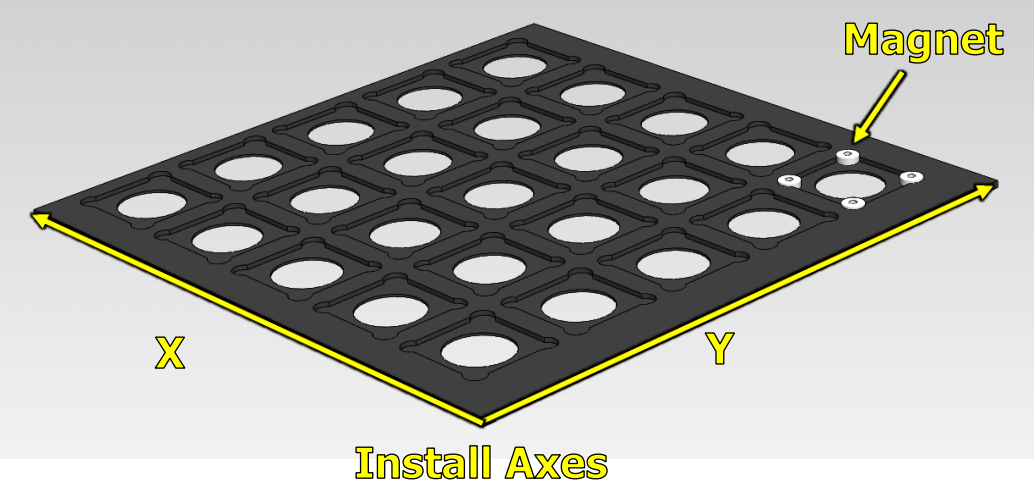

Fig. 8: The sample tray. Note the larger flange indicated which shows the direction it is to be installed in the system (mentioned later).

One of the innovative features of the S-40-SPF system is the fact that new sample trays can be machined with a custom number of sample positions and diameters or shapes. Resonance Ltd. will work with the needs of our customers to design trays for specific applications. Since the software uses a configuration file for the sample positions, there is minimal setup required to start using different configurations and still maintain the convenient automation features of the system. You may contact Resonance Ltd. to discuss the design and arrange for different sample holders to be made.

Installing Samples into Tray

As previously mentioned, the innovative sample tray uses rare-earth magnets to hold the samples or substrates in place. Fabrics can easily be applied and stretched by all 4 corners with this method. The key to quick and efficient removal and application of the magnets lies in the use of the longer cylindrical magnet to pull the smaller ring magnets off the stainless steel holder. Applying magnets can be done by allowing them to stick in place and then sliding the larger magnet tool over the raised ridge near the edge, leaving the smaller magnet constrained snuggly in its groove. Figure 9 below shows this method, but without a piece of fabric for clarity.

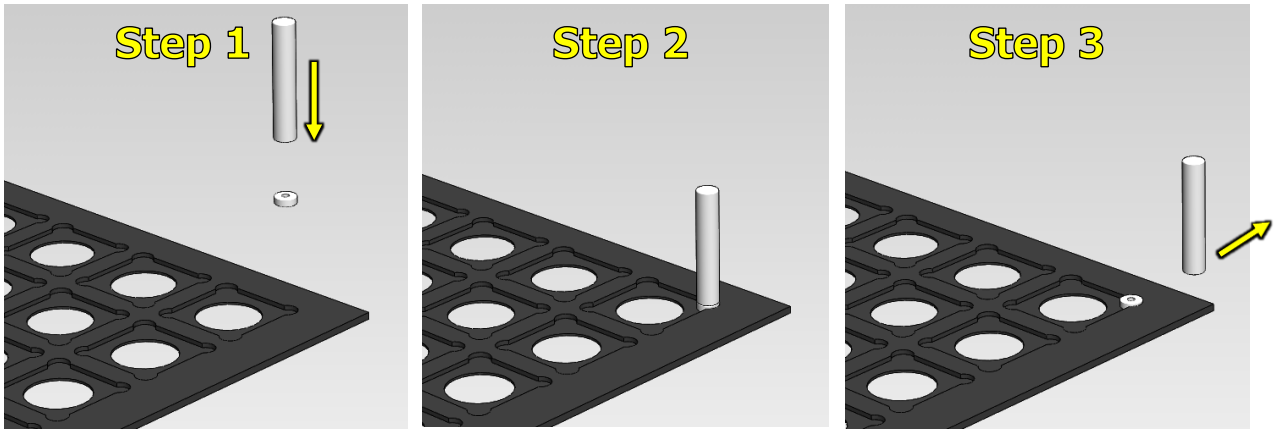

Fig. 9: The magnet installation process to hold a sample's corner, from left to right.

As for magnet removal - there is a bit of a trick to properly getting the larger magnet to attract the smaller ones. Once the large magnet has been attached to a smaller one, tilt the larger one on a 45 degree angle and then pull away. Refer to figure 10 below for an illustration of this process. The smaller magnets can also be removed by using their hollow centers and picking them up with a tool such as a paper clip inserted into the center and applying leverage to lift them out.

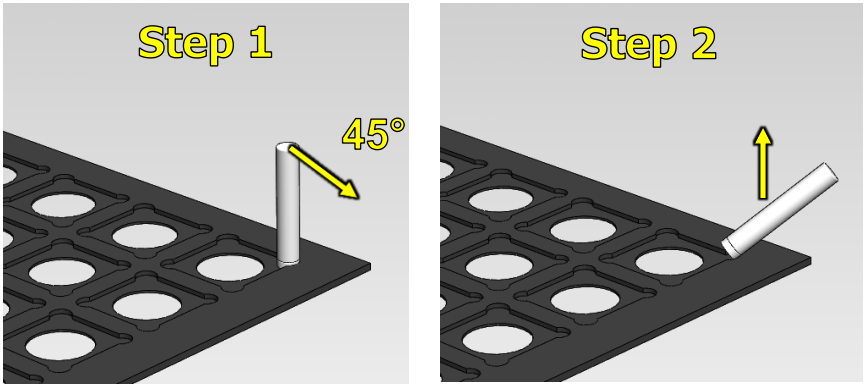

Fig. 10: The magnet removal process. Tilt the larger magnet before lifting upwards.

Installing Sample Tray into System

Once the sample tray has been populated it can be installed into the system. The mounting method is very simple and consists of a slot and two screws to lock it in place. The Z-axis may have to be moved up in order to slide the tray in without hitting the collecting optics, depending on how thick the samples are. Refer to figure 11 below.

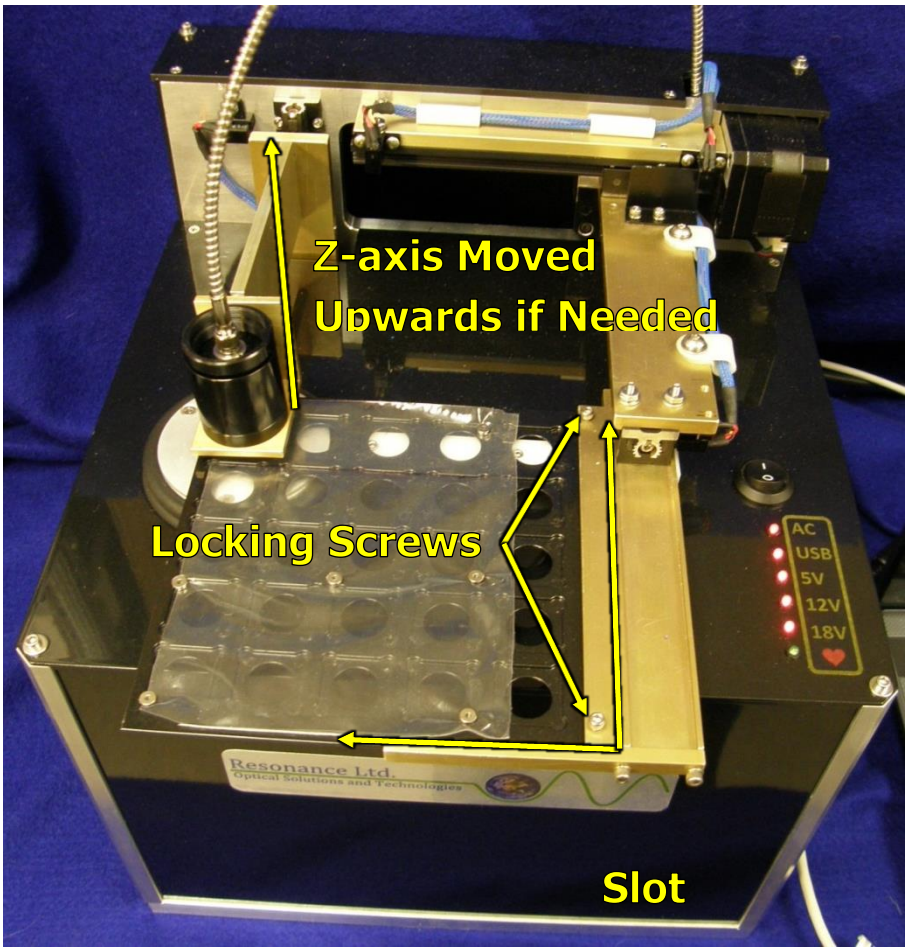

Fig. 11: The sample tray seen installed into the system with a large plastic sample.

The sample tray can be removed or installed by loosening or tightening the locking screws and sliding the tray into the grooves. Make sure the tray is seated fully into the groove and tighten the screws for installation. The grooves ensure the tray is in the correct position. Note the sample tray orientation in the slots; the largest flange goes into the slot along the Y axis.

Taking Measurements

Now that the samples have been loaded and the tray inserted into the system, a measurement may be taken of a given sample. Follow the directions below to perform a quick measurement. Some of the information is taken from the software manual [1], and information regarding more advanced measurements and automation can be found in the software manual.

Quick Measurement Guide

The *Measurement* tab is the main area of the software, where all measurements are taken and all data is displayed and exported / saved. Refer to figure 12 below for a screenshot of the software after taking some measurements.

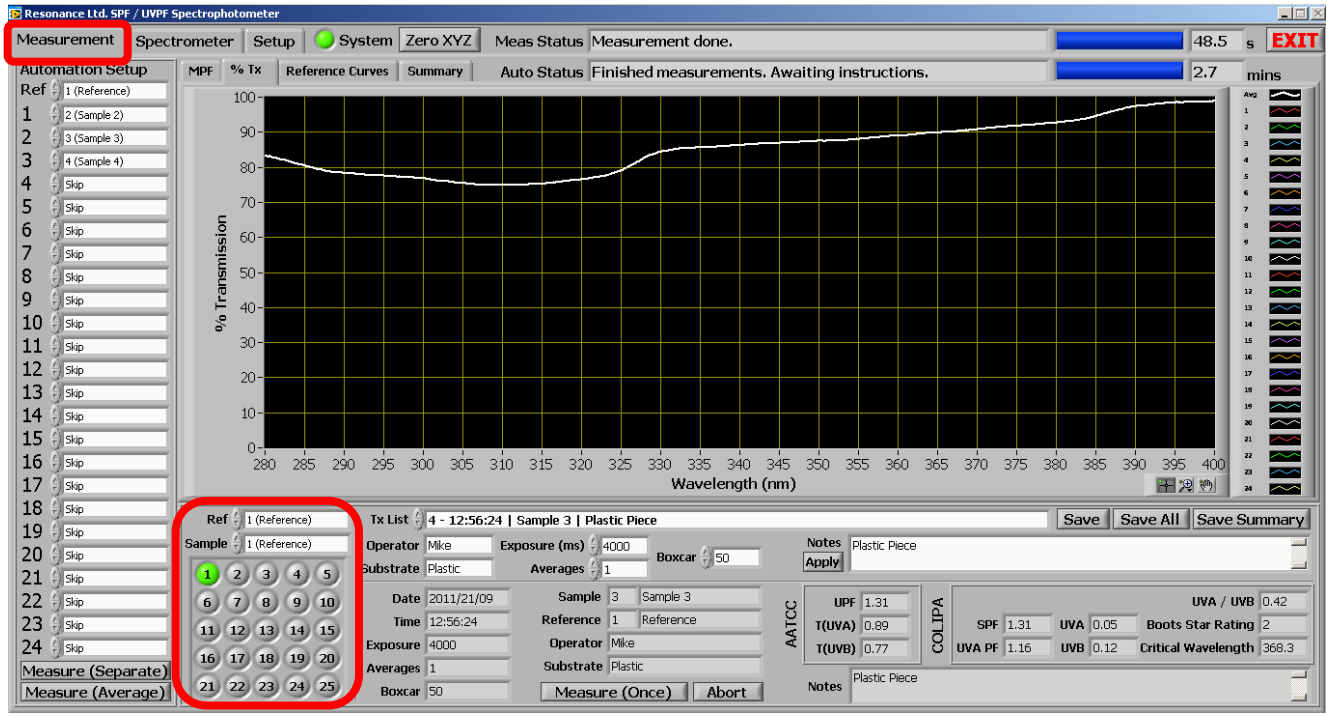

Fig. 12: The *Measurement* tab with the sample grid highlighted (bottom-left).

Taking Measurements

Perform a Measurement

To perform a single measurement move the sample stage to the desired position using the grid as seen in the bottom-left corner of figure 12. Simply click on a position (1 – 25) and the system will move to that position. Make sure you have designated a position to be blank for the reference, and select that position in the *Ref* box just above the grid. The sample position can also be chosen and moved to by selecting it from the drop-down menu called *Sample* directly above the grid as well. Once the sample and reference positions have been chosen click on *Measure (Once)* and a 7-step process will begin to produce a measurement. A progress bar and elapsed time indicator are activated, which can be seen in figure 12 in the top-right. During this process the sample stage will move between the sample and reference position automatically. You can abort this process by clicking the *Abort* button. The current measurement will be discarded and the software will wait for further instructions from the user.

Measurement Data & Display

Once a measurement has been taken, it will appear in the *Tx List* drop-down box found directly under the graph as seen in figure 13 below.

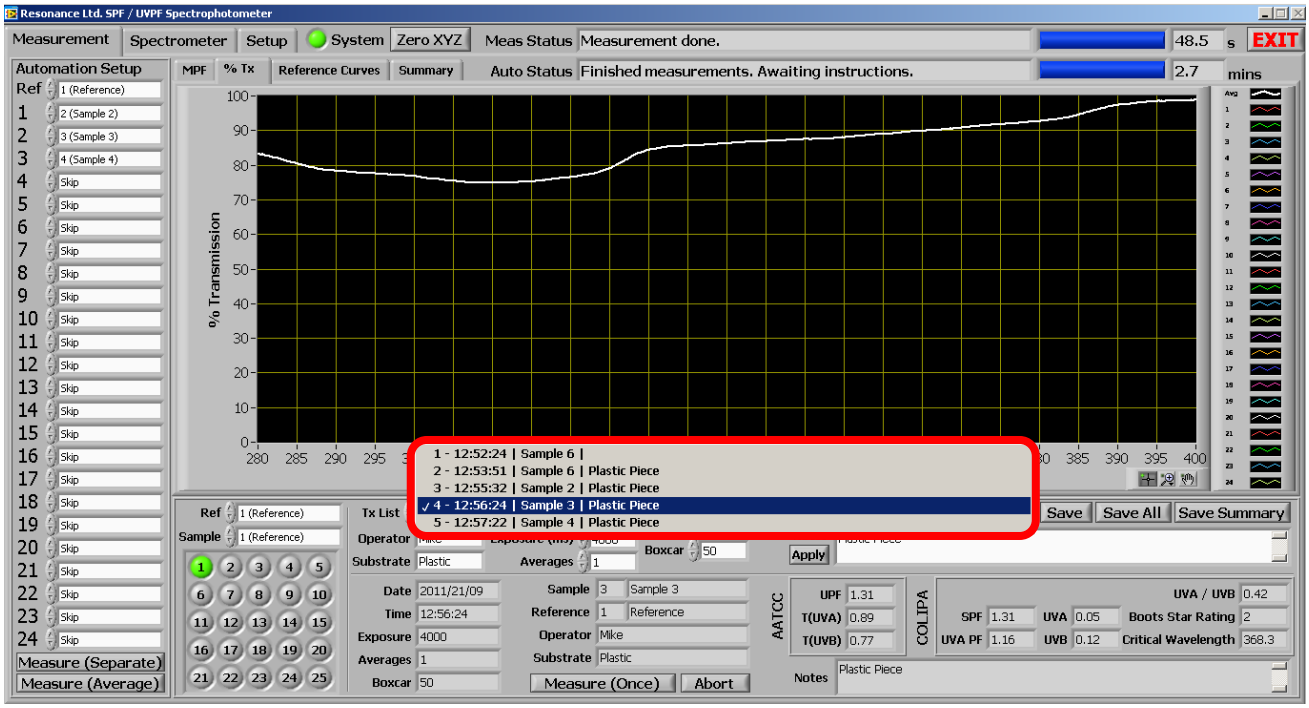

Fig. 13: The *Tx List* in the *Measurement* tab.

Taking Measurements (continued)

You can use this list to scroll through all previous measurements taken in the current session. Only one measurement can be viewed at a time in this mode. When a measurement is selected, all the parameters associated with the measurement are loaded into the indicator boxes below the graph, including the UPF and SPF values, among other useful information. Notes can be edited after a measurement has been taken. With a measurement selected, enter a new note in the white entry box (figure 12 displays this area better) and click *Apply* to save it to that specific measurement. These notes are automatically saved in the spreadsheet file if data is exported, and therefore quite useful for tagging data.

Both X and Y scales of the graph can be changed manually and also independently support an *autoscale* function. Right-click on the axis you want to change and either check or un-check the autoscale option. In order to manually set the scale limits, autoscale must be off. To change the limits themselves, simply double-click the extreme value of the scale (intermediate values can be edited but will snap back to what they were when they are applied) and edit the value. Press “enter” when finished to apply the value and the scale will adjust to the new limit.

The graph visible in figures 12 and 13 is showing the percent transmission (% Tx) curve of the sample. The MPF (monochromatic protection factor), reference curves (explained later) and summary section (figure 14 below) can also be selected in the tabs directly above the graph.

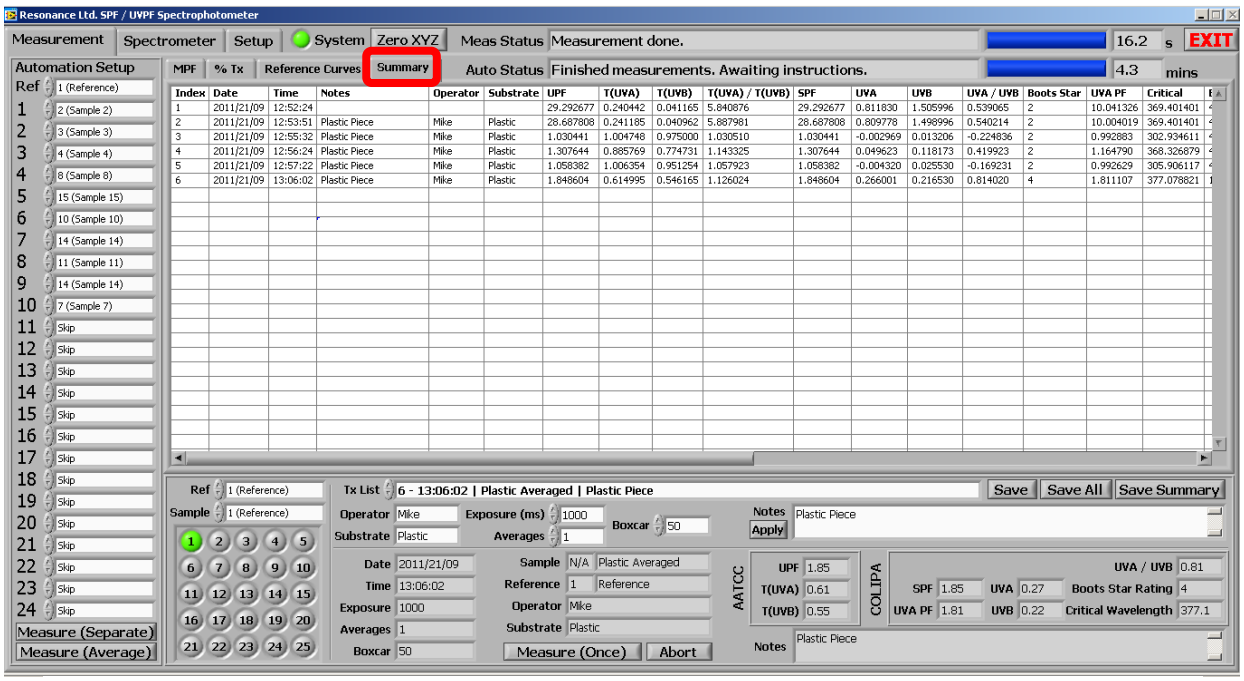

Fig. 14: The *Summary* option in the *Measurement* tab.

The summary section shows a list of detailed parameters for every measurement taken, in spreadsheet style. This is a very useful view for comparing a series of measurements to one another.

Advanced Measurements

Advanced Measurements

There are many more modes of operation and ways to take measurements that are not explained in this hardware manual that include automated, multiple, and averaged measurements. For a complete and detailed walkthrough of such modes, please refer to the S-40-SPF software manual [1], obtained from the Resonance website or directly from Resonance Ltd. (see the *Contact Resonance Ltd.* section).

Measurement Standards

When characterizing a sample and taking measurements, most customers need to conform to standards and guidelines produced by organizations that deal with metrology. The S-40-SPF system conforms specifically to three major organizations: AATCC (American Association of Textile Chemists and Colorists) [2], COLIPA (The European Cosmetics Association) [3], and the *Boots Star Rating System* [4] by which all the measurement parameters such as SPF are defined. The way in which the parameters are calculated are also detailed in the various documents released by these organizations, and will be discussed in their respective sections below.

AATCC

The American Association of Textile Chemists and Colorists published a test method titled *Transmittance or Blocking of Erythemally Weighted Ultraviolet Radiation through Fabrics* [2]. In this document the calculations for UPF, T (UVA), and T (UVB) are given. These measurement parameters are described below with their respective formulae.

UPF

UPF is an acronym for ultraviolet protection factor, and is calculated with the following formula:

$$UPF = \frac{\int_{280\ nm}^{400\ nm} E(\lambda) * S(\lambda) * \Delta\lambda}{\int_{280\ nm}^{400\ nm} E(\lambda) * S(\lambda) * T(\lambda) * \Delta\lambda}$$

Where:

E (λ) = The relative erythemal spectral effectiveness (see the *Reference Curves* section)

S (λ) = The solar spectral irradiance (see the *Reference Curves* section)

T (λ) = The average measured spectral transmittance of the specimen

Δλ = The measured wavelength interval (nm)

Measurement Standards (continued)

T (UVA)

This is the average ultraviolet-A (UVA) transmittance through the range 315 – 400 nm. Its formula is given below:

$$T(UVA) = \frac{\int_{315\ nm}^{400\ nm} T(\lambda) * \Delta\lambda}{\int_{315\ nm}^{400\ nm} \Delta\lambda}$$

Where:

T (λ) = The average measured spectral transmittance of the specimen

Δλ = The measured wavelength interval (nm)

T (UVB)

This is the average ultraviolet-B (UVB) transmittance through the range 280 – 315 nm. Its formula is given below:

$$T(UVB) = \frac{\int_{280\ nm}^{315\ nm} T(\lambda) * \Delta\lambda}{\int_{280\ nm}^{315\ nm} \Delta\lambda}$$

Where:

T (λ) = The average measured spectral transmittance of the specimen

Δλ = The measured wavelength interval (nm)

Measurement Standards (continued)

COLIPA

The European Cosmetics Association has extensive test methods and guidelines for SPF measurements for creams and liquids. The document titled *Method for in vitro determination of UVA protection, 2011* [3] provides the basis for calculating SPF, UVA PF, and critical wavelength.

MPF

MPF is an acronym for monochromatic protection factor, and is simply the reciprocal of percent transmittance (% T). Therefore, its simple formula is:

$$MPF = \frac{1}{T(\lambda)}$$

Where:

T (λ) = The average measured spectral transmittance of the specimen

SPF

SPF is an acronym for sun protection factor, and is very similar to UPF, however the integration limits start at 290 – 400 nm instead of 280 – 400 nm. It is calculated using the following formula:

$$SPF = \frac{\int_{290\,nm}^{400\,nm} E(\lambda) * S(\lambda) * \Delta\lambda}{\int_{290\,nm}^{400\,nm} E(\lambda) * S(\lambda) * T(\lambda) * \Delta\lambda}$$

Where:

E (λ) = The relative erythemal spectral effectiveness (see the *Reference Curves* section)

S (λ) = The solar spectral irradiance (see the *Reference Curves* section)

T (λ) = The average measured spectral transmittance of the specimen

Δλ = The measured wavelength interval (nm)

Measurement Standards (continued)

UVA PF

UVA PF is an acronym for ultraviolet-A protection factor. Similar to the SPF parameter, its formula is the same except instead of the erythemal curve it uses the persistent pigment darkening curve (PPD – see the *Reference Curves* section). Its formula can be found below:

$$UVA\ PF = \frac{\int_{320\ nm}^{400\ nm} P(\lambda) * S(\lambda) * \Delta\lambda}{\int_{320\ nm}^{400\ nm} P(\lambda) * S(\lambda) * T(\lambda) * \Delta\lambda}$$

Where:

P (λ) = The persistent pigment darkening (PPD) action spectrum (see the *Reference Curves* section)

S (λ) = The solar spectral irradiance (see the *Reference Curves* section)

T (λ) = The average measured spectral transmittance of the specimen

Δλ = The measured wavelength interval (nm)

Measurement Standards (continued)

Critical Wavelength

The critical wavelength (λc) is defined as the upper wavelength limit of integration at which 90% of the absorption has occurred. It is represented by the formula below:

$$\left[\int_{290\,nm}^{\lambda c} -\log(T(\lambda)) * \Delta\lambda\right] = 0.9 * \left[\int_{290\,nm}^{400\,nm} -\log(T(\lambda)) * \Delta\lambda\right]$$

Where:

T (λ) = The average measured spectral transmittance of the specimen

Δλ = The measured wavelength interval (nm)

Boots Star Rating

The *Boots Star Rating* [4] is derived from the ratio of the UVA and the UVB values. It is a simple 5-star system that classifies a sample depending on the UVA / UVB ratio value. Table 4 below shows the rating criteria, and the UVA and UVB calculations can be found directly afterwards.

Table 4: The *Boots Star Rating* criteria based on the UVA / UVB ratio.

UVA / UVB Ratio		Boots Star Rating	Rating Descriptor
≤ 2 nm Δλ	≥ 2 nm Δλ		
0 to 0.19	0 to 0.2	-	No claim
0.2 to 0.39	0.21 to 0.4	✪	Minimum
0.4 to 0.59	0.41 to 0.6	✪✪	Moderate
0.6 to 0.79	0.61 to 0.8	✪✪✪	Good
0.8 to 0.89	0.81 to 0.9	✪✪✪✪	Superior
0.9 and above	0.91 and above	✪✪✪✪✪	Ultra

Measurement Standards (continued)

UVA

This is the absorbance area per unit wavelength from 320 – 400 nm. Its formula is given below:

$$UVA = \int_{320\ nm}^{400\ nm} -\log(T(\lambda)) * \Delta\lambda$$

Where:

T (λ) = The average measured spectral transmittance of the specimen

Δλ = The measured wavelength interval (nm)

UVB

This is the absorbance area per unit wavelength from 290 – 320 nm. Its formula is given below:

$$UVB = \int_{290\ nm}^{320\ nm} -\log(T(\lambda)) * \Delta\lambda$$

Where:

T (λ) = The average measured spectral transmittance of the specimen

Δλ = The measured wavelength interval (nm)

Reference Curves

The AATCC [2], COLIPA [3], and *Boots Star Rating* [4] guidelines all rely on reference curves for calculation of the various parameters described in the *Measurement Standards* section. Figure 15 below is a graph with the erythemal and PPD curves using the left Y axis and the solar curve using the right Y axis. Each curve is explained after the graph.

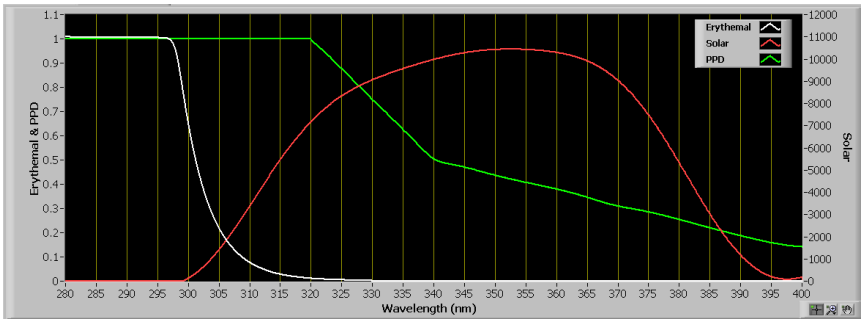

Fig. 15: The erythemal, solar, and PPD curves used in the SPF-related calculations.

Erythemal

This is the McKinlay-Diffey Erythema action spectrum (also known as CIE action spectrum from 1987) which is used to weight the solar curve relative to the effects of UV wavelengths on human skin for the UPF and SPF calculations. It is specifically recommended by the AATCC and COLIPA guidelines. It can be found in table-form in the AATCC paper [2]. You can see from the curve that the shorter wavelengths are many times more potent in terms of causing sunburns (or erythema) than longer wavelengths, and therefore are weighted heavily.

Solar

This is an intensity curve which shows the typical relative intensities of light with respect to wavelength from the sun. More specifically, the curve often used was taken at noon, July 3rd, Albuquerque, New Mexico, and can be found in table-form in the AATCC paper [2]. This curve is multiplied by the erythemal curve to produce a weighted result that is used in the calculation of UPF and SPF.

PPD (Persistent Pigment Darkening)

Similar to the erythemal curve, this action spectrum is a weighting function used for the calculation of the UVA PF value as a measure of UVA blocking performance. It is multiplied by the solar curve in the same way the erythemal is for other values. Its curve can be found in table-form in the COLIPA guideline [3].

Troubleshooting

This section is written to provide some quick advice and suggestions for problems that may occur throughout the use of the S-40-SPF system.

1. **When the main power cable is plugged into the back of the instrument, the red *AC* LED does not illuminate.**

   The purpose of the red *AC* LED is to indicate a proper connection to a 100 to 240 V (60 / 50 Hz) power supply. The LED itself could have failed however this can be easily tested by turning the main power on. If other red front panel LEDs illuminate, the *AC* LED has burned out. More likely, however, is a situation where main power is not making its way into the instrument. Ensure that the power cable in the back has been firmly connected and is plugged into a live outlet. Contact Resonance ltd. for further instructions if power remains off.

2. **When the USB cable is plugged into a PC with an active USB port, the red *USB* LED does not illuminate.**

   The red *USB* LED indicates whether a connection has been made to a PC with a powered USB port. The PC must be on in order for its USB ports to be powered. The main power switch on the instrument can be off and the *USB* LED will still illuminate. If the LED remains off, ensure the USB cable is plugged securely into the back of the instrument and also securely into the PC. If that does not fix the problem try using a new USB cable. It is a standard B-type cable.

3. **When the main power switch is on, and the red AC LED illuminated, all or some of the other red LEDs for 5V, 12V, or 18V are not illuminated.**

   The 5V, 12V, and 18V re LEDs indicate whether the internal power supplies are operational. If some or all of them are not illuminated, aside from the rare possibility of the LED itself being burnt out, it indicates its respective supply is not functioning. Contact Resonance Ltd. for further instructions.

4. **The software reports no instrument is connected on startup.**

   This is a relatively common error and is caused by improper handshaking between the instrument and the PC, which can be a derivative of a driver malfunction. This is often resolved by following these steps:

   a. Close the SPF software.
   b. Disconnect the USB cable from the PC
   c. Turn the main power off on the instrument.
   d. Wait 5 seconds.
   e. Turn the main power back on.
   f. Plug the USB cable back into the PC
   g. Execute the SPF software.
   h. Perform this procedure multiple times if necessary.

   If this procedure does not solve the issue, contact Resonance Ltd. for further instructions.

Troubleshooting (continued)

5. **The instrument begins the zero procedure but does not finish.**

   This problem could be caused by a hardware malfunction in the limit switches used to zero the instrument. In this case the instrument is essentially frozen – software included, to prevent any possible damage from over-extension of the XYZ stage. Contacting Resonance Ltd. for further instructions is best course of action in this situation.

6. **The intended sample positions are not agreeing with the physical sample holes in the sample tray.**

   The sample tray is paired with a *Sample Configuration File* which holds all the XYZ co-ordinates for every sample position. This file can be edited in the software, and therefore a missing, corrupt, or improperly populated file will result in XYZ co-ordinates which do not make the sample holes line up with the optical window over the integrating sphere. Refer to the software manual [1] for instructions to adjust the file.

7. **The reported SPF values are very high (> 100) and vary wildly.**

   Very high SPF values are reported when the transmission through a sample is very low. However, if a sample is so highly absorbent that little or no light makes it through to be measured, very erratic and high SPF values are reported. This can be alleviated to an extent by increasing the exposure time, so more light eventually makes it through the sample. This is a tricky setting, however, and one must be careful not to set it too high, or else the spectrometer could saturate before the exposure has finished during the reference measurement (because it's an open hole, all the light makes it through). If this happens, the SPF reading will be highly inaccurate. It would be a good idea to contact Resonance Ltd. for advice on measuring samples with very high absorbance.

8. **The XYZ stage moves erratically or is jumpy.**

   This condition indicates the stepper motors driving the XYZ rails are missing steps. The cause could be binding or increased friction along the rail, or a weakened electronic driver circuit. Contact Resonance Ltd. for further instructions.

9. **The software has stopped responding or appears to be stuck, or frozen.**

   Sometimes, due to numerous reasons commands are lost while being sent to and from the instrument. When this occurs the software will lock-up to prevent any unwanted movement which could potentially cause damage to the instrument. Often restarting the software is all that's needed to fix this condition if it occurs, however if this is a common occurrence Resonance Ltd. should be contacted and the problem reported.

10. **Some portions of the percent transmission spectrum are very noisy and seem unnaturally uncharacteristic.**

    This problem is due to one of the UV LEDs in the light source array failing. This creates a gap in the light source spectrum and therefore that region of the transmission spectrum will remain unmeasured. Contact Resonance Ltd. for further instructions.

Calibration

Calibrating the S-40-SPF system requires samples of known SPF values to be measured, and constants within the software adjusted to compensate for any variations. Resonance Ltd. is currently working with the AATCC and COLIPA organizations to provide a hardware calibration kit, and a software update to pair it with. Resonance is researching various measurement standards and working on a solution to provide an instrument that is calibrated for textiles, creams, and liquids with a simple software setting.

Contact

Resonance Ltd. stands behind every product we sell. We welcome feedback and encourage any of our customers to contact us with questions, or concerns. You may contact us through e-mail, our website, telephone, or fax!

Resonance Ltd.

143 Ferndale Drive North

Barrie, ON

L4N 9V9

Tel: 705-733-3633

Fax: 705-733-1388

Email: res@resonance.on.ca

Web: www.resonance.on.ca

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[1] Resonance S-40-SPF Software Manual

M. Taras, “Resonance S-40-SPF Software Manual”, available at the Resonance Ltd. website or by request, Barrie, ON, September, 2011.

[2] AATCC Guidelines

AATCC, “Transmittance or Blocking of Erythemally Weighted Ultraviolet Radiation through Fabrics”, AATCC Technical Manual, 2011

[3] COLIPA Guidelines

COLIPA *In vitro* UV Protection Method Task Force, “Method for in vitro determination of UVA protection, 2011”, available at the COLIPA website, 2011

[4] Boots Star Guidelines

Boots the Chemist Ltd., “The Revised Guidelines to the Practical Measurement of UVA: UVB Ratios According to the Boots Star Rating System”, The Boots Co. PLC, Nottingham, UK